Gouso5

THE SILVICULTURE

OF

INDIAN TREES

VOLUME III

Lauraceae to Coniferae

OXFORD UNIVERSITY PRESS
LONDON EDINBURGH GLASGOW NEW YORK
TORONTO MELBOURNE CAPE TOWN BOMBAY
HUMPHREY MILFORD
PUBLISHER TO THE UNIVERSITY

2307.3

THE SILVICULTURE

OF

INDIAN TREES

BY

R. S. TROUP, M.A., C.I.E.

INDIAN FOREST SERVICE; FELLOW OF ST. JOHN'S COLLEGE, OXFORD, AND

PROFESSOR OF FORESTRY IN THE UNIVERSITY

VOLUME III

Lauraceae to Coniferae

PUBLISHED UNDER THE AUTHORITY OF HIS MAJESTY'S

SECRETARY OF STATE FOR INDIA IN COUNCIL

OXFORD

AT THE CLARENDON PRESS

1921

CONTENTS OF VOLUME III

LIST OF ILLUSTRATIONS, VOLUME III

ORDER XLVII. LAURACEAE

An order largely represented in India by trees and shrubs, usually aromatic, for the most part evergreen and often shade-bearing. A very large proportion of the members of this order are little known. It contains a few timber trees of interest and also certain species yielding aromatic products of commercial importance; of the latter the most important are the cinnamon tree, *Cinnamomum zeylanicum*, Breyn, indigenous to India, and the camphor tree, *C. Camphora*, Nees, often cultivated.

Genera 1. Beilschmiedia, Nees; 2. Machilus, Nees; 3. Phoebe, Nees; 4. Cinnamomum, Bl.; 5. Litsaea, Lam.

1. BEILSCHMIEDIA, Nees.

Ten Indian species, chiefly evergreen.

Beilschmiedia sikkimensis, King. Vern. *Tarsing*, Nep.

A large evergreen tree, usually tall with a straight clean cylindrical bole, found in Sikkim and Bhutan, chiefly between 5,000 and 6,000 ft. and occasionally higher. Manson (Darjeeling working plan) says seedlings are not very common; they grow well under shade, are occasionally found in grassy blanks, and are easily raised in nurseries.

The fruit, an ellipsoidal 1-seeded berry, ripens in June–July. Wood soft, used for building, tea-boxes, &c. Growth, according to Gamble, 5 to 9 rings per inch of radius, giving a mean annual girth increment of 0·7 to 1·26 in.

2. MACHILUS, Nees.

Eleven Indian species of evergreen trees.

Species 1. *M. odoratissima*, Nees; 2. *M. Duthiei*, King; 3. *M. Gamblei*, King; 4. *M. edulis*, King; 5. *M. bombycina*, King.

1. **Machilus odoratissima, Nees.** Vern. *Kawla*, *dalchini*, Hind.

A moderate-sized evergreen tree with oblong-lanceolate leaves 4–6 in. long, dark green and shining above, slightly glaucous beneath. Bark dark brown. Wood grey, moderately hard, apparently not used as timber.

Distribution and habitat. Outer Himalayan valleys and hill slopes from the Sutlej eastwards, at 2,000–7,000 ft., Khasi hills, and hills of the Ruby Mines district, Upper Burma. The tree is found mainly in moist ravines and shady places.

Flowering and fruiting. The panicles of small flowers appear in March–April, and the fruit ripens about June. The fruit (Fig. 298, *a*) is a one-seeded ellipsoidal berry about 0·6 in. long, dark purplish blue with a waxy bloom and a fragrant pulp. The fruits fall from the tree as soon as they ripen,

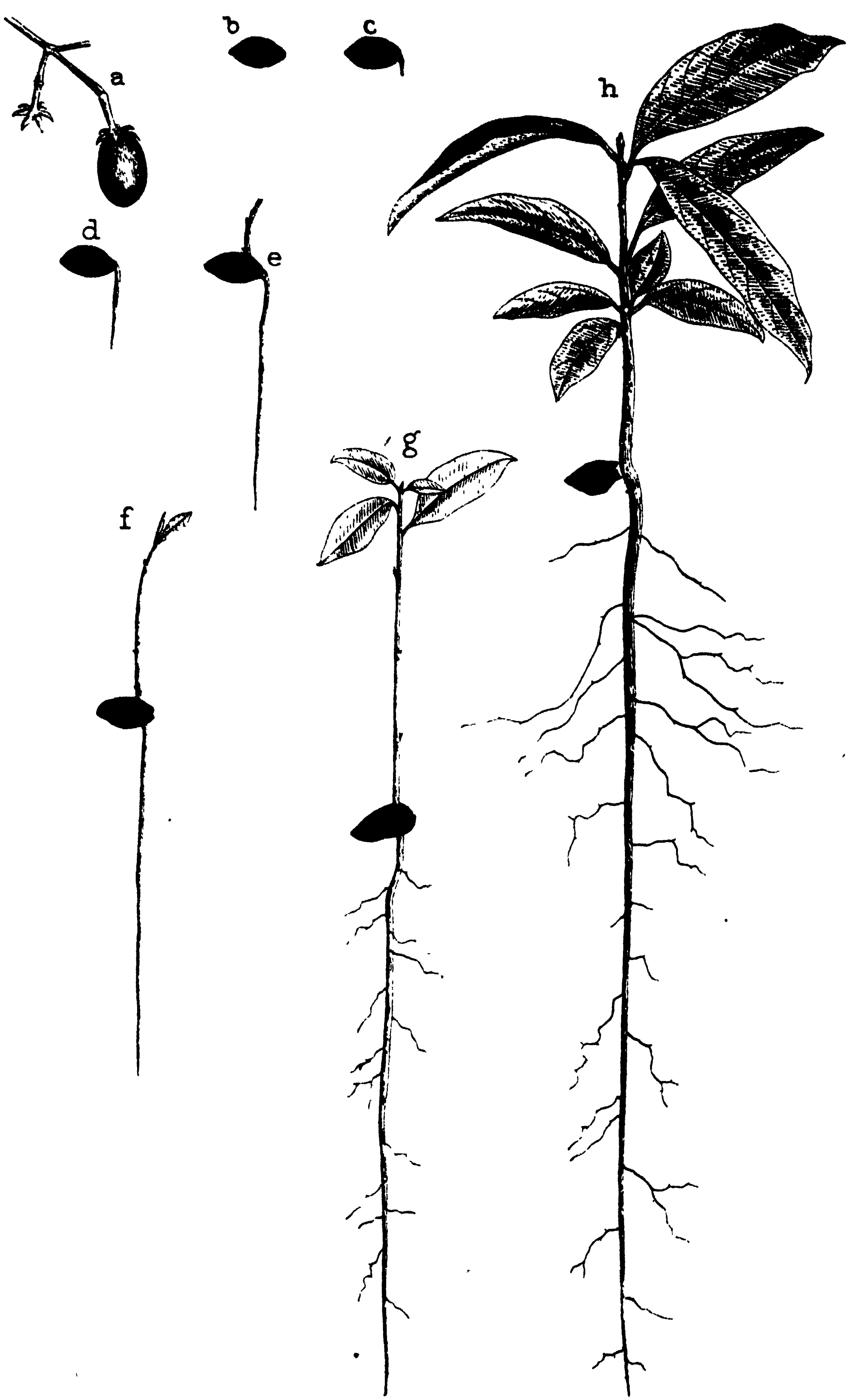


FIG. 298. *Machilus odoratissima.* Seedling × $\frac{5}{8}$.
a, fruit; *b*, seed; *c–e*, germination stages; *f–h*, development of seedling to end of first season

and may be collected off the ground in quantity. The seeds (Fig. 298, *b*) are 0·4 in. long; about 80–100 weigh 1 oz. They do not retain their vitality long.

GERMINATION (Fig. 298, *c–e*). Hypogeous. The radicle first emerges from one end of the seed, and then the young shoot breaks through the testa and emerges from the upper side of the seed. The cotyledons are left within the testa on or under the ground.

THE SEEDLING (Fig. 298).

Roots: primary root moderately long and thick, terete, tapering, woody, dark brown; lateral roots numerous, moderately long, fibrous. *Hypocotyl* indistinguishable. *Cotyledons* sessile, 0·4–0·5 in. by 0·25 in., thick, fleshy, elliptical, outer surface rounded, smooth, inner flat. *Stem* erect, terete or slightly compressed, wiry, green, or young parts often red, glabrous; internodes 0·1–1·5 in. long. *Leaves* alternate, sometimes sub-opposite, exstipulate, first few leaves often rudimentary and scale-like. Petiole 0·25–0·5 in. long, channelled above, green or red, glabrous. Lamina 0·9–4 in. by 0·5–1·1 in., oblong lanceolate, acuminate, entire, glabrous, dark green and shining above, slightly glaucous beneath, venation arcuate reticulate, lateral veins 6–8 pairs, midrib sometimes red.

The growth of the seedling is somewhat slow, the height ordinarily attained being about 3 or 4 in. by the end of the first and 9 or 10 in. by the end of the second season. Subsequently the growth is faster; young plants raised at Dehra Dun reached a height of 5 ft. by the end of the fourth season. Seedlings require moisture and a certain amount of shade for their best development, and are sensitive to drought.

SILVICULTURAL CHARACTERS. The tree is a shade-bearer, especially in youth, but later it is apt to become suppressed if the cover is dense. It is, however, fairly hardy, and will thrive without shade; it grows best in moist situations. It is not browsed by cattle.

NATURAL REPRODUCTION. Under natural conditions germination takes place early in the rainy season, not long after the fall of the fruit. Experiments carried out at Dehra Dun showed that shade, probably from its effect in producing the necessary moisture conditions, is a factor favourable to successful reproduction. Bare ground and loose soil in which the seed becomes quickly buried by rain are also favourable, while weed-growth is an adverse factor. Seedlings often appear in large quantities near seed-bearers in the shade of the forest, particularly where the ground has been cleared or the soil worked, as along newly-made paths. The admission of moderate light stimulates the development of natural seedlings.

ARTIFICIAL REPRODUCTION. Fresh seed should be sown in the nursery soon after the fruits ripen, in June–July, and lightly covered. The beds should be kept shaded and regularly watered. The seedlings usually commence to appear in about three weeks, and may be transplanted at the beginning of the rainy season when one or two years old. They stand transplanting well. This is a useful tree for underplanting purposes under moderate shade.

RATE OF GROWTH. A cross-section in the silvicultural museum at Dehra Dun showed 31 rings for a girth of 2 ft. 4 in., giving a mean annual girth increment of 0·9 in.

2. **Machilus Duthiei,** King. Vern. *Kawla,* Hind.; *Bhojo,* Jaunsar.

A shady evergreen tree, larger than *M. odoratissima,* and with leaves 5–10 in. long, very coriaceous, glaucous beneath. Western Himalaya, in ravines and shady places, at 4,000–8,000 ft., usually at higher elevations than *M. odoratissima,* but resembling it more or less in requirements. Flowers April–May; fruits June–July. The fruit is globose, about 0·5 in. in diameter. Growth slow (Gamble).

3. **Machilus Gamblei,** King. Vern. *Kawla,* Nep.

The low-level *Machilus* of the outer Himalaya and sub-Himalayan tract, at 2,000–4,000 ft. along ravines and streams, and in moist shady places. In the Dehra Dun valley it is a characteristic swamp species. Leaves 3–5 in. long, thinly coriaceous. Flowers March–April; fruits June–July. Fruit globose, black, 0·3 in. in diameter.

4. **Machilus edulis,** King. Vern. *Lepcha phal,* Nep.

A large evergreen tree of the eastern Himalaya at 4,000–8,000 ft. An important tree in the Darjeeling forests. Leaves 5–12 in. long, narrow, thickly coriaceous. Fruit 1·5 in. in diameter, edible. The tree reproduces well; the seedlings are frost-tender, and suffered much in the abnormal frost of 1905. The wood is used for planking, tea-boxes, &c. Growth, according to Gamble, 5 to 9 rings per inch of radius, giving a mean annual girth increment of 0·7 to 1·26 in.

5. **Machilus bombycina,** King. *Soom,* Ass.; *Kawla,* Duars.

A moderate-sized tree with elliptical lanceolate leaves, 4–5 in. long. The bark, especially on the lower part of the stem, is often covered with warty excrescences somewhat resembling small potatoes, and having the same colour and consistency; these later turn black and dry up. This tree is the principal one on which the *muga* silkworm is raised in Assam. It is common in the Bengal Duars and in parts of Assam, especially in the Sibsagar district, and is frequently cultivated and has run wild. In the Buxa Duars it forms pure forests on damp clayey flat localities or is mixed with sal and other species. On old savannah lands which have been brought under fire-protection, it springs up freely and gregariously on moist low-lying places, eventually killing out the grass. In the forest also it regenerates with great freedom, seedlings being found in large quantities; they somewhat resemble seedlings of *Eugenia Jambolana,* except that they have alternate instead of opposite leaves. The tree coppices well. The panicles of small flowers appear about March, and the fruits ripen at the commencement of the rainy season. The fruit is about 0·3 in. in diameter.

3. PHOEBE, Nees.

Seven Indian species of evergreen shrubs and trees.

Species 1. *P. lanceolata,* Nees; 2. *P. attenuata,* Nees.

1. **Phoebe lanceolata,** Nees. Vern. *Bhadroi,* Jaunsar; *Tumri,* Dehra Dun; *Kat kawla,* Kumaun.

A small or moderate-sized evergreen tree with narrow coriaceous leaves 5–8 in. long crowded at the ends of the branches. Bark yellowish white. Sub-Himalayan tract and outer valleys, ascending to 6,500 ft., Khasi hills, Chittagong, Upper Burma, hills of southern India. A shade-bearing species found chiefly in moist shady ravines and near swamps (e. g. in the Dehra Dun valley). Flowers February–June; fruits June–September. The fruit is 0·3–0·4 in. long, ellipsoidal, black when ripe. Growth, according to Gamble, 3 to 4 rings per inch of radius, giving a mean annual girth increment of 1·57 to 2·1 in., which is fast.

2. **Phoebe attenuata,** Nees. Vern. *Lepcha kawla, angaria,* Nep.; *Hlega, thitya-wa,* Burm.

A large evergreen tree of the eastern Himalaya, ascending to 4,000 ft., Assam and Upper Burma. Manson (Darjeeling working plan) says that it germinates profusely even under low cover provided the ground is fairly clear of weeds, that the fruit is eaten by bears, and that at low elevations it is a good tree to plant amidst scrub.

4. CINNAMOMUM, Blume.

About 20 or perhaps more Indian species of evergreen trees and shrubs. Two are of special economic importance, *C. zeylanicum,* Breyn, the cinnamon tree, indigenous, and *C. Camphora,* Nees, the camphor tree, introduced.

Species 1. *C. Tamala,* Nees; 2. *C. Cecidodaphne,* Meissn.; 3. *C. zeylanicum,* Breyn; 4. *C. Camphora,* Nees.

1. **Cinnamomum Tamala,** Nees. Cassia cinnamon. Vern. *Dalchini,* Hind.; *Thitchabo,* Burm.

A moderate-sized handsome evergreen tree with shining 3-nerved aromatic leaves. Bark thin, dark brown, wrinkled, aromatic. The leaves (vern. *tezpat*) are used in medicine and for flavouring purposes; the bark, which is known as 'cassia bark', is used in medicine and as a substitute for true cinnamon. Sub-Himalayan tract and outer ranges, ascending to 7,000 ft., but commonest at 3,000–5,000 ft.; rare west of the Sutlej; Assam, Upper Burma. A shade-bearing species frequenting moist ravines. The young leaves, which are pink, appear in April or May. The panicles of yellowish white flowers appear from February to May, and the fruit, a black ovoid drupe 0·5 in. long, ripens from June to August. Growth, according to Gamble, 6 to 10 rings per inch of radius, giving a mean annual girth increment of 0·63 to 1·05 in.

2. **Cinnamomum Cecidodaphne,** Meissn.

A tall handsome evergreen tree of the eastern sub-Himalayan tract, ascending to 4,000 ft., Assam and Manipur. A clump of trees is growing well in the Kaunli garden, Dehra Dun, and trees felled have coppiced vigorously. These trees seed freely at intervals of two or three years, in October–November, the fruits falling from November to January; hitherto efforts to raise plants from Dehra Dun seed have failed, the seed possibly being infertile. The flesh of the drupes is very fragrant.

3. **Cinnamomum zeylanicum,** Breyn. Cinnamon tree. Vern. *Dalchini,* Kan.; *Karuva,* Tam.; *Hmanthin,* Burm.

A moderate-sized to large very variable evergreen tree with thickly coriaceous 3- or 5-veined leaves, shining above, dull beneath. Old bark rough, brown; young bark smooth, pale coloured. The bark and leaves are very aromatic, the former yielding the cinnamon of commerce and the latter being used for flavouring.

The tree is indigenous to the Western Ghats and adjoining hill ranges from the Konkan southwards, ascending to 6,000 ft.; very common in North Kanara. Also in Tenasserim and the moist low country of Ceylon. In Ceylon the tree is extensively cultivated in gardens and worked under a system of coppice selection, which is thus described by Brandis:[1]

'According to Leschenault de la Tour, *Mémoires du Muséum d'histoire naturelle*, viii (1822), 436, and notes on the subject collected during a late visit to Ceylon, which I owe to the kindness of Dr. George King, the Cinnamon tree in Ceylon is generally grown in irregular coppice-woods, pure or mixed with other shrubs. Some of the stools are of great age and girth, and are said to have been planted by the Dutch when they held the island. The formation of fresh Cinnamon coppice is thus described by Leschenault de la Tour: The tree flowers more or less throughout the year, but most abundantly in January, February, and the fruit ripens from June to August. The seeds, which are oily, do not long retain their vitality; they are sown soon after ripening, either in nurseries to be transplanted in October or November, or on the spot in plots about 1 ft. square and 6–7 ft. apart. The plants attain 7–8 ft. in 6–7 years, and those which are then fit to be peeled are cut, and the shoots which spring up are thinned out when they are 2, 3, or 4 years old, or even at an earlier age. They are not cut when less than ½ in., or more than 2½ in. diam. The whole growing crop in one plot is never cut over at once, as would, for instance, be done in a regularly managed Oak coppice-wood, but those shoots only are selected which appear fit to be used, and are in such a state as to be peeled readily. The main point attended to seems to be, to cut the shoots when quite young and tender; it is said that the bark of the older shoots yields inferior Cinnamon (G. King). The cutting is done during the rainy season, between May and October; the bark is peeled off after cutting in three or four long narrow strips from each shoot; it is then tied tightly together in parcels, and left for twenty-four hours. At the end of this time the epidermis and the outer bark are removed, and the inner bark, which is the aromatic and valuable part, is dried, the first day in the shade, the second day in the sun, when it gradually rolls up, forming the quills of Cinnamon, which are placed into each other and tied in bundles. The fruit of the Cinnamon tree is eaten greedily by crows, pigeons, and other birds; the seeds pass uninjured, and thus the spread and preservation of the tree is secured apart from the planted coppice-woods. Indeed, formerly almost all Cinnamon brought to market was from naturally-grown trees; and to enable their Cinnamon collectors to enter the forests beyond the limits of their own possessions, the Dutch concluded a treaty with the King of Candy, and it is said that planting was only resorted to when the supply from natural sources had become deficient.'

In North Kanara the right of collecting cinanmon bark from wild trees is sold, but the revenue received is not large, the bark obtained being inferior in quality to that grown in Ceylon. In the Western Ghats the tree grows on any soil, but perhaps best on laterite (Foulkes). Flowers November–February; fruits June–July (Talbot). The fruit is a dark purple one-seeded ellipsoidal berry 0·5–1 in. long.

4. **Cinnamomum Camphora**, Nees. Syn. *Camphora officinarum*, Bauh. Japan or Formosa camphor tree.

A large handsome evergreen tree, attaining in its natural habitat a height

[1] For. Fl.: North-West and Central India, p. 375.

of 100 ft. and a girth of 6 to 8 ft. or more, but in India often rather stunted if grown in unfavourable situations. Leaves coriaceous, shining, 2–4 in. long, smelling strongly of camphor when crushed. Bark brown, rough when old. When grown in an open position the tree tends to branch low, forming a short thick bole, massive branches, and a dense rounded crown. When grown in a dense crop, however, the trees form comparatively straight clean boles (Fig. 299). Apart from its economic value, the tree is an excellent one as an avenue tree and as an ornamental and shade tree in parks and gardens. It has been found at Dehra Dun, however, that other plants do not grow well in its vicinity; whether this is due to the fact that the roots tend to spread near the surface or to some toxic influence, is not certain. The wood is moderately hard, somewhat rough, strongly scented with camphor, and used mainly for cabinet-making. The chief product of the tree, however, is camphor, used largely in the manufacture of celluloid and smokeless powders and also to some extent as a drug and insectifuge. Camphor oil is obtained from the camphor by separation; it is used in soap manufacture and for other purposes. In the normal times preceding the outbreak of war in 1914 the world's consumption of camphor was about 11,000,000 lb. annually, the price on the London market varying from 1*s.* 4½*d.* to 3*s.* 6*d.* per lb. Almost the whole outturn of camphor is obtained from Japan, Formosa, and China; the trade in camphor from Japan and Formosa is practically a Japanese Government monopoly, and about 70 per cent. of the world's output within recent years has been obtained from Japanese sources. The manufacture of synthetic camphor was commenced a few years ago by several factories, but the process proved too expensive, while the camphor produced had not the requisite properties and proved too highly inflammable. The high prices obtained for camphor within recent years have led to efforts being made in various parts of the world to form plantations of this tree for profit, and in suitable localities the prospects are distinctly good.

Camphor can be distilled from all parts of the tree, from chips of wood from the stem, branches and roots, as well as from the twigs and leaves: it has even been distilled from the fallen leaves. As the method of growing the tree must depend on a decision as to whether the principal yield is to be obtained from the wood or from the leaves and twigs it is of importance to know the probable outturn of camphor from different parts of the tree. This appears to vary largely in different localities, as is shown in the summary of tests quoted below. In the natural forests of Formosa the camphor is obtained by distilling chips of the wood, since the trees are already of comparatively large size, while the yield of camphor from Formosan wood appears to be much higher than in the case of wood samples tested from trees grown in other parts of the world. For plantation purposes it is recognized that the yield can be most profitably obtained from the leaves and twigs, and the plants are grown in bush-like form accordingly.

A description of the processes of distillation is beyond the scope of this work. The old Japanese methods are crude. Improved methods of steam distillation with various types of stills have been carried out by different investigators from time to time. Among others the apparatus designed by Mr. Puran Singh and described on p. 273 of my *Indian Forest Utilization*, 2nd edition, 1913, has been found to work satisfactorily; in this apparatus the oil is separated from the camphor by a centrifugal machine. A useful account of distillation and condensation methods is given in a note entitled *Camphor Cultivation in the United States*, by S. C. Wood and R. H. True,[1] as also in a note entitled *Camphor from Cinnamomum Camphora*, by B. J. Eaton.[2]

DISTRIBUTION AND HABITAT. The natural habitat of the tree is in eastern Asia from Cochin China to Shanghai and in the islands from Hainan to southern Japan, that is between 10° and 34° N. lat. The most extensive camphor forests are those of Formosa, which are situated chiefly in the northern portion of the island: the climate of this island is moist and tropical to sub-tropical, the vegetation being rich and varied and containing some trees of the Indian region, such as *Bombax malabaricum*, *Bischoffia javanica*, *Calophyllum Inophyllum*, and *Terminalia Catappa*.

The tree has been cultivated more or less successfully in many parts of the world, including India, Burma, Ceylon, the Malay States, Java, Australia, East and South Africa, Italy, Algiers, Florida, California, Brazil, the West Indies, Mauritius, and Madeira. This indicates that it is capable of growing in a wide range of climates throughout the tropical and warm temperate parts of the globe. It was introduced into Ceylon in 1852, and grows at all elevations from sea-level up to the highest elevations provided the soil and climate are suitable, but probably thrives best below 5,000 ft.; generally speaking it has done best where the rainfall is 90 in. or over.

In India it has been grown successfully in a number of localities. There are fine trees at Dehra Dun, for instance the camphor avenue at the Forest Research Institute, and in the Botanic Gardens at Saharanpur and Calcutta; the latter gardens possess a fine avenue of camphor trees introduced in 1802. In the Nilgiris it does well even up to 7,000 ft. It has been grown successfully in many parts of Burma. It does very well at Maymyo, 3,500 ft.: in the Bhamo district it thrives up to 3,000 ft., but at high elevations it does not endure the cold well. In the Southern Shan States it has not been very successful at Taunggyi, 4,700 ft.; it has done better at Kalaw, 4,300 ft., and better still at Lawksawk, 3,000 ft., where the growth is said to be very rapid. In India and Burma generally speaking it seems to do best at low to moderate elevations where the rainfall is about 60 in. and over, though it grows fairly well even where the rainfall is under 50 in., as at Saharanpur.

For its best growth the tree requires a deep well-drained fertile sandy loam and a sheltered situation. It will not thrive on stiff badly drained soils. Eaton states that it appears to thrive in the Federated Malay States on comparatively poor laterite soil provided it is well drained and not swampy. On poor ground the growth is usually stunted.

LEAF-SHEDDING, FLOWERING, AND FRUITING. In northern India the leaves are shed about February–March, and the new leaves appear in February while the old ones are falling. In March–April the trees are covered with masses of pale green fragrant flowers. The fruits ripen in October. The fruit is a dark green, rather dry, globose, one-seeded berry, about 0·3 in. in diameter,

[1] U.S.A. Yearbook, Dept. of Agriculture, 1910.

[2] Federated Malay States, Dept. of Agric., Bull. No. 15, 1912.

turning black after ripening; it should not be collected until it has turned a dull black colour. The seed is very oily, and retains its vitality only a few months. According to Nock,[1] about 5,600 seeds weigh 1 lb. In the case of samples collected at Dehra Dun 2,100 to 3,200 of the fruits weigh 1 lb. Good seed if cut open is white inside; if it is brown or black it may be regarded as useless.

In Japan the seed ripens in October–November, and in order to obtain it in fresh condition orders should be timed to reach that country not later than September. Packing in damp charcoal is said to preserve the fertility of the seed better than any other method. Fertile seed can, however, be procured to a limited extent in India. Some of the trees grown at Dehra Dun seed freely, but not every year. In Japan the tree is said to commence producing seed at the age of 20–25 years. Trees 17 years of age have been observed in flower at Dehra Dun, but the seed from these has not been tested.

SILVICULTURAL CHARACTERS. The tree stands a fair amount of shade, but develops best with a liberal supply of light. It coppices vigorously, the shoots growing rapidly; coppice-shoots persist well under shade, as shown in a plantation at Dehra Dun where the stools of trees removed in thinnings all sent up coppice-shoots, but the shoots round the edge of the plantation, where they received plentiful light, grew far more vigorously than those under shade in the interior of the plantation. The tree also produces root-suckers. It stands repeated pruning, and can be trimmed down to the form of a bush or hedge. Large trees at Dehra Dun sometimes become dry-topped, sending out masses of shoots at the base in token of bad condition, while the smaller branches sometimes fall off, leaving cankerous hollows in the stem and main branches. In America the tree has been found to be hardy where the temperature does not fall below 15° F., though even at this temperature unlignified twigs may be killed by frost.

ARTIFICIAL PROPAGATION AND CULTIVATION. The camphor tree can be raised from seed, layers, branch-cuttings or root-cuttings, or by transplanting root-suckers. The first method is the most satisfactory for plantation purposes. Layering is fairly successful but slow; the method found most satisfactory in Ceylon is that known as tonguing or heeling; the branch at the lowest point of the bend where it will be under the soil being cut half-way through on the under side below a bud and slit upwards for a short distance. Branch-cuttings do not as a rule prove successful, a very small proportion surviving. Root-cuttings about 2½ in. or more in length, provided they possess good buds, have proved very successful. The best results in Ceylon have been attained by inserting the cutting more or less vertically in such a position as to bring its upper cut surface (which should be that nearest the stem of the plant) near the surface of the ground. Nock estimates that 75 to 100 good root-cuttings could be obtained from a tree eight to ten years old without harmful results.

For raising plants from seed, fresh seed should be sown in the nursery during late winter. At Dehra Dun sowing in boxes has proved more successful

[1] Propagation of Camphor, J. K. Nock, Cir. and Agric. Journ. Roy. Bot. Gardens, Ceylon, vol. iv, No. 3, May 1907.

than sowing in seed-beds, but in either case a well-worked porous soil is necessary, this consisting preferably of an equal mixture of loam, sifted leaf-mould, and pure sand, all well mixed and pulverized. It is sometimes customary to soak the seeds in water for twenty-four hours before sowing, those which sink being sown about 1½ in. apart, and those which float, and of which very few will be fertile, being sown thickly. The soil should be watered before sowing and the seeds covered to a depth of about half an inch, the beds or boxes being shaded; drip should, however, be avoided. Germination may take some months, and in order to prevent the seed rotting in the meantime, water should be given sparingly though regularly. During the first rainy season the plants should be pricked out in the nursery with a spacing of about 6 in. by 8 in., or into baskets. They will be ready to plant out during the second rainy season, but as a long taproot is often developed it may be necessary to trim it down and to prune down the stem; the plant stands this treatment.

For camphor distillation plantations are formed with the object of producing crops of leaves and small twigs, and are trimmed into bush or hedge form for the purpose. The best spacing for Indian requirements has not yet been ascertained. but probably one of 6 ft. by 6 ft. to 8 ft. by 8 ft. will be found suitable. In America a spacing of 6 ft. by 15 ft. has been tried; this seems unnecessarily wide, but was adopted to facilitate cultivation. The ground should be well tilled and harrowed before planting, and dug up periodically. The first harvest of leaves is obtained when the plants have produced thick woody stems, that is, ordinarily in about five years, or under favourable conditions less. They are then trimmed to bush-like form and a size convenient for easy working; the number of flushes of leaves and twigs obtainable will probably be found to vary locally. Estimates of the yield from plantations are given below.

Rate of growth. Under favourable conditions the rate of growth is rapid, but on poor soils it is slow. In the natural habitat of the tree a height of 30 ft. and a diameter of 6 in. in ten years is said to be good growth. According to Gamble some Dehra Dun specimens showed nearly 1 ring per inch of radius, that is, a mean annual girth increment of about 6 in., which is very rapid. Cross-sections of three trees grown at Dehra Dun showed the following growth:

1. Girth 5 ft. 10 in; rings 31; mean annual girth increment 2·26 in.
2. Girth 3 ft. 4 in.; rings 23; mean annual girth increment 1·74 in.
3. Girth 1 ft. 10 in.; rings 17; mean annual girth increment 1·30 in.

The third specimen was from a close-grown plantation. In Ceylon under favourable conditions the tree attains a height of 18–20 ft. and a diameter of 6–7 in. in five years (Nock). According to Hood and True, experiments were made in the United States in coppicing trees six to ten years old, and in all cases the coppice-shoots made a growth of 6 to 10 ft. in the first year.

A plantation formed in 1898 in the Kaunli garden, Dehra Dun, was thinned in 1915 and again in 1917. The following measurements were recorded after each thinning:

Cinnamomum Camphora: measurements in Kaunli plantation, Dehra Dun.

Year of measurement.	Age.	No. of stems per acre.	Mean girth.	Mean height.	Solid volume per acre.	Intermediate yields from thinnings. Solid volume.
			ft. in.	ft.	cub. ft.	cub. ft.
1915	17	561	1 5·5	53	2,366	885
1917	19	383	1 9·2	54	2,317	648

Fig. 299 shows the appearance of the plantation after the first thinning.

YIELD. According to the results of analyses carried out by various investigators in different parts of the world, the yield of camphor from the wood, branches, twigs, and leaves varies greatly under different conditions. Formosan wood is generally reported to yield 3–4 per cent. of camphor, but this has not been nearly equalled by tests carried out in other countries; in Formosa, however, the trees in question are probably much older than those experimented with elsewhere. The statement on page 796 gives the results of tests recorded by different investigators.

Accurate estimates of the yield per acre from trimmings of leaves and young twigs of plants grown as bushes have not yet been made, but the following rough estimates may be quoted:

1. Bamber and Willis estimate that 12 to 15 lb. of clippings a year may be expected; this yield has been exceeded in the Hakgala Gardens, Ceylon, so far as rough experiments show. With a spacing of 6 ft. by 6 ft. or 1.210 plants per acre this will give a yield of 14,000 to 18,000 lb. of clippings per acre, or 140 to 180 lb. of camphor per acre per annum at 1 per cent.

2. Eaton estimates that in the Federated Malay States an acre of camphor three years old, planted 8 ft. by 8 ft., that is 700 plants per acre, should yield about 60 lb. of camphor from one pruning or 180 lb. per annum in three prunings.

3. Hood and True estimate that in the United States bushes spaced 6 ft. by 15 ft. and grown 8 ft. high will give 8,000 lb. of trimmings per acre for each of two cuttings, making a total of 8 tons per acre per annum, and yielding 175 to 200 lb. of marketable camphor per acre.

These three estimates, it will be seen, are very near each other. It is of interest to note that Hood and True consider that 200 acres is the minimum planted area which would warrant the erection of a distilling and refining plant, and that 500 acres would probably ensure the minimum cost of production of marketable camphor.

5. LITSAEA, Lam.

A large genus containing nearly 50 species of evergreen or deciduous trees, none of any great importance. The flowers are dioecious, in small umbellate heads.

Species 1. *L. sebifera*, Pers.; 2. *L. polyantha*, Juss.

1. **Litsaea sebifera**, Pers. Syn. *L. chinensis*, Lam.; *Tetranthera laurifolia*, Roxb.; *T. apetala*, Roxb. Vern. *Maida lakri*, Hind.; *Elumpurukki*, Tam.; *Ondôn*, Burm.

A moderate-sized very variable evergreen tree with slightly aromatic

Cinnamomum Camphora: recorded tests giving yield of camphor.

Locality.	Investigator.	Wood.	Branches and twigs.	Young shoots.	Leaves and twigs.	Leaves.	Remarks.
		Percentage of crude distillate from different parts of tree.					
India							
Nilgiris	Hooper [1]					1·0	Yield of camphor 10–15 per cent. of distillate from tree at Ootacamund and 75 per cent. from tree at Naduvatam.
Dehra Dun	Puran Singh [2]	Stem 0·66 [0·97]	Large branches 0·46 [0·51] Small branches 0·21 [0·25]	0·27 [0·31]		0·24 [0·42]	Figures in square brackets show percentage of dry camphor calculated on *dry* material.
Ammayanayakanur (Madras)	Puran Singh [2]					[1·79]	Figures in square brackets show percentage of dry camphor calculated on *dry* material.
Cochin State	Puran Singh [2]				[1·70]		Figures in square brackets show percentage of dry camphor calculated on *dry* material. Camphor oil 0·29 per cent.
Abroad							
Ceylon	Willis and Bamber [3]	No appreciable quantity from wood of branches and stem			Average 0·75–1 per cent. of camphor and a small quantity of camphor oil		
Malay States	Eaton [4]			0·06–0·45	1·25 and 1·58	1·10–1·54	
East Africa	Lommel [5]		0·06–0·1	0·22		1·0	
West Indies	Watts and Tempany [5]	0·5			0·5 and 1·7		
Italy	Giglioli [5]			0·02 and 0·25		Green 1·2–1·5 Dried 2·4–3·0	
U.S.A.	Hood and True [6]				Average 1·75–2·25 on weight of green material (crude distillate gave 75–80 per cent. camphor, i. e. pure camphor averaged 1·35–1·50 per cent.)	Fallen dead leaves 0·2	
Jamaica	Kennedy and Duncan [7]	0·61		0·05		Green 2·37 Dried 2·52 Dead 1·39	

[1] Ind. Forester, xxii (1896), p. 111. [2] Ibid., xli (1915), p. 291. [3] Cir. Roy. Bot. Gardens, Ceylon, Series I, No. 24, Nov. 1901.
[4] F.M.S., Dept. of Agric., Bull. No. 15, 1912. [5] Quoted by Eaton, loc. cit. [6] U.S.A. Yearbook, Dept. of Agric., 1910. [7] Harper's Magazine, Feb. 1911.

leaves and grey smooth corky bark, viscous inside. Wood moderately hard, fairly durable and of good quality. Widely distributed throughout India and Burma, but nowhere very abundant; usually in valleys and fairly moist places. In the sub-Himalayan tract it is common in sal forest. In northern India the old leaves fall from December to February, often turning greyish brown or yellow, mottled with green and bluish black spots. The new leaves appear before the old ones have all fallen. The flowers appear in the rainy season, and the fruits ripen in the following cold season; the fruit is a black globose drupe about 0·3 in. in diameter. The tree stands a fair amount of shade and coppices well. Gamble gives the rate of growth as 6·7 rings per inch of radius, representing a mean annual girth increment of about 0·94 in. A cross-section in the silvicultural museum at Dehra Dun showed 51 rings for a girth of 3 ft. 9 in., giving a mean annual girth increment of 0·88 in. Two trees measured for a period of twelve years in a sample plot in the Siwalik tract showed a mean annual girth increment of 1·01 in. for the period. Coppice growth, for some years at least, is usually fast. Measurements in 1910 by Mr. C. M. McCrie in coppice coupes in the Gorakhpur district, United Provinces, and in 1886 by Mr. A. F. Broun in the Bullawala coppice near Dehra Dun, gave the following results for *Litsaea sebifera* as compared with sal:

Litsaea sebifera: coppice measurements, United Provinces.

	Gorakhpur.		Bullawala (Dehra Dun).			
	Mean height.		Mean height.		Mean girth.	
Age.	*Litsaea.*	Sal.	*Litsaea.*	Sal.	*Litsaea.*	Sal.
years.	ft.	ft.	ft.	ft.	in.	in.
2	6·5	3·0	.	..	..	..
4	9·4	7·0	..	..	..	..
6	12·0	10·3	..	..	..	..
8	14·1	13·0	18·3	13·2	6·9	7·1
9	.	..	(1) 12·5	16·0	8·4	8·6
..	..	.	(2) 16·6	13·5	13·2	8·7
10	15·4	15·3	18·4	11·9	11·0	5·9
12	17·0	17·5	..	..	..	..
14	18·3	19·2	..		.	..
16	19·0	20·9	..	.	..	..

In the Gorakhpur measurements the mean girth in a coupe sixteen years old was 9·7 in. for *Litsaea* as compared with 6 in. for sal.

Measurements in young coppice coupes in the Tikri forest, Gonda, United Provinces, showed slower growth, namely:

Age 1 year: mean height, *Litsaea* 4 ft., sal 4·7 ft.
Age 2 years: mean height, *Litsaea* 4·3 ft., sal 7·6 ft.

2. **Litsaea polyantha,** Juss. Syn. *Tetranthera monopetala*, Roxb. Vern. *Katmarra*, *meda*, *singran*, *karkáwa*, Hind.; *Ondôn*, Burm.

A small to large tree, evergreen or nearly so, with a large spreading crown. Bark dark grey, smooth. Common in the sub-Himalayan tract, usually in scrub forests; also in Bengal, Assam, the Central Provinces (chiefly along streams), the Circars and Burma (common in the plains forests). The tree is often planted for ornament. In northern India the leaves are shed in March and April, at which time also the flowers appear chiefly on the upper leafless branches while the lower branches are still in leaf. The fruit, a drupe 0·2–

0·4 in. long, ripens in the rainy season. Growth, according to Gamble, 2 to 6 rings per inch of radius, giving a mean annual girth increment of 1·05 to 3·14 in., which is fast. A tree measured for a period of four years in a sample plot in the Siwalik tract showed a mean annual girth increment of 0·59 in. for the period.

ORDER XLVIII. PROTEACEAE

This order is represented chiefly in Australia and South Africa, and contains only one Indian genus, *Helicia*, Lour. The only tree which is of special interest in India is the Australian tree *Grevillea robusta*, A. Cunn.

GREVILLEA, R. Br.

Grevillea robusta, A. Cunn. Silky oak.

A moderate-sized evergreen tree with a long conical crown, a definite leader, and deeply pinnatifid leaves. Bark dark grey, rough. A native of Australia (Queensland and New South Wales), it is often planted in suitable localities in India. In the Nilgiris it grows well at moderate elevations, chiefly at 4,000–6,000 ft., and is used as a shade tree in coffee plantations. It does well at Dehra Dun, at Maymyo in Burma, and generally at moderate elevations where there is a fair rainfall. It grows very rapidly, and is a graceful tree up to an age of about fifteen to twenty years, after which it often becomes ragged and unsightly. It makes an excellent temporary avenue tree, growing up quickly while some slower growing but more enduring species grown with it is ready to take its place. It is not particular as to soil, and is easily raised in the nursery, standing transplanting well. It is somewhat brittle and liable to be broken by wind in exposed places. In India natural seedlings are often found ; they come up readily through hedges and bushes where they obtain protection. The tree flowers from March to May, when masses of golden-yellow flowers cover the branches in flat horizontal tiers. The fruit is a small 1- or 2-seeded follicle ; about 3,000 seeds weigh 1 oz.

ORDER XLIX. THYMELAEACEAE

AQUILARIA, Lam.

Aquilaria Agallocha, Roxb. Eaglewood. Vern. *Agar*, Beng. ; *Sasi*, Ass. ; *Akyaw*, Burm.

A tall evergreen tree of the eastern Himalaya, Assam, eastern Bengal. and Burma, especially in Tenasserim. It furnishes the eaglewood or agarwood of commerce, occurring in the form of dark-coloured resinous fragrant masses in the centre of the bole ; these are used for burning as incense, while the light-coloured wood in which the masses are embedded is distilled into an oil called agar-attar, which is used as a perfume. The tree is said to regenerate freely. An experimental plantation of it has been in existence for some years in the Sibsagar district of Assam ; the plants are reported to have suffered from the ravages of wild elephants.

FIG 299 *Cinnamomum Camphora*, plantation 17 years old at Kaunli, Dehra Dun

FIG. 300. *Santalum album*, a well-grown young tree.

FIG. 301. *Santalum album*, normal leaves on left, and spiked leaves on right.

ORDER L. LORANTHACEAE

This order consists of evergreen parasitic shrubs which are of importance owing to the damage they do to trees. They obtain nourishment from their hosts by means of haustoria which penetrate into the tissues of the hosts ; as they possess green leaves they are able to carry out the process of assimilation. A severe attack of loranthaceous parasites may kill the host, and when the host dies the parasite itself in turn dies. The commonest Indian species is *Loranthus longiflorus*, Desr., a widely distributed species with a large variety of host plants, even *Pinus longifolia* being subject to its attacks. It does much damage to mango trees, and it is probably the chief species responsible for the extensive injury done to *mohwa* (*Bassia latifolia*) trees in the Indian Peninsula, where it is a serious menace and the cause of much mortality. *L. vestitus*, Wall., is a common species on the oaks of the western Himalaya. *Viscum album*, Linn., the mistletoe, is found in the Himalaya and other hill ranges and attacks fruit trees as well as poplar, willow, and other trees. *Arceuthobium minutissimum*, Hook. f., is a minute parasite which damages *Pinus excelsa* in the western Himalaya. It can be detected from the small warty excrescences which it produces on the twigs of the pine, the injury somewhat resembling that of an insect attack.

Perhaps the only method of keeping loranthaceous parasites in check is by removing them systematically or lopping off affected branches : where the hosts are deciduous trees, this can best be done when they are leafless, the evergreen parasites showing up conspicuously. The seeds appear to be spread for the most part by birds.

ORDER LI. SANTALACEAE

An order of trees, shrubs, and herbaceous plants, mostly root-parasites, but some parasitic on the stems and branches of their hosts. The only Indian tree of special importance is *Santalum album*, Linn.

SANTALUM, Linn.

Santalum album, Linn. Sandalwood. *Chandana*, Sans. Vern. *Chandan*, *chandal*, *sandal*, Hind. ; *Gandada*, *gandha*, Kan. ; *Suket*, Guz. ; *Chandanam*, Tel. ; *Santhanam*, *srigandam*, Tam. ; *Chandana*, Coorg ; *Santagu*, Burm. (Fig. 300.)

A small evergreen glabrous tree with slender drooping branchlets. Leaves opposite, sometimes alternate, occasionally ternate, ovate or ovate-lanceolate, 1·5–3 in. long, sometimes larger in fertile localities, glabrous and shining above, glaucous beneath. Bark reddish brown or dark brown, red inside, smooth in young trees, rough with deep vertical cracks in old trees. Wood hard, very close-grained, oily ; sapwood white, scentless, heartwood yellowish brown, strongly scented, used for carving and other fancy work, and largely distilled for its fragrant oil, which is used in perfumery and medicine. For distillation purposes the heartwood of the stem, branches, and roots is used, every part of the tree which contains heartwood down to about 1 in. in diameter being utilized. The wood is sold by weight, and pound for pound is by far the most valuable wood in India, if not in the world.

Ordinarily the tree attains a height of 40 to 50 ft. and a girth of 3 or 4 ft., though larger specimens are sometimes met with. The largest tree recorded is one felled about 1874 in the Hassan district of Mysore, which had a girth of 8 ft., and yielded 1½ tons of good heartwood; it grew in sandy soil on the bank of a perennial river.

Distribution and habitat. The sandalwood tree is indigenous to the Indian Peninsula from Nasik and the Northern Circars southwards (Brandis). The principal sandal tracts, however, are confined to definite parts of Mysore and Coorg and to some districts of Madras. In northern Travancore, according to Bourdillon, it is apparently wild in the Anjinaad valley, and elsewhere is naturalized and well established both on the hills and in the low country in gardens and on waste land. In Bombay Talbot says it occurs throughout the Deccan trap region, where it rarely forms heartwood of marketable size; the best and largest trees are in the Dharwar district and North Kanara along the Mysore border. He says that the total annual yield of marketable sandalwood from the Bombay forests does not exceed 100 tons, and adds that many attempts have been made at sandalwood planting in the Northern and Central forest circles, but these have invariably resulted in failure. Mr. Srinivasalu Naidu [1] says it is indigenous in the heads of ravines in the Gerumatergaon reserve round Borala in the Buldana district of Berar, but that most of the old trees have been cut away. Sowings in the Akola and Buldana districts have been successful, and so far the results attained hold out promise that considerable tracts of very poor forest in Berar will in time become valuable sandalwood areas by the artificial introduction of this tree. Sandalwood is grown in gardens and other places far outside its habitat, not only in the Peninsula but as far north as Saharanpur and Dehra Dun, and where conditions are favourable it sometimes tends to spread naturally where introduced. Attempts have been made in recent years to introduce the tree in certain forests in the dry zone of Upper Burma, but although the seed germinated well, the seedlings have not shown much promise, as they suffer much from drought in the hot season.

Mysore contains the most important sandal tracts in India, the present outturn being about 2,000 tons of heartwood per annum. The Mysore plateau contains a well-marked belt of sandal extending eastward to where the rainfall is about 35 in., and westward to where it is about 55 in.; sandal is also scattered over the greater part of the state, but is not found in the driest parts in the north, where the rainfall is about 20 in. It is most plentiful in the Shimoga, Kadur, Hassan, Mysore, and Bangalore districts, and thrives best at an elevation of 2,000 to 3,000 ft.

In Coorg it occurs in the northern and north-eastern part of the province where the rainfall varies from 30 to 75 inches. The present outturn from natural forests is about 200 tons of heartwood per annum, but with tending operations and better estimates of yield the outturn will probably rise to 500 tons in the next fifteen or twenty years, and possibly to 1,000 tons or more in the distant future, as sowings are being vigorously prosecuted.

[1] Working Plan Report, Buldana, par. 58.

In the Madras Presidency sandal is found chiefly in the districts of Coimbatore Salem, the Nilgiris, and North Arcot; it also occurs, sparsely or of small size, in Cuddapah, Bellary, Tinnevelly, Trichinopoly, Kurnool, and South Canara, and is said to have established itself long in Chittoor and more recently in Anantapur, where it is tending to spread naturally. The most important sandal tracts in Madras are situated in (1) the Javadi and Yelagiri hill ranges in the Salem and North Arcot districts at elevations chiefly between 2,000 and 4,000 ft., but occasionally down to 1,200 ft., with a rainfall of 30–40 in.; (2) the Shevaroy hills in the Salem district, at 1,500–4,500 ft., with a rainfall of 30–60 in.; (3) the plateau lands of the Coimbatore district, at 2,000–4,500 ft., with a rainfall of 40–50 in.; and (4) the south-eastern Wynaad of the Nilgiris district.

Speaking generally, it may be said that the tree flourishes best between 2,000 and 3,500 ft., though it ascends to over 4,000 ft. and descends in places as low as 1,200 ft. It flourishes, when planted, even at sea-level, but naturally it is a tree of the upland plateaux, growing chiefly on undulating ground, but often on hill-sides and in open spaces along the banks of rivers and in ravines.

The important sandal tracts lie in regions where the rainfall varies from 25 to 65 in., but the tree is occasionally found where the rainfall is above or below these limits, while it is sometimes cultivated in gardens where it is as high as 100 in. or more. Generally speaking, the climate within its habitat is comparatively cool, with a moderate rainfall, much sunshine, and long periods of dry weather. Frost is unknown, and the temperature varies as a rule from 50° to 95° F. The most common form of soil on which it occurs is a red ferruginous loam varying in fertility, the underlying rock often being metamorphic, chiefly gneiss. It is frequently found on rocky ground or on stony or gravelly soil, and is not exacting as to depth of soil. It shows the best growth on rich fairly moist fertile soil, for example in garden loam and on well-drained deep alluvium along river-banks. Trees grown on poorer ground, and particularly on stony or gravelly soil, although they do not attain such large dimensions, are said to have more highly scented wood, but this has not yet been definitely proved. The tree requires good drainage, and does not stand water-logged ground. It avoids saline and calcareous soils, and is not as a rule found on black cotton soil.

The sandal tree is not found in dense high forests of good growth, but occurs mainly in open scrub forests, hedgerows, among lantana bushes or bamboo clumps, and round the edges of cultivated lands. No doubt sandal has been preserved to some extent owing to the fact that on all lands, whether state or private, it has for long been regarded as a royal or reserved tree in Mysore and Coorg, and more recently so in Madras. Still, the earlier forest reservations were carried out mainly in types of forest containing teak and other timber trees where sandal did not occur, and in forests not burdened with rights of user. In this way sandal tracts largely escaped reservation, and the area of sandal in Government forests, which must be relied on for future permanent supplies, is not so great as it might have been, and the natural sandal-bearing area has become much restricted.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is a true evergreen. Mr. F. B. Dickinson[1] says the foliage gets thinner in protracted monsoons with continual rainy weather, and also in the dry season ; a flush of new leaves appears during the early showers in May, and after the monsoon in October. The flowering and fruiting seasons appear to vary. Mr. Dickinson, writing from Coorg, says the flowering season lasts from February till April, and the fruits ripen in May and June and during the monsoon if a light one, or the ripening is sometimes put off till after the monsoon. Mr. D. E. Hutchins,[2] writing from Mysore, says the tree flowers at the end of the hot weather or early in the rains, and the fruit is ripe in a few months, usually by the close of the rains. Mr. P. M. Lushington[3] says that in North Coimbatore there are two distinct periods of flowering and fruiting, one general and the other confined to only a portion of the trees, and these as a rule are of the dark-leaved kind. The ordinary flowering begins in May, and is at its full height by the end of June ; the seeds begin to form in October, but the bulk do not ripen till November or December. The other flowering takes place from February 15, and is at its height in March, though it sometimes extends up to June ; the fruit ripens in July and August, but there is some doubt as to the value of the seed produced. Mr. Rama Rao[4] says its ordinary and general fruiting season extends from June to September, but it also bears fruit rather sparsely between November and February. He mentions that it is not uncommon to find at one and the same time trees laden with flowers and fruits in various stages from the nascent flower-bud to the ripe fruit ready to drop.

The flowers are purplish brown, unscented, in axillary or terminal cymose panicles. The fruit is a purplish black globose succulent drupe 0·3–0·5 in. in diameter, with a brown endocarp which is moderately hard but brittle and easily broken. The fruit-stones (Fig. 302, *a*) are globose, 0·2–0·3 in. in diameter; about 120 to 170 weigh 1 oz. The seed has a copious white albumen and a straight embryo. It retains its vitality for some time if kept dry, but is apt to rot with damp. The seeds are very subject to the attacks of rats and squirrels, which destroy them in quantities. Birds readily eat the fruits, and are important agents in disseminating the seeds, which they do not destroy.

Flowering and fruiting often commence at an early age ; trees three or four years old have been noticed to flower, but it is not certain if they produce fertile seed. Mr. Lushington[5] expresses the opinion that good seed can be obtained from all trees over twenty years of age. Good seed-years occur every year, with only occasional exceptions.

GERMINATION (Fig. 302, *b–d*). Epigeous. The fruit-stone cracks and the radicle emerges and at once descends. The hypocotyl elongates by very pronounced arching, the loop appearing above ground while the cotyledons, enclosed in the albumen, remain underground. The lower portion of the hypocotyl becomes very swollen and fleshy, the nutriment from the albumen being transferred to that portion of the seedling. After this transference of nutriment is completed the hypocotyl becomes erect. The seed is either carried above ground, soon falling off, or is left in the ground, where it rots. The cotyledons break off, remaining within the seed and leaving their petioles

[1] Ind. Forester, ix (1883), p. 64.
[2] *Ibid.*, x (1884), p. 208.
[3] *Ibid.*, xxvi (1900), appendix, p. 14.
[4] *Ibid.*, xxx (1904), p. 357.
[5] *loc. cit.*, p. 15.

FIG. 302. *Santalum album* SEEDLING × $\frac{7}{8}$

-Fruit-stone b - d—Germination stages e - g—Development of seedling during first season (g shows white cushion-like haustoria on roots of seedling, and attachment to roots of host)

attached to the stem in the form of a pair of stumps, above which the young foliage leaves quickly develop.

THE SEEDLING (Fig. 302).

Roots : primary root moderately long, flexuose, whitish, delicate ; lateral roots moderate in number, short or moderately long, fibrous, delicate, distributed down main root ; roots at an early stage develop nodular growths, the first signs of haustoria. *Hypocotyl* distinct from root, 1·4–3·5 in. long, fusiform, much swollen in lower part in earlier stages. *Cotyledons* : petiole 0·2–0·3 in. long ; lamina 0·2–0·3 in. long, ovate lanceolate, fleshy, yellow, outer surface convex, inner flat, remaining within the albumen of the seed. *Stem* erect, green, glabrous ; internodes 0·3–0·8 in. long. *Leaves* simple opposite or sub-opposite decussate, exstipulate, earlier leaves smaller than later ones. Petiole 0·15 in. long or less. Lamina 0·4–1·8 in. by 0·15–0·5 in., oblong lanceolate or elliptical, earlier leaves often oblique, apex and base acute, entire, glabrous.

Under average conditions nursery-raised seedlings attain a height of 8–10 in. in the first season and 1–2 ft. by the end of the second season, though this growth is often exceeded. Under less favourable conditions a height of not more than 4 or 5 in. may be attained in the first year. Mr. F. B. Dickinson [1] states that he has seen seedlings grow 3 to 4 ft. in the first year, and as much in the second year, and has seen some plants not three years from seed which were 11 ft. high.

Mr. Tireman has furnished the following measurements showing the height of young plants of different ages in sowings in Coorg :

Santalum album : height growth of young plants, Coorg.

Locality.	Date of sowing.	Mean height at age of 1 year. ft. in.	2 years. ft. in.	3 years. ft. in.	4 years. ft. in.	5 years. ft. in.	6 years. ft. in.
Malarubi near Kargode	1913	..	2 6	4 9	7 3	..	..
	1914	1 11	5 2	7 6	..	..	..
	1915	2 3	5 3	..	..	..	..
Kurubara-panchi near Murkal	1911	..	..	..	5 7	7 10	9 8

The seedling is sensitive to drought, and is readily killed by sudden exposure to the sun. It requires lateral shade, but is intolerant of low overhead cover even in the first year, and tends to damp off in the rains unless its head is freed. It is also sensitive to water-logging, and in cold wet soil is apt to rot. Seedlings are much subject to the attacks of insects, and are sensitive to this form of injury ; in the germinating stages and soon after the cotyledons, the fleshy hypocotyl, the young leaves, and the taproot are all readily attacked, and the seedlings may be killed off in quantity. Hares, deer, cattle, and goats browse on young plants, hares and deer in particular seeking them out and causing much injury. Rats and squirrels also damage them in their earlier stages. Rats are perhaps the worst offenders of all : they pull up young seedlings and eat the fleshy hypocotyls, but after the stems have hardened, that is, when the plants have attained an age of five or six months, this form of damage ceases.

One of the most important characters of the seedling, and of the plant

[1] Ind. Forester, ix (1883), p. 65.

in general, is the root-parasitism exhibited by it ; this character is considered below.

Further investigation is necessary into the question of the dying back of seedlings under certain conditions. Mr. P. M. Lushington has noted cases indicating that this has taken place in the second year, and remarks : 'In some sowings at Pecheruvu, Kurnool, A. W. Lushington going the year before I did said the one-year-old was a success and the two-year-old a failure. I found his failure to be a great success, but with a very careful search could find nothing in the then two-year-old coupe. Since that time I have constantly observed the same thing. I am talking of plants under the cover of scrub.' Mr. Lushington suggests that there may possibly be some relation between this apparent dying back and the formation of root-attachments which is not yet understood.

ROOT-PARASITISM. The fact that the sandal tree is a root-parasite was established in 1871 by Mr. John Scott, Curator of the Royal Botanic Gardens, Calcutta.[1] For many years the importance of this fact does not appear to have been realized in the silvicultural treatment of the tree, and Scott's work seems to have been lost sight of, for although its possible parasitic nature was at times alluded to vaguely and sometimes with expressions of doubt, no serious effort appears to have been made to carry out any scientific investigation into this most important character till Dr. C. A. Barber was led to examine the roots of the sandal in connexion with his study of the spike disease in 1902. 'Beginning with seedlings,' he writes,[2] 'I was much surprised . . . to find an abundance of connexions between their roots and those of other plants. There is no doubt that the young sandalwood will, if allowed the chance, at once attach itself to foreign plants. . . . When, however, I came to look into the root-system of the larger trees, I was astounded at the immense number of functional haustoria whereby the roots were actually attached to those of other plants. The sandalwood trees, wherever I have examined them, greedily attach themselves to the surrounding vegetation.'

Dr. Barber published the results of further investigations on the subject in two subsequent papers ;[3] in the first he dealt with the root-system of sandal seedlings grown under different conditions and the formation of haustoria on the roots, and in the second he described the microscopic structure of the haustoria and their mode of attachment to the roots of host plants. These papers were followed by a more detailed description of the haustorium in the *Memoirs of the Department of Agriculture in India*.[4] Based on the experimental cultivation of sandal seedlings in pots, and on a study of the haustoria developed under various conditions, the chief results of Dr. Barber's earlier investigations may be summarized as follows :

1. Seedlings grown in pure sand, without hosts, form a well-developed and much-branched root-system with a fine network of delicate rootlets ; this root-system is produced largely from the stores of nutriment in the seed, which are located after germination in the swollen hypocotyl. Many of the

[1] Journ. Agric. and Hort. Soc., Calcutta, ii. 287. [2] Ind. Forester, xxviii (1902), p. 340.

[3] *Ibid.*, xxx (1904), p. 545 ; and xxxi (1905), p. 189.

[4] C. A. Barber, Studies in Root-Parasitism, Mem. Dept. Agric., Bot. Ser., vol. i, No. 1, pt. i, January 1906, and pt. ii, July 1907.

finer rootlets are covered with short root hairs, although these are usually too minute to be seen with an ordinary hand-lens. Certain of the rootlets develop small haustoria, also covered with root hairs, as if the plant felt its need of some outside assistance. Seedlings grown in pure sand are light green in colour, and although perfectly formed, are not well nourished.

2. Seedlings grown in a mixture of sand and vegetable mould, without hosts, assume a darker colour and a more healthy appearance. There is comparatively little branching in the root-system; the roots are thicker, as in the case of humus-loving plants, and there are fewer root hairs. In the specimens grown the roots were unhealthy, the rootlets dying quickly, and there was a remarkable absence of haustoria. The healthier appearance of the seedlings as compared with those grown in pure sand would indicate that a certain amount of nutriment is derived from the richer soil, apart from what is derived from the swollen hypocotyl. The unhealthy root-system indicates that it is doubtful if the raising of sandal seedlings in vegetable mould by itself is a wise practice.

3. Seedlings grown in pots with well-established plants of other species growing in them had a root-system differing little from that of the mature plant in nature. They varied greatly in the number of root-attachments formed, and, what is of importance, the number of attachments seemed to depend on the species of plant with which they were grown; thus there were no attachments in a pot full of roots of *Livistona* palm, while seedlings only a few months old had formed numerous attachments when grown with *Pterospermum Heyneanum, Tecoma stans, Casuarina equisetifolia*, and certain other species.

4. The presence or even nearness of foreign roots is not necessary for the development of haustoria on sandal roots, and haustoria will even attach themselves firmly to small pebbles. When a rootlet commences to form haustoria it usually does so in many places, so that rows of these are met with on certain roots, while others have none.

5. Seedlings grown in pure sand without the aid of a host have survived for over a year.

6. The haustoria on the roots of sandal seedlings arise from the external layers of the rootlet, unlike the lateral rootlets, which are formed deep in its tissues. If no host is met with it is probable that the haustorium remains small and ultimately withers away, but if a foreign rootlet is met with it grows rapidly, attaching itself closely to the rootlet and developing into a mass of white tissue, at first club-shaped, but later on adapting itself to and enfolding the surface of the root attacked, becoming elongated through the growth in length of the latter and assuming more or less the shape of a flattened bell. The usual dimensions of a fully developed haustorium are: height, 3–10 mm.; longer diameter, 2–12 mm.; shorter diameter, 2–8 mm. The formation of haustoria is more or less confined to the younger roots; the main roots, although clothed with large haustoria, probably take little part in the absorption of nutriment. The white cushion-like haustoria are exhibited in Fig. 302, *g*.

Since Dr. Barber drew attention to the importance of this question, others have recorded the results of their observations, chiefly as regards the extent of root-parasitism exhibited and the species found to be most suitable as host-plants. In a series of experiments commenced in 1905–6, Rao Sahib M. Rama Rao found that sandal seedlings were incapable of growing beyond a year at the most unless nourished by attachment to the roots of other plants, without which they turned pale, withered, and died within a year of germination.[1] He also confirmed Dr. Barber's conclusions as to the selective habit of sandal in relation to its hosts, and found that although the sandal plant may attack the roots of almost any other plant, it shows a decided preference for and grows best in the company of certain species; of species selected for experiment, *Pongamia glabra* and cotton (*Gossypium arboreum*) proved the most favourable, *Albizzia Lebbek* coming next, *Cleistanthus collinus* next, and teak (*Tectona grandis*) next.

Various observations regarding the species which act as hosts to the sandal tree have been recorded from time to time within recent years. Barber[2] in 1907 gave a list of 122 sandal hosts. Rama Rao[3] has dealt in some detail with the subject in his paper on *The Host Plants of the Sandal Tree.* He points out that the sandal has been found to attack the roots of almost all species with which it comes in contact, though in very varying degree; it has also been found to form root-attachments with other sandal plants. As regards the suitability of various hosts, however, matters appear to be complicated by the fact that a species readily attacked in one locality may be sparingly attacked in another, and there are apparently other factors, such as the physical condition of the soil, which influence the degree to which the sandal attacks a given species. An exact classification of host plants according to their influence on the growth of the sandal would on this account alone seem to be difficult if not impossible, though the sandal does appear to show a decided preference for certain species. Rama Rao gives a list of 144 host plants observed and examined by himself and others, as well as 252 associates of the sandal in its natural habitat and elsewhere. Among good hosts included among the former may be mentioned *Acacia concinna*, *A. Intsia*, *A. Suma*, *Alangium Lamarckii*, *Albizzia Lebbek*, *A. odoratissima*, *Bambusa arundinacea*, *Casearia tomentosa*, *Cassia auriculata*, *Casuarina equisetifolia*, *Dalbergia Sissoo* (exotic), *Eucalyptus Globulus* (exotic), *Gossypium arboreum* (cotton), *Limonia acidissima*, *Mallotus philippinensis*, *Melia Azadirachta*, *Mimusops Elengi*, *Morinda citrifolia*, *Pongamia glabra*, *Thespesia populnea* (exotic), *Vitex Negundo*, *Wrightia tinctoria*, and *Zizyphus Oenoplia*. This list is far from exhaustive. In addition the lantana is freely attacked, but this troublesome weed can hardly be recommended for introduction as a host, especially while the question of its possible connexion with the spike disease of sandal remains unsettled.

The choice of nurses for sandal must necessarily be restricted to plants suitable for other reasons than the mere fact of their being good hosts; thus short-lived plants, such as many shrubs, would be unsuitable by themselves, as their disappearance would mean the death of the sandal, while hosts with heavy shady crowns would suppress it. From an economic point of view, again, a valuable species would form a more suitable host than one of little or no value, other conditions being equal.

[1] Ind. For. Records, vol. ii, pt. iii. [2] *loc. cit.*, pt. ii, app. I.
[3] Ind. For. Records, vol. ii, pt. iv, 1911.

Mr. C. C. Wilson [1] has given a list of 36 plants on which he has found sandal to be parasitic in South Vellore and North and South Salem. This list includes the two bamboos *Bambusa arundinacea* and *Dendrocalamus strictus*. Other writers had previously remarked on the favourable effect of bamboos on the growth of sandal. The chief objection to them, however, is the fact that they may flower and die at any time, and this in itself is sufficient to preclude their use as hosts ; but apart from this, experience in Coorg has shown that bamboos require constant cutting to prevent the suppression of the sandal, and when they die they are a source of danger from fire.

Silvicultural characters. In its early stages the tree is partial to shade, and thrives under cover of hedgerows and thickets of scrub ; in open country it has considerable power of pushing through scrub growth, and shows a tendency to free its head from the surrounding growth. Where there is an upper story of high forest, however, it rarely succeeds in pushing its way through the undergrowth. In its middle and later life it is intolerant of heavy overhead shade, but is often found growing under comparatively light cover. Although it forms a taproot most of its roots are surface feeders, and it produces long lateral roots not far below the surface of the ground ; these may reach a length of 100 ft. or more. Root-suckers are freely produced where the roots are exposed or cut through, or where the parent tree has been felled and the stump grubbed up. Young trees coppice fairly well ; older trees are said to have little or no coppicing power except on moist ground along the banks of watercourses ; but since trees large enough to produce heartwood are always grubbed up, observations as to their coppicing power are not very extensive.

Frost is unknown in the natural habitat of the sandal. It is sometimes killed by long-continued drought. It often suffers from bark scorching caused by insolation and possibly to some extent by wind. This form of damage takes place mainly on the south-west side, and is most prevalent on young trees which have grown up with surrounding cover and have been suddenly isolated. It commences with a cracking and peeling of the bark in thin strips, and later develops into a long, more or less triangular blister, often extending 3 or 4 ft. up the stem, while in bad cases the wood is exposed to a considerable extent, and death may result. The best protective measure is to retain side cover round the bole as long as possible.

The leaves are readily browsed by cattle, goats, and deer, particularly in the dry season when grass is scarce, and much damage is done, more especially by goats and deer, unless the plants are well surrounded by bushes and thorny growth ; the damage is often accentuated by the fact that graziers lop the tree to provide goat fodder. Cattle often nibble and rub the bark. The tree is extremely sensitive to fire, and may be killed outright or badly injured and rendered unsound : when the stems are killed new shoots are frequently sent up from the base. Mr. C. C. Wilson has advanced the theory that its susceptibility to damage by fire may be due in part to the fact that the roots bearing the haustoria themselves are killed by the heat and rendered incapable of performing their functions. The same theory may explain the fact sometimes observed that extremes of soil temperature are injurious to the sandal.

[1] Ind. Forester, xli (1915), p. 247.

Spike disease. 'Spike' is the name given to a diseased condition of the leaves and twigs of sandal. This disease, the origin and nature of which is as yet obscure, has for years past been the cause of immense mortality among sandal trees throughout a considerable extent of the natural sandal-bearing areas. The annual loss caused by spike disease for some years past in Mysore and Coorg has been estimated at 5 or 6 lakhs and 1 lakh of rupees respectively (1 lakh of rupees = £10,000 nominal). As far as is known the disease is of comparatively recent origin. The first account of it appears in a memorandum written in 1899 by Mr. C. D. McCarthy, then Deputy Conservator of Forests in Coorg, although it seems to have been generally noticed prior to this. Mr. McCarthy thus describes the appearance of the disease:

'The new shoots and leaves of a tree, instead of presenting the graceful appearance natural to the species, begin to grow out stiff and straight; the leaves also stand up stiff and erect like bristles, and as their arrangement is opposite and alternate, the shoot looks like a spike with four lines of erect leaves growing down it, something like a chimney brush. There is no discernible change in the new axis except that it grows out stiff and straight. As regards the leaves, in the first place the distance between the alternate pairs is greatly decreased, then the petiole and blade are from base to tip in one straight line, and lastly the blade is shorter, narrower, and more pointed. However, there is no sign of spot or sickness in the leaf substance. As the disease progresses the new leaves become still smaller, narrower, more pointed, and fewer each successive year, until the new shoots present the appearance of fine spikes bearing four rows of small bristles. After this the tree rapidly dies off. I have never seen recovery.'

Cases of recovery have, however, since been reported. Mr. McCarthy also notes the following additional characteristics: (1) spiked twigs appear at the commencement of the growing season, and affect the new shoots only; there is no change in the leaves or branches which existed prior to the appearance of the abnormal growth; (2) the abnormal branches never flower and fruit, although the rest of the tree may be normal in this respect and may bear flowers and fruits; (3) root-suckers from a spiked tree are invariably spiked also (Dr. Barber, however, subsequently found an apparently healthy tree every root-sucker from which was spiked); (4) the growth of spiked twigs is far more active than that of normal twigs, the growing point remaining active long after the normal shoots have completed their annual growth, and there being little or no mark of separation between the successive annual flushes, so that it is difficult to determine the length of time a tree has been attacked.

The appearance of a spiked twig side by side with a normal twig is shown in Fig. 301.

Some years ago the spike disease was the subject of brief investigations by Drs. Barber and Butler; the former issued his report on July 24, 1902,[1] and the latter on February 27, 1903.[2] Among other characteristics Dr. Barber noted the occurrence of phyllody, a peculiarity usually due either to excess of nutrition or to the stimulation of a parasite, though in this case neither of these causes was revealed. From a microscopic examination he also brought to light the significant fact that the tissues of the diseased branches were loaded with an excess of starch, and Dr. Butler found a similar excess of starch in

[1] Ind. Forester, xxix (1903), p. 21. [2] *Ibid.*, App. series.

the internal tissues of affected leaves. This accumulation of starch, as Dr. Butler points out, is due to forced carbon-assimilation, by reason of which the tree or some isolated branches of it suddenly proceed to manufacture starch out of all proportion to the demand for it, with the result that growth is forced, the tree gets no rest, and dies of exhaustion, the result of starch poisoning. The cause of this intensified carbon-assimilation, however, remained untraced.

Neither Dr. Barber nor Dr. Butler were able to find any trace of a parasitic disease, both attributing the disease to physiological changes. An examination of the root-system made by Dr. Barber revealed the fact that in diseased trees the root extremities were invariably dead and rotten, while their haustoria were absent or dead. He concluded, therefore, that there were strong grounds for assuming that the disease is communicable through the roots, an assumption strengthened by the fact that when it appears in a locality it tends to spread progressively from tree to tree. For the same reason Dr. Butler concluded that spike is a definite and communicable disease, of which the virus spreads from root to root, and that injury by fire might be a predisposing cause to this as to other diseases. He made a large number of inoculations with different parts of the diseased tissues, but these all failed to communicate the disease to healthy parts.

Various observations on the occurrence of the disease and theories as to its origin have been recorded from time to time, and the Mysore Government some years ago offered a handsome reward to the discoverer of its true origin and of an effective and practicable remedy for it, but the reward has never been earned. There is one point on which observers appear to be generally agreed, namely, that the disease is particularly prevalent in lantana-infested localities, though the connexion of the two has not been definitely determined. The disease is not, however, by any means confined to lantana-infested tracts, and has been noticed in localities where there is no lantana present. Rao Sahib M. Rama Rao[1] has advanced a theory to account for the connexion between lantana and spike disease. He suggests that in a lantana-infested area where the sandal has to rely mainly or entirely on the lantana as a host plant, the root-system of the latter becomes weakened by the demands of the sandal, and the latter in turn suffers, its root-ends and haustoria dying off. The process of assimilation by its leaves, however, continues, starch being formed which cannot be converted into tissue-forming material since the supply of water and salts from the roots is cut off, and the plant eventually dies, since fresh adventitious roots are rarely if ever formed from the older parts of the root-system. In this case fire would accentuate the exhaustion and decay of the lantana and sandal roots.

Experiments carried out since 1911 in demarcated plots in badly affected areas in Coorg have shown that the uprooting of lantana is followed by a very considerable decrease in the percentage of trees attacked. In the same province an experiment has been in progress to test the effect of digging trenches round healthy trees in the vicinity of diseased trees. This appears to have been effective to a considerable extent, and seems to strengthen the assumption that the disease is communicated through the roots.

Although he recognized that the question of treatment of the disease is

[1] Ind. Forester, xxx (1904), p. 56.

difficult in the absence of any precise knowledge of its nature, Dr. Butler in 1903 suggested two measures based on the assumption that the disease is an infectious or contagious one, communicable through the roots, namely, (1) to make a complete clearing of trees in a strip at least 100 yds. wide round all affected areas, and (2) to uproot all spiked trees as soon as the disease appears, utilizing any saleable material and burning all the refuse.

The policy of uprooting all affected trees has been pursued steadily in Coorg, and up to 1915 about 340,000 trees, chiefly immature, had been uprooted in that province; the disease, however, continued to make headway, and in 1916 it was found to have spread across what had hitherto been regarded as its northern limit.

An important contribution to the literature on spike disease was furnished by Dr. L. C. Coleman in 1917, with the publication of the results of detailed investigations carried out in Mysore.[1] Dr. Coleman's experiments showed that the disease can be communicated by grafting diseased scions on to originally healthy stock. They also showed that some time elapses before the disease appears outwardly, although there is always internal evidence of it in the shape of starch formation before its outward appearance; the disease starts nearest the point of grafting and spreads outwards, extending to the roots and causing the death of the root extremities and haustoria. Dr. Coleman thus concluded that spike is not primarily a root disease, since it can be communicated to the roots from infection above ground; it has not yet been determined if it can be communicated from root to root. Dr. Coleman further concluded that as there is no evidence of fungus or insect attack the disease, which is an infectious one, is in all probability produced by a virus whose active principle is an ultra-microscopic organism. Experiments in injecting filtered extracts made by macerating in distilled water fresh spiked leaves and twigs, in order to ascertain if the organism or virus could be transmitted in this way, gave negative results, all the trees inoculated remaining healthy. It may be noted that other species besides sandal are attacked by spike disease, notably *Zizyphus Oenoplia*, and Dr. Coleman has demonstrated the communicability of the disease, by grafting, in the case of this plant as well as of *Stachytarpheta indica*. Dr. Butler had previously recognized the analogy of spike to certain obscure plant diseases, notably the disease known in America as peach yellows, and this view Dr. Coleman corroborates. Other diseases bearing some resemblance to spike are peach rosette, the mosaic disease of tobacco, and the leaf roll disease of potatoes.

The question of the method of communication of the disease is still obscure. In the case of trees in root contact, Dr. Coleman considers that it is most probably communicated through the roots, but this does not explain how spike suddenly appears in isolated situations. He suggests the possibility of spread through diseased seeds carried by birds or otherwise, through the agency of insects, particularly sucking insects, as carriers of the virus, or by infection from other plants attacked by a similar disease. This question is being further investigated.

A theory recently propounded by Mr. R. S. Hole, as a result of field investigations in Coorg and garden experiments at Dehra Dun, attributes

[1] Spike Disease of Sandal, Dept. of Agric., Mysore State, Mycol. Ser., Bull. No. 3, 1917.

spike to quite a different cause from that to which Dr. Coleman attributes it. The theory advanced by him in a note published in October 1917[1] is to the effect that the diseased condition known as spike is not due to a specific parasitic organism or virus, but that it is merely a pathological condition due to an unbalanced circulation of sap which may be caused by a number of different factors, which are able to reduce the quantity of water supplied to the leaf surface. Unbalanced sap circulation is caused by the gradual reduction of the water-supply below that which is required for a balanced circulation, and this results in an accumulation of carbohydrates such as starch in the leaves and twigs, which gradually cuts off the food supply necessary for the health of the roots. Four factors in particular have been observed to be the apparent primary causes of unbalanced sap circulation resulting in spike, namely fire, death or damage to hosts, partial suppression by lantana or other growth, and the exposure of trees hitherto growing under shade. Additional factors which, it is considered, will probably be found to be responsible in at least some cases are drought, bad soil-aeration, and damage by insects.

As regards Dr. Coleman's grafting experiments, Mr. Hole contends that the results may be explained otherwise than by assuming the existence of a virus or organism, namely, by the transference of starch—after conversion to soluble sugars by the enzymatic activity of the stock—from the scion to the stock, and its subsequent deposition in the tissues of the latter in the form of an excess of starch owing to weakened enzymatic activity caused by this transference.

It is admitted that this theory requires proof, and steps are being taken to carry out a series of careful experiments to test it. In anticipation of proof, the chief measures necessary to prevent spike are indicated, on the basis of the theory, to be (1) fire-protection, (2) elimination of lantana by uprooting, (3) maintenance of good host plants and avoidance of severe damage to them, (4) provision of free and natural expansion of the crown of sandal plants from early youth, (5) careful and gradual freeing of trees which are more or less suppressed, (6) provision of light side shade to avoid damage from drought and sun-scorch, with free overhead light except in dry localities, (7) prevention of heavy growth of grass and herbaceous plants, which are bad hosts, (8) prevention of compacting of the surface of heavy soil by grazing.

Much experimental work remains to be done on the basis of the theories advanced by Dr. Coleman and Mr. Hole respectively, before any definite conclusions can be reached as to the primary cause of spike disease and the measures necessary for preventing or eradicating it. But the importance of investigating the disease from every possible standpoint is fully realized, and every facility is being given to those concerned in the investigations. Definite results, however, are still awaited.

Natural reproduction. Natural sandal seedlings are to be found mainly under bushes, hedgerows, and scrub, and not as a rule in the open. This is due not only to the fact that birds settle in such growth and drop the seeds, but also to the fact that the seedlings require protection, on the one hand from excessive drought and the heat of the sun, and on the other from

[1] Ind. Forester, xliii (1917), p. 429.

browsing animals ; this protection they receive under cover of bushes and hedgerows, particularly of thorny species. Seedlings perish in large numbers if exposed to excessive drought or to a hot sun, while on the other hand soil moisture, if not excessive, is an important factor, as may be seen from the manner in which sandal often reproduces itself along the banks of streams. In dry localities seedlings which have not perished altogether have been observed to die back to ground-level for a year or two and eventually to establish themselves. Damping off of seedlings owing to an excessive amount of dense wet herbaceous undergrowth is in some situations a hindrance to reproduction.

Natural seedlings suffer much in their earlier stages from the attacks of rats, while hares also seek them out readily ; as the plants grow larger, deer, goats, and cattle browse them eagerly if they are not protected by bushes.

Lantana acts as a good nurse to sandal in its early stages, and if the growth is not too dense the sandal is often able to make its way through it ; a dense growth of lantana, however, is sufficient to kill out any seedlings that may appear. The great risk of fire in lantana-infested areas is in itself so great a danger to sandal reproduction as to outweigh all advantages it may possess as a nurse.

Outside its natural habitat the tree often shows a marked tendency to spread naturally by the agency of birds. Thus in North Chanda, where it has been planted, the seed has spread from the plantations and natural reproduction is springing up on the shady banks of neighbouring streams. In the Poona district natural reproduction of sandal is in some places tending to replace *Acacia arabica* on riverside areas. In the red sanders plantation at Kodur in the Cuddapah district, Madras, formed in 1865, other trees, including sandalwood, were subsequently introduced ; from the seed of these trees sandal has since spread naturally over the whole area of the plantation. In the Narsingarh State, Central India, sandal originally planted in gardens has reproduced itself freely in the neighbourhood of wells and streams, where the soil is moist and there are shady thickets of trees and undergrowth. Near Ajmer in 1884 Mr. A. E. Lowrie [1] noted the presence of good natural reproduction of sandal under bushes on poor shallow soil, the seed having been spread by birds from a few trees planted in a garden several years previously.

ARTIFICIAL REPRODUCTION. Numerous plantations of sandal, dating from 1870 or perhaps earlier, have been formed in Mysore, Coorg, North Coimbatore, and the Nilgiris, some by transplanting from the nursery and others by dibbling or sowing *in situ.* The history of these is difficult to trace, but in the majority of cases failure is recorded. Often the plantations appear to have succeeded for the first ten years or longer, after which the plants became unhealthy and died off by degrees. A few plantations have proved moderately successful. Various reasons have been given for the numerous failures. In many cases failure must have been due to the fact that the parasitic nature of the sandal was insufficiently realized, for there are various records of transplanting as well as of direct sowing being carried out in open glades or clearings where no host

[1] Ind. Forester, x (1884), p. 261.

plants were available, and such operations invariably resulted in failure. Again, during cleaning operations the complete removal of the surrounding scrub growth has resulted in the death of the sandal; at the time death was attributed to the sudden exposure of the plants, but it was no doubt due also, if not altogether, to the removal of the host plants. Other plantations appear to have failed for want of attention, having suffered much from browsing by deer and other animals, from suppression by climbers, lantana, and other vegetation, and in some cases even from fire and from lopping.

Transplanting from the nursery was the chief method of creating plantations in the early days. This was quite successful provided care was taken, but as a rule it proved very costly. It was usually found necessary to transplant in baskets or bamboo or tile cylinders owing to the sensitiveness of the seedling to damage to the root-system. More recent experiments have shown that it is advisable to raise host plants along with the sandal, seeds of both being sown in the cylinders, rather than to raise the sandal seedlings alone and to trust to their finding their own hosts after being transplanted. The seed should be sown in the cylinders about February–March, and the plants put out in the rainy season when about 3–6 in. high; large plants are transplanted at greater risk, owing to the danger of disturbing their root-attachments. Germination usually takes place about 1–3 months after sowing; some seed sown in a pot in September at Dehra Dun did not germinate until the following June.

It is now many years since transplanting on a large scale has been abandoned in favour of dibbling *in situ*; the latter has in many instances proved very successful, and is much cheaper than transplanting. Care is always necessary to dibble underneath bushes. One of the chief dangers is the damage done by rats, and in Coorg Mr. H. Tireman has found it advisable to disturb the ground as little as possible during dibbling, in order not to attract these animals. The seed is pressed into the ground with the thumb as soon as the soil has been softened by the early showers preceding the monsoon, the earlier the better. By dibbling underneath bushes in this way he has succeeded in stocking considerable areas successfully, the cost, after preliminary experience had been bought, amounting to about Rs. 15 per acre; it is proposed to continue similar operations in future at the rate of 150 to 200 acres a year.

The question of selecting suitable nurses in connexion with the artificial reproduction of sandal has already been alluded to, and it has been mentioned that care is necessary to select species which are likely to survive until the sandal attains maturity. Casuarina has proved an excellent nurse in the earlier stages, but, as Mr. Pigot notes,[1] it survives on the Mysore plateau for only about fifteen to twenty-five years, and the chances are that the sandal would die out with it.

Wherever deer or cattle are to be feared, the fencing of sandal plantations is necessary. Fire-protection is essential. The tending of plantations is dealt with in the next section.

SILVICULTURAL TREATMENT. The method of working the sandal tracts hitherto has been of a somewhat rough and ready nature, consisting of selection

[1] Ind. Forester, xxv (1899), p. 404.

or improvement fellings varying in detail. In some localities the spike disease has to a large extent controlled fellings by necessitating the removal of dead or affected trees as rapidly as possible. Some working plans have prescribed a minimum girth limit for sound trees ; in Coimbatore the limit has been fixed at 32 in. girth, and in Salem at 36 in. girth at breast-height. A recent working plan for the Javadi and Yelagiri hills [1] prescribes the removal of dead and dying trees only, sound trees which are capable of continuing to grow satisfactorily being retained. In this plan a short felling cycle, namely six years, has been adopted. In other plans the felling cycle varies from seven to thirteen years.

Reproduction is secured partly by natural means, the result of protection and tending to the extent possible, and partly by artificial means, dibbling under bushes being the method now in vogue. Protection from fire, and as far as possible from grazing and other forms of injury, is supplemented by tending operations whereby sandal plants, whether of natural or of artificial origin, are saved from suppression. In these tending operations care is necessary not to remove completely any scrub or trees which act as host plants, but merely to free the heads of the sandal plants where they are in danger of suppression. Climbers are also systematically cut.

In the absence of accurate knowledge regarding the nature of the spike disease and the means necessary to counteract it, it is difficult to devise any special system of management for the sandal other than the somewhat rough method of selection hitherto in force, and in the meantime, provided measures are taken to ensure adequate reproduction, it is doubtful if this method of working could be much improved on.

Trees which are felled are uprooted, all but the smaller roots being dug up ; the larger roots yield an appreciable amount of scented wood. Stringent rules are framed to prevent the theft of this valuable wood during felling and subsequent transport of the material to the sale dépôts.

Rate of growth. The visibility of the concentric rings varies greatly. On some specimens they are quite indistinguishable, while on others they are distinguishable in varying degree. In 1917 and 1918 I had an opportunity of examining nine sections from Coorg and 39 sections from Mysore, cut at a height of 6 in. from ground-level from trees in plantations of known age. It was found that in some cases the rings were fairly distinct on a dry smooth surface : water usually made them more distinct, and black coffee had a similar effect, but aniline dye obscured them. The following were the general conclusions reached after examining the 48 sections in question :

1. The concentric rings, where distinguishable, were almost certainly annual, since they corresponded more or less to the known rate of growth on that part of the radius on which they were clearly visible.

2. The specimens were obtained from different localities and types of soil and from trees of various ages and rates of growth ; these factors did not appear to have any decided effect on the clearness of the rings, though in very slow-grown specimens the rings were so close together as to be more difficult to distinguish than in the case of fast-grown specimens. On the sapwood the rings were usually, but not always, more distinct than on the heartwood.

[1] Working Plan for the Javadi and Yelagiri Hills, C. C. Wilson, 1916.

3. In only one case did the number of rings counted coincide with the correct age of the section ; as a rule it fell far short of it, and frequently a recount gave a different result from the original counting, owing to the indistinctness of the rings. On some of the sections it was impossible to form even a rough estimate of the rate of growth, hardly any of the rings being visible. In the case of 33 of the Mysore sections, in which the rings were sufficiently clear but the number counted fell short of the correct age, this discrepancy amounted to twelve years for an average correct age of thirty-seven years, representing a discrepancy of 32 per cent.

4. So far as the specimens examined are concerned, and they are representative of varying conditions, the only conclusion to be drawn is that ring-countings cannot be relied on to give anything approaching an accurate estimate of the rate of growth except in occasional individual cases.

Statistics regarding the rate of growth of sandal are not as complete as they might be. The following measurements of planted trees of known age may be quoted :

1. Bylur plantation, North Coimbatore, measurements made in 1894 and recorded by Mr. P. M. Lushington,[1] but considered by him to be above the average.

Santalum album : rate of growth in plantations, Bylur, N. Coimbatore.

Age. years.	Mean height. ft.	Mean girth. in.	Age. years.	Mean height. ft.	Mean girth. in.
16	12	9	21	14	11
17	13	10	22	14	11
18	13·5	14	23	15	12
19	13	13	24	15·5	12
20	15	13	..	..	..

Other measurements recorded in the same plantation are—(*a*) age nineteen years, mean girth $9\frac{1}{3}$ in., mean bole $9\frac{1}{2}$ ft. ; (*b*) age twenty years, mean girth $12\frac{3}{4}$ in., mean bole $8\frac{1}{2}$ ft.

2. Mr. F. B. Dickinson [2] recorded trees planted at Fraserpet, Coorg, eighteen years old, 25 ft. high, 18 in. in girth, with heartwood about 2 in. in diameter.

3. Mr. A. E. Lowrie [3] recorded a tree near Ajmer on very poor rocky soil, occasionally watered, age eight years, height 12 ft., girth 9 in.

4. Mr. J. L. Pigot [4] states that he has measured trees up to 18 ft. high in seven years, the result of dibbling along with casuarina ; another tree similarly raised attained a height of 35 ft. and a girth of 18 in. in twelve years.

In 1917 Mr. Tireman furnished me with the following results of measurements of plantation-grown and natural trees in Coorg, which were measured in 1913 and remeasured in 1917 :

[1] Notes on the Sandal Tree in Southern India, 1900.
[2] Ind. Forester, ix (1883), p. 65.
[3] *Ibid.*, x (1884), p. 261.
[4] *Ibid.*, xxv (1899), p. 398.

Santalum album: rate of growth, Coorg.

Serial No.	Locality.	Elevation.	Rainfall (approximate).	Age at first measurement.	No. of trees measured.	Girth. 1913	Girth. 1917	Mean annual girth increment for 4 years' period.	Remarks.
		ft.	in.	years.		in.	in.	in.	
1	Kargode (plantation)	3,300	65	26	23	14·20 (mean)	15·64 (mean)	0·36	Plantations neglected for several years prior to first measurement, but tended subsequently.
2	Kattepura (plantation)	3,100	60 or less	16	37	9·05 (mean)	10·75 (mean)	0·42	
3	Mullur village (natural trees near Kargode plantation)	3,330	65	..	19	4 to 40	..	0·15	Not tended prior to 1913, when they were freed from suppressing shade.
4	Somwarpet (natural trees)	3,600	80	..	10	3 in. to 3 ft.	..	0·16	Trees growing on a grassy down, not cultivated.
					12	3 in. to 3 ft.	..	0·3	Trees growing in a neighbouring coffee garden, more or less cultivated.

The rate of growth deduced from measurements in 1918 in twenty plantations of known age in Mysore was as follows:

Santalum album: rate of growth in plantations, Mysore.

Age.	Mean girth.		Mean height.	Age.	Mean girth.		Mean height.
years.	ft.	in.	ft.	years.	ft.	in.	ft.
5	0	1·5	3·5	30	1	5	18
10	0	6	7	35	1	7	20·5
15	0	9·5	10	40	1	9	22·5
20	1	0	13	45	1	10·5	24·5
25	1	2·5	15·5	50	2	0	26·5

Perhaps the most exhaustive measurements based on ring-countings are those recorded by Mr. C. C. Wilson in the form of curves in the working plan for the Javadi and Yelagiri hills, 1916, of which the following is a summary:

Santalum album: rate of growth, Javadi and Yelagiri hills, based on ring-countings.

Age.	Mean height.	Mean diameter at 4 ft.	Mean volume per tree.	Age.	Mean height.	Mean diameter at 4 ft.	Mean volume per tree.
years.	ft.	in.	cub. ft.	years.	ft.	in.	cub. ft.
5	3·4	0·4	..	35	..	6·7	2·26
10	6·3	1·0	..	40	..	7·8	3·23
15	10·0	1·9	..	45		8·7	4·55
20	15·2	3·0	0·59	50		9·4	6·70
25	19·0	4·1	1·00	55		10·0	..
30	21·3	5·4	1·54	60		10·5	..

The following measurements recorded by Mr. P. M. Lushington, based on ring-countings on stumps of natural trees at Bylur, may be compared with the plantation measurements in the same locality given above:

Santalum album: rate of growth of naturally-grown trees, Bylur, N. Coimbatore.

Age.	Mean girth.	Age.	Mean girth.
years.	in.	years.	in.
9	4·75	26	16·25
17	7·25	32	21
20	12·5	..	..

At Bylur the growth was found to vary from 7 to 9¼ rings per inch of radius, and in the Bhavani *taluq* from 6½ to 7⅝ rings. These figures have formed the basis of rough working plans in North Coimbatore, under which the minimum girth at which sound trees may be felled was fixed at 32 in., corresponding to an estimated age of at least forty years.

Records of measurements in different localities show averages varying from 6½ to 10 rings per inch of radius for natural trees, giving mean annual girth increments varying from about 0·6 to 1 in. On the whole, therefore, the sandal may be regarded as a rather slow-growing tree, though its growth is fast compared with that of many of the scrub species associated with it.

The age of commercial maturity has been variously estimated at from forty to sixty or even sixty-five years, the lower age applying more particularly to plantations. These estimates, however, are very rough.

YIELD OF HEARTWOOD. As the heartwood alone is scented it is the only valuable portion of the tree. Mr. P. M. Lushington says it commences to form rapidly at about twenty years of age, and is at its prime between thirty and fifty years, when the trees vary from 2 to 3½ ft. in girth. Mr. Hutchins estimated that the average formation of heartwood per annum in Mysore up to the age of commercial maturity was about 0·15 cubic feet. Mr. Lushington gives the following outturn of cleaned heartwood from trees cut in 1898 in Punnachi, North Coimbatore :

Santalum album : outturn of heartwood, Punnachi, N. Coimbatore.

Girth class.	Number of trees.	Average weight of scented wood per tree.	Girth class.	Number of trees.	Average weight of scented wood per tree.
in.		lb.	in.		lb.
9–12	31	14	24–30	29	63
12–15	64	20	30–36	12	107
15–18	79	21	36–42	1	62
18–21	61	34	42–48	2	269
21–24	45	43			

Mr. C. C. Wilson, in his working plan for the Javadi and Yelagiri hills, gives the following outturn figures based on a number of measurements :

Santalum album : outturn of heartwood, Javadi and Yelagiri hills.

Girth of tree.	Weight of heartwood per tree. Quarters.	Equivalent in lb.	Girth of tree.	Weight of heartwood per tree. Quarters.	Equivalent in lb.
ft. in.			ft. in.		
2 0	4·4	123	4 0	25·9	725
2 6	7·8	218	4 6	30·7	860
3 0	11·5	322	5 0	34·3	960
3 6	18·7	524	5 6	38·0	1,064

Mr. Rama Rao [1] gives the following outturn figures collected in 1902–3 and 1903–4 from trees growing at different elevations on the Salem Javadis :

[1] Ind. Forester, xxx (1904), p. 251.

Santalum album : outturn of heartwood, Salem Javadis.

Girth class.	No. of trees.	Weight of heartwood per tree.	Girth class.	No. of trees.	Weight of heartwood per tree.
in.		lb.	in.		lb.
16–18	2	81	43–45	47	396
19–21	..	..	46–48	24	392
22–24	1	84	49–51	8	529
25–27	4	126	52–54	6	659
28–30	8	147	55–57	5	578
31–33	5	89	58–60	5	699
34–36	3	647	61–63	1	496
37–39	103	299	64–66	2	495·5
40–42	73	318			

The factors which govern the formation of heartwood and the yield of oil from heartwood produced under different conditions are as yet imperfectly understood. In 15 samples analysed by Puran Singh the oil value varied from 0·85 to 5 per cent.:[1] he notes that the range given by Gildmeister and Hoffman is 3 to 5 per cent., and that given by Parry is 1·5 to 6 per cent. The yield obtained in Europe is usually about 3 to 6 per cent., while in India the average yield is said to be about 2·5 per cent.; the Kanauj distillers in the United Provinces, however, are said to obtain about 5 to 6 per cent., and to regard wood yielding less than this as inferior.. The analyses carried out by Puran Singh showed generally that wood of trees grown on dry rocky ground is harder and richer in oil than that grown in fertile soils, though further analyses are necessary to decide this question definitely.

It was at one time held that scented heartwood is not formed at low elevations, and particularly near sea-level. Mr. P. M. Lushington quotes numerous figures of outturn exhibiting great variation even in the case of trees grown under apparently similar conditions; on the whole his statistics indicate that scented wood appears to form more quickly at the lower elevations, but to increase less in proportion to the growth of the tree than does that formed in trees grown at the higher elevations. The tests carried out by Puran Singh were not exhaustive enough to decide the question of elevation in its effect on the yield of oil.

That scented heartwood is produced at low elevations has been definitely established. Mr. F. B. Dickinson examined a tree at sea-level in a garden on the coast at Cannanore and found that it had heartwood as strongly scented as any grown at higher elevations. Mr. Rama Rao[2] records the results of an examination of a tree believed to be about thirty years old at sea-level at Pondicherry with moderately well developed scent; he mentions that near sea-level on deep soils, both rich and sandy, the development of scented heartwood appears to be much slower than in the natural habitat of the tree. He gives further instances of the formation of scented heartwood (1) at Quilon, at sea-level, (2) on the Thirumalai (Jasper hill) near Trivandrum, at 400 ft., (3) in the village of Navaikulam, near Attengal, at 200 ft.,[3] (4) at Kurnool, at 900 ft., and (5) at Vizagapatam at sea-level; in this case the scent was slight, owing probably to the fact that the tree was young and immature.[4] In

[1] Memorandum on the Oil Value of some Sandal Woods from Madras. For. Bull., No. 6, 1911.

[2] Ind. Forester, xxxiv (1908), p. 151.

[3] *Ibid.*, p. 715.

[4] *Ibid.*, xxxii (1906), p. 393.

none of these cases, however, was the percentage of oil determined by analysis.

The effect of host plants on the production of heartwood and oil, if they do influence it in any way, has never been studied; it is possible that such a study may reveal to some extent the cause of the variations in the production of heartwood and oil in the case of trees grown under similar conditions of locality.

ORDER LII. EUPHORBIACEAE

This order contains a large number of Indian woody species, but no timber trees of first-class importance. The best timber tree is perhaps *Bischoffia javanica*, while some are common accessory species, for instance *Mallotus philippinensis*, *Phyllanthus Emblica*, *Bridelia retusa*, and *Cleistanthus collinus*. The boxwood, *Buxus Wallichiana*, is valuable, but comparatively scarce. Of species favouring moist and even swampy ground may be mentioned *Bischoffia javanica* and *Trewia nudiflora*, while *Putranjiva Roxburghii* is found most typically on moist river alluvium. Of specialized xerophilous trees and shrubs some species of *Euphorbia* which have fleshy stems and grow on dry rocky ground are the most typical. Many species have poisonous properties in their milky juice, seeds, or fruits. Of trees of economic value by far the most important is the Para rubber tree, *Hevea brasiliensis*, now extensively grown in the East, including India and Burma. A somewhat less important exotic rubber tree, which grows well in some parts of India and Burma, is the Ceara rubber, *Manihot Glaziovii*. These two rubber trees are of interest rather to the planter than to the forester, and are therefore very briefly dealt with here.

Genera 1. Euphorbia, Linn.; 2. Bischoffia, Bl.; 3. Bridelia, Willd.; 4. Putranjiva, Wall.; 5. Phyllanthus, Linn.; 6. Cleistanthus, Hook. f.; 7. Buxus, Linn.; 8. Baccaurea, Lour.; 9. Mallotus, Lour.; 10. Trewia, Linn.; 11. Excaecaria, Linn.; 12. Sapium, P. Br.; 13. Macaranga, Thouars; 14. Croton, Linn.; 15. Jatropha, Linn.; 16. Hevea, Aubl.; 17. Manihot, Adans.

1. EUPHORBIA, Linn.

This genus, consisting chiefly of herbaceous plants, contains a few xerophilous shrubs or soft-wooded trees with fleshy branches and copious milky juice, characteristic mainly of dry localities, where they are sometimes useful for clothing dry rocky hill-sides and as nurses under which seedlings of other species obtain protection and are enabled to establish themselves. They grow from cuttings, pieces of the fleshy branches 1–2 ft. long striking readily: it has been found that cuttings grow best if planted in the hot season, not in the rains. Hedges can be easily formed in this way, while on dry hill-sides this form of propagation is also useful.

Species 1. *E. Nivulia*, Ham.; 2. *E. neriifolia*, Linn.; 3. *E. Royleana*, Boiss.; 4. *E. antiquorum*, Linn.

1. **Euphorbia Nivulia,** Ham. Vern. *Thor*, Hind.; *Sij*, Beng.; *Shasaung*, Burm.

A bushy tree 15–30 ft. high, with branchlets terete, not angular, usually whorled, and spirally or vertically arranged prickles. Bark thick and corky when old. Common on barren rocky ground in many parts of India and in the drier parts of Burma.

2. **Euphorbia neriifolia,** Linn. Vern. *Newrang*, Mar.; *Zizaung*, Burm.

A shrub or small tree up to 20 ft. high with sharp stipular thorns on tubercles arranged in vertical or spiral lines. Common on waste lands and near villages in India and Burma. Wild on poor rocky ground.

3. **Euphorbia Royleana,** Boiss. Vern. *Thor*, Hind.

A small tree attaining a height of 15 ft., with 5- to 7-angled branchlets. Common on the outer hot dry slopes of the western Himalaya, chiefly between 3,000 and 5,000 ft., where it is often gregarious (see Fig. 303). It is not browsed, and is often plentiful on grazed areas, the young plants springing up in abundance. It is frequently associated with *Pinus longifolia* where the latter is open enough to allow of its growth, for it is a strong light-demander.

4. **Euphorbia antiquorum,** Linn. Vern. *Tidhara-send*, Hind.; *Narsej*, Mar.; *Shasaung-pyathat*, Burm.

A small tree with jointed branches, 3- or sometimes 5-angled. Common in the drier forests throughout Burma, also in parts of the Indian Peninsula. Often cultivated for hedges.

2. BISCHOFFIA, Blume.

Bischoffia javanica, Bl. Vern. *Kaen, pankain, kot semla, irum, paniala, bhillar*, Hind.: *Uriám*, Ass.; *Gobra nerul, nilimara*, Kan.; *Thondi, milachittyan*, Tam.; *Pogaungsa, aukkyu, ye-padauk*, Burm.

A large deciduous or evergreen tree with a large shady crown and shining dark green trifoliate leaves. Bark dark grey, fairly smooth, inner cortex soft, juicy, and astringent. Wood red, durable, particularly under water, used for piles, bridge-construction, building, railway sleepers, and other purposes. Owing to the soft juicy astringent cortex the trees are sought after by tigers for the purpose of cleaning their claws, and in places where these animals abound the bark of the trees is often deeply scored with their claw-marks.

Distribution and habitat. Sub-Himalayan tract and outer valleys from the Ravi eastwards, rather scarce in the west, becoming common in the east, Assam, Chittagong, Burma, Chota Nagpur, and the Indian Peninsula. The tree is characteristic of moist shady ravines, river-banks, and swamps. In the western sub-Himalayan tract it is one of the species of the swamp forests, where it occurs with *Eugenia Jambolana, Trewia nudiflora, Ficus glomerata, Albizzia procera, Diospyros Embryopteris, Putranjiva Roxburghii*, and other species. In the eastern sub-Himalayan tract it is common in low-lying moist savannahs, along streams, and in swampy ground, but is also found in some quantity on sandy alluvium on drier savannah tracts along with *Bombax malabaricum, Terminalia Chebula, Dillenia pentagyna, Premna, Callicarpa*, and other species. In southern India it occurs in evergreen forests with *Vitex altissima, Mesua ferrea, Litsaea zeylanica, Heritiera Papilio*, and many other species, as well as in other moist types of forest. In the Western Ghats it is fairly common in evergreen forests.

FIG. 303. *Euphorbia Royleana* on the hot dry slopes of the outer Himalaya at 4,000 ft., Punjab.

Fig. 304. *Phyllanthus Emblica*, Dehra Dun

LEAF-SHEDDING, FLOWERING, AND FRUITING. In moist localities the tree is sometimes evergreen, but in drier situations it becomes leafless or nearly so for a short time during the cold season, the leaves turning red before falling; the new bright green leaves appear from January to March (northern India). The much-branched terminal panicles of minute flowers, which are unisexual and usually dioecious, appear from March to May. The fruits, in lax pendulous clusters, ripen from December to February. The tree sometimes fruits in great abundance, particularly in somewhat dry localities. The fruit (Fig. 305, *a*) is a brown 3- or 4-seeded globose berry 0·3–0·4 in. in diameter. The seeds (Fig. 305, *b*) are 0·15 in. long, trigonous with one rounded and two flat sides, light brown, smooth, with a hard testa and a thin papery albumen. About 2,600 seeds weigh 1 oz. Tests carried out at Dehra Dun showed a fertility of 50 per cent. for fresh seed, but seed kept for one year failed to germinate.

GERMINATION (Fig. 305, *c–h*). Epigeous. The radicle emerges from one end of the seed and quickly descends. The hypocotyl elongates by arching, and in straightening carries above ground the cotyledons enclosed in the testa and the thin albumen, which ultimately fall to the ground with the expansion of the cotyledons.

THE SEEDLING (Fig. 305).

Roots: primary root long, moderately thick, terete, tapering, whitish to light brown; lateral roots numerous, long, fine, fibrous, distributed down main root. *Hypocotyl* distinct from the root, 0·7–1 in. long, obscurely quadrangular, green, glabrous. *Cotyledons*: petiole 0·1 in. long or less, flattened, channelled above, glabrous; lamina 0·6–0·7 in. by 0·5–0·6 in., foliaceous, broadly elliptical or elliptical ovate or orbicular, entire, glabrous, venation pinnate reticulate. *Stem* erect, quadrangular, green or reddish, glabrous; internodes 0·2–0·5 in. long. *Leaves* alternate, at first several simple leaves, subsequent leaves trifoliate. Stipules up to 0·3 in. long, linear acuminate, slightly falcate, caducous. Simple leaves with petiole 0·4–2 in. long, channelled above, glabrous, lamina 0·9–4·5 in. by 0·8–3 in., elliptical or elliptical ovate, serrate to crenate, apex acute or acuminate, base acute or obtuse, sub-coriaceous, glabrous, shining, venation arched, lateral veins 3–7 pairs, young leaves light green, turning darker later.

The seedling develops satisfactorily only in very moist ground. Numerous experiments carried out at Dehra Dun have shown that shade is less essential than abundant moisture; in fact the best development has been secured in plots fully exposed to the sun, provided the soil is kept well saturated. If the soil is only moderately moist then shade is essential, otherwise germination fails, or if it does take place the seedlings speedily die of drought. Loose soil favours development. Young plants commence their new growth rather early in the season (February in Dehra Dun), and in frosty localities the young shoots are apt to be injured by late frosts. The seedlings are able to struggle through grass and weeds, but their development is hindered thereby; they are capable of standing a fair amount of shade. The following measurements in experimental plots at Dehra Dun give some indication of the rate of growth of seedlings under different conditions:

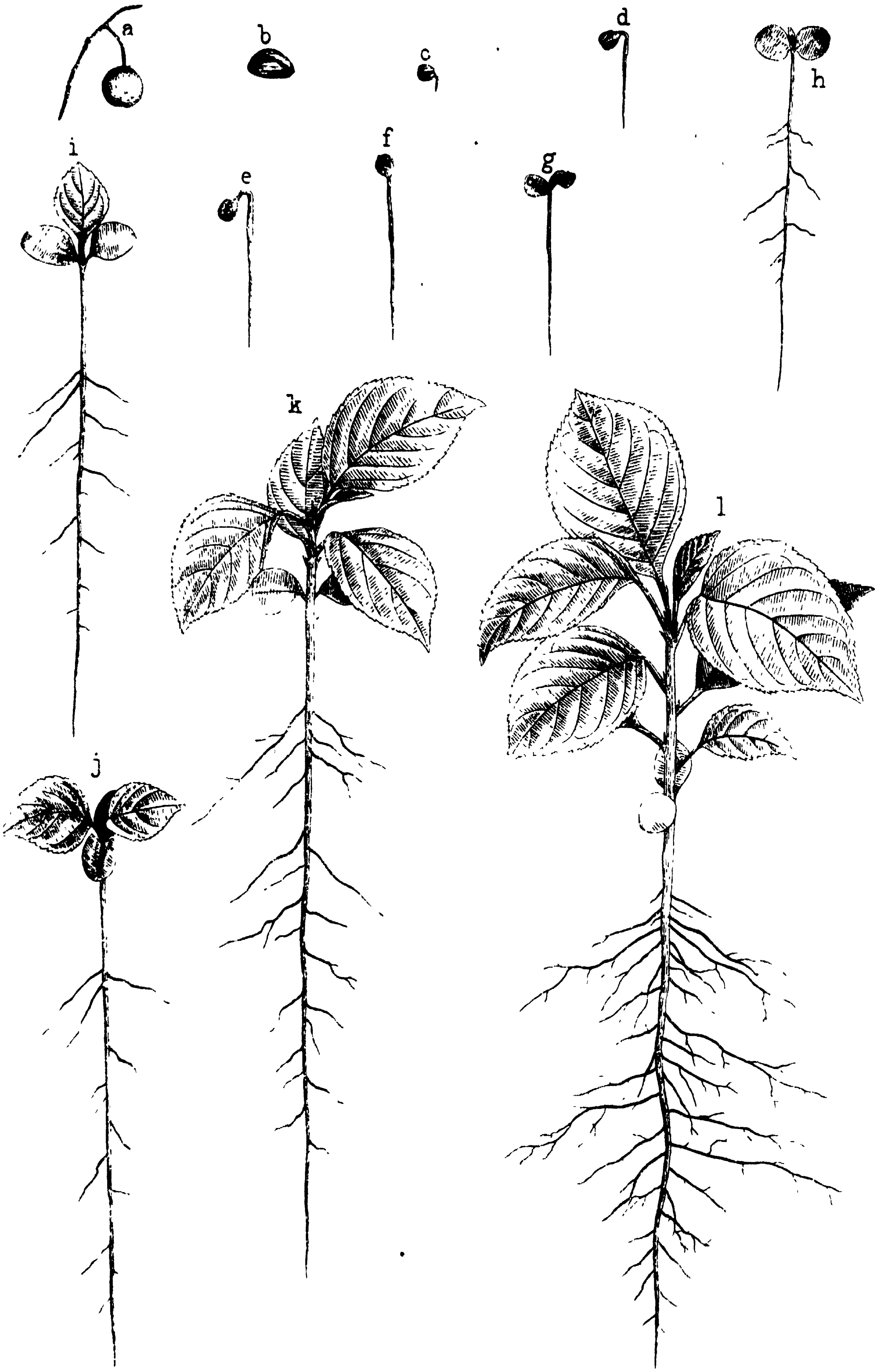


FIG. 305. *Bischoffia javanica*. Seedling.

a, fruit × $\frac{2}{3}$; *b*, seed × 2; *c–h*, germination stages × $\frac{2}{3}$; *j–l*, development of seedling to end of first season × $\frac{2}{3}$.

Bischoffia javanica: growth of seedlings, Dehra Dun.

Condition under which grown.	Height at end of season. 1st season.	2nd season.	3rd season.
Nursery plants, moderate shade and moisture	Maximum 1 ft. 2 in.	..	..
Natural conditions, shade, not very moist	0 ft. 2 in.–0 ft. 6 in.	..	..
Natural conditions, very moist, sunny, seed fallen on bare ground	0 ft. 3 in.–2 ft. 0 in.	..	Maximum 8 ft. 3 in.
Natural conditions, very moist, sunny, seed fallen in grass	0 ft. 3 in.–0 ft. 6 in.	..	..
Natural conditions, very moist, moderate shade, seed fallen on bare ground	0 ft. 4 in. and 0 ft. 8 in.	..	..
Natural conditions, very moist, moderate shade, seed fallen on grassy ground	0 ft. 3 in.–1 ft. 3 in.	..	..
Nursery-raised transplants	Maximum 1 ft. 0 in.	1 ft. 3 in.–3 ft. 0 in.	1 ft. 9 in.–5 ft. 11 in.

SILVICULTURAL CHARACTERS. The tree stands moderate shade. It thrives best in moist and even wet situations, though it is capable of growing on comparatively dry ground, provided it is watered in the earlier stages of its life. It resists ordinary frosts, but in the severe frost of 1905 it suffered severely in the sub-Himalayan tract. It has good coppicing power, producing vigorous shoots in abundance.

NATURAL REPRODUCTION. Numerous experimental plots were laid out at Dehra Dun to ascertain the conditions which favour natural reproduction. It was found that under natural conditions the seed germinated in very moist ground or under shade from April onwards, germination continuing into the rainy season. No germination was ever found to take place on dry ground in the sun, while if, as sometimes happened, seed germinated on dry ground under shade owing to the occurrence of heavy rain during the hot season, the seedlings invariably died of drought in the subsequent dry weather preceding the monsoon. On ground kept constantly saturated seed was found to germinate freely both in the shade and in the sun, the seedlings surviving in either case, though they died off under heavy shade. It was found to be of great advantage if the seed became covered with earth before germination, the percentage of success being considerably higher than in the case of seed germinating on the surface of the ground; in the alluvial or swampy ground on which this species thrives it is probably customary for much of the seed to become covered before it germinates. Bare loose ground also favours natural reproduction. In April seed was scattered evenly over two plots side by side, one with bare soil recently dug up and levelled and the other on grass-covered ground; both plots were exposed to the sun, and in either case the soil was kept constantly saturated. By the end of the year the plot with bare soil contained 78 seedlings 3 to 24 inches in height, while the grass-covered plot contained six seedlings 3 to 6 inches in height; by that time both plots were covered with grass. Next June the former plot contained a vigorous crop of plants up to 4 ft. 7 in. in height, while there were no surviving seedlings in the latter. The beneficial results of bare loose ground are probably due partly to the fact that the covering of the seed is facilitated, partly to the absence of competition with weeds during the early life of the seedlings; in the experimental plots in question, also, the development of the seedlings in the originally bare plot was no doubt greatly stimulated by the aeration of the soil owing to its having been dug up.

Artificial reproduction. Experiments at Dehra Dun have shown that direct sowing cannot always be relied on, though it has proved successful on saturated ground. Transplanting from the nursery proved quite successful. The best results were obtained by sowing the seed in porous soil in boxes kept under shade and copiously watered. Good results were also obtained by sowing in March in nursery beds of porous soil well dug up, the drills being about 9 inches apart, and the seed being lightly covered; germination began in two to three weeks, and continued for some time. It was found necessary to keep the beds shaded and to water them regularly and copiously, the soil being frequently loosened. Until the seedlings appeared above ground it was also found advantageous to cover the beds with straw in order to retain the moisture in the soil. The seedlings were transplanted without difficulty and with complete success during the first rainy season.

Rate of growth. The growth is fast, sometimes, according to Gamble, as fast as 4 rings per inch of radius, representing a mean annual girth increment of 1·57 in.

3. BRIDELIA, Willd.

About twelve Indian species of trees, shrubs, and climbers. The commonest and best known tree is *B. retusa*, Spreng., the other tree species being somewhat local. *B. stipularis*, Bl., is a common climber in the sub-Himalayan tract from the Ganges eastward and in various parts of the Indian Peninsula and Burma.

Bridelia retusa, Spreng. Syn. *Cluytia spinosa*, Willd. Vern. *Kaj*, *khaja*, *karka*, *kassi*, Hind.; *Asana*, *kutki*, Mar.; *Muljane*, Kan.; *Koramadi*, Tel.; *Mullu-maruthu*, Tam.; *Seikchi*, Burm.

A moderate-sized or large deciduous tree with variable coriaceous leaves with straight parallel lateral veins. Bark grey to dark brown, longitudinally cracked. Young trees often have the stems covered with strong spines. Wood grey to olive-brown, durable, used for house-posts, carts, cart-shafts, and agricultural implements. The bark is used for tanning, and the leaves for cattle-fodder.

Distribution and habitat. Throughout the greater part of India and Burma, but not in the driest parts of India; it extends into the dry zone of Burma. This is a common tree in mixed deciduous forests, though it is not gregarious; it is a common accessory species in sal forests. In some types of lower mixed forest in Burma it is so plentiful as to be almost gregarious in patches.

Leaf-shedding, flowering, and fruiting. The leaves are shed in the hot season, usually turning yellowish or reddish before falling; the new leaves appear about May–June, sometimes before the old ones have all fallen. The lateral clusters of small yellow monoecious or dioecious flowers appear from May to August, sometimes later, and the fruits ripen in January–February (northern India). The fruit (Fig. 306, *a*) is a globose fleshy sweetish drupe about the size of a pea, yellowish green turning purplish black when overripe, containing one or two pyrenes with fairly thick bony shells; about 450–500 pyrenes weigh 1 oz. Seed tested at Dehra Dun showed 75 per cent. of fertility. The seeds have a brownish papery testa. The fruits are greedily eaten by birds, especially green pigeons and also parrots and hornbills, and the seeds are spread by their agency.

GERMINATION (Fig. 306, *b–e*). Epigeous. The shell of the pyrene splits, the radicle emerging. The hypocotyl elongates by arching, and in straightening raises above ground the cotyledons enclosed in the testa, which falls to the ground with the expansion of the cotyledons.

THE SEEDLING (Fig. 306).

Roots: primary root moderately long and thick, terete, tapering; lateral roots moderate in number, long, fibrous. *Hypocotyl* distinct from root, 0·5–0·8 in. long, terete, tapering slightly upwards, pubescent. *Cotyledons*: petiole 0·05 in. long, pubescent; lamina 0·3–0·4 in. by 0·4–0·5 in., foliaceous, broadly obovate or sub-orbicular, apex truncate or emarginate, base obtuse or acute, entire, minutely pubescent. *Stem* erect, terete, wiry, pubescent; internodes 0·2–1 in. long in first season. *Leaves* simple, alternate. Stipules about 0·1 in. long, linear falcate, acuminate. Petiole 0·05–0·15 in. long. Lamina 0·3–1·5 in. by 0·25–1 in., elliptical or obovate, apex rounded, acute or obtuse, base acute, entire or obscurely crenate, glabrous or young leaves with pubescent margins, green above, glaucous beneath, venation pinnate, lateral veins 6–13 pairs.

The growth of the seedling is somewhat slow, a height of 3–6 in. being ordinarily attained in the first season in the case of nursery plants. Natural seedlings in the forest were found to reach a height of only 2–3 in. in the first season. By the end of the second season a height of 6–20 in. may be attained. At Dehra Dun the leaves of seedlings turn yellow and fall about December to February, new growth commencing in February–March. Natural seedlings with their leaves still present were found in February in Singhbhum, Chota Nagpur, and the early fall of the leaves at Dehra Dun is no doubt attributable to cold. The seedlings are somewhat sensitive to frost. They stand moderate shade well, but under heavy shade they may die off in a single season. They have good power of struggling through a moderate growth of grass and weeds, but their development is much impeded thereby.

SILVICULTURAL CHARACTERS. The tree stands moderate but not heavy shade. Its leaves are somewhat readily touched by frost, but it has good power of resisting permanent injury, and is often found as one among comparatively few survivors on grassy areas subject to frost. In the abnormal drought of 1907 and 1908 in the forests of Oudh it proved to be decidedly hardy. It coppices well, and produces root-suckers.

NATURAL REPRODUCTION. As already mentioned, the seed is spread by green pigeons and other birds. Some of it, however, falls round the parent trees and germinates there, the fleshy portion of the fruit drying up or becoming consumed by insects. Much of the seed is destroyed by rats, which break open the hard pyrenes. Under natural conditions germination commences early in the rainy season and continues to some extent throughout that season. Germination is favoured if the seed becomes buried during the early showers preceding the rainy season, or if it lies under moderate shade; seed lying on the surface of the ground exposed to the sun as a rule fails to germinate successfully.

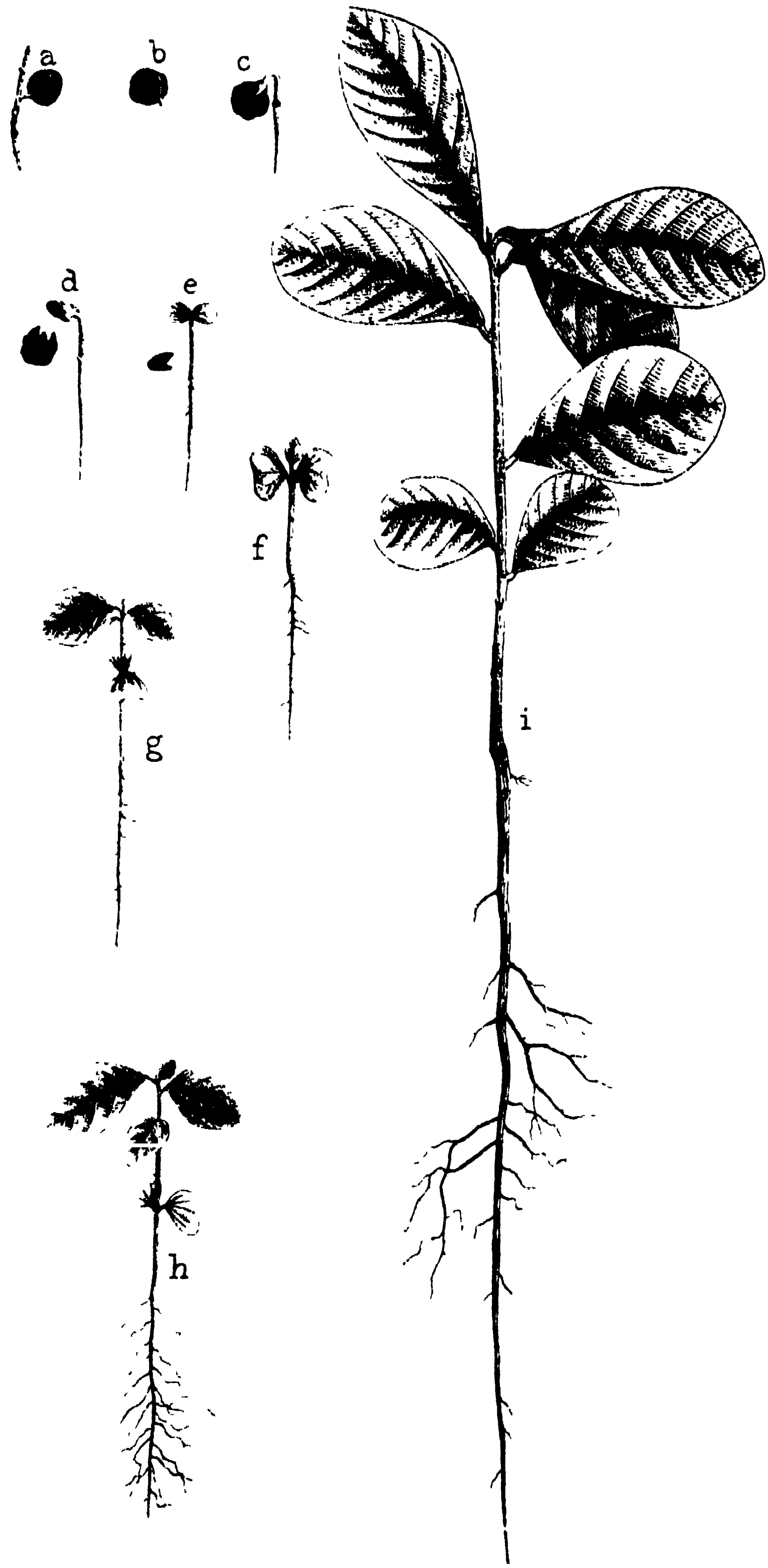


Fig. 306. *Bridelia retusa.* **Seedling × ½.**

***a*, fruit; *b–e*, germination stages; *f–h*, development of seedling during first season; *i*, seedling towards close of second season.**

Artificial reproduction. Seedlings can be most successfully raised in the nursery if the beds are kept shaded from the sun in the heat of the day and regularly watered. The seed should be sown about March, and the seedlings can be transplanted without much difficulty during the first rainy season. Transplanting in the second rains requires more care owing to the length of the taproot. Direct sowings have not been tried.

Rate of growth. The following girth increments have been obtained in periodically measured high forest sample plots in sal forest :

Bridelia retusa : girth increments in high forest sample plots.

Province.	Forest division.	Locality.	Number of trees under measurement.	Girth classes.	Mean annual girth increment (period not stated).
				ft.	in.
United Provinces	Lansdowne	Giwain	1	..	0·31
Central Provinces	Balaghat	Raigarh and Baihar ranges	3	1–2	0·15
			1	3–4	0·47

A cross-section in the silvicultural museum at Dehra Dun showed 96 rings for a girth of 5 ft., giving a mean annual girth increment of 0·62 in. Gamble gives the growth at about 5 to 6 rings per inch of radius, representing a mean annual girth increment of 1·05 to 1·26 in.

Coppice growth is fairly fast. Measurements of coppice-shoots one year old in the Bhandara district, Central Provinces, in 1912–13, gave a mean height of 6 ft. 9 in. for *Bridelia,* as compared with 7 ft. 1 in. for teak and 6 ft. 6 in. for *Terminalia tomentosa*. The following are the results of measurements made in 1911 in young coppice coupes in the Tikri forest, Gonda, United Provinces, the growth of *Bridelia* and sal being compared :

Bridelia retusa : coppice measurements, Gonda.

Age.	Mean height. *Bridelia retusa.*	Mean height. Sal.	Average number of shoots per stool. *Bridelia retusa.*	Average number of shoots per stool. Sal.
years.	ft.	ft.		
1	4·3	4·7	3	2·2
2	9·9	10·0	2·7	1·7
2	6·3	7·6	2	1·8

The following are the results of coppice measurements made in 1910 by Mr. C. M. McCrie in the Gorakhpur district, United Provinces :

Bridelia retusa : coppice measurements, Gorakhpur.

Age.	Mean height. *Bridelia retusa.*	Mean height. Sal.	Mean girth. *Bridelia retusa.*	Mean girth. Sal.
years.	ft.	ft.	in.	in.
2	3·0	3·0	—	..
4	6·7	7·0	1·7	2·0
6	9·6	10·3	2·7	2·9
8	12·0	13·0	3·7	3·8
10	14·2	15·3	4·7	4·8
12	16·2	17·5	5·7	5·8
14	17·8	19·2	6·6	6·7
16	19·0	20·9	7·5	7·5

4. PUTRANJIVA, Wall.

Putranjiva Roxburghii, Wall. Vern. *Jiaputa, putrajiva,* Hind.; *Putájan,* Pb.; *Karupale,* Tam.; *Kuduru,* Tel.; *Taukyat, badibyu, egayit,* Burm.

A moderate-sized graceful evergreen tree with drooping branches and glossy leaves with wavy margins. Bark grey, somewhat smooth, studded with lenticels, green inside. Wood close-grained, used for turning.

Distribution and habitat. Sub-Himalayan tract from the Ravi eastwards, Indian Peninsula and Burma, usually on alluvial ground along rivers, or in swamps or evergreen forests, but occasionally met with in rather stunted form in drier situations. Along rivers and in swamp forests in the sub-Himalayan tract it is sometimes gregarious. It is not infrequently planted for ornament, and requires a fairly moist fertile soil.

Flowering and fruiting. The flowers, which are dioecious, appear with the new leaves from March to May, the small yellow male flowers in axillary heads or short spikes and the green female flowers solitary or a few together. The fruit (Fig. 307, *a, b*), which ripens in January and February (northern India), is an ellipsoidal, obovoid, or nearly globose light grey tomentose drupe, 0·5–0·6 in. long, with a very hard pale yellow putamen almost filling it; the seed has a copious white albumen. About 40–50 fruit-stones weigh 1 oz. The drupe is normally 1-seeded, but is occasionally 2-seeded. The fruits are eaten by deer, the hard stones being disgorged during rumination and the seed being thus disseminated. The germinative power of the seed is somewhat uncertain; fertility is retained to some extent, however, for at least a year, tests with seeds one year old having shown 23 per cent. of success.

Germination (Fig. 307, *c–h*). Epigeous. The hard putamen dehisces and the radicle emerges from one end of the fruit-stone, descending and forming a taproot of some length before any upward growth takes place. The hypocotyl then elongates by arching, withdraws the cotyledons from within the putamen, and in straightening raises them above ground enclosed in the white albumen, which eventually falls to the ground as the cotyledons expand. Sometimes two seedlings appear from one fruit.

The seedling (Fig. 307).

Roots: primary root long, moderately thick, terete, tapering, whitish; lateral roots numerous, moderately long, fibrous, distributed down main root. *Hypocotyl* distinct from the root, 1·4–2·2 in. long, terete, fusiform or tapering upwards, yellow turning green, minutely tomentose. *Cotyledons*: petiole 0·1 in. long or less, minutely tomentose; lamina 0·8–1 in. by 0·6–0·8 in., foliaceous, cordate, entire, apex rounded, glabrous, 5-veined from the base, the central three veins more distinct than the lateral two; the cotyledons persist through part of the second season. *Stem* erect, terete, wiry, green, minutely pubescent; internodes 0·3–0·8 in. long. *Leaves* simple, alternate. Stipules minute, subulate, deciduous. Petiole 0·1–0·2 in. long, pubescent. Lamina 1·2–2·2 in. by 0·5–0·7 in., elliptical lanceolate, acute or acuminate, sharply serrate, bright green, shining, glabrous or with minute scattered hairs on lower surface.

The growth of the seedling is slow, a height of only 1 to 6 in. being attained by the end of the first season. Plants raised at Dehra Dun and kept regularly weeded and watered attained a height of 9 in., 4 ft., and 6 ft. by the end of the second, third, and fourth seasons respectively; under natural conditions the growth is probably slower. The seedling commences to form long side branches from about the second year. Young plants stand moderate shade, but become

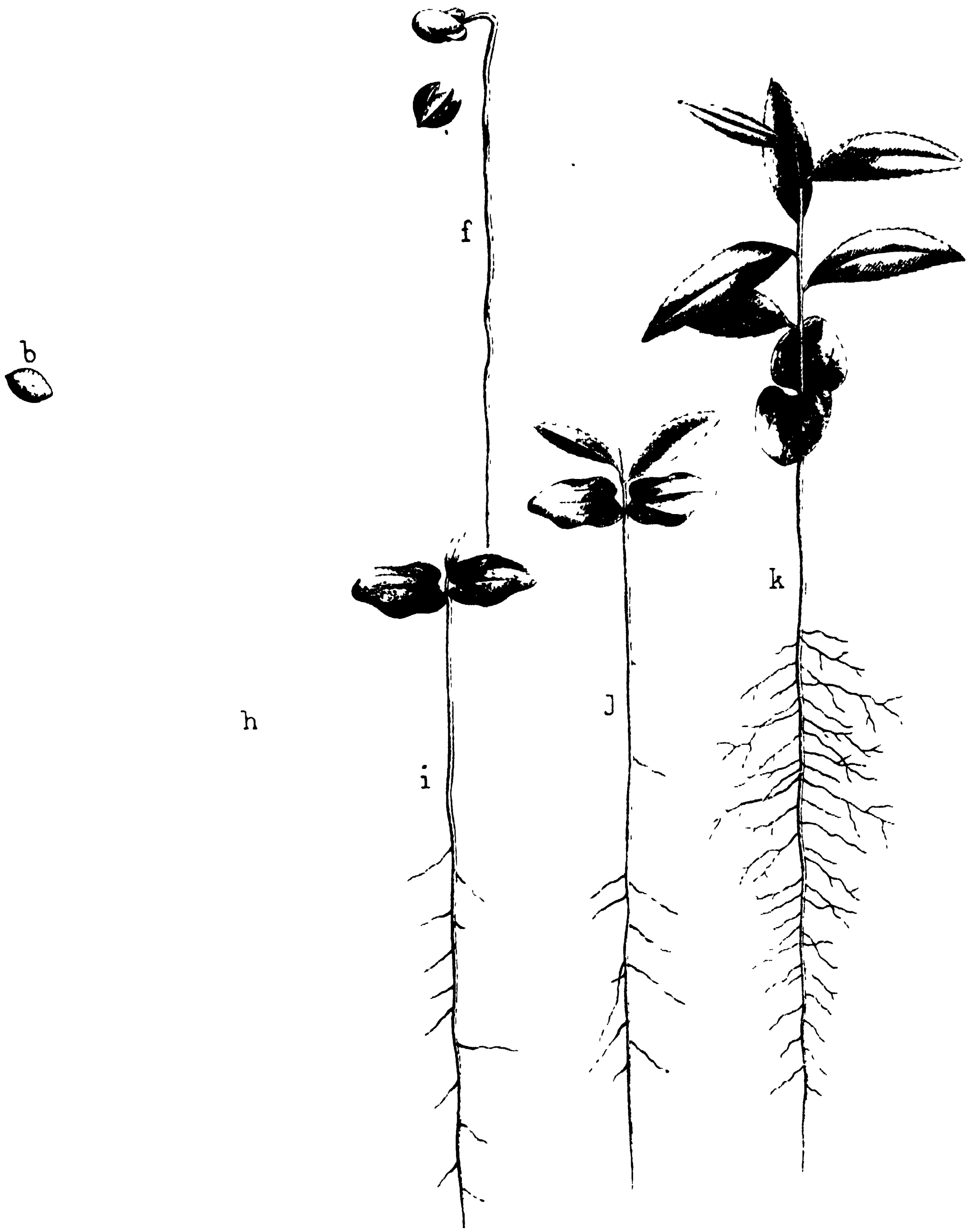


FIG. 307. *Putranjiva Roxburghii.* Seedling × ½.
a, fruit; *b*, endocarp; *c–h*, germination stages; *i–k*, development of seedling during first season.

suppressed and die off in dense shade; they are sensitive to frost and drought, particularly in the first two years. During and soon after germination the seedlings suffer from the attacks of crickets.

NATURAL REPRODUCTION. The fruits fall during the early part of the hot season. They are often deprived of their fleshy covering by deer, and the light yellow fruit-stones may be found lying where these animals have ruminated. Fruits which lie on the ground for some time often become deprived of their fleshy covering by white ants. Many of the fruits become wholly or partially buried by the action of rain, and this is of great advantage, since if the seed germinates on the surface of the ground the germinating seedling is apt to perish from drought before the root penetrates the soil. Germination takes place at various times during the rainy season, and numerous seedlings may often be found around and beneath the parent trees.

ARTIFICIAL REPRODUCTION. The fruit-stones should be sown in nursery-beds about April and lightly covered with earth, the beds being kept regularly watered and weeded. Germination takes place in six weeks to six months. Frosty localities should be avoided, but if frost is to be feared the seedlings should be protected during the first winter by a covering of thatch. The more vigorous plants will be ready for planting out the following year, when about a year old, while the less vigorous ones should be kept for another year in the nursery. Transplanting should be carried out during the rainy season, and the seedlings stand it well, provided care is taken not to injure the taproot, which is often of some considerable length.

5. PHYLLANTHUS, Linn.

A large genus of herbs, trees, or shrubs, mostly of little importance. *P. reticulatus*, Poir., is a large straggling or climbing shrub, common in many of the drier parts of India and Burma, especially on low moist ground near streams ; it occurs in the riverain forests along the Indus in Sind. By far the commonest tree of this genus is the following :

Phyllanthus Emblica, Linn. Syn. *Cicca Emblica*, Kurz ; *Emblica officinalis*, Gaertn. Vern. *Aonla, amla, amlika*, Hind. ; *Amli*, Pb. ; *Amluki*, Ass. ; *Nelli*, Tam. ; *Usiriki*, Tel. ; *Zibyu, tasha*, Burm. (Fig. 304.)

A moderate-sized deciduous tree with feathery light green foliage and small narrow linear leaves. Bark smooth, grey, exfoliating in irregular rounded scales, exposing the young yellow bark beneath ; there is a distinct chlorophyll layer immediately below the surface, beneath which is the soft red astringent cortex. Wood red, hard, apt to split, durable under water, used for agricultural implements, well-construction, and inferior building and furniture. The bark, leaves, and fruits are used for tanning, and the tree promises to become important as a yielder of tannin.

DISTRIBUTION AND HABITAT. Common in mixed deciduous forests throughout the greater part of India and Burma, ascending the Himalaya to 4,500 ft. Not common west of the Ravi, and not found in the arid regions.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves commence falling about November or December, and the trees are leafless from about February or March to March or April, when the new shoots appear. The twigs are frequently deciduous, falling with the leaves attached, the whole resembling compound pinnate leaves. The minute yellowish flowers, densely fascicled in the axils of the young leaves, appear from March to May, and are visited by swarms of bees. The fruits (Fig. 308, *a*), which ripen from November

FIG. 308. *Phyllanthus Emblica*—SEEDLING × $\frac{3}{4}$

a—Fruit. b—Hard endocarp. c—Endocarp splitting. d—Seed. e–h—Germination stages. i–k—Development of seedling during first season.

to February or sometimes later, are 0·5–0·8 in. in diameter, globose, yellowish green, smooth, fleshy, and very astringent, with a 6-ridged bony endocarp (Fig. 308, *b*, *c*) containing about four to six dark brown smooth 3-gonous seeds (Fig. 308, *d*), of which about 1,800 to 1,900 weigh 1 oz. The seeds may be extracted by placing the ripe fruits in the sun until the hard putamen dehisces and the seeds escape. Tests at Dehra Dun showed that the percentage of fertility is comparatively low, and that the seed does not retain its vitality long, seed kept for a year having failed to germinate.

GERMINATION (Fig. 308, *e*–*h*). Epigeous. The radicle emerges from the end of the seed and descends. The hypocotyl elongates by arching, and in straightening carries the cotyledons above ground. The testa is carried up over the cotyledons, falling with their expansion or frequently clinging for a time to the apex of one of them after they expand.

THE SEEDLING (Fig. 308).

Roots: primary root long, wiry, flexuose; lateral roots numerous, fibrous, distributed down main root. *Hypocotyl* distinct from root, 0·8–1 in. long, tapering upwards, pink or green turning light brown, glabrous or very finely pubescent in upper part. *Cotyledons*: petiole 0·04 in. long; lamina 0·4–0·6 in. by 0·2–0·3 in., elliptical or oblong, apex rounded, entire, foliaceous, green, glabrous. *Stem* erect, terete, wiry, reddish brown, minutely pubescent. *Leaves*, first 2–6 sub-opposite or alternate, very shortly petiolate, situated singly on main stem, 0·4–0·5 in. by 0·15–0·25 in., oblong, entire, mucronate, glabrescent or minutely pubescent; subsequent leaves distichously arranged on finely pubescent branchlets, sub-sessile, 0·2–0·4 in. by 0·05–0·1 in., linear oblong, entire, minutely mucronate, glabrous; stipules 0·04 in. long, linear falcate.

Under favourable conditions the growth of the seedling is rapid. At Dehra Dun seedlings on weeded but unwatered ground attained a maximum height in the first four years of 2 ft. 8 in., 7 ft., 9 ft. 7 in., and 16 ft. 6 in., the basal girth at the end of the fourth year being 7 in. Weeding greatly stimulates development, while the presence of weeds retards it, although after the seedlings have outgrown the weeds their growth is rapid. The maximum growth in unweeded plots during the first three years was 5 in., 3 ft. 8 in., and 9 ft. 10 in. Under natural conditions the growth is probably slower. The young plant is intolerant of shade or suppression of any kind, and when several young plants grow together one or two vigorous specimens quickly tend to take the lead and to suppress the remainder. In the first few months the seedlings are somewhat delicate; they are sensitive to drought, are apt to be washed away or beaten down by heavy rain, and are much subject to the attacks of insects, rats, and squirrels. Although the leaves are often touched by frost before falling, young plants do not appear to suffer permanently from ordinary frosts.

SILVICULTURAL CHARACTERS. *Phyllanthus Emblica* is a decided light-demander. It is sensitive both to frost and to drought. In severe frosts the fruit becomes whitish, with the appearance of having been boiled. In the Indian Peninsula it suffered much in the abnormal drought of 1899–1900 and in the dry years preceding 1913–14; many trees were killed outright, while a common form of injury was the formation of large cracks down the stem, the thin bark affording little protection against the sun.

The tree coppices well and pollards moderately well; coppice-shoots in particular grow vigorously. An experiment was carried out in North Chanda in 1909 in which the effect of coppicing in different months from April to September was tested. The percentage of stools which coppiced successfully was as follows: April, 100; May, 95; June, 90; July, 100; August, 100; September, 100.

NATURAL REPRODUCTION. Under natural conditions the fruits fall during the latter part of the cold season and a portion of the hot season. They lie on the ground until the fleshy covering dries up and the hard fruit-stones split open, which they do with some force, the seeds thus escaping. Germination takes place early in the rainy season. The fruits are eaten by deer, the hard stones being disgorged during rumination and afterwards dehiscing on the ground. Natural reproduction is seldom found in any great abundance; this is possibly due partly to the fact that the fertility of the seed is not high, but mainly perhaps to the sensitiveness of the seedling in its early stages and to its liability to insect attacks.

ARTIFICIAL REPRODUCTION. Seedlings have been raised successfully at Dehra Dun by sowing the seed in the nursery about March, watering regularly but sparingly and protecting the seedlings for the first few months from the sun and from heavy rain. If the beds are regularly weeded the seedlings should be large enough to plant out in the first rainy season, but care is necessary not to expose the roots, as the seedlings are somewhat sensitive to transplanting. Direct sowing has been tried on a small scale, but owing to the infertility of the seed gaps are apt to be frequent; the best results were obtained by sowing at the commencement of the rainy season and subsequently weeding regularly. Tolerably well stocked lines can be ensured by thinning out congested seedlings during the first rainy season and using the surplus plants for filling up gaps.

SILVICULTURAL TREATMENT. For the production of tan-bark, which is probably the chief use to which the tree will be put in future, coppice is the system indicated, though the best rotation remains to be ascertained. The concentration of supplies of bark over a limited area can be secured only by artificial reproduction.

RATE OF GROWTH. The growth of young plants, as already noted, is fairly rapid, but subsequent growth appears to be somewhat slow. In sample plots in the Balaghat district, Central Provinces, periodic measurements of nine trees 12 to 36 in. in girth showed a mean annual girth increment of only 0·15 in.

Ring-countings by Mr. D. A. Thomson in 1905, in respect of seven trees in the Supa fuel reserves in North Kanara, gave the following results:[1]

Phyllanthus Emblica: rate of growth, Supa fuel reserves.

Age.	Mean diameter.	Corresponding girth.	Age.	Mean diameter.	Corresponding girth.
years.	in.	ft. in.	years.	in.	ft. in.
5	1·05	0 3	30	6·11	1 7
10	2·12	0 6	35	7·12	1 10
15	3·06	0 9	40	8·06	2 1
20	4·11	1 1	45	8·76	2 3
25	5·10	1 4			

[1] Working Plan for the Supa Fuel Reserves, 1906.

A cross-section from the United Provinces in the silvicultural museum at Dehra Dun had 48 rings for a girth of 3 ft. 4 in., giving a mean annual girth increment of 0·83 in.

Coppice measurements made in 1910 by Mr. C. M. McCrie in the Gorakhpur district, United Provinces, gave the following results :

Phyllanthus Emblica : rate of growth of coppice, Gorakhpur.

Age. years.	Mean height. ft.	Mean girth. in.	Age. years.	Mean height. ft.	Mean girth. in.
2	4·7	1·4	10	12·0	4·6
4	7·7	2·6	12	12·7	5·0
6	9·6	3·5	14	13·1	5·3
8	10·9	4·2	16	13·3	5·6

Measurements of coppice-shoots one year old in the Bhandara district, Central Provinces, in 1912–13, showed an average height of 7·4 ft.

6. CLEISTANTHUS, Hook. f.

Cleistanthus collinus, Benth. Syn. *Lebidieropsis orbicularis,* Muell. Arg.; *Cluytia collina,* Roxb. Vern. *Garar, garari,* C.P.; *Korei, korshe,* Tel.; *Wodan,* Tam.

A small tree with orbicular obovate or broadly elliptical leaves, glaucous beneath. Bark dark brown, almost black, rough, exfoliating in small woody rectangular scales, red inside. Wood dark reddish brown, hard, durable, much used for house and fence posts.

Distribution and habitat. Common in many parts of the Indian Peninsula as far north as the Ganges river and Chota Nagpur, especially in the Singhbhum district. It is one of the commonest trees in some of the dry types of mixed forest, and thrives on dry rocky ground, where it often becomes more or less gregarious. In the Alapilli forest of South Chanda it attains 6 ft. in girth. In the Central Provinces it is frequently found on laterite, where it flourishes, particularly where the rock is decomposing.

Leaf-shedding, flowering, and fruiting. The tree is leafless in March–April. The small greenish flowers appear with the new leaves in April–May, sometimes also in September (Haines), and the fruits ripen the following March–April. The fruit is a globose, 3-valved, 3-seeded capsule, brown, shining, and woody when ripe, bursting open with an audible crack in the hot weather and scattering the seeds.

Silvicultural characters. The tree is very hardy and survives fire and grazing better than almost any other species; it is seldom browsed, and is said to be poisonous, on which account it is often the commonest species on grazed areas. Although it thrives in dry localities it suffered considerably in the abnormal drought of 1899–1900 in the Central Provinces. It produces root-suckers and coppices very well, though it often takes some time for one shoot to develop separately into a pole from the mass of shoots produced from the stool.

Artificial reproduction. The tree has been raised with success with the aid of field crops in Berar; vide C. G. Rogers's note in *Indian Forester,* vol. xxxvii (1911), p. 8.

RATE OF GROWTH. Measurements made in 1916 in the Saitba coppice coupes, Kolhan, Chota Nagpur, gave the following average growth :

Cleistanthus collinus : rate of growth in coppice coupes, Saitba.

Age. years.	Mean girth. in.	Mean height. ft.	Age. years.	Mean girth. in.	Mean height. ft.
2	1·6	4·5	10	6·8	17·7
4	3·2	9·0	12	7·7	20·0
6	4·5	12·0	14	8·5	22·2
8	5·8	15·0			

Measurements of coppice-shoots one year old, made in 1912–13 in the Bhandara district, Central Provinces, showed an average height of 6 ft. 11 in. for *Cleistanthus* as against 7 ft. 1 in. for teak, 6 ft. 6 in. for *Terminalia tomentosa*, and 6 ft. 4 in. for *Acacia Catechu*. Gamble gives the average growth as six rings per inch of radius, representing a mean annual girth increment of 1·05 in.

7. BUXUS, Linn.

Evergreen shrubs or trees with opposite coriaceous leaves. There are two distinct forms in India, the habits of which differ greatly. Brandis (*Indian Trees*) describes one species only, *B. sempervirens*, Linn., which is also the European species. Parker (*Forest Flora of the Punjab*) describes two separate species, *B. Wallichiana*, Baill., and *B. papillosa*, C. K. Schn. The habits of the two forms are so divergent that it will be necessary for our purpose to consider them separately. *B. Wallichiana* has leaves shining above, pale green beneath, the horns of the capsule spreading ; it grows in moist situations at elevations of 4,000 ft. and upwards. *B. papillosa* has leaves dull green above, pale or whitish beneath, longer and narrower than those of *B. Wallichiana*, the horns of the capsule erect ; it grows in dry situations below 4,000 ft., and if not a separate species, is at all events a marked xerophytic form of *B. Wallichiana* or *B. sempervirens*.

Species 1. *B. Wallichiana*, Baill. ; 2. *B. papillosa*, Schn.

1. **Buxus Wallichiana,** Baill. Syn. *B. sempervirens*, Linn. (in part). Box, boxwood. Vern. *Papri, shamshad, sansád, chikri*, W. Him.

An evergreen shrub or small tree with opposite coriaceous shining leaves, 1 to 2, or occasionally 3 in. long. Bark yellowish grey, corky, soft, cut into numerous small rectangular plates on old stems. Wood yellowish white, hard, very close and even grained, used for engraving, turning, carving, mathematical instruments, &c. In India it is much used for the manufacture of combs. Boxwood, which commands a high price, is well known in European markets. In unfavourable situations the box is a mere shrub, but under favourable conditions it reaches fair dimensions. Mr. Beadon Bryant, in his report on the boxwood forests of Kumaun and British Garhwal,[1] says he measured one tree with a girth of 86 in. at 5 ft. from the ground, and trees of 5 ft. in girth with a trunk of 25 ft. to the first branch and a total height of 40 to 50 ft. were often to be found ; many of the larger trees, however, were unsound, and the best size to cut he considers to be from 2 to 4 ft. in girth.

DISTRIBUTION AND HABITAT. In India the tree is found in the Western Himalaya, extending eastward to Nepal at elevations from 4,000 to 9,000 ft. ;

[1] Ind. Forester, xi (1885), p. 283.

also in Bhutan. Its occurrence in the Punjab and the United Provinces has been the subject of reports by Messrs. B. Ribbentrop [1] and F. Beadon Bryant,[2] and from these reports it would appear that its distribution is very local and not always easy to explain. In the Punjab Himalaya it occurs locally in Bashahr at 6,000 to 8,000 ft., in Kulu at about 7,500 ft., and in Chamba at about 6,500 ft. In 1885 Ribbentrop estimated the total area of boxwood in the Punjab at 1,387 acres, of which only a very small area contained pure box; this estimate included *B. papillosa*. The number of mature trees above 2 ft. in girth amounted to 7,047 in Bashahr, 520 in Kulu, and 140 in Chamba. Since these enumerations were made a considerable amount of boxwood appears to have been extracted from Bashahr, but the cost of extraction proved to be prohibitive.

In the United Provinces the tree occurs in Jaunsar, chiefly at about 7,000 ft., in Tehri Garhwal at about 8,000 ft., and in Kumaun and Garhwal at 7,000 to 9,000 ft., where, according to Mr. Bryant, it is rarely found far from the snowy range; and when quite close to the snows, although often plentiful, it is badly grown and of little value, probably owing to the heavy snowfall. He estimated the total number of trees in Kumaun and Garhwal in 1885 at 25,000, and on the assumption that a tree is fit to cut at eighty years, the annual outturn was estimated at 300 trees, giving, at an average of 3 cubic ft. per tree, 900 cubic ft.

In 1883 Mr. Hearle [3] noted that on the Jumna box forests probably occurred at one time in a continuous belt for 20 miles from Kotnur to Kharsali, the last village before the snows are reached, but only small isolated patches then remained, the rest having been cleared for cultivation. The elevation varied from 4,000 to 8,000 ft., but most of the box was found in a narrow belt along the lower edge of the forest between 6,000 and 7,000 ft.

In Bashahr the box occurs on shale and gneiss, in Chamba on mica schist, and in the Jumna valley on gneiss and mica schist. The essential conditions for its successful growth appear to be moisture and shelter, for it is characteristically found in moist sheltered ravines, and along the banks of perennial streams. It avoids hot aspects, and seeks northerly and north-westerly slopes. Although found pure or nearly so in patches, which may extend to several acres in area, it is frequently found associated with other species, such as oaks, maples, horse-chestnut, yew, walnut, holly, alder, spruce, &c., while on rich soil there is often a dense undergrowth of ferns, shrubs, and dwarf bamboo.

Silvicultural characters, &c. The tree is a shade-bearer, and often grows under a canopy of other species. If the shade is too dense, however, it becomes suppressed and the growth suffers. The leaves are poisonous to cattle, though goats eat them sparingly with impunity (Gamble). The tree regenerates freely in moist sheltered situations, but not in exposed places; seedlings often establish themselves under the shelter of rocks. The flowers, which are monoecious, appear from March to May, and the fruits ripen from June to August. The capsule is 0·4 to 0·5 in. long, broadly ovoid, 3-valved, with spreading horns, and the seeds are 0·25 in. long, 3-angled, oblong, with a black shining testa.

[1] Ind. Forester, xi (1885), p. 25. [2] *Ibid.*, p. 283. [3] *Ibid.*, ix (1883), p. 196.

ARTIFICIAL REPRODUCTION. The tree reproduces well from cuttings; Gamble mentions that it is extensively raised in this way for hedges in the Government cinchona estates on the Nilgiris, and suggests planting box for profit on northern aspects in those hills, where the nearness to the coast would make the sale of the wood more profitable than it is in the remoteness of the Himalaya.

According to Mian Moti Singh,[1] attempts to raise the tree from seed in nurseries in Bashahr had up to the time of writing always failed. This he attributes to the fact that the seed had been extracted from the capsules before sowing, and was therefore destroyed by frost; on the other hand, a quantity of capsules left in the corner of a field produced a dense crop of seedlings. He recommends sowing entire capsules, when thoroughly ripe, early in the rainy season. Possibly success might be attained by sheltering the nursery beds sufficiently, even if seeds are extracted from the capsules before sowing.

RATE OF GROWTH. The rate of growth is very slow. Gamble's specimens showed 14 (from the Shali hill) to 75 (from Kunawar) rings per inch of radius, and averaged 33½ rings. This represents a mean annual girth increment varying from 0·084 to 0·45 in. and averaging about 0·18 in. Taking 20 rings per inch as the rate, a diameter of 1 ft. would be reached in 120 years, which, as Gamble mentions, is probably a minimum. Brandis gives 15 to 20 rings per inch of radius, or a mean annual girth increment of 0·31 to 0·42 inch.

Ribbentrop gives the following results of ring-countings in different parts of the Punjab:

Buxus Wallichiana: rate of growth, Punjab.

Locality.	Average number of rings per inch.	Mean annual girth increment.	Approximate number of years required to attain a workable size of 2 ft. girth.
Bashahr . . .	18	0·35	70
Chamba . . .	28	0·22	110
Kulu . . .	30	0·21	115

2. **Buxus papillosa,** C. K. Schn. Syn. *B. sempervirens*, Linn. (in part). Vern. *Shamshád*, Pb.

A large evergreen shrub or small tree with a crooked stem. Leaves usually 1·5–3 in. long, dull green above, whitish papillose beneath. Wood similar to that of *B. Wallichiana*, but the tree only grows to a small size, and the wood is used only for fuel.

This species grows on the dry and arid slopes of the outer Himalaya from the Jhelum westwards at 2,000 to 4,000 ft., the Salt Range, trans-Indus, the Kalachitta and Margalla forests of the Ralwalpindi district, and the Garamthun reserve in Hazara. It is found usually on dry limestone hills; in the Shahpur Salt Range it occurs on sandstone. It is cultivated at Lahore. Natural reproduction is usually reported to be poor; the seedlings appear to require the shelter of bushes and rocks, and to benefit by the presence of pockets of soil with a certain amount of moisture. The flowers appear from December to February, and the fruits ripen from June to August (?); in the Rawalpindi

[1] Ind. Forester, xxi (1895), p. 89.

district I have found fruits in May full-sized but not quite ripe. The capsules are 0·4 to 0·5 in. long, ovoid, with erect horns. The plant can be propagated from cuttings. Ribbentrop found the average number of rings per inch of radius to be 30 to 40, giving a mean annual girth increment of 0·15 to 0·21 in.

8. BACCAUREA, Lour.

Baccaurea sapida, Muell. Arg. Vern. *Latqua*, Beng.; *Leteku*, Ass.; *Kanazo*, Burm.

A moderate-sized evergreen tree with a round shady crown and grey, somewhat rough and corky bark. The tree is found in the eastern sub-Himalayan tract and lower hills, Assam, Chittagong, Burma, and the Andamans, chiefly in moist tropical forests. It is often cultivated for the sake of its edible fruits, which ripen early in the rainy season. The fruits, which grow in clusters, are yellow globose 3-seeded berries about the size of a large cherry, with a pleasant acid pulp formed by the arillus of the seeds. The tree stands shade and prefers a moist climate and a deep moist soil.

9. MALLOTUS, Lour.

Trees or shrubs, chiefly evergreen. Brandis (*Indian Trees*) enumerates 27 species, most of which are quite local.

Mallotus philippinensis, Muell. Arg. Syn. *Rottlera tinctoria*, Roxb. Vern. *Rohni*, *roini*, *raini*, *rauni*, Hind.; *Kamila*, Pb.; *Kapila*, Kan., Tam.; *Tawthidin*, Burm.

A small much-branched evergreen tree with a short and often fluted bole. Bark thin, dark grey, red within. Wood hard and close grained, useful for bobbins. A dye known as *kamela*, used for dyeing silk, is obtained from the red glands on the surface of the capules. Silviculturally the tree is important as an accessory or undergrowth species owing to its great abundance in many forest tracts; it is a useful nurse to more important species such as the sal, and is a good soil-improver.

Distribution and habitat. Sub-Himalayan tract and outer hills from the Indus eastwards, ascending occasionally to nearly 5,000 ft. into the region of *Pinus longifolia* and *Quercus incana*, Bengal, Chota Nagpur, Indian Peninsula, and Burma. This is a very common tree in sal forest and in certain types of mixed and scrub forest. Talbot says it is common and often gregarious throughout the Bombay Presidency and Sind in mixed monsoon or open thorn forest. In sal forest it is frequently gregarious as an underwood.

In grassy tracts within the sal forests it often appears in advance of the sal, helping to kill out the grass, thus removing inflammable material, and protecting the young sal from frost. Experiments in the use of *Mallotus* as an artificial nurse to sal are referred to in Vol. I, p. 105.

Flowering and fruiting. In northern India the flower-buds begin to appear about July, and the trees are in full flower in October, the male trees in particular being conspicuous at this time. The flowers are dioecious, the males in clusters of pale yellow spikes 5 to 10 in. long, and the females in spikes 2 to 3 in. long. The fruits, which ripen from March to May, or June at the higher elevations, are 3-lobed capsules, 0·3 to 0·5 in. in diameter, densely

FIG. 309. *Mallotus philippinensis.* Seedling × ⅓.
a, seed ; *b–f*, germination stages ; *g–i*, development of seedling during first season.

covered with red glands. The seeds (Fig. 309, *a*) are about 0·15 in. in diameter, globose, black, smooth, with a moderately thick brittle testa; about 600 to 700 weigh 1 oz. Tests at Dehra Dun showed that the seed is rather uncertain in germinative power, and that it does not retain its fertility long.

GERMINATION (Fig. 309, *b–f*). Epigeous. Shortly after the emergence of the radicle the hypocotyl elongates by arching, and in straightening carries above ground the cotyledons, usually enclosed in the testa, which afterwards falls off with the expansion of the cotyledons.

THE SEEDLING (Fig. 309).

Roots: primary root long, moderately thick, terete, tapering; lateral roots fairly numerous, fibrous, chiefly on upper part of main root. *Hypocotyl* distinct from the root, 2–2·5 in. long, terete, tapering slightly upwards, white turning green, tomentose. *Cotyledons*: petiole 0·3–0·4 in. long, tomentose; lamina 0·4–0·5 in. by 0·4–0·6 in., foliaceous, irregularly orbicular and usually broader than long, apex rounded or truncate, base often slightly tapering, entire or irregularly undulate, green, glabrous, with a fringe of minute hairs round the margin, 5-veined from the base. *Stem* erect, terete, woody, green, tomentose, internodes 0·2–0·5 in. long. *Leaves* simple, alternate, exstipulate. Petiole 0·3–1·8 in. long, terete, pubescent. Lamina 0·7–4 in. by 0·5–2·8 in., the earlier leaves small, ovate, acuminate or acute, usually cordate, serrate, glabrescent above, pubescent and covered with red glandular dots beneath, venation pinnate with five or six pairs of lateral veins, the largest pair basal, subsidiary veins prominently reticulate on lower surface.

The seedling ordinarily attains a height of 4 to 8 in. during the first season, while under favourable conditions the growth is more rapid the second year. It is frost-hardy, but is sensitive to drought, dying back in dry places from October onwards; some plants shoot up again from the base, while others are killed outright. At Dehra Dun young plants 1 to 2 ft. high suffered from the attacks of rats, which gnawed through the taproot. The seedling benefits by a certain amount of shade during early youth, and also requires a comparatively moist soil. All those experimental plots at Dehra Dun which were situated in sunny localities were complete failures, the seed usually failing to germinate; the only successful plots were those in which the early stages were spent in partial shade. In northern India the season's growth ceases about November, new growth commencing in February and March.

The following measurements in experimental plots at Dehra Dun give some indication of the rate of growth of seedlings:

Mallotus philippinensis: development of seedlings, Dehra Dun.

Condition under which grown.	Height at end of season. 1st season.			2nd season.		
		ft.	in.		ft.	in.
(1) Line sowings along bottom of trench, not watered .	Maximum	0	5			
(2) Sown in box, under shade, well watered . .	,,	0	5			
(3) Line sowings with field crops, weeded, not irrigated	,,	0	9	Maximum	3	0
(4) Line sowings with field crops, weeded, not irrigated	,,	1	0	,,	5	0

SILVICULTURAL CHARACTERS. The tree stands a considerable amount of shade. It coppices very well and produces root-suckers. It proved frost-hardy in the severe frost of 1905 in northern India, while in the abnormal drought of 1907 and 1908 in Oudh it was found to be decidedly drought-resistant, in contrast to what has been found to be the case in the seedling stage. It is not readily browsed by goats and cattle.

Natural reproduction. The seed falls to the ground in the hot season, and germination under natural conditions takes place in the following rainy season. It is of great advantage, and in dry localities essential, that the seed should become covered as soon as possible, partly as a protection against insects, which readily attack the seeds, and partly because seedlings germinating on the surface of the ground are very liable to perish from drought before the root establishes itself. Loose, bare soil is thus of great advantage, as the seed becomes quickly covered during showers of rain. Experiments at Dehra Dun showed that germination under natural conditions is seldom successful except in comparatively moist soil in shady situations ; in the open it frequently fails, while any seedlings which do appear tend to die of drought. The establishment of natural reproduction is greatly facilitated by the comparative immunity of this species from damage by browsing, and its prevalence in many localities may be attributed largely to this circumstance.

Artificial reproduction. For the artificial propagation of this tree shade and moisture are necessary in the earlier stages. Fresh seed should be sown about April and lightly covered with earth. Nursery beds should be kept shaded and watered and weeded regularly. Germination begins in about three weeks, and continues for some time ; the more vigorous seedlings are ready for transplanting during the first rainy season, but the smaller plants may be kept for a year in the nursery. Line sowings with the aid of field crops have proved successful at Dehra Dun, the field crop affording the necessary side shade during the early months. The crop employed was the lesser millet or *mandwa* (*Eleusine coracana*), which was sown in May and reaped in October. The lines of *Mallotus* were left clear of field crops to a width of about 1½ ft. in order to afford sufficient light to the seedlings, and the results were satisfactory. Owing to the uncertain germinative power of the seed it is advisable to sow the seeds fairly close together, say about 2 in. apart, and to thin out congested seedlings during the first rainy season, employing the surplus plants to fill gaps in the line. Regular weeding and loosening of the soil should be carried out during the first two years, and as often as may be necessary afterwards.

Rate of growth. The growth is comparatively slow. Periodic measurements of sixteen trees from 1 to 3 ft. in girth in the forests on the south of the Saharanpur Siwaliks in the United Provinces, showed a mean annual girth increment of only 0·26 in. These trees, however, were in sal sample plots, and were probably to some extent suppressed.

Coppice measurements in 1910 by Mr. C. M. McCrie in the Gorakhpur forests of the United Provinces gave the following results :

Mallotus philippinensis : rate of growth of coppice, Gorakhpur.

Age.	Mean height.	Mean girth.	Age.	Mean height.	Mean girth.
years.	ft.	in.	years.	ft.	in.
2	4·8	1·2	10	12·7	4·5
4	7·5	2·2	12	13·7	5·1
6	9·5	3·0	14	14·5	5·6
8	11·3	3·8	16	15·2	5·9

10. TREWIA, Linn.

Trewia nudiflora, Linn. Vern. *Tumri*, *khamara*, *bhillaur*, *gumhar* (which is also the name for *Gmelina arborea*), Hind. ; *Pitali*, Beng. ; *Kat kumbla*, Kan. ; *Pitari*, Mar. ; *Yehmyôk*, *setkadôn*, Burm.

A moderate-sized to large deciduous tree, often with a short bole and spreading branches, but under favourable conditions producing a long clear bole, often much buttressed at the base. Leaves opposite, long-petioled, broadly ovate cordate, giving the tree a superficial resemblance to *Gmelina arborea*. Bark smooth, grey. Wood white, soft, not durable, used for drums, cheap planking, and carved images, and has been reported suitable for match manufacture.

Distribution and habitat. Sub-Himalayan tract from immediately west of the Jumna eastwards, Bengal, Assam, Chittagong, Burma, Chota Nagpur, and the Indian Peninsula, chiefly in moist forests and particularly along streams and in moist and swampy situations. This is one of the most characteristic trees of the swamp forests of the western sub-Himalayan tract, where it is often more or less gregarious in association with *Albizzia procera*, *Ficus glomerata*, *Diospyros Embryopteris*, *Cedrela Toona*, *Pterospermum acerifolium*, and other characteristic species, together with the cane *Calamus tenuis*. It is common in moist places along the foot-hills of the eastern sub-Himalayan tract, where the trees produce large clear boles often much buttressed at the base. It is sometimes planted on ordinary ground away from streams and swamps, and provided the climate is a fairly moist one it grows tolerably well on fertile soil.

Leaf-shedding, flowering, and fruiting. In northern India the leaves turn yellow about November and begin to fall, and the trees are leafless from about December to February or March, when the new leaves appear. The flowers, which are dioecious, appear from January to March, when the trees are leafless or the new leaves are sprouting. The male flowers are in long drooping racemes 3 to 8 in. long, and the females are solitary or two to three together on stout peduncles. In northern India the fruits ripen in July ; for Chota Nagpur, Haines gives May. The fruit (Fig. 310, *a*, *b*) is a globose obscurely quadrangular pale green berry, 1–1·5 in. in diameter, with a fleshy mesocarp of the consistency of a potato, containing usually four seeds, sometimes two, three, or five, each in a separate locule. The seeds (Fig. 310, *c*) are compressed ellipsoidal to globose, about 0·4 by 0·3 in., with a thick hard smooth black testa, and surrounded by a yellowish fleshy arillus ; there is a whitish leathery albumen within the seed. About 150 to 230 seeds weigh 1 oz. Fresh seed gives a fairly high percentage of germination, the best obtained at Dehra Dun being 87 per cent. Seed stored in tins was found not to retain its vitality for one year ; nevertheless in one case seed sown in the ground under shade remained fertile and germinated a year later. The extraction of the seeds from the fruit is best effected by spreading the ripe fruits in the sun for a few days, when they become soft and the seeds can be pressed out.

The fruits are buoyant in water, a matter of importance in connexion with the dissemination of the seed in the riverain tracts where the tree commonly grows; the fact that the fruits ripen in the rainy season when the streams are swollen is a further advantage in spreading the seed.

GERMINATION (Fig. 310, *d–f*). Epigeous. The testa splits in two, the radicle emerging and a ring of lateral rootlets being produced almost at once round the base of the young taproot. The hypocotyl elongates by pronounced arching, and in straightening raises above ground the cotyledons, which then expand, becoming green and foliaceous. The testa is usually left in or on the ground, while the leathery albumen, enclosing the cotyledons like a bag, is carried up, splitting and falling off with their expansion.

THE SEEDLING (Fig. 310).

Roots: primary root long, at first thin, rapidly thickening, terete, tapering, white, turning yellowish brown; lateral roots numerous, fibrous, at first round base of taproot, later distributed down it, rootlets round base longer than those farther down. *Hypocotyl* distinct from the root, 1·5–2 in. long, terete, tapering upwards, delicate, green, glabrous or very finely pubescent in upper part. *Cotyledons*: petiole 0·2–0·3 in. long, channelled above; lamina 1–1·3 in. by 0·9–1·1 in., thin, foliaceous, broadly elliptical or elliptical ovate, obtuse, base obtuse or sub-truncate, entire, green, glabrous, prominently 5-veined from the base. *Stem* erect, terete, green or pinkish, pubescent, 0·5–1·3 in. long. *Leaves* simple, alternate, or first one or two pairs opposite or sub-opposite; stipules absent. Petiole 0·6–1 in. long, channelled above, later terete, green or pink, pubescent. Lamina 1·5–2·5 in. by 0·8–1·6 in., cordate, acuminate, dentate or undulate, sometimes entire, pubescent, venation reticulate, with five basal nerves.

The above description refers to seedlings of the first season. A remarkable character in the case of *Trewia* seedlings and coppice-shoots is the fact that on the main stem the leaves and branches are alternate, while on the side branches they are opposite. Seedlings of *Gmelina arborea*, to which those of *Trewia* bear a superficial resemblance, have all leaves opposite.

The growth of the seedling during the first year is comparatively slow, a height of 5 to 10 in. being ordinarily attained by the end of the season. Sometimes natural seedlings do not produce more than the cotyledons during the first season, the foliage leaves beginning to appear only the following year. Under favourable conditions growth after the first year is rapid, vigorous plants growing 5 ft. or more in a season. Weeding and irrigation, particularly the former, greatly stimulate growth, while the development of the young plant suffers in the presence of weeds. The taproot, which shows moderate development during the first season, subsequently lengthens and thickens considerably, a length of 4 ft. or more being sometimes attained by the end of the second season, while at the same time large lateral roots develop round the base of the taproot immediately below ground-level.

The seedlings are fairly frost-hardy but are sensitive to drought, from which they may be killed outright or partially killed, with the result that forked stems are produced. Side shade from the sun has proved an efficient protection from drought in the case of line sowings. Young plants endure slight shade, but become suppressed under heavy shade. In the struggle for existence the more vigorous plants readily suppress the weakly ones.

The growth of seedlings is suspended for a comparatively short time in winter; it hardly stops at all if the plants are regularly watered, but other

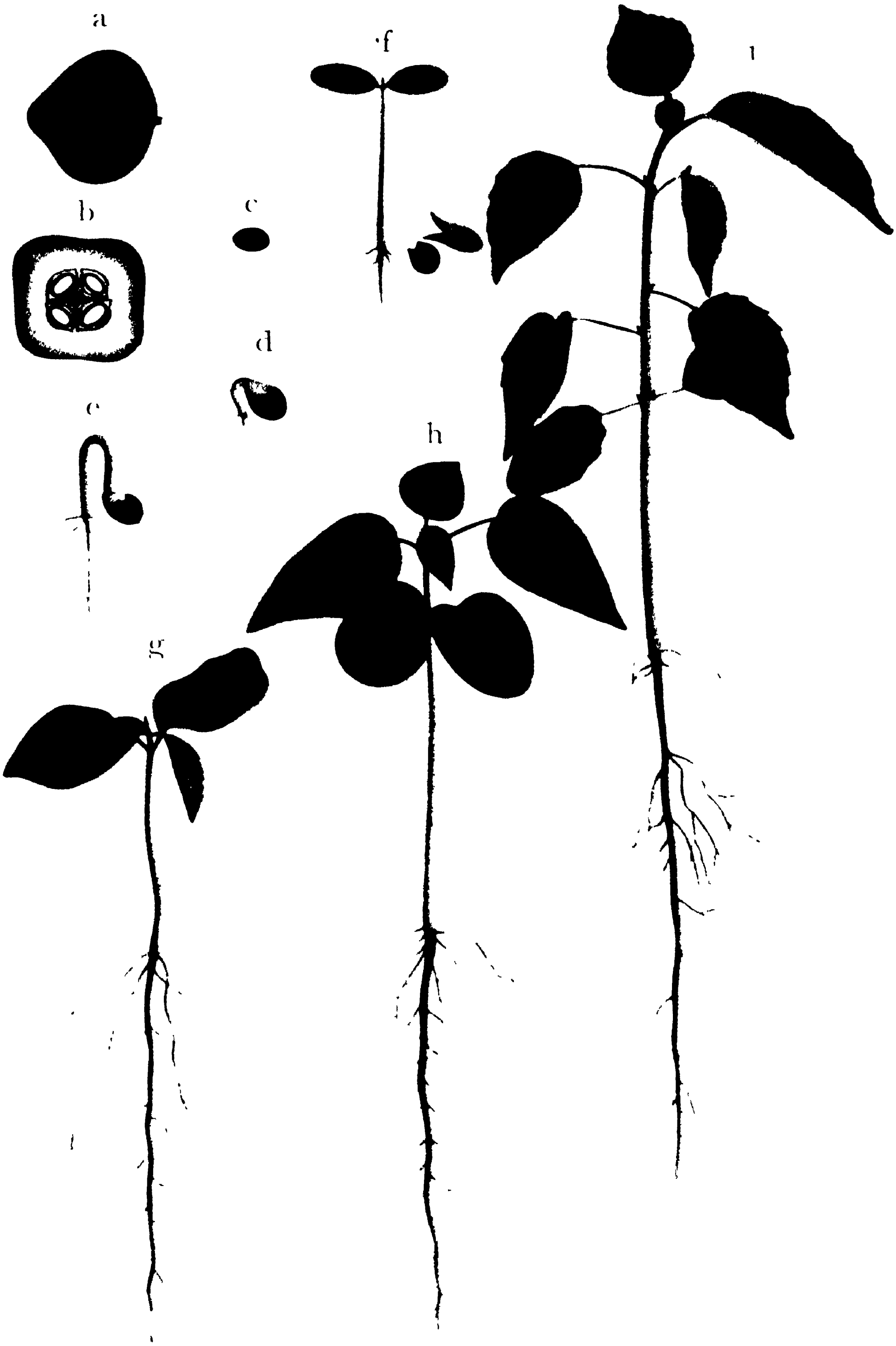


FIG. 310 *Trewia nudiflora* SEEDLING × ½

a—Fruit b—Fruit in section c—Seed d-f—Germination stages
g-i—Development of seedling during first season

wise ceases about December, new growth starting in February or March. The leaves commence falling in December, and have usually all dropped by the end of February. These dates apply to northern India.

The following measurements in experimental plots at Dehra Dun give some indication of the rate of growth of young plants under different conditions, and exhibit the marked effect of weeding :

Trewia nudiflora : development of seedlings, Dehra Dun.

Condition under which grown.	Height at end of season. 1st season.	2nd season.	3rd season.	4th season.
(1) Plants in nursery, weeded and watered	0 ft. 3 in.–0 ft. 9 in.	Maximum 5 ft. 0 in.		
(2) Plants in nursery, weeded and watered	0 ft. 3 in.–0 ft. 10 in.	„ 7 ft. 0 in.		
(3) Plants in nursery, weeded and watered	Maximum 0 ft. 6 in.	„ 6 ft. 3 in.	3 ft. 3 in.–13 ft. 2 in.	Maximum 15 ft. 0 in.
(4) Transplants of 1st season, not weeded or watered after transplanting	„ 0 ft. 6 in.	„ 1 ft. 5 in. (thick growth of grass and weeds)	0 ft. 10 in.–1 ft. 5 in. (growth hindered by weeds)	
(5) Transplants of 1st season, not weeded or watered after transplanting	„ 0 ft. 5 in.	Maximum 2 ft. 7 in.	No further growth owing to suppression by weeds	
(6) Fruits scattered on ground, as under natural conditions; subsequently weeded, not watered	„ 0 ft. 5 in.	„ 5 ft. 1 in.	1 ft. 2 in.–10 ft. 2 in.	Maximum 16 ft. 8 in. (girth 0 ft. 7 in.).
(7) Line sowings, irrigated, weeded	„ 0 ft. 8 in.	1 ft.–5 ft. 3 in.	Maximum 10 ft. 0 in. (vigorous)	
(8) Line sowings, irrigated, unweeded, adjacent to (7)	„ 0 ft. 11 in.	0 ft. 8 in.–5 ft. 6 in. (only 2 large plants where weeds absent).	Little further growth: condition poor owing to weeds	
(9) Line sowings, unirrigated, weeded	„ 0 ft. 8 in.	0 ft. 3 in.–3 ft. 10 in.	0 ft. 3 in.–5 ft. 7 in. (partially killed back by drought during the year)	
(10) Line sowings with field crops; unirrigated, weeded	„ 0 ft. 5 in.	Maximum 3 ft. 2 in.	0 ft. 4 in.–2 ft. 9 in. (line fairly well stocked)	Killed back by drought in 3rd season.
(11) Line sowings with field crops; unirrigated, unweeded, adjacent to (10)	„ 0 ft. 5 in.	„ 2 ft. 11 in.	1 ft. 2 in.–2 ft. 8 in. (only 5 survivors)	Killed back by drought in 3rd season.

SILVICULTURAL CHARACTERS. The tree is a moderate light-demander. It coppices vigorously and produces root-suckers, sometimes in great quantity, from its superficial roots, which spread in a network near the surface of the ground. It is fairly frost-hardy, but is sensitive to drought ; it suffered considerably in Oudh in the abnormal drought of 1907 and 1908, when the streams along which it grew dried up.

NATURAL REPRODUCTION. The ripe fruit falls early in the rainy season, much of it falling around the trees and germination taking place *in situ*, while some of it is transported to a distance by water. The fruit after reaching the ground soon rots ; the fleshy mesocarp becomes soft and is further disintegrated by heavy rain, partially exposing the seeds, which germinate at different times throughout the rainy season. The seedlings often appear in little groups of three or four together, each group representing the collection of seeds in a single fruit. Experiments at Dehra Dun showed that dry or hard ground is unfavourable for germination, while seedlings readily spring up on moist loose soil. Germination is more successful if the fruits and seeds become wholly or partially buried than if they lie on the surface of the ground; in this respect the loose alluvial soil on which the fruits often fall or are stranded by water is particularly favourable.

ARTIFICIAL REPRODUCTION. The fruits should be collected as soon as they ripen, early in the rainy season, the seeds being extracted in the manner already described and sown at once. It is of importance to sow early, in order that the seedlings may develop as far as possible during the first year, since they are handicapped naturally by a late start. Direct sowing in lines has proved more satisfactory at Dehra Dun than transplanting from the nursery, although the latter proved quite successful where plants a few weeks old were put out before the end of the rainy season. The soil of the seed-beds should be porous. The seeds may be sown 3 in. apart in drills 9 in. apart, and should be covered with earth to a depth of about ½ in.; the beds should be weeded regularly and watered copiously in dry weather. Germination usually begins in ten to fourteen days.

Line sowings have proved very successful at Dehra Dun, particularly where irrigation was carried out, the seeds being sown along the base of the ridge of earth heaped up alongside the water-channel, on the side next the channel. Unirrigated line sowings in conjunction with the raising of field crops on ploughed land also proved thoroughly successful. The crop employed was the lesser millet or *mandwa* (*Eleusine coracana*), which was sown towards the end of May and reaped in October. It was found slightly advantageous to leave a clear line about 1½ to 2 ft. wide unsown with crops, along which the *Trewia* seeds were sown; but even where the crops were sown continuously the results were fairly good, though the development of the seedlings during the first season was somewhat poorer than along the cleared lines where they were free from suppression by the crops.

In line sowings 1 lb. of seed suffices for about 550 ft. of line. It is essential that regular weeding and loosening of the soil should be carried out, and in the second year the young plants should be thinned out where they are congested; in the first rainy season surplus seedlings should be removed and transplanted to fill gaps, and this is a further reason for leaving clear lines in sowing with field crops.

Propagation by cuttings was tried at Dehra Dun. Cuttings planted in the rainy season sprouted well, but invariably died off in the ensuing dry weather. They might possibly succeed in ground which is permanently moist.

11. EXCAECARIA, Linn.

Seven Indian species of trees or shrubs with acrid juice, of somewhat local distribution except *E. Agallocha*, Linn., which is a common littoral species.

Excaecaria Agallocha, Linn. Blinding tree. Vern. *Gengwa, geor, geria*, Beng.; *Geva, suran, surund*, Mar.; *Tilai*, Tam.; *Thilla*, Tel.; *Tayaw, kayaw*, Burm.

A small evergreen bushy tree, sometimes attaining 30 ft. in height, but often stunted and crooked, with stout smooth branches and shining elliptical ovate leaves. Bark grey, smooth, covered with prominent lenticels. Wood

FIG. 311. *Excoecaria Agallocha*—SEEDLING $\times \frac{3}{8}$

Fruit b-g—Germination stages h-j—Development of seedling during first season
k—Seedling early in second season

soft, whitish, used chiefly for fuel, but suitable for purposes for which a soft white wood is required. The tree exudes a very acrid poisonous juice, particularly from the fresh cortex when cut, which raises blisters on the skin and is injurious to the eyes of wood-cutters, whence the name 'blinding tree'.

DISTRIBUTION AND HABITAT. Common in tidal forests on both sides of the Indian Peninsula, the Sundarbans, Chittagong, Burma, and the Andamans. In the Sundarbans it is fairly well distributed throughout the tidal forests, mixed with *Heritiera Fomes* and *Ceriops Candolleana*. As a general rule *Ceriops* springs up first on the newly formed islands, *Excaecaria* appearing next as the ground becomes more elevated, while *Heritiera* comes in last on the highest and driest ground.

FLOWERING AND FRUITING. The minute yellowish green flowers appear about July, and the fruits ripen in August and September. The fruit (Fig. 311, *a*) is a 3-lobed capsule 0·3–0·5 in. or more in diameter. The seed is 0·2 in. in diameter, globose, with a moderately hard but brittle testa and with albumen surrounding the embryo; about 250 seeds weigh 1 oz. on an average. Under natural conditions the seed germinates immediately after falling. Tests at Dehra Dun showed that the germinative power is high.

GERMINATION (Fig. 311, *b–g*). Epigeous. The testa cracks and the radicle emerges at one end of the seed. The hypocotyl elongates, with slight arching, carrying above ground the cotyledons enclosed in the albumen and testa, which eventually fall to the ground when the cotyledons expand.

THE SEEDLING (Fig. 311).

Roots: primary root moderately long and thick, terete, tapering; lateral roots moderate in number and length, fibrous. *Hypocotyl* distinct from root, 2·8–4·2 in. long, quadrangular in the upper part, more or less terete below, tapering slightly upwards, red or green, glabrous. *Cotyledons*: petiole 0·1–0·2 in. long, flattened above; lamina 0·6–0·9 in. by 0·5–0·8 in., foliaceous, somewhat fleshy, orbicular, entire, green, glabrous, with three conspicuous and two less conspicuous veins from the base. *Stem* erect, terete or slightly compressed, green turning brown, glabrous; internodes 0·3–1·2 in. long. *Leaves* simple, alternate. Stipules minute. Petiole 0·4–0·7 in. long, channelled above, sometimes red, glabrous. Lamina 1·2–2·5 in. by 0·6–1·3 in., ovate lanceolate, acuminate, remotely serrate crenate, dark green, glabrous, shining, midrib sometimes red.

Seedlings raised at Dehra Dun in moist earth attained a height of 4 to 5 in. during the first season, 1 to 1½ ft. by the end of the second season, and 4 to 4½ ft. by the end of the third season.

ARTIFICIAL REPRODUCTION. Seedlings have been raised in large numbers at Dehra Dun by sowing fresh seed in boxes of moist earth and transplanting in the rainy season when the plants were a year old; transplanting proved quite successful. In the natural home of the tree broadcast sowings *in situ* are likely to give good results, as the seed germinates readily and has a high percentage of fertility.

RATE OF GROWTH. In the Sundarbans the growth is said to be slow, particularly in salt-water areas.

12. SAPIUM, P.Br.

Five species of soft-wooded trees, one introduced.

Species 1. *S. sebiferum*, Roxb.; 2. *S. insigne*, Benth.

1. **Sapium sebiferum,** Roxb. Syn. *Excaecaria sebifera*, Muell. Arg. Chinese tallow tree. Vern. *Vilayati shisham*, Hind.

A moderate-sized deciduous tree, often with a gnarled trunk, with leaves somewhat resembling the leaflets of *Dalbergia Sissoo*. Bark grey, with vertical cracks. The seeds are coated with a white wax, separable by boiling in water, used in China and Japan for making candles. Puran Singh found that in India its value as a tallow- and oil-yielding plant has been somewhat underrated in the past; according to him the tallow and oil should be extracted by the aid of a solvent extraction plant and not by bruising the seeds and steaming them as in China, since the yield of tallow by the latter process is at least 50 per cent. less than by the former.

The tree is a native of China, but is largely cultivated in northern India, occasionally up to 6,000 ft. in the Himalaya; also sometimes in other localities, including Burma. In the Changa Manga plantation near Lahore it does well only near water. In northern India it has run wild and has spread extensively, not only from seed but also by means of root-suckers, which it produces in great abundance, and as it is not browsed by cattle it is able to survive in grazed areas. It coppices well. The tree is frost-hardy, and stands a certain amount of shade. In order to run wild it seems to require a fairly heavy rainfall or else a moist soil. It has established itself thoroughly around Dehra Dun, particularly on gravelly soil in ravine lands, in the moister parts of the Kangra valley and on islands in the Jhelum river on the plains. It is a useful tree for fixing sides of ravines and banks of rivers. It is easily raised from seed, and can also be grown from cuttings. The leaves turn a beautiful orange to scarlet colour in the autumn, and fall early in the cold season, the trees remaining leafless till about April. The greenish yellow monoecious flowers, in terminal racemes, appear from June to August; they are very fragrant and are visited by swarms of bees. The fruits ripen from November to January; the fruit is a sub-globose 3-valved capsule, with three seeds coated with a white wax. The rate of growth is fast. Parker says that in the Jhelum Chhanda plantation it averages three rings per inch of radius, giving a mean annual girth increment of 2·09 in. Gamble gives six rings per inch of radius, or a mean annual girth increment of 1·05 in.

2. **Sapium insigne,** Benth. Syn. *Excaecaria insignis*, Muell. Arg. Vern. *Boddar*, *khinna*, W. Him.; *Ure*, *dudla*, Mar.; *Kurda*, Kan.

A deciduous tree, usually of small or moderate size, but sometimes attaining fairly large dimensions, with large elliptic or oblong-lanceolate leaves crowded at the ends of the branchlets. Bark smooth in young trees, corky and very rough with deep furrows when old, exuding when cut a thick milky acrid juice, which is said to be poisonous. The wood is soft, white, and spongy. The tree is common, though scattered, along the Himalayan foot-hills, ascending to 5,000 ft. or more, usually in dry rocky situations; also in western India from the Konkan southwards, the hills of Kurnool and Cuddapah, Assam, Chittagong, and the Pegu Yoma in Burma. Talbot says that it is common on laterite near the coast of North Kanara and the Konkan, and sometimes in monsoon forest on the *ghats*, but always in dry rocky localities, and that on account of its poisonous qualities it and *Strychnos Nux-vomica* are the only trees found over large areas in the evergreen scrub along the North Kanara coast.

The tree is leafless from December to April, when it is easily recognized from the long terminal erect flowering and fruiting spikes, the flowers appearing in the cold season and the fruits ripening in the following hot season. It can be easily grown from cuttings taken from the ends of the shoots.

13. MACARANGA, Thouars.

Fast-growing, soft-wooded, and short-lived trees or shrubs, usually with large peltate leaves. Ten Indian species, some of them important by reason of their capacity for rapidly reclothing forest clearings and savannahs.

Species 1. *M. pustulata*, King ; 2. *M. indica*, Wight ; 3. *M. Roxburghii*, Wight ; 4. *M. Tanarius*, Muell. Arg. ; 5. *M. denticulata*, Muell. Arg.

1. **Macaranga pustulata,** King. Vern. *Mallata*, Nep.

A small often gregarious tree of the Himalaya from Kumaun eastwards at 3,000 to 6,000 ft., chiefly on old clearings. The leaves are not peltate. The tree is comparatively short-lived, and soon gives place to other species, but the growth is very rapid ; Gamble says that in ten years it may reach a height of 40 ft. with a girth of 3 ft.

2. **Macaranga indica,** Wight. Vern. *Papri*, Dehra Dun ; *Rámálo*, Kumaun ; *Jogi mallata*, Nep. ; *Vatta thamarei*, Tam.

A small evergreen often gregarious tree with peltate leaves and smooth grey bark. Outer Himalaya locally from the Malkot hills, Dehra Dun, eastwards at 3,000 to 5,000 ft., Assam, Andamans, the hills of southern India, and in moist ravines in Singhbhum, Chota Nagpur ; also in Ceylon. The growth is rapid ; Gamble gives 3 rings per inch of radius (one specimen), representing a mean annual girth increment of 2·09 in.

3. **Macaranga Roxburghii,** Wight. Syn. *M. tomentosa*, Wight. Vern. *Chanda*, Mar. ; *Upaligi*, Kan. ; *Vatta*, Tam.

A small or moderate-sized resinous tree with peltate leaves and dark grey, fairly smooth bark, common in the evergreen forests of the Western Ghats : also in the hills of the Deccan and Circars and the hills of southern India. It comes up plentifully on old clearings, and is of rapid growth.

4. **Macaranga Tanarius,** Muell. Arg. Syn. *M. moluccana*, Wight.

A species which springs up freely on newly cleared areas in the Andamans.

5. **Macaranga denticulata,** Muell. Arg. Vern. *Mallata*, Beng. Duars ; *Taung petwun*, Burm.

A soft-wooded moderate-sized evergreen tree with a smooth light grey stem and peltate broadly ovate acuminate leaves, somewhat glaucous beneath. It reaches a height of 60 ft. or even more, and a girth of 4 ft. or more, tending to branch low down and to send up several straight limbs like the spokes of an umbrella, though if forced up between other trees it forms a straight single stem. The crown is light, consisting of a single layer of leaves, and the canopy forms a thin umbrella-like cover. The root-system is superficial, young saplings being easily pulled up by hand.

The natural habitat of the tree is in the sub-Himalayan tract from Sikkim eastwards, ascending occasionally to 5,000 ft., Assam, Chittagong, and Burma. It thrives in a moist warm climate, and will not tolerate frost or drought. In the Bengal Duars it flowers in March–April, and the fruit ripens about July ; the seed is small and spreads to a remarkable degree, and in localities where the soil and climate favour it the tree quickly invades open ground, springing up luxuriantly on abandoned forest clearings and on fire-protected savannah lands. Mr. Rodger informs me that he has observed it to be an excellent tree for reclothing abandoned hill *taungya* (shifting cultivation) in the Katha district of Upper Burma at 2,000–3,000 ft. The growth is very rapid ; trees of known age in the Muraghat forest, Jalpaiguri, were found to have an average height of 30 to 35 ft. in eight years, and 50 ft. in thirteen years, while the average and maximum girths at eight years were 1 ft. and 2 ft. 2 in. respectively. The tree coppices, at all events in its younger stages. Young plants are very liable to be browsed by deer.

In the Duars tract *Macaranga* has no equal as a natural afforesting agent in fire-protected savannahs, quickly killing out the grass and in turn making way for shade-bearing and usually evergreen species. It is very sensitive to fire, but as soon as fire-protection is introduced it is probably the most invasive tree in the tract in question ; burning kills it out equally rapidly. When fire-protection is introduced it regenerates profusely not only on bare ground, but also on grass-lands, in gaps in the forest and even under slight shade ; it is not found in the driest parts of the Duars, but is abundant throughout the moister parts, and occurs even on fairly swampy ground.

The progressive succession from burnt savannah or semi-evergreen forest in the Duars, in which *Macaranga* plays a prominent part, is an interesting study. The successive stages are illustrated in Figs. 312 to 315, which show the establishment of *Macaranga* on the introduction of fire-protection in the savannahs of this tract ; where conditions are favourable its rapid growth soon pushes it through the tall grasses, which do not long survive the unequal struggle and are killed out. A stage then usually follows when the ground under the canopy of the *Macaranga* is bare or nearly so, or seedlings of sal or other species may be found on the ground, though such seedlings are unable to establish themselves unless they are of decidedly shade-bearing and moisture-loving species. Where the locality is moist a soil-covering of ferns often appears. Simultaneously or subsequently shade-bearing, and for the most part evergreen species of trees, shrubs, and climbers make their appearance ; the trees grow up through the *Macaranga* and kill it out, and the shrubs form a dense undergrowth, the climbers, together with canes, helping to form an impenetrable mass. This transition can be seen in all stages, and is often rapid.

The capacity of the *Macaranga* for killing out savannah grasses has from time to time been regarded as a useful means of obtaining natural reproduction of sal, but, as has been explained in Vol. I, p. 100, under *Shorea robusta*, my own observations in the Duars have led to an exactly contrary conclusion. for although sal seedlings may often be found in quantity under *Macaranga*, no case has yet been observed in which they have been able to establish themselves under its canopy. This does not, however, detract from the importance

FIG 312. Progressive succession from savannah to evergreen forest through the medium of *Macaranga denticulata*. Bengal Duars: (1) *Macaranga* overtopping savannah grasses and killing them out.

FIG. 313. Progressive succession from savannah to evergreen forest through the medium of *Macaranga denticulata*, Bengal Duars (2) dense crop of *Macaranga*, which has killed out the savannah grasses.

of *Macaranga* as an agent in effecting the introduction of shade-bearing species in savannah lands, while it may yet prove to be similarly useful in the introduction of sal and other more or less light-demanding species provided it is cut out as soon as it has performed its useful function of killing out a rank growth of grass.

The tree can be easily raised by sowings, the seed being scattered in the rainy season, when it ripens. Fig. 316 shows the result of sowing up a former savannah tract.

14. CROTON, Linn.

A fairly large genus of trees, shrubs, and climbers, mostly of little or no importance in Indian forestry. Perhaps the commonest is the following:

Croton oblongifolius, Roxb. Vern. *Arjunna*, Oudh ; *Akh*, Nep. ; *Gunsur*, Mar. ; *Thityingyi*, Burm.

A moderate-sized deciduous tree of the sub-Himalayan tract from Oudh eastwards, Chota Nagpur, rare in Bombay ; Burma, in upper mixed forests. This tree is very common in the forests of Gonda in Oudh, often occurring gregariously in belts on undulating or flat ground along the base of the outer hills. It is often planted for ornament. Its leaves assume a bright red colour before falling. It reproduces freely by root-suckers, and coppices well. Measurements made in 1910 by Mr. C. M. McCrie in coppice coupes in Gorakhpur, United Provinces, gave the following rate of growth as compared with that of sal :

Croton oblongifolius : rate of growth of coppice, Gorakhpur.

	Mean height.		Mean girth.	
Age.	*Croton.*	Sal.	*Croton.*	Sal.
years.	ft.	ft.	in.	in.
2	3·8	3·0	..	..
4	7·0	7·0	1·6	2·0
6	9·5	10·3	2·3	2·9
8	11·6	13·0	3·0	3·8
10	13·2	15·3	3·7	4·8
12	14·7	17·5	4·2	5·8
14	16·2	19·2	4·6	6·7
16	17·5	20·9	5·0	7·5

15. JATROPHA, Linn.

Shrubs or perennial herbs. There are four indigenous and three introduced species, two of the latter, *J. gossypifolia*, Linn., and *J. Curcas*, Linn., natives of South America, being of more importance than the indigenous species. *J. Curcas* is much cultivated as a hedge-plant in village lands, and is not browsed ; it grows readily from cuttings. The seeds yield an oil used for burning and in medicine. *J. gossypifolia* has run wild in many parts of India. It is carefully avoided by cattle, and forms thick clumps on heavily grazed areas, acting as a protection to tree species, which establish themselves under its protection. Even grass growing amongst it, which can be reached by cattle, is not readily eaten, showing that for some reason the mere presence of the shrub is obnoxious.

16. HEVEA, Aubl.

Hevea brasiliensis, Muell. Arg. Pará rubber.

A large evergreen tree with glabrous trifoliate leaves on long petioles. This tree is the most important source of caoutchouc in the world, and furnishes the well-known Pará rubber of commerce.

HABITAT. The natural home of the tree is the Amazon valley in Brazil, where it grows in dense moist forest on deep rich soil at low elevations, extending down to low-lying, often inundated lands, and even to the edge of tidal limits. The climate is characterized by high atmospheric humidity and great uniformity of temperature, the absolute maximum and minimum temperatures being about 95° and 74° F. respectively, and the mean temperature at sea-level averaging from 77° to 81° F. The rainfall is 80 in. or over; the rain falls chiefly between January and June, little falling during the remaining six months, though periods of drought are seldom of more than two months' duration.

As the tree has been so much planted outside its natural habitat it will be useful to consider the conditions under which it has been found to thrive. Generally speaking the temperature should be warm and equable, with a range of about 75° to 95° F. A rainfall of 70 to 150 in. is probably the most favourable, but a well-distributed rainfall is of much greater importance than a copious one. Heavy and prolonged deluges of rain with a dark cloudy sky for many days in succession are unfavourable, as are long intervening periods of drought; the ideal is an alternation ot moderate showers at fairly frequent intervals with warm bright weather. The atmosphere should be moist but not saturated. The most favourable situation is a valley well sheltered from strong and dry winds by hills or by belts of high forest, preferably evergreen, at a low elevation, that is, up to about 2,000 or 2,500 ft. The ground should not be swampy or water-logged. Deep, rich, well-drained river alluvium is excellent, but undulating ground, provided the soil is deep, rich, and well drained, is equally good; steep, broken, or rocky hill-sides are not suitable. The soil should be a deep, rich, moist, porous loam, containing a fair percentage of clay; the soil which produces moist evergreen forest is as a rule suitable. The subsoil should be well drained, preferably sand and gravel. A stiff clayey subsoil is unfavourable, but laterite, if soft and if overlain by a reasonable depth of soil, is not unsuitable.

INTRODUCTION INTO THE EAST. The early introduction of *Hevea brasiliensis* into the East was undertaken by Kew at the expense of the Indian Government. In 1873 seeds, obtained from the Amazon by Mr. J. Collins, were forwarded by Mr. (afterwards Sir Clements) Markham to Kew, but owing to the rapid deterioration of the seed in transit, only about a dozen plants were raised. Six of these were brought out to Calcutta by Dr. King, and from these others were raised by cuttings. The plants were tried both at Calcutta and in Sikkim, but these localities proved unsuitable. In 1876 Mr. H. A. Wickham brought from Pará to Kew 70,000 seeds, of which about 2,500 are said to have germinated. From this supply 1,919 plants were in the same year sent to Ceylon, and about 1,700 arrived in good condition. Smaller supplies were at the same time sent to Burma, Singapore, Java, and elsewhere. Those

FIG. 314 Progressive succession from savannah to evergreen forest through the medium of *Macaranga denticulata*, Bengal Duars (3) interior of *Macaranga* crop after savannah grasses have been killed out, no undergrowth yet appeared

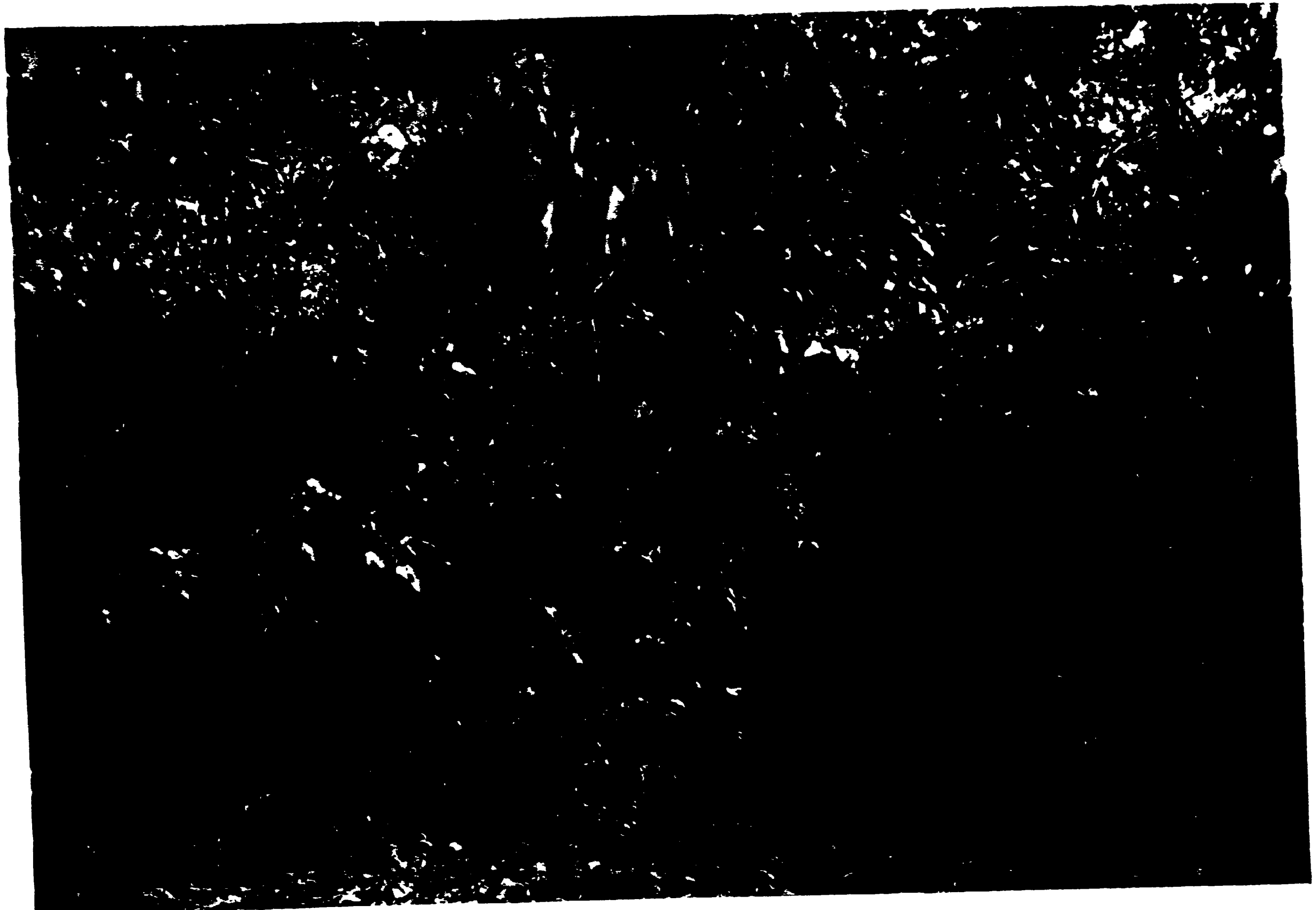


FIG 315. Progressive succession from savannah to evergreen forest through the medium of *Macaranga denticulata*. Bengal Duars: (4) shade-bearing evergreen species appearing under cover of *Macaranga*; the former will eventually make their way through the latter and kill it out

sent to Burma all died, but later in the year Mr. Duthie took out another case of plants to Calcutta ; some were sent to Assam and sixteen were sent in 1877 to Burma, of which eight survived and were planted in the Forest office compound at Mergui. Meanwhile in 1876 Mr. R. Cross brought to England from Pará over 1,000 seedlings, of which hardly 3 per cent. survived. From these cuttings were propagated and about 100 plants were sent to Ceylon, small parcels being sent to Singapore, Java, and elsewhere. The plants thus distributed in the seventies of last century, mainly to Ceylon, formed a useful nucleus for the production of seed for the extension of rubber planting in the East, which commenced on a small scale in the eighties of last century and has proceeded more recently on an extensive scale in Ceylon, Malaya, Borneo, Sumatra, Java, southern India, and Burma.

In the Indian Empire Pará rubber has so far been grown successfully in three regions, southern India, Burma, and the Andamans. It was first introduced into southern India in 1879, when twenty-eight plants received from the Royal Botanic Gardens, Ceylon, were planted at Nilambur in South Malabar. These were neglected and many were allowed to die, but some still survive. The first rubber estate in southern India was started in 1902 at Thattakad on the banks of the Periyar river in Travancore. Further estates were opened there in 1904, and these were followed in 1905 by the opening of estates in Cochin ; since then many other estates have been started, and in 1917 the total area under rubber (mainly *Hevea*) was 47,631 acres, distributed as follows : Travancore, 30,144 acres ; Malabar, 8,783 acres ; Cochin, 7,425 acres ; Nilgiris, 1,065 acres ; and Salem, 214 acres.

The introduction of Pará rubber into Burma dates, as already mentioned, from 1877, when eight plants were planted at Mergui. In the following year an area of 59 acres was planted by the Forest Department at Mergui. Various experiments in rubber planting have been undertaken since then. Among the earlier efforts may be mentioned a small experimental plantation started in 1899 by the late Mr. W. S. Todd at Kyaukadat, eight miles from Amherst. An experiment on a larger scale was commenced by the Forest Department in 1901 by the formation of a rubber plantation at Mergui. This plantation was continued until 1910, when the area aggregated about 1,660 acres ; by that time the plantation had fulfilled its object, namely to prove that rubber could be grown successfully in Tenasserim, and it was accordingly leased to a company. Rubber is now successfully grown in many parts of Lower Burma. Even as far north as Myitkyina trees have, contrary to expectation, been found to grow well and to yield a fair amount of latex. In 1917 the total area under rubber in Burma was 63,567 acres, the chief rubber-growing districts being Mergui, 22,454 acres ; Amherst, 8,028 acres ; Thaton, 7,969 acres ; Tavoy, 5,153 acres ; Hanthawaddy, 5,087 acres ; Insein, 4,939 acres ; Toungoo, 4,547 acres ; Myitkyina, 4,232 acres : there are small areas in a few other districts.

Pará rubber was first introduced into the Andamans in 1887. Plantations were commenced by the Forest Department in 1905, and were extended subsequently, the total planted area in 1918 being 500 acres. The growth is good, and the plantations are promising.

Plantations of Pará rubber have been tried on an experimental scale in

Bengal and Assam, but the industry has never been taken up in those provinces, and the prospects are apparently not good. In Bombay rubber has been tried in Kanara, but has not proved a success ; the rainfall is heavy, but the deluges of rain in July and August with an almost total absence of sunshine, alternating with a long dry season between October and June, are conditions which the plants appear to be unable to contend with.

PROPAGATION AND TREATMENT. The propagation and treatment of this important tree in the East has been the subject of detailed investigation by various workers, particularly in Ceylon and the Malay States, and there is an extensive literature dealing with its propagation and treatment, tapping systems, pests, and diseases, and other matters relating to it.

The practical rubber planter will find much of value in such publications as the following: (1) *Hevea brasiliensis*, by Herbert Wright; (2) *The Cultivation and Preparation of Pará Rubber*, by W. H. Johnson; (3) *Notes on Rubber Cultivation*, by Lieutenant-Colonel J. A. Wyllie and O. G. Ferreira (Madras: Higginbotham & Co.); (4) *Rubber and Rubber Planting*, by R. H. Lock (Cambridge University Press): (5) *Rubber in the East*, being the official account of the Ceylon Rubber Exhibition, 1906, ed. J. C. Willis, M. Kelway Bamber, and E. B. Denham; (6) *Bulletins of the Department of Agriculture*, Ceylon; (7) *Circulars and Agricultural Journal of the Royal Botanic Gardens*, Ceylon; (8) *The Agricultural Bulletin of the Straits and Federated Malay States*; and (9) *The Cultivation of the Pará Rubber Tree in Burma*, by A. M. Sawyer (Department of Agriculture, Burma, Bulletin No. 7, 1911). Frequent articles on rubber appear in the *Tropical Agriculturalist*, Colombo, and occasional papers appear in the *Agricultural Journal of India*. The pages of the *Indian Forester* at one time contained articles on *Hevea*, but this tree now concerns the planter rather than the forest officer, and that journal does not now ordinarily contain information regarding it.

It is therefore unnecessary here to enter into details on the subject, though a few remarks on conditions in Burma and southern India which differ from those obtaining in the Malay States may not be out of place. In Burma and in most parts of southern India in which rubber planting is carried out, planters are faced with a heavy rainy season alternating with a long dry season extending over several months, during which little or no rain falls, while in the Malay States sufficient moisture may be said to be present almost throughout the year. In Burma and southern India, therefore, special precautions are necessary to preserve the soil moisture during the dry season, and this is best effected by means of green mulching and keeping the soil to a depth of several inches in a state of fine tilth. This can be done by mulching weeds into trenches and then harrowing and cross-harrowing until a deep loose fine tilth is obtained. Disk harrows have proved most effective for this work. 'Scrape' weeding, that is, scraping weeds off the surface of the ground, has proved distinctly harmful in Burma and India, since not only does it fail to conserve moisture in the dry season, and cause the exposure of the roots by the gradual removal of the surface soil, but during the monsoon it causes denudation and the formation of ruts and channels where the ground slopes. This is liable to occur with any system of clean weeding, and accordingly on some estates the effective plan has been adopted of introducing leguminous cover crops such as *Erythrina* and *Crotolaria*. The former when high enough is cut half through, bent over, and pegged down, a dense cover being formed which prevents the growth of weeds. Thereafter the shoots are cut from time to time and laid on the ground as a mulch.

As regards the efficacy of cultivation and mulching, Mr. Fenoulhet notes that in the Shwegyin rubber estate, Burma, in April 1915, a crop of 4,553 lb. was obtained from 184,183 trees. During 1915 systematic cultivation and mulching was carried out by forking and harrowing. In 1916 a crop of 13,129 lb. was obtained from only 99,999 trees, every alternate row being rested throughout the dry months, that is, an increase of 8,576 lb. was obtained from 84,184 trees less, under exactly similar climatic conditions, which is well above the normal increase for an estate averaging eight years in age.

A point which is of great importance, but one to which sufficient attention is not always paid in clearing forest land for rubber cultivation, is the necessity for burning the felled material as thoroughly as possible. Logs and stumps lying about a cleared area cost a large sum to remove, and if not removed prevent regular planting, hinder weeding and cultivation, harbour moles, and, it is believed, promote fungus attacks. Thorough burning consumes all logs and a good many stumps as well as the seed of weeds and climbers, prevents regrowth from felled trees, and enriches the soil with a deep layer of ashes ; it may mean all the difference between failure and success. The secret of this operation is to fell the trees soon after the rainy season is over, to cross-cut the felled material and allow it to lie through the cold and hot seasons, to protect the area carefully from fire meanwhile, and to burn well on in the hot season without risking too long a delay in case of rain. The felled material thus dries as thoroughly as time permits, and the result is a very severe conflagration which may consume it all, together with any regrowth and weeds which may have sprung up after the felling, and at least a portion of the stumps. It seldom happens, however, that all the felled material is completely consumed at the first burning, and it is generally necessary to collect the unburnt refuse and burn it again.

In India and Burma the growth of rubber trees is not as a rule equal to that in the Malay States, owing to the long dry season. It is therefore not generally considered advisable to commence tapping under six years from the time of planting. For the same reason planting is, as a rule, closer in India and Burma than in the Malay States. In the Government plantation at Mergui the spacing first tried was 12 ft. by 12 ft., but this was soon found to be too close, and from the third year onwards a spacing of 16 ft. by 16 ft. was adopted. Perhaps the most usual spacing is 20 ft. by 20 ft. rectangular ; this is sometimes effected by planting 20 ft. by 10 ft., and cutting out intermediate lines some years later. A spacing which has been adopted in some good estates is 18 ft. by 18 ft. in quincunx form. In the Andamans the oldest plantation was spaced 15 ft. by 15 ft., but this was found to be too close, and on flat ground the more recent plantations have been spaced 22 ft. on the triangular system, giving 104 plants per acre. On hilly ground the spacing adopted has been one of 15 ft. along contours 30 ft. apart, giving 96 plants per acre ; the advantage claimed for this method is that it facilitates tapping on hilly ground.

Yield. In India and Burma the industry is as yet young, and exhaustive figures of yield are not yet available. It was thought at one time that owing to the heavy rains of the monsoon alternating with a long dry season, rubber planting in these countries would not prove remunerative. The yields derived so far in well-managed plantations, however, have dispelled such fears. One estate in Travancore has recently produced 150 lb. per acre from trees five years old, while two other estates have produced 360 and 326 lb. per acre from trees ten years old. In Burma it is generally estimated that an estate in full bearing should yield at least 350 to 400 lb. of rubber per acre per annum.

17. MANIHOT, Adans.

Manihot Glaziovii, Muell. Arg. Ceara rubber.

A moderate-sized tree with palmate leaves deeply cut into segments usually five to seven in number. Bark peeling off in horizontal strips like that of the cherry tree. The Ceara rubber tree is indigenous to the province of Ceara in Brazil, where it occurs in somewhat dry situations. It has been introduced into the East and thrives well in parts of Burma and Ceylon, growing in the latter country up to at least 3,000 ft. elevation and even on the most barren soils. It has succeeded well in Calcutta and Madras, and at Kulsi in Assam. In the Forest compound at Tharrawaddy, Burma, there were some years ago several trees, which reproduced so freely that the thickets of young plants became a nuisance and were eradicated in 1903, together with a number of the older trees. It grows well in Bhamo and Myitkyina. In Napier's Park, Ganjam, Madras Presidency, it grows very well and reproduces freely; trees fourteen years old attained a height of 40 ft. and a girth of 24 in., but produced practically no rubber. A number of trees grown in Malabar were tapped experimentally in 1896 and 1897, but the yield was very poor.

So far as India is concerned, although the tree grows well in many places, and would probably thrive over a wider area than *Hevea brasiliensis*, the poor results obtained by tapping hitherto have not justified the formation of plantations.

In India the tree is leafless for some time early in the hot season, usually about February–March. The flowers appear in the cold season and the fruits ripen about March, opening and shedding the seeds round the trees. The seed has a caruncle at one end, and somewhat resembles that of the castor-oil plant in shape.

The testa is extremely hard, and germination is very slow unless the testa is filed almost through on either side of the caruncle. The plant is then easy to raise from seed, and it grows also from cuttings. The growth is very rapid, but the tree seldom reaches a height of more than 40 ft.

ORDER LIII. ULMACEAE (Urticaceae, tribes Ulmeae and Celtideae)

Genera 1. Ulmus, Linn.; 2. Holoptelea, Planch.; 3. Celtis, Linn.; 4. Trema, Lour.

1. ULMUS, Linn.

There are five elms of the Indian region: (1) *U. Wallichiana*, Planch., the common elm of the western Himalaya; (2) *U. lancifolia*, Roxb., the eastern elm, found in Sikkim, Bhutan, Assam, Chittagong, and Burma; (3) *U. villosa*, Brandis (*U. laevigata*, Royle), the small-leaved elm of the Punjab Himalaya,

FIG 316. *Macaranga denticulata* raised by sowings in a savannah tract, South Muraghat forest, Jalpaiguri, Bengal, age 8 years, height 30–35 ft.

FIG. 317. *Ulmus Wallichiana*, Hazara.

closely akin to *U. campestris* ; it occurs at somewhat lower elevations than (1), ascending to 7,000 ft. ; it produces root-suckers freely ; (4) *U. campestris*, Spach., the common elm of Europe ; Baluchistan and Kurram valley at 7,000–9,000 ft. ; it produces root-suckers freely ; (5) *U. parvifolia*, Jacq. (*U. virgata*, Roxb.), an evergreen shrub, possibly wild in Nubra, northern Kashmir (Brandis).

Ulmus Wallichiana, Planch. The Western Himalayan elm. Vern. *Kain, marál, emroi*, W. Him. (Fig. 317.)

A large deciduous tree with rough grey thick bark deeply furrowed with longitudinal and diagonal furrows. The tree has a fine timber which deserves to be better known as a furniture wood. It reaches large dimensions ; Gleadow records one of 16½ ft. girth in Jaunsar, and Brandis one of 24 ft. girth. Large trees often have dry tops or become hollow.

This elm occurs throughout the western Himalaya from the Indus to Nepal at 3,500 to 10,000 ft. It is nowhere very common, but is found scattered in mixture with other trees, both conifers and broad-leaved species. It is found most commonly in fairly moist situations along the sides of ravines ; on dry ridges and at high elevations it is usually stunted. Natural reproduction sometimes springs up in abundance on newly exposed ground such as is found in cuttings and on embankments, landslips, the sides of ravines, and abandoned cultivation ; gregarious young crops have been noticed in Hazara on abandoned fields in the open. The tree is somewhat light-demanding, though it stands a little shade in youth. It does not produce root-suckers. It is often planted round villages and lopped for fodder. The tree is leafless during the winter months, the new leaves appearing about April–May. The flowers appear immediately before the new leaves, and the fruit, a membraneous elliptical samara 0·6–0·7 in. long, ripens in May–June ; much of the seed is barren. The growth, according to Gamble, is slow ; of specimens examined by him the fastest showed 6 rings per inch of radius, giving a mean annual girth increment of 1·05 in.

2. HOLOPTELEA, Planch.

Holoptelea integrifolia, Planch. Syn. *Ulmus integrifolia*, Roxb. Indian elm. Vern. *Papri, papar, kanju, karanji, chilla, banchilla, kunj, bisenda*, Hind. ; *Rajáin*, Pb. ; *Wavuli, papara*, Mar. ; *Tapasi*, Kan., Tel. ; *Aya, avali*, Tam. ; *Myaukseik, pyaukseik*, Burm.

A large deciduous tree with strong ascending or spreading branches and elliptical leaves. Bark grey, fairly smooth. The bark when cut and the leaves and twigs when crushed have an offensive smell. Wood yellowish grey, strong, used for agricultural implements, and has been pronounced suitable for brush-backs.

Distribution and habitat. The sub-Himalayan tract from the Chenab eastwards, ascending to 2,000 ft., central India, Chota Nagpur, the Indian Peninsula, Upper Burma. It is commonly found in mixed deciduous forests of a somewhat dry type : Bourdillon says that in Travancore it is common in evergreen forests at low elevations. In the sub-Himalayan tract it is one of the largest and most characteristic trees at the foot of the outer hills and in the dry stony *bhabar* country flanking those hills, where there are thick boulder deposits and water is at a great depth below the surface. Along the foot-hills it is found in association with *Adina cordifolia*, *Cassia Fistula*, *Schleichera trijuga*, and other species; in places it springs up in great profusion and forms gregarious patches on the rocky débris along the lower slopes of the outer hills and on the dry stony ground at their base. Fig. 319 shows a group of large trees on a boulder deposit in the sub-Himalayan foot-hills; the elm-like form is noticeable. In the dry *bhabar* tract its chief associates are *Hymenodictyon excelsum*, *Bombax malabaricum*, *Odina Wodier*, *Garuga pinnata*, *Lagerstroemia parviflora*, and *Acacia Catechu*. On poor shallow soil the tree becomes stunted and crooked. Haines[1] notes that there is a shrubby, stunted form common on the Palamau hills in Chota Nagpur.

LEAF-SHEDDING, FLOWERING, AND FRUITING. In northern India the leaves fall chiefly in January and February, and the trees are leafless until April or May, when the new leaves appear. The fascicles of small greenish flowers appear on the leafless trees from February to April, and the winged fruits, hanging in clusters, ripen in April and May, when the trees are still leafless or the new leaves are appearing: the fruits fall soon after ripening and are carried by the wind to some distance from the tree. The samara (Fig. 318, *a*) is broadly elliptical or ovate, about 1 in. long; about 700 to 800 fruits weigh 1 oz. Tests at Dehra Dun have shown that the seed does not retain its vitality long, though the percentage of fertility of good fresh seed may be high.

GERMINATION (Fig. 318, *b–e*). Epigeous. The radicle issues from the apex of the fruit and descends, while the hypocotyl elongates with slight arching and raises above ground the cotyledons, which are conduplicate until the hypocotyl has almost attained full length, when they unfold and expand, the young shoot appearing from between them.

THE SEEDLING (Fig. 318).

Roots: primary root long, terete, tapering, wiry, flexuose; lateral roots numerous, fibrous, distributed down main root. *Hypocotyl* distinct from and thicker than root, 0·6–1 in. long, terete, tapering upwards, with a decided bend at the lower extremity formed during germination, white turning green, pubescent. *Cotyledons*: petiole about 0·05 in. long; lamina 0·3–0·35 in. by 0·35–0·4 in., foliaceous, bifid to one-third or one-half the length, apices of lobes truncate or broadly rounded, base truncate, entire, finely pubescent, conduplicate in the seed. *Stem* erect, terete, zigzag at the nodes, green, pubescent; internodes 0·3–1 in. long. *Leaves* simple, first pair opposite, subsequent leaves alternate. Petiole 0·05–0·1 in. long. Lamina 0·6–4 in. by 0·3–2 in., elliptical or ovate, acuminate, base cordate, serrate crenate, pubescent. The leaves of seedlings differ from those of adult trees in that the latter are normally entire.

Under natural conditions the growth of the seedling is at first slow, a height of only a few inches being attained by the end of the first season, but under favourable conditions the growth becomes fairly rapid subsequently. As a rule branching does not commence until the second season, and even then only in the case of the more vigorous seedlings. Weeding greatly stimulates development, while seedlings are liable to be suppressed and killed by a heavy growth of weeds. Good growth is attained only on porous soils, stiff soils preventing satisfactory development. Seedlings are sensitive both to frost

[1] For. Flora Chota Nagpur, pp. 389–90.

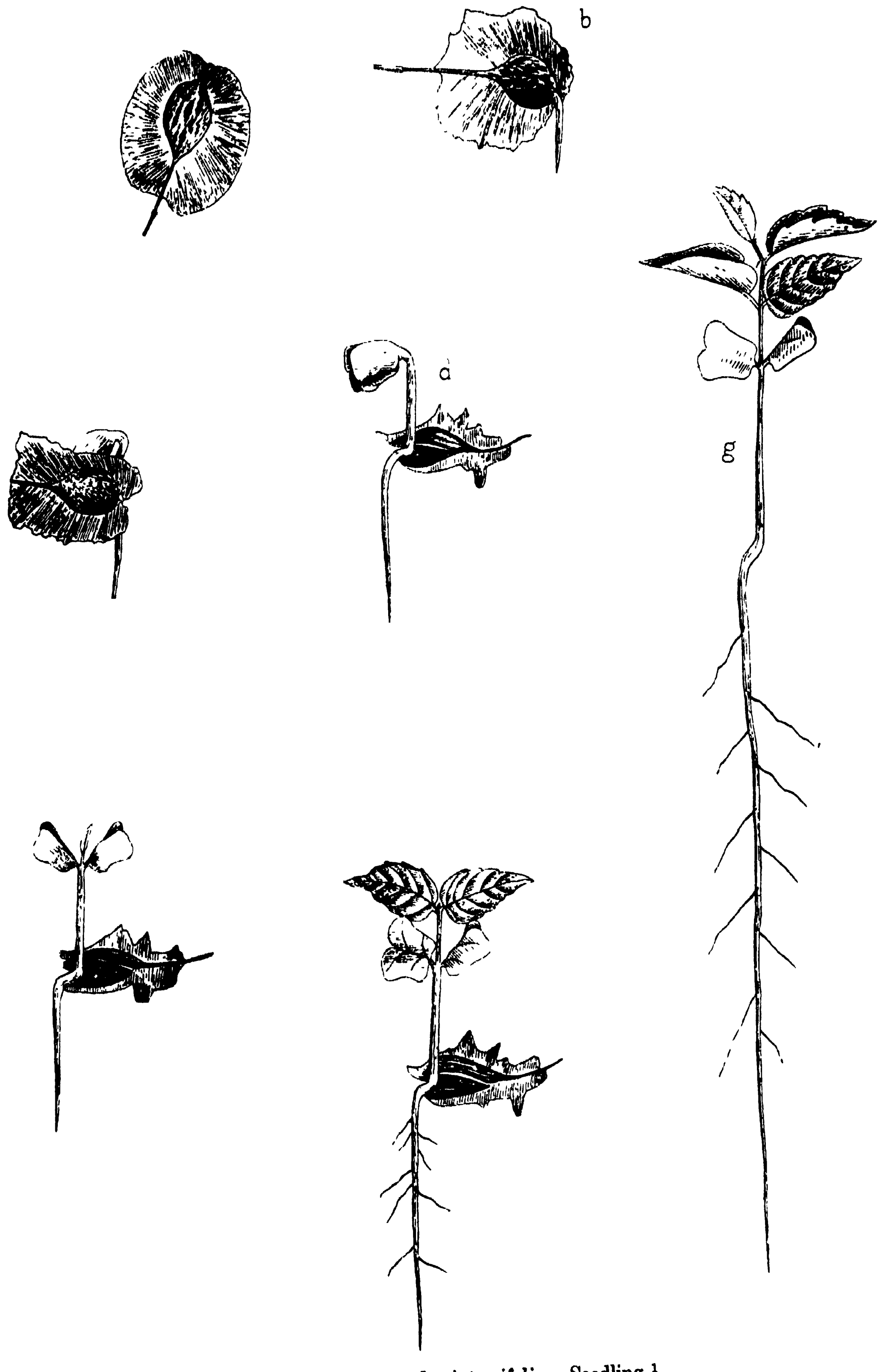


FIG. 318. *Holoptelea integrifolia.* Seedling $\frac{1}{1}$.
a, winged fruit; *b–e*, germination stages; *f*, *g*, development of seedling during first season.

and to drought, and heavy mortality may be caused by both agencies; if killed down to ground-level the young plants have little power of recovery.

The following measurements of seedlings grown in experimental plots at Dehra Dun give some indication of the rate of growth under different conditions:

Holoptelea integrifolia: rate of growth of seedlings at Dehra Dun.

Condition under which grown.	Height and other particulars at end of season. 1st season.	2nd season.	3rd season.	4th season.
(1) Natural conditions	Maximum 0 ft. 4½ in.	..	..	10–13 ft.
(2) Broadcast sowing, irrigated, unweeded	Maximum 0 ft. 4 in. (weakly)	Maximum 0 ft. 2½ in. (suppressed by weeds)	All killed by weeds in 3rd season	..
(3) Broadcast sowing, unirrigated, unweeded	Maximum 0 ft. 4 in.	Maximum 0 ft. 5 in. (suppressed by weeds)	0 ft. 3½ in.–0 ft. 4½ in. (suppressed by weeds)	..
(4) Broadcast sowing, unirrigated, weeded	Maximum 0 ft. 4 in.–1 ft. 3 in.	3 ft. 0 in. and 3 ft. 5 in. (Two survivors; remainder killed by frost and drought)	6 ft. 2 in. and 7 ft. 7 in.	..

SILVICULTURAL CHARACTERS. The tree is a moderate light-demander. It requires good drainage, and is capable of thriving without much moisture in the soil, provided the soil is deep and porous. It produces a strong spreading root-system. It is not frost-hardy, and on the Punjab plains, where it is planted, it suffers considerably in years of severe frost. The leaves are not readily browsed by goats or cattle. The tree coppices, but there is no information available as to the extent of its coppicing power.

NATURAL REPRODUCTION. The seeds, which are distributed by wind during the hot season, do not as a rule germinate until the beginning of the rainy season; if owing to abnormal rain germination takes place during the hot season the seedlings almost invariably perish of drought during the ensuing dry weather. In order to ensure successful germination and the survival of the seedling under natural conditions, it is important that the seed should fall on loose bare soil clear of weeds. This facilitates the covering of the seed with earth before germination takes place, an important matter in preventing the death of the germinating seedling from drought, while in addition the absence of weeds and the loose soil aid the development of the seedling, enabling it to establish itself and resist drought, which is perhaps the commonest cause of mortality. Some protection from the sun in early youth, such as is afforded by bushes and rocks, is beneficial. In the sub-Himalayan tract natural reproduction springs up in places in great profusion amongst the rocky débris on the lower slopes of the outer hills and on the dry stony porous ground along their base; here may be found patches of almost pure forest containing plants of all sizes from small seedlings to mature trees. In Burma natural reproduction sometimes springs up readily on recently formed alluvial ground.

ARTIFICIAL REPRODUCTION. This species has been raised successfully at Dehra Dun both by direct sowing and by transplanting nursery-raised seedlings, the more vigorous plants in the first rainy season and the less vigorous ones a year later. In either case fresh seed should be sown soon after collection, about April or May, and lightly covered with earth. Stiff soil should be avoided and regular weeding and loosening of the soil should be carried out, whether in the nursery or in the plantation. In the nursery regular watering is neces-

FIG. 319. *Holoptelea integrifolia*. trees in the Himalayan foot-hills, Kotdwara. United Provinces.

FIG 320. *Ficus*-bound teak tree, girth over *Ficus* 17 ft 5 in., Toungoo, Burma

sary, and it has been found advisable to shade the beds during the heat of the day from the time the seed is sown until the rainy season has set in, otherwise there is considerable mortality from drought during and after germination.

Rate of growth. The growth is fast. Gamble states that it is usually about 6 rings per inch of radius, giving a mean annual girth increment of 1·05 in., but that it is sometimes as fast as 2 rings to the inch, giving a mean annual girth increment of 3·14 in. A cross-section from the United Provinces in the silvicultural museum at Dehra Dun had 93 rings for a girth of 7 ft. 1 in., showing a mean annual girth increment of 0·91 in.

3. CELTIS, Linn.

Four Indian species, of which the two most important are *C. australis*, Linn., of the western Himalaya, and *C. tetrandra*, Roxb., a large tree of the eastern Himalaya and the hills of the Indian Peninsula, particularly the Nilgiris, where it ascends to 7,000 ft.

Celtis australis, Linn. Syn. *C. caucasica*, Willd. Nettle tree. Vern. *Kharak*, *kharik*, *ku*. W. Him.; *Taghar*, Pushtu; *Batkarar*, Haz.; *Brimij*, Kashm.

A moderate-sized, sometimes fairly large, deciduous tree with variable ovate acuminate leaves oblique at the base and strongly 3-nerved. Bark smooth, bluish-grey, often with horizontal wrinkles and small round excrescences, much resembling that of the European beech. Wood tough, strong, and elastic, used for oars, tool-handles, and ploughs. The tree is much lopped for cattle fodder.

Distribution and habitat. Western Himalaya eastward to Nepal, ascending to 8,000 ft., hills of Afghanistan and Baluchistan, extending westward through southern Europe. It is often cultivated on the plains, where it grows well. In the Himalaya it is often found in forests associated with deodar and blue pine, and with horse-chestnut, maple, bird-cherry, oaks, and other broad-leaved species; it is also frequently cultivated round villages and regularly lopped for fodder. This tree is interesting as being one of those which ascend to fairly high elevations and also occur in swamp forests in the outer valleys below 2,000 ft. One of the best examples of its occurrence at a low elevation is to be found in the swamp forest at Sitabani near Ramnagar, where it grows gregariously.

Leaf-shedding, flowering, and fruiting. In the Himalaya the leaves are shed in December and January, and the new leaves appear in March or April. The small greenish flowers appear with the new leaves. The fruits form rapidly, attaining full size by June or July, though they remain green till September or October, when they become yellow. From October to December they turn black and become dry, falling to the ground during December and January; some are eaten on the trees by birds, including crows, by whose agency the seeds are spread. The fruit (Fig. 321, *a*) is an ovoid or nearly globose drupe, 0·3 in. long.

Germination (Fig. 321, *b–g*). Epigeous. The putamen of the drupe splits into two parts, the radicle emerging from the under side of the fruit and the plumule through the upper side. The hypocotyl is arched at first, and in straightening raises above ground the cotyledons, which are conduplicate in the seed, but soon unfold and expand. The remains of the fruit are left in or on the ground.

THE SEEDLING (Fig. 321).

Roots: primary root moderately long, thin, terete, wiry, flexuose; lateral roots numerous, somewhat long, fibrous. *Hypocotyl* distinct from root, 0·8–1·4 in. long, terete, tapering slightly upwards, green, minutely pubescent in upper part, glabrous elsewhere. *Cotyledons*: petiole about 0·05 in. long; lamina 0·4–0·6 in. by 0·35–0·4 in., foliaceous, oblong, cleft to nearly one-quarter of the length, base rounded or truncate or slightly auriculate, entire, green, minutely pubescent or glabrescent, conduplicate in the seed. *Stem* erect, terete, zigzag at the nodes, wiry, greenish brown, young parts green and pubescent. *Leaves* simple, first pair usually opposite, subsequent leaves alternate. Stipules 0·1 in. long or less, falcate, acuminate, pubescent, caducous. Petiole 0·1–0·2 in. long. Lamina 0·8–2·8 in. by 0·5–1·1 in., obliquely ovate, acuminate, base rounded or slightly cordate, serrate, basal portion entire, minutely scabrous, prominently 3-veined from the base.

The growth of the seedling is slow to moderate. Plants raised at Dehra Dun attained a height of 5 to 12 in. by the end of the first season, and 8 to 18 in. by the end of the second season. The seedlings were found to be frost-hardy but somewhat sensitive to drought.

SILVICULTURAL CHARACTERS. The tree stands a moderate amount of shade. It is not very exacting as to soil, growing both on swampy and on dry rocky ground, but in the latter case it becomes stunted. In India it is fairly frost-hardy; the leaves are often affected by frost before they fall, but there is little or no permanent injury done. It pollards and coppices well.

ARTIFICIAL REPRODUCTION. Experiments at Dehra Dun showed that seedlings can be raised without much difficulty in the nursery, the seed being sown in February or March and the seedlings being transplanted in the first or second rainy season; care is necessary not to expose the roots too much during transplanting.

SILVICULTURAL TREATMENT. In India the tree is regularly pollarded in village lands. In southern France it is worked in close-grown coppice mainly for the production of poles and whip-handles.

RATE OF GROWTH. The growth, according to Gamble, is moderate, about 8 to 9 rings per inch of radius, giving a mean annual girth increment of 0·7–0·78 in.

4. TREMA, Lour.

Species 1. *T. orientalis*, Bl.; 2. *T. amboinensis*, Bl.; 3. *T. politoria*, Planch.

1. **Trema orientalis**, Bl. Syn. *Sponia orientalis*, Planch.; *S. Wightii*, Planch. Charcoal tree. Vern. *Jiban*, Beng.; *Kargol, ranambada*, Mar.; *Oman*, Tam.; *Gada-nelli*, Tel.

A small, soft-wooded, fast-growing, and short-lived tree with straight spreading branches and ovate acuminate leaves usually with oblique bases. Bark thin, smooth, greyish green; with numerous lenticels. The wood makes good gunpowder charcoal. Found throughout the sub-Himalayan tract from the Jumna eastwards, Bengal, Chota Nagpur, and the Indian Peninsula. It has a remarkable capacity for springing up on forest clearings, landslips, and wherever the ground is exposed; in such places it is often the first tree to appear, coming up gregariously. It is thus a most useful plant for reclothing

FIG. 321. *Celtis australis.* Seedling × ¾.

a, fruit; *b–g*, germination stages; *h–k*, development of seedling to end of first season.

landslips and exposed ground. In the Dehra Dun valley it affects swampy places. In southern India it is often planted as a shade tree for coffee. The fruit is a small black drupe, 0·15 in. in diameter ; the seed is possibly spread by birds, though this requires verification. The growth is very fast. Gamble mentions a tree cut by him at Sivoke, Bengal, which in five years had attained a height of 25 ft. and a girth of 40 in.

2. **Trema amboinensis**, Bl. Syn. *Sponia velutina*, Planch. Vern. *Kywèsa*, *satsha*, Burm.

This tree is nearly allied to the preceding species, and is perhaps not specifically distinct. It occurs in Sikkim, Assam, Chittagong, Burma, Andamans. It appears in abundance on abandoned *taungya* clearings in Burma. In the Andamans it sometimes comes up almost pure in *taungya* areas cleared for padauk sowing, and spreads in remarkable fashion ; it is beneficial to young padauk if merely lopped or cut back to free the leading shoot of the padauk.

3. **Trema politoria**, Planch. Syn. *Sponia politoria*, Planch. Vern. *Kuri*, *khagshi*, *khardal*, *banharria*, Hind.

A small evergreen tree with scabrous leaves, which are used for polishing wood. Sub-Himalayan tract, Salt Range, Rajputana, Central Provinces, Chota Nagpur, Upper Burma. This tree, like the other two species, comes up in profusion on landslips, abandoned cultivation, cuttings, or embankments, and other places where the soil is exposed, as well as on sandbanks in the beds of streams and shingle deposits in dry river-beds. It is a useful species for binding the soil on landslips and similar places. The fruit is a small drupe, 0·1–0·15 in. in diameter.

The growth is rapid. Gamble gives 2 rings per inch of radius, representing a mean annual girth increment of 3·14 in.

ORDER LIV. MORACEAE (Urticaceae, tribes Moreae and Artocarpeae)

An important order. containing some valuable timber trees (particularly species of *Artocarpus*), rubber-yielding trees (*Ficus elastica* and the exotic *Castilloa elastica*), and fruit trees (*Ficus*, *Artocarpus*, and *Morus*). The important part which birds play in distributing seeds is strikingly illustrated in this order.

Genera 1. Ficus, Linn. ; 2. Artocarpus, Forst. ; 3. Morus, Linn. ; 4. Broussonetia, Vent. ; 5. Castilloa, Cerv.

1. FICUS, Linn.

This is a very large genus, containing about 80, or perhaps more, Indian species, of which only a few of the commoner or more important are dealt with here. Economically by far the most important is *F. elastica*, the india-rubber fig, though the promise at one time held out by it has not been fulfilled owing to the successful introduction into the East of *Hevea brasiliensis*, the cultivation of which has proved far more profitable. Several of the wild Indian figs produce more or less edible fruits, and the true edible fig, *F. Carica*, is cultivated in India.

The habits of the figs vary. Many start life as epiphytes and remain as such for years or even throughout their life ; of these may be mentioned *F. gibbosa, F. bengalensis, F. elastica, F. retusa, F. Rumphii,* and *F. religiosa.* These epiphytic figs can, however, be grown as terrestrial trees. Many epiphytic species produce large aerial roots, which may interlace or may grow vertically downwards, taking root in the ground and enabling the crown of the tree to spread over a large area ; the most notable examples of aerial root production are to be found in *F. bengalensis* and *F. elastica.* Of species which are never epiphytic may be mentioned *F. hispida, F. Cunia, F. palmata, F. Carica, F. Roxburghii,* and *F. glomerata.* In addition there are certain small scandent species, for example *F. scandens, F. foveolata,* and *F. pumila,* the last named a Chinese species cultivated in India ; these are of no special importance in forestry, but are interesting from their habit of clinging like ivy to rocks, tree trunks, or walls by means of numerous small aerial rootlets. An interesting fact regarding the figs is the part played by minute hymenopterous insects in the fertilization of the female flowers, and possibly the natural distribution of each species of *Ficus* may be limited by the presence of the particular species of insect which effects its fertilization.

As far as observations go, the epiphytic figs, even when their roots become established in the ground, appear to possess no coppicing power when felled, though this statement requires verification. On the other hand, some at least of the non-epiphytic species have this power, while some, notably *F. hispida,* have the power of producing root-suckers.

The epiphytic figs are regarded as very troublesome pests in forest operations in India. The fruits are eagerly devoured by birds and the seeds are dropped by them in the forks and hollows of trees throughout the forest. The seedlings thus develop out of reach of danger, and as the plants grow they gradually send their aerial roots down to the ground and establish themselves, encircling and strangling their hosts, which are often valuable timber trees (see Fig. 320). The only preventive measure is systematically to fell these fig-bound trees, a costly operation, otherwise they become centres for the further spread of the fig. Opportunity is taken to remove such trees when felling for the market. It is interesting to note that in the abnormal drought of 1907 and 1908 in the forests of Oudh the epiphytic figs proved conspicuously drought-resistant.

Most if not all species of fig can be propagated by cuttings (see under *F. bengalensis* and *F. elastica*). They can be raised from seed only if special precautions are taken, since the seeds are very minute. The process of preparing the seed and raising seedlings, as described for *F. elastica,* is applicable generally to species of this genus. The main points to bear in mind are (1) to sow the seed in boxes or well-raised beds in very fine soil of sifted rich mould and sand, made specially porous towards the surface by a mixture of powdered charcoal or brick-dust, (2) to shade the beds or boxes from the sun and to prevent any drip from rain, (3) to keep them always moist by watering with a very fine spray. When large enough the seedlings are pricked out in well-raised open nursery beds, after which they give very little trouble.

Species 1. *F. gibbosa,* Bl. ; 2. *F. bengalensis,* Linn. ; 3. *F. elastica,* Roxb. ; 4. *F. retusa,* Linn. ; 5. *F. Rumphii,* Bl. ; 6. *F. religiosa,* Linn. ; 7. *F. hispida,* Linn. f.; 8. *F. Cunia*, Ham.; 9. *F. palmata*, Forsk.; 10. *F. Carica*, Linn.; 11. *F. Roxburghii*, Wall.; 12. *F. glomerata*, Roxb.; 13. *F. pumila*, Linn.; 14. *F. scandens*, Roxb.; 15. *F. foveolata*, Wall.

1. **Ficus gibbosa**, Bl. Syn. *F. Ampelos*, Roxb.; *F. tuberculata*, Roxb.; *F. parasitica*, Koen.; *F. excelsa*, Vahl. Vern. *Chanchri*, Garhwal; *Majni, chirwal*, C.P.; *Datir*, Mar.; *Itthi*, Tam.; *Nyaung thabye*, Burm.

An evergreen epiphyte, sometimes becoming an independent tree. Leaves variable, elliptical, smooth above, rough beneath (var. *tuberculata*) or broad sub-rhomboid, hispid above (var. *parasitica*). Bark smooth, greenish yellow to greyish brown. This is a much-branched fig with numerous interlacing aerial roots, and is often found completely embracing other trees, particularly other figs and *Adina cordifolia*, also clinging to walls. Widely distributed. Fruits 0·2–0·3 in. in diameter, ripening from February to May, yellow when ripe.

2. **Ficus bengalensis**, Linn. Syn. *F. indica*, Roxb.; *Urostigma bengalense*, Gasp. Banyan. Vern. *Bor, bar, bargat*, Hind.; *Wad*, Mar.; *Al, alada*, Kan.; *Ala*, Tam.; *Pyinyaung*, Burm.

A very large evergreen tree, usually starting life as an epiphyte, with large spreading horizontal branches from which numerous aerial roots are thrown down, these taking root in the ground, growing into new trunks and helping to spread the crown of the tree. Leaves 4–8 in. long, elliptical or ovate, thickly coriaceous, shining. In dry localities the tree becomes leafless for a short time in the hot season, but ordinarily it is evergreen. Various records of large trees exist, and large specimens with a crown cover more than 200 ft. in diameter are by no means rare. The famous tree in the Royal Botanic Gardens, Calcutta, which was ascertained to have grown from a seed deposited in the crown of a date palm in 1782, had, according to Colonel Prain, quoted by Gamble, the following measurements in 1900: circumference of the trunk 51 ft., of the crown 938 ft.; height, 85 ft.; number of rooted drops, 464. 'Mr. Warner, quoted by Sir G. King, describes a banyan at Wysatgarh near Satara which had in 1882 a circumference of spread of 1,587 ft., while another, in the Andhra valley near Poona, had a circumference of spread of about 2,000 ft.' (Gamble).

This tree is widely distributed through the forest tracts of India, and is extensively planted for shade in gardens and villages and along roadsides. It is a useful elephant fodder, and is lopped for this purpose; in some localities the felling of the tree is forbidden within a mile of a camping ground, in order to ensure supplies of elephant fodder. In the forest, however, it is one of the most noxious of the epiphytic figs, occupying a large amount of space to the exclusion of useful species. The seeds, dropped by birds in the forks and boughs of trees, germinate there, and as the plant is fast-growing it soon envelops and kills its host and spreads by means of its aerial roots. It is extremely difficult to eradicate, owing to the tenacity of the roots and the large size of the tree. It is very destructive to walls and buildings, the roots penetrating the crevices and being difficult to eradicate.

The tree is decidedly drought-hardy, as was proved in the abnormal drought of 1907 and 1908 in the forests of Oudh. Severe frosts damage the leaves, but the tree shows good power of recovery, and did not suffer to any great extent in the abnormal frost of 1905 in northern India.

The fruits, which are red when ripe and 0·5–0·7 in. in diameter, ripen chiefly from March to May, but they may often be found at other seasons of the year. They are readily eaten by birds and monkeys and in times of scarcity by human beings.

The tree can be propagated from seed or from cuttings. The seed should be sown as soon as it ripens, preferably in pots or boxes in fine mould mixed with powdered brick or charcoal, and the young plants should be kept shaded in the heat of the day. Large cuttings 8 to 10 ft. high should be planted about January to March and well watered until the rainy season, or if watering cannot be carried out they may be put down at the commencement of the rains, though this is usually less successful. Small cuttings put down in pots or baskets in March and well watered sometimes prove successful.

3. **Ficus elastica,** Roxb. Indiarubber fig, Indian caoutchouc, Assam rubber. Vern. *Attah, bor attah, bor,* Ass.; *Nyaung kyetpaung,* Burm.

A very large handsome evergreen tree, with spreading branches and a dense crown of dark green shiny leaves; usually epiphytic in the natural state, sending down numerous aerial roots, and often much buttressed or fluted in the trunk. Leaves elliptical, coriaceous, shining, 5–10 in. long, with a prominent midrib, enclosed in the bud in terminal red stipular sheaths which fall as the leaves expand. Bark greyish or reddish brown, fairly smooth but scurfy. In its natural habitat the tree attains very large dimensions, a height of 100 to 120 ft. being not uncommon, while occasionally it reaches a height of 150 ft. or even more.

This, the most important indigenous rubber tree of India, at one time held out promise of being of great future value, and plantations of it have been formed on a fairly large scale in Assam. The extensive plantations of Pará rubber in the East, however, have sealed its doom as a commercial proposition, for Pará rubber comes into bearing much sooner than Assam rubber, and, age for age, produces higher yields per acre. It is more than doubtful, therefore, if the plantations now in existence can claim to be a commercial success, though this was not foreseen when the majority of them were formed, and *Ficus elastica* has accordingly been entirely discarded by planters in the East in favour of *Hevea brasiliensis.*

Distribution and habitat. The outer Himalaya from Nepal eastwards, ascending to 5,000 ft., Assam, Khasi hills, Hukong valley and other valleys of Upper Burma, ascending to nearly 5,000 ft., and extending south to just below the 20th parallel of north latitude in the Minbu district.

In Assam the tree is most plentiful in the Darrang and Lakhimpur districts; it was at one time found in considerable quantity in Bhutan, the Naga hills, and the Akah and Daphla territories, while Mr. Milroy [1] notes its occurrence in the Abor country. In tribal territories there is reason to fear that it has largely disappeared through excessive tapping. Mr. Jacob [2] notes that in Bhutan it has for this reason almost disappeared from the forests west of the Manas river, while east of that river it is still fairly plentiful, though he observed numbers of dead trees killed by excessive tapping. It is a conspicuous tree in the evergreen forests of Assam, often towering over the

[1] Report on the Forests of the Abor country, 1912.

[2] Report on the Forests of Bhutan, 1912.

surrounding forest ; it occurs scattered and not gregariously. In his report on the Hukong valley of Upper Burma, Mr. H. N. Thompson mentions that the tree is found scattered generally through the dense evergreen forests, a mature tree being found every 200 or 300 yards in the richer forests. In Upper Burma the tree does not ordinarily extend south of 24° N. lat., but Mr. W. T. T. McHarg [1] found it in limited quantity in the drainages of the Pani, Maton, and Kyaungtha streams in the Minbu district just south of 20° N. lat. He notes that it always starts life as an epiphyte, and that the trees in that locality are always found near water, the roots forming a regular lace-work over the bank and running down into the bed of the stream.

The chief factor which determines the natural distribution of the tree appears to be excessive humidity, which also denotes an equable climate ; actually it is found typically in warm steamy localities, though it ascends to altitudes which are moderately cool, and where fairly severe frost must almost certainly be encountered. Its commonest situation is in damp valleys, and on the sides of gorges and moist hill slopes ; it is capable of accommodating itself to different types of soil, but requires good drainage.

Apart from the plantations which have been formed in Assam and elsewhere, the tree is often cultivated as an ornamental or shade tree, and thrives well in many localities outside its habitat. It shows very fair growth at Dehra Dun, and is even grown as a shade tree in Egypt. It is familiar as a pot plant in houses in Britain.

FRUITING. The fruits are greenish yellow to red when ripe, ovoid, about 0·4–0·5 in. long, sessile in pairs at the nodes, and containing numerous small seeds. The fruits commence ripening in May, and continue ripening and falling throughout the rainy season and sometimes onwards until December ; some trees shed all their fruits by the end of June. The fruits are eagerly sought after by birds, and the greater part of the crop is often devoured on the tree. Claud Bald [2] says the best seed is obtained in the hottest months—May, June, and July. Seed should not be collected except from fruits which are thoroughly ripe and soft, and should be used quite fresh. The ripe fruits, when collected, should be divided in two with the fingers, spread out to dry in the sun, and then rubbed into powder between the hands ; the powder containing the seeds should then be sown. If the seed has to be sent to a distance it should be mixed with charcoal dust to assist it in retaining its vitality.

GERMINATION AND DEVELOPMENT OF SEEDLING. Germination is epigeous. The following description of the seedling is by Rai Bahadur U. N. Kanjilal [3] from specimens raised at Dehra Dun (see Fig. 322) :

'At first a pair of cotyledonary leaves appear, which are about one-tenth inch in diameter, orbicular-ovate emarginate, dull green, minutely petioled. Above these come out a pair of opposite leaves. These are stipulate (as are all succeeding leaves), slightly crenate, distinctly emarginate, membranous, with faint indications of arcuate nerves at the sinuses of an intramarginal vein, very shining above, until superseded by the next leaf ; one of the two leaves is somewhat larger than the other. Above these the leaves are sub-opposite when they appear, but soon become distinctly alternate by the elongation of the stem, each succeeding one larger in size than the one next below, second

[1] Ind. Forester, xxi (1895), p. 389. [2] The Cultivation of *Ficus elastica*, 1906.
[3] Ind. Forester, xxv (1899), p. 64.

much brighter, especially when fully grown. The fourth leaf above the cotyledons is about 1 by 6 in., ovate, distinctly crenate, emarginate. The next two leaves, the fifth and sixth, are oblong, 2 to 2·5 in. long, still emarginate, but the crenations are very shallow in the last leaf; lateral nerves four to six pairs, slightly arcuate. Then comes out the seventh leaf, all by itself, 3 by 1·2 in., oblong, with six to eight pairs of parallel nerves and two to three intermediate ones between, no longer emarginate, but acute and almost entire,

FIG. 322. *Ficus elastica*. Seedling $\frac{1}{1}$. (After Kanjilal.)
a, about ten days old; *b*, about one month old; *c*, about six weeks old.

with a row of white glandular dots along the margins. This is the first leaf that reveals the identity of the plant. Beyond this the leaves become thicker and thicker, the eleventh being about as thick as a normal India-rubber leaf. By the time the fifth leaf appears, a swelling is noticed below the root-collum, which goes on increasing in size.'

As the seedling increases in size the bulbous swelling gradually disappears.

SILVICULTURAL CHARACTERS. Although the tree grows naturally among evergreen shade-bearers it exhibits decided light-demanding tendencies. Thus the seeds brought by birds germinate in the summits of tall trees, and the young plants develop in the enjoyment of an abundance of light; they find nourishment in the débris which lodges in the forks and hollows of the tree and for some years grow purely as epiphytes, sending down aerial roots which eventually reach the ground and establish themselves. Thereafter the tree increases in size, producing numerous fresh aerial roots and eventually killing its host. The absence of young plants of terrestrial origin under the forest canopy is given as a reason, and no doubt a valid one, for concluding that the tree is a light-demander. A note in the *Indian Forester*, vol. xxiii (1897), p. 369, maintains that in order to permit the young plant to establish itself and to become sufficiently strong to form a connexion with the soil below, it is absolutely necessary that the tree on which it finds itself placed should be either dead or diseased; if not, the young plant cannot obtain sufficient nourishment, and dies. That this is the case, the note continues, has been clearly established by experiments in the Charduar rubber plantations, where many hundred plants were planted in the forks of trees. They were supplied with a considerable quantity of soil and grew to be healthy plants, but they lived the life of pot plants, and after more than ten years not one of those growing on a healthy tree had established its connexion with the soil.

The terrestrial roots of the rubber tree are superficial, and form a dense network along the surface of the ground, often spreading to a distance of 150 ft. or more from the tree. These roots have a remarkable power of anastomosing, and all the trees of a plantation may have their roots so amalgamated that the plantation becomes virtually one extensive tree. The aerial roots also exhibit a strong tendency to anastomose.

Although in its natural state the tree extends into regions of frost, the young plants, situated high up in trees, probably escape severe frost. At Dehra Dun trees grow well and appear to be unaffected by the annual frosts of that place. Trees planted at Shillong were killed during the abnormal frost of 1905, which, however, also killed large numbers of indigenous trees.

In plantations rubber plants suffer much from the depredations of wild elephants and deer; in their natural epiphytic state they escape this form of damage owing to their elevated position.

Artificial reproduction. The tree may be propagated either by transplanting nursery-raised seedling plants or by means of cuttings or layers. The latter method has long been discarded for plantation work in favour of transplanting seedling plants, which are found to produce aerial roots more prolifically and also to be more hardy. Plants raised by cuttings or layers, however, may be conveniently employed in planting avenues or single trees for shade or ornament. The various methods of raising plants and transplanting may be described briefly.

Nursery treatment. In Assam the usual time for sowing is the rainy season, from June to September, as rapid germination takes place at that time. Seed-beds 3 to 3½ ft. wide should be formed of light pulverized sandy loam, not of stiff soil, and should be raised several inches and kept from collapsing at the sides by walls of reed-work supported by stakes. The surface soil should be well mixed with powdered charcoal and flattened down to a smooth surface. The minute seeds, dried and prepared as already described, are mixed with about two to five times their weight of sifted wood-ash and five to ten times their weight of fine mould, the mixture being spread evenly over the surface of the bed and flattened down. According to Mr. D. P. Copeland,[1] 4 to 6 lb. of seed should suffice for a seed-bed 40 ft. by 3½ ft.; with good germination this should yield 2,000 seedlings and should be sufficient to plant up 100 acres of rubber 70 ft. by 35 ft.

Shading of the beds is essential. The shades, made of thatch, should be made to slope towards the south, and should be high enough to admit a fair amount of light and thick enough to prevent rain dripping through. These shades may be removed during dull weather after the seedlings are sufficiently strong, and should be dispensed with altogether for some weeks before the young plants are removed from the nursery. The beds should be regularly watered from the commencement, and should never be allowed to become dry; excessive watering, however, causes the seedlings to damp off, and should be carefully avoided. The soil should be kept free from weeds and periodically loosened to prevent caking.

Sowing in seed-boxes or pans as a rule gives better results than sowing in open beds, the soil and the method of sowing being otherwise the same. A covering of glass over the boxes is sometimes recommended in order to force germination.

When about 2 in. high the seedlings are pricked out about 1 ft. by 1 ft. in nursery lines, in well-raised beds. In the Assam plantations it has been customary, owing to the risk of damage by deer and wild elephants, to remove the plants in the following rains, when about 1–2 ft. high, to stockaded nurseries in the forest, where they are planted 5 ft. by 5 ft. on well-raised beds; they are kept there until they are 10 to 12 ft. high, by which time they are about three years old, when they are dug up, the roots are trimmed where too long, and the saplings are finally planted out on mounds.

Transplanting. Some care is necessary in selecting the site for a plantation. Swampy or badly drained ground should be avoided. Well-drained high ground is the most suitable, but alluvial flats, if well drained, are also good. Soil consisting of little except sand and shingle is said to produce poor yields. Since a fair degree of atmospheric and soil moisture, and protection from the desiccating effect of the sun, are essential to the best growth, plantations in Assam have been formed by clearing lines through existing forest in a direction from east to west, a belt of forest being left between the lines to afford side shade in the heat of the day. The most suitable spacing has been the subject of some debate at various times. In the earlier plantations lines 40 ft. wide were cleared 100 ft. apart from centre to centre, leaving a 60 ft. belt of forest between the lines, and the plants were spaced 25 ft. apart along the lines. This spacing was found to be too close, and from 1893 onwards the lines were cut 70 ft. apart from centre to centre and the plants were spaced 35 ft. in the lines. In the Kulsi plantation spacings first of 100 ft. by 25 ft., later of 50 ft. by 25 ft., and finally 25 ft. by 25 ft. have been adopted. Few figures are available showing to what extent the spacing affects the yield of rubber, but such as they are they show that very wide spacing produces less rubber per acre than moderately close spacing. This being so, complete

[1] Ind. Forester, xxiii (1897), p. 420.

clearing and planting would seem to be preferable to partial clearing in lines, not only in producing higher yields but also in avoiding the high cost of keeping the belts of forest from encroaching on the lines.

The actual planting is carried out on mounds of varying size, usually 4 ft. high with a basal diameter of 10 ft. sloping to a diameter of 4 ft. at the top. In the centre of each mound a stout stake about 20 ft. long is planted, and to it the sapling is tied to keep it from being blown down or pulled down by deer or monkeys. In the case of large plants it is preferable to plant early in the rains, but small plants bear transplanting at most seasons of the year.

Attempts have been made to plant seedlings in soil placed in the forks and hollows of trees or in hollow stumps, but these have in most cases resulted in failure.

Subsequent tending. Frequent cleanings are necessary in the early years of the plantation, and vacancies have to be filled, while at that time as well as subsequently the belts of forest between the lines of plants require to be kept from encroaching on the lines by felling or girdling all threatening trees.

Cuttings and layers. The tree can be propagated by cuttings or by layers. Cuttings should be made from young branches in which the wood has become thoroughly lignified, and not from tender young shoots. They may be planted in nursery beds any time from February till May, and should be shaded from the sun in the heat of the day and regularly watered. It is advisable to keep them in the nursery for at least a year, and preferably for two years, before planting out.

Rooted cuttings or *gooties* can be propagated very successfully. In this case branches about 5 to 10 ft. long are selected, and at a point where the wood is thoroughly lignified the bark is removed all round the branch to a length of 3 or 4 in., care being taken not to injure the wood. The wound is covered with a ball of clay which is bound round with moss, grass, or sacking, and kept moist. In time rootlets are formed at this point, and make their way through the clay. The branch is then sawn off some inches below the wound and planted out.

Assam plantations. The most important plantations in Assam are the Forest Department plantations of Charduar in the Darrang district and Kulsi in the Kamrup district, both commenced in 1873. The expenditure during the earlier years was high, the work being largely experimental, but after experience had been gained it was found possible to bring the cost of stocking an acre with young established plants to between 40 and 50 rupees. Financially these plantations have proved a failure. In 1912 in the case of the Charduar plantation, the area of which was then 2,746 acres, the total cost, with interest to date, worked out at Rs. 9,83,633, the receipts with interest amounting to Rs. 3,13,295, leaving a debit of Rs. 6,70,338. In 1917 the area of the Charduar plantation was 2,904 acres, and that of the Kulsi plantation was 160 acres.

RATE OF GROWTH. The râte of growth is rapid. The following statement gives a summary of numerous measurements recorded from time to time in the Assam plantations :

Ficus elastica : rate of growth in Assam plantations.

Age.	Mean height. Charduar.	Mean height. Kulsi.	Mean girth. Charduar.	Mean girth. Kulsi.
years.	ft.	ft.	ft.	ft.
5	23	25	1·4	1·4
10	43	46	4·5	3·4
15	61	66	8·5	5·4
20	75	82	12·9	8·0
25	87	95	17·4	12·4
30	98	106	22·0	

The faster height increment and the slower girth increment in Kulsi as compared with Charduar is due to the fact that the planting was closer in the former than in the latter.

Girth measurements vary much owing to the production of aerial roots, which tend to anastomose round the main stem. These roots account to a large extent for what appears from the figures to be phenomenal girth increment.

TAPPING. Careful experiments have shown that even moderate tapping carried out annually soon results in the death of the trees tapped. In the Assam plantations a system of tapping once in three years has been adopted, and so far this has not proved to be excessive. Tapping is carried out by means of horizontal cuts made with a V-shaped gouge 15 in. apart on alternate sides of the stem and main branches and extending from half to two-thirds the distance round. The latex flows for two or three minutes after tapping; some of it coagulates in the cuts and is collected from them, and the remainder falls on mats spread below the trees. The tapping season in Assam is from the middle of October to the end of March. On no account should the terrestrial roots be tapped, as is done by collectors of wild rubber, since this kills the tree; aerial roots of large size which have developed into separate stems may, however, be tapped. The age at which tapping should commence has not yet been accurately determined in Assam. The yield from small trees up to 3 or 4 ft. in girth is so small as to make it hardly worth while tapping them. It has generally been held in Assam that regular tapping should commence at about twenty years more or less, though the size of the tree rather than the age determines the time for starting. Under favourable conditions of growth and with light and careful tapping, however, trees may be tapped some years earlier. Reports in recent years have shown that the Assam system of tapping is not altogether satisfactory owing to the injury inflicted on the trees, and possibly further experiments in tapping by pricking, suction, or other methods may yet reveal a better system.

YIELD. The results of tapping in the Assam plantations have been so variable that it is difficult to obtain reliable average figures of yield. In 1912 it was estimated that the average yield for the previous ten years was 20·7 lb. per acre per annum in Kulsi with 66 trees per acre tapped, as against 8·9 lb. per acre per annum in Charduar with 13 trees per acre tapped. The trees tapped probably varied from twenty to thirty-five years of age. The variation from year to year may be illustrated from the fact that in Charduar in 1909–10 a yield of 37·3 lb. per acre was obtained over the area tapped as against 18·1 lb. per acre in the preceding year; normally the area tapped is only one-third of the total area of the plantation, since trees are tapped once in three years, so that these figures require to be divided by three in order to compare them with the averages given below. Variations are no doubt due partly to physical causes, but they are also due in large measure to the manner in which the control of operations is carried out under successive managers. The Assam plantations have not yet come into full bearing, and it is therefore difficult to estimate what their eventual yield will be. Based on the experimental tapping of natural trees it is believed that a fair average yield for trees fifty years old may be estimated at 10 lb. per tree for a season's tapping, while the yield from younger trees, say twenty to thirty years old, may be estimated at from 8 oz. to over 2 lb. per tree. It is said that in Sikkim a yield of 40 lb. per tree used to be common under the excessive system of tapping wild trees which was in vogue until the trees were killed out by over-tapping.

The yields from the Assam plantations compare very unfavourably with that reported by Berkhout [1] to have been obtained in a private plantation in the province of Kranong in the west of Java. This plantation was formed in 1872 on abandoned coffee land, the trees being planted 8¼ yds. apart with 72 trees per acre. The total area amounted to 72½ acres, containing 5,200 trees. Tapping commenced when the plantation was fourteen years old; the yield after seven years' tapping showed an average of 71 lb. per acre per annum, and the plantation was found to have produced a net money yield of £1 12*s*. 10*d*. per acre per annum since its establishment.

4. **Ficus retusa**, Linn. Syn. *F. nitida*, Thunb. Vern. *Barri*, Kumaun; *Jamu*, Nep.; *Nandruk*, Mar.; *Pilala*, Kan.; *Ichi*, Tam.; *Yerra juvi*, Tel.; *Nyaungôk*, Burm.

A large handsome evergreen, usually epiphytic, tree with a dense shady crown of rather small dark green leaves. Bark dark grey, smooth. Aerial roots slender.

Distributed throughout the sub-Himalayan tract from the Siwaliks near Dehra Dun eastwards, Assam, Chittagong, Burma, Andamans, Chota Nagpur, and the Indian Peninsula. It is found most commonly in moist ravines. It is often planted for shade or ornament, and makes a particularly handsome avenue tree. This is one of the most frost-hardy species of *Ficus*; in the abnormal frost of 1905 it remained unaffected in the Agri-Horticultural Gardens at Lahore, where other species suffered, some badly. It may be propagated in the manner described for *F. bengalensis*. In Dehra Dun the fruits commence ripening about December and continue ripening for some time; they are 0·2–0·3 in. in diameter, sub-globose, yellowish or pinkish when ripe.

5. **Ficus Rumphii**, Bl. Syn. *F. cordifolia*, Roxb. Vern. *Pilkhan*, *khabar*, Hind.; *Pair*, *ashta*, Mar.; *Nyaungbyu*, Burm.

A moderate-sized to large, often epiphytic, almost deciduous tree, with oblong, ovate or broad ovate acuminate leaves. Bark yellowish grey, smooth. This tree is sometimes mistaken for the pipal (*F. religiosa*), the leaves being somewhat similar; it is a smaller and less handsome tree than the latter, the acumen is not so long, and the petioles are stouter and less flexible.

Distributed throughout the sub-Himalayan tract and outer hills, ascending to 5,000 ft., Assam, Bengal, Chota Nagpur, the Indian Peninsula, and

[1] Ind. Forester xxiv (1898), p. 160.

Burma. It is often grown on roadsides. In the forest it is frequently epiphytic, and may be classed as one of the noxious figs which strangle and kill their hosts. The fruits commence ripening about February–March, and continue ripening for some time ; they are about 0·5 in. in diameter, globose, sessile in axillary pairs, blackish when ripe. The new leaves appear about March, by which time most of the old ones have fallen.

6. **Ficus religiosa,** Linn. Pipal. Sans. *Pippala.* Vern. *Pipal,* Hind. ; *Aswat,* Beng. ; *Ashvatha,* Mar. ; *Arali,* Kan. ; *Ragi, ravi,* Tel. ; *Arasi,* Tam. ; *Nyaung bawdi,* Burm.

A large tree, evergreen or nearly so, epiphytic when young, with spreading branches. Leaves broadly ovate, with an acumen 1 to 3 in. long, glabrous and shining, and a slender petiole which causes the leaves to oscillate readily in a breeze. Bark grey, smooth, exfoliating in irregular rounded flakes.

Indigenous in the sub-Himalayan tract, and wild if not indigenous in other localities ; largely planted and run wild throughout India and Burma ; rare in the arid region of north-western India. It makes a good avenue tree. This is the Bodhi tree under which Buddha sat and received enlightenment at Budh Gaya ; it is one of the most sacred trees of India, is venerated both by Hindus and by Buddhists, and is often planted near temples and wells. Hindus have a strong religious objection to felling it. In the forest it is a destructive epiphyte, and it also does much harm to buildings and walls, sending its roots into crevices in them. It is often lopped for elephant and cattle fodder.

The tree grows fast and is easily raised from seed sown in boxes in fine mould mixed with powdered charcoal. It can be propagated from cuttings, but these do not strike so well as those of *F. bengalensis.* In the abnormal drought of 1907 and 1908 in the forests of Oudh the pipal proved to be conspicuously hardy ; this was also found to be the case in the severe drought of 1899 and 1900 in the Indian Peninsula. It is frost-hardy, and was only slightly affected in the severe frost of 1905 in northern India.

In northern India the new leaves appear about December, by which time most of the old leaves have fallen ; the young leaves are usually reddish. The fruits ripen from March to June, occasionally again later ; they are depressed, globose, about 0·5 in. in diameter, sessile in axillary pairs, dark purple when ripe. They are eagerly devoured by birds and are a favourite food of the green pigeon.

7. **Ficus hispida,** Linn. f. Syn. *F. oppositifolia,* Roxb. Vern. *Dadúri, kagsha,* Hind. ; *Kala-umber,* Mar. ; *Chona atthi,* Tam. ; *Kadut,* Burm.

A small to moderate-sized tree with opposite leaves 4–12 in. long, scabrous above. Not epiphytic. Common in many parts of India and Burma, usually in shady places and along ravines. It coppices and produces numerous root-suckers. The fruits are about 1 in. long, pale green when ripe, usually clustered on leafless, often drooping branchlets ; they ripen at most seasons of the year. This tree has been introduced by canal water into the Changa Manga plantation near Lahore, where it suffers much from frost.

8. **Ficus Cunia,** Ham. Syn. *F. conglomerata,* Roxb. Vern. *Khunia, khain, khini, jarhphali,* Hind. ; *Yekaôn,* Burm.

A small or moderate-sized usually evergreen tree, sometimes leafless in the hot season, easily recognized from its short-petioled semicordate or semi-sagittate rough leaves. Not epiphytic. The fruits are 0·5–0·7 in. long, clustered on usually leafless drooping branches, often several feet long, issuing from the stem, often near the root, and from the larger branches. The tree is distributed throughout the greater part of India and Burma, and is common particularly on the sides of ravines, and along watercourses and moist shady banks and cuttings. The fruits commence ripening about March, and continue ripening almost throughout the year.

9. **Ficus palmata**, Forsk. Syn. *F. caricoides*, Roxb.; *F. virgata*, Roxb. Vern. *Pheru*, *phedu*, *khemri*, *anjiri*, Hind.

A moderate-sized tree with orbicular-ovate, sometimes deeply palmately-lobed leaves. Not epiphytic. A common species in the outer Himalayan ranges and valleys, extending eastward to Nepal and ascending to 7,000 ft., occasionally higher; also in Baluchistan, the Suliman and Salt ranges, Mount Abu, and the hills of Merwara. This is a common species in the outer Himalaya, often on somewhat dry hill-sides. It extends some distance into the plains, usually along watercourses, which indicates that the fruits or seeds are washed down the streams from the hills, since the tree is essentially a hill species. The fruits are sub-globose or pyriform, 0·5–1 in. in diameter, yellow when ripe; the fruit ripens from May to October. The fruits are eaten; this species, indeed, is closely allied to the edible fig, *F. Carica*, Linn. In the hills the tree is lopped for cattle-fodder.

10. **Ficus Carica**, Linn. Fig. Vern. *Anjir*, Hind.

A moderate-sized deciduous tree with cordate more or less deeply lobed leaves. Not epiphytic. This is the well-known edible fig. It is believed to be indigenous to Baluchistan, Afghanistan, western Asia, and the eastern Mediterranean region. It is cultivated in these regions as well as in southern and western Europe, including the warmer parts of England. It is cultivated in northern India, both in the plains and in the outer hills up to about 5,000 ft., and in the Deccan, especially round Poona, where it yields excellent fruit. In India the fruit ripens as a rule from May to August. The tree is grown from cuttings, which are kept in shaded nursery beds until well rooted and then planted out. It grows best in rich soil in irrigated gardens. The fruit requires protection, while ripening, from birds, fruit bats, and insects; small baskets are sometimes fixed round the fruits for this purpose.

11. **Ficus Roxburghii**, Wall. Syn. *F. macrophylla*, Roxb. Vern. *Timla*, *timal*, Hind.; *Sinthapan*, Burm.

A moderate-sized handsome spreading evergreen tree with large broadly ovate, cordate or rounded leaves, sometimes as much as 1½ ft. in length and 1 ft. in breadth. Not epiphytic. The large fruits appear in large clusters on short leafless branches issuing from the trunk, often near the ground, and from the larger branches. The tree is indigenous to the sub-Himalayan tract and outer Himalaya, Assam, Chittagong, Burma, Chota Nagpur, and Orissa, and is sometimes cultivated for ornament and for the sake of its edible fruits. It is found most commonly in moist places and along streams. It is not very frost-hardy, and was badly damaged in the Agri-Horticultural Gardens, Lahore, during the abnormal frost of 1905. The fruits usually ripen from March to June.

12. **Ficus glomerata,** Roxb. Syn. *F. Chittagonga*, Miq. Vern. *Gular, umar*, Hind.; *Umbar*, Mar.; *Atti*, Tel.; *Thapan, ye thapan*, Burm.

A moderate-sized to large deciduous tree with a spreading crown. Not epiphytic. Leaves ovate or elliptical lanceolate. Bark reddish brown, smooth, with occasional large cracks.

A common forest tree throughout the greater part of India and Burma, as a rule in moist localities along the banks of streams, the sides of ravines, and similar places. In the Dehra Dun valley it is a common constituent of swamp forests in association with *Eugenia Jambolana, Cedrela Toona, Pterospermum acerifolium, Albizzia procera, Trewia nudiflora, Diospyros Embryopteris*, and *Putranjiva Roxburghii*. It is, however, by no means confined to low-lying moist ground, but may be found, sometimes almost gregariously, on rocky hill slopes, and is often found sporadically in sal forest and mixed forests of various types. It is often preserved round villages for the sake of its fruit, and is frequently cultivated.

The tree appears to shed its leaves at different seasons. In some localities the leaves are shed early in the cold season, the new leaves appearing from December onwards. Gamble notes that in some localities (Dehra Dun, Mysore) it is deciduous in the middle of the rainy season about August. The fruits are sub-globose or pyriform, 1–1·5 in. in diameter, red when ripe, in large clusters on short leafless branches emerging from the trunk and main branches; they ripen chiefly from March to July. They are edible, but are usually too full of insects to be agreeable. They are a favourite food of monkeys, and when they fall to the ground they are greedily eaten by deer.

The tree is not very frost-hardy, and suffered in northern India in the severe frost of 1905. It coppices, but the growth of coppice-shoots appears to be slow, judging from the following results of measurements made in 1910 by Mr. C. M. McCrie in Gorakhpur, United Provinces:

Ficus glomerata: coppice measurements, Gorakhpur.

Age. years.	Mean height. ft.	Age. years.	Mean height. ft.
2	5·2	10	8·7
4	7·1	12	8·9
6	8·0	14	9·1
8	8·5		

13. **Ficus pumila,** Linn.

A Chinese species of small climbing fig frequently cultivated on walls in India, and sometimes popularly termed 'ivy', owing to its habit of climbing by large numbers of small aerial rootlets which cling tenaciously to walls like those of the true ivy. This fig grows fairly rapidly, covering the walls of a house in a few years with a dense growth of dark green foliage. The leaves of the barren climbing stems are much smaller than those of the fruiting branches; the fruit itself is 2–3 in. long. The plant is easily grown from layers or from cuttings planted in pots and kept in the shade and watered until they have established themselves; it grows better on cool northerly walls than on hot southerly ones.

14. **Ficus scandens,** Roxb.; 15. **Ficus foveolata,** Wall.

Of scandent habit, similar to the preceding, climbing over moist rocks and tree trunks in shady places in the sub-Himalayan tract and outer Himalaya.

2. ARTOCARPUS, Forst.

This genus comprises eight Indian species, of which some are important timber trees or fruit trees. The breadfruit tree, *A. incisa*, Linn. f., a native of the South Sea islands, is cultivated to some extent in the tropical parts of India. The trees of this genus are somewhat shade-bearing, especially in youth; in their natural state they are all found in moist, usually tropical forest, sometimes in deciduous but usually in dense evergreen types. They bear fleshy fruits and rather large seeds which perish quickly. The fruits ripen as a rule early in the rainy season, and are eagerly devoured by birds or animals, the seeds being scattered beneath and around the trees or removed to some distance; germination takes place during the rains soon after the seeds fall.

Species 1. *A. hirsuta*, Lam.; 2. *A. integrifolia*, Linn.; 3. *A. Chaplasha*, Roxb.; 4. *A. incisa*, Linn. f.; 5. *A. Lakoocha*, Roxb.

1. **Artocarpus hirsuta, Lam.** Vern. *Ranphannas, patphannas*, Mar.; *Heb halasu*, Kan.; *Anjili*, Tam.; *Aini*, Coorg.

A very tall handsome evergreen tree, attaining a height of 150 ft. and a girth of 15 ft. or more, with a straight clean stem and dense foliage. Leaves broadly ovate or elliptical, entire in mature trees, deeply lobed in young plants and coppice-shoots. Wood moderately hard, yellowish brown, durable, of very good quality, much used for house- and boat-building, furniture, and other purposes

Distribution and habitat. Evergreen forests of the Western Ghats from the Konkan southwards, ascending to 4,000 ft. It is not commonly found in the deciduous forests, but where found it appears to grow well, and its scarcity may be due to fires. It is fairly common in the forests of North Kanara, the *ghat* forests of Mysore and Coorg, and southwards through South Canara and Malabar to Travancore, where it is considered one of the most important timber trees of that state. It is often planted in the moister parts of southern India. It requires heavy rainfall, probably not less than 70 in.; otherwise it appears to thrive equally well on the laterite soils at the foot of the *ghats*, on the decomposed gneiss of the slopes, and on rich soils.

Flowering and fruiting. The yellowish green flower-heads appear from December to March, and the fruit ripens in May-June. The fruit is yellow, ovoid, about the size of a lemon, covered with spines, and containing numerous white seeds, 0·5–0·75 in. long (Fig. 323, *a*). The tree seeds freely every year. The seeds quickly lose their vitality; they germinate readily, but are eagerly devoured by monkeys, which often destroy much of the crop.

Germination (Fig. 323, *b–e*). Hypogeous. The radicle emerges from one end of the seed and descends rapidly, the cotyledonary petioles at the same time elongating and enabling the plumule to extricate itself. The fleshy cotyledons remain underground within the testa.

The seedling (Fig. 323).

Roots: primary root long, moderately thick, terete, tapering, flexuose, orange brown; lateral roots numerous, short to moderately long, fibrous, distributed down main root. *Hypocotyl* less than 0·1 in. long, sometimes hardly distinguishable, subterranean. *Cotyledons*: petiole 0·1–0·15 in. long, thick, fleshy, flattened; lamina 0·4–0·7 in. by 0·25–0·35 in., thick, fleshy, outer surface rounded, inner flat. *Stem* erect, terete, woody, finely tomentose; first internode (between cotyledons and first pair of opposite leaves) 2–5 in., subsequent internodes 0·5–1·5 in. long. *Leaves* simple, first pair opposite, subsequent leaves alternate. Petiole 0·1–0·3 in. long, tomentose. Lamina 1–3·5 in.

FIG. 323. *Artocarpus hirsuta*. Seedling × ⅜.
a, seed; *b–e*, germination stages; *f–h*, development of seedling during first month; *i*, seedling towards end of first season.

by 0·6–1·8 in., ovate or obovate, acute or acuminate, base acute or rounded, dentate or serrate, scaberulous tomentose, particularly on lower surface, lateral veins 6–11 pairs.

By the end of the first season the seedling ordinarily attains a height of 5–8 in. with 4–8 leaves and a taproot about 8–10 in. long.

The growth of the seedling is somewhat slow. Plants raised from seed sown in 1914 under shade in abandoned cultivation in Coorg reached an average and maximum height of 2 ft. 4 in. and 4 ft. 9 in. respectively by January 1918. Seedlings require a fairly moist soil and protection from the sun, as they are sensitive to drought. They stand a moderate amount of shade.

SILVICULTURAL CHARACTERS. The tree can stand much shade, but thrives best with a fair amount of light ; it does equally well in the open, and appears capable of standing exposure to the sun after the first few years. Fire is very harmful, scorching the larger trees and killing saplings. The young plants are readily browsed by deer, elephants eat the bark and leaves, and monkeys devour the young shoots. The tree coppices and produces root-suckers ; its coppicing power appears to vary.

NATURAL REPRODUCTION. The seeds fall under and around the trees at the beginning of the rainy season and germinate readily, while birds eat the fleshy fruits and help to scatter the seeds. Natural reproduction, however, is often scanty, usually, it is believed, owing to the heavy shade of the forests in which the tree is found, which prevents the development of the seedlings. Possibly clearing round seed-bearers would help matters. Germination is particularly good in the open, but the seedlings if exposed to the sun are liable to die of drought. Reproduction is prevented to some extent by the destruction of seed by monkeys and of seedlings by deer.

ARTIFICIAL REPRODUCTION. The seedlings are difficult to transplant, and direct sowings are therefore recommended. As the seed is perishable, it should be sown as soon as it ripens. In recent years sowings have been carried out in Coorg in *kumris* (shifting cultivation), five or six seeds being sown at each stake, the stakes being spaced 6 ft. by 6 ft. It has been found necessary, however, to shade the plants in the dry season. This species is therefore more useful for raising as an underwood than for planting in the open, and has been employed successfully in Travancore for undersowing teak plantations. Sowings require protection from deer and monkeys. Bourdillon notes that a whole sowing of 8 or 10 acres in Travancore was completely destroyed one year by monkeys before it was realized that watchers were necessary.

RATE OF GROWTH. According to Bourdillon the growth at first is slow, but when the plants are once established it is rapid. Trees measured at Malayattur in Travancore showed an average growth of 30 ft. in height and 15 in. in girth in five years. At ten years old the girth was 33½ in., and at fourteen years old it was 40 in. Yearly measurements of trees in other places showed a diameter increase of about 1 in. per annum, representing an annual girth increment of over 3 in.

2. **Artocarpus integrifolia**, Linn. Jack. Vern. *Kanthal, kathal, kathar*, Hind. ; *Phannas*, Mar. ; *Halasu*, Kan. ; *Panasa*, Tel. ; *Pilla, pilavu*, Tam. ; *Peinnè*, Burm.

A large evergreen tree with a short thick bole and a dense round crown of dark green foliage. Leaves 4–8 in. long, elliptical or obovate, thickly coriaceous, shining above. Bark dark brown, rough with warty excrescences, inside pale pink or yellow streaked with white, exuding when cut a copious milky juice. Heartwood bright yellow, darkening on exposure, used for furniture, cabinet-work, turnery, brush-backs, &c. A decoction of chips of the wood is used in Burma for dying the yellow robes of priests. The chief importance of the tree lies in its fruit, for which it is extensively cultivated.

DISTRIBUTION AND HABITAT. Probably indigenous to the Western Ghats, in moist evergreen forests, ascending to 4,000 ft. Extensively cultivated for its fruits, or as a shade or ornamental tree, throughout tropical India and Burma. It is actually grown as far north as Dehra Dun and Lahore, but does not thrive. For its best growth it requires a moist tropical climate and a deep rich soil, but is capable of growing on almost any soil. Mr. A. J. W. Milroy [1] has an interesting note on the prevalence of jack trees in the hills of the Abor country bordering on Assam. 'In any report on the jums (shifting cultivation)', he says, 'mention should be made of the striking feature of the Abor hills, the jack tree. Every Abor village is, as a rule, buried in jack trees, but in addition they plant hill slopes, where the soil happens to be particularly stony and shallow, and unsuited for cropping. It so happened that, on one or two occasions, I was disappointed to find that hill-sides, which from a distance of two or three days' march had held out promise of being silviculturally interesting, were merely orchards of jack fruit. These were literally well-stocked forests of jack trees, containing trees of all ages from old and gnarled veterans down to seedlings a year old. The younger trees are protected from the mithun (*Bos frontalis*) by tree guards made of bamboo. On the jums, where crops are grown, there are not as a rule many jack trees. The Abors have no doubt found they thrive sufficiently well on land unsuited for field crops, and so they are only planted on the more unpromising hill-sides, after the tree jungle has been felled.'

The tree is sometimes met with in forest tracts outside the Western Ghats, but in such places it has probably either run wild or marks the site of an abandoned village or former cultivation.

FLOWERING AND FRUITING. The numerous yellowish green flowers, the males on cylindrical receptacles 2–6 in. long and the females on ovoid oblong receptacles, appear from December to March. The large yellowish green ovoid oblong fruits, reaching 1–1·5 ft. or more in length, with a tubercled surface, borne on short stalks on the stem and larger branches, ripen during the rainy season. The fruits contain a number of pale brown, smooth ovoid or reniform seeds, 1–1·5 in. long, surrounded by a yellow pulp (Fig. 324, *a*). The seeds are oily, and have a thin testa; they quickly lose their vitality. Both the pulp and the seeds are eaten, the latter as a rule cooked. The fruits are readily eaten by elephants.

GERMINATION (Fig. 324, *b–d*). Hypogeous. The radicle emerges first. The thick fleshy cotyledons are very unequal; the smaller one separates from the larger like a valve, enabling the young shoot to make its way up from between them. The cotyledons remain underground, supplying the young plant with nutriment for some time before they finally rot off.

This method of hypogeous germination in a large seed with thick fleshy cotyledons is interesting. In many such cases—as in the oaks, *Mesua ferrea*, *Bassia*, *Aesculus*, and even other species of *Artocarpus*—the emergence of the plumule is assisted by the elongation of the cotyledonary stalks and the

[1] Report on the Forest Resources of the Abor Country, 1912.

cotyledons do not separate. In the present case, however, no such elongation takes place, but the emergence of the plumule is effected by the separation of the cotyledons, as is the general rule in epigeous germination ; here the fact that one cotyledon is much smaller than the other, and separates from it like a lid opening, is of special significance in facilitating germination.

THE SEEDLING (Fig. 324).

Roots : primary root long, thick, terete, tapering, pale yellow and delicate when young, afterwards woody ; lateral roots numerous, moderately long, fibrous, distributed down main root, or in germinating stages forming a whorl round its upper part. *Hypocotyl* seldom more than 0·1 in. long, often scarcely distinguishable, subterranean. *Cotyledons* : petiole 0·1–0·3 in. long, broad and flattened, fleshy ; laminae thick, fleshy, unequal, the smaller separating from the larger like a valve ; larger lamina 1·1–1·7 in. by 0·5–0·6 in., ovoid ; smaller lamina 0·8–1 in. by 0·3–0·4 in., elliptical or oblong. *Stem* erect, terete, green, finely pubescent ; internodes 1·2–2·5 in. long. *Leaves* simple, alternate, first few often rudimentary, scale-like and caducous, leaving scars on the stem. Stipules sheathing the terminal bud caducous. Petiole 0·15–0·25 in. long. Lamina 1·5–3·5 in. by 1–2 in., elliptical ovate, acute or acuminate, base rounded or acute, obscurely crenate or entire, coriaceous, dark green, minutely pubescent and scaberulous, lateral veins 6–9 pairs.

The seedling can stand a considerable amount of shade, but develops best in full light, and does not appear to mind the sun provided the soil is kept moist. It is sensitive to drought and very frost-tender. During the first season its growth is slow to moderate, a height of 6 to 18 in. being ordinarily attained by the end of the season.

SILVICULTURAL CHARACTERS. The tree is a pronounced shade-bearer, but develops best with a fair amount of light and growing space ; it is decidedly frost-tender. It coppices well. The bark and leaves are eaten by elephants.

ARTIFICIAL REPRODUCTION. Owing to its long and delicate taproot the seedling does not bear transplanting well, and seed should therefore be sown *in situ* or seedlings should be raised in baskets. The seed should be sown perfectly fresh at the commencement of the rains. Basket plants should be watered regularly in dry weather, and are ready to plant out at the beginning of the rainy season when one year old.

RATE OF GROWTH. The growth is slow at first, but later it is more rapid. Bourdillon says that trees planted at Malayattur in Travancore had a girth of 18½ in. at six years, 29 in. at ten years, and 37 in. at fourteen years.

3. **Artocarpus Chaplasha**, Roxb. Vern. *Chaplash*, *chaplis*, Beng. ; *Lutta*, Nep. ; *Cham*, *sam*, Ass. ; *Taungpeinnè*, Burm.

A large deciduous tree with a tall straight bole, attaining a height of 100–120 ft. or more and a girth of 10–15 ft. or more, developing a large spreading crown if sufficient room is given. Mature leaves 6–10 in. long, broadly ovate or elliptical, entire, those of young trees and coppice-shoots serrate, lobed or pinnatifid, up to 2 ft. long. Bark smooth, grey with dark blotches in young trees, brown, rough with tubercles and small fissures when old, exfoliating in large rounded flakes, brown inside, exuding a milky juice. Wood yellowish brown, durable, of good quality, used for furniture, building, canoes, boat-building, &c.

DISTRIBUTION AND HABITAT. Sub-Himalayan tract and outer hills from Nepal eastwards, ascending to 5,000 ft., Assam, Chittagong, Burma, and the

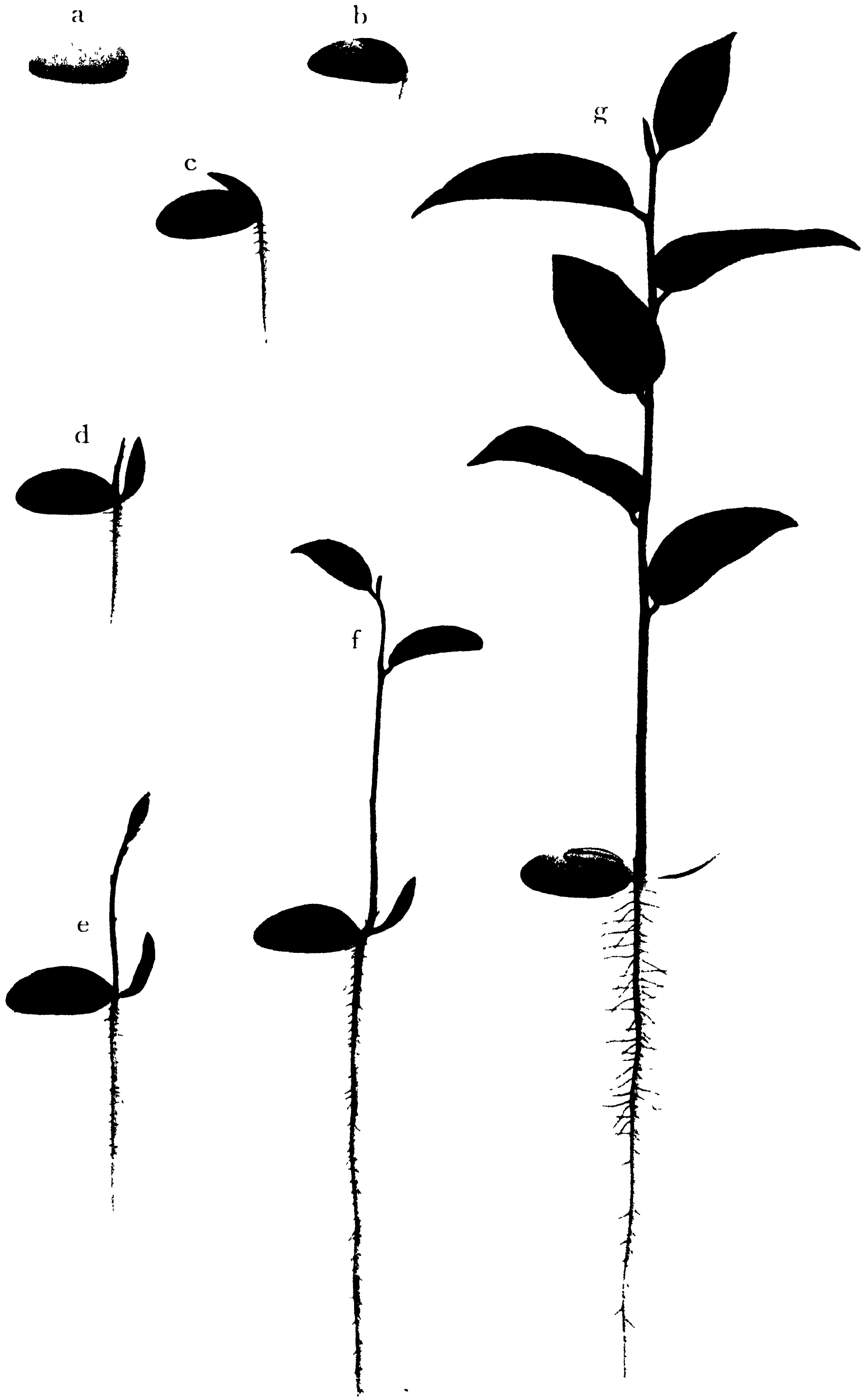


FIG. 324. *Artocarpus integrifolia*—SEEDLING × $\frac{3}{8}$

a—Seed b-d—Germination stages e-g—Development of seedling to end of first season

Andamans. The tree is not gregarious, but is found scattered in moist deciduous and evergreen forests. In Bengal and Assam it occurs scattered in the moist types of mixed deciduous sal and evergreen forests. In Chittagong and Burma it is found in moist tropical forests. In the Andamans it is an important constituent of the evergreen, semi-evergreen, and deciduous forests; in the evergreen forests it is associated with *Dipterocarpus* spp., *Hopea odorata*, *Planchonia andamanica*, *Calophyllum spectabile*, and many others, and in the deciduous forests with *Pterocarpus dalbergioides*, *Albizzia Lebbek*, *Terminalia bialata*, *Lagerstroemia hypoleuca*, &c.

The tree thrives only in moist localities, and is not found in the drier types of forest; the drainage, however, must be good. It is often found along the banks of streams, and prefers a rich deep loam, though it thrives even on clayey soil provided the drainage is good.

In its natural habitat the absolute maximum shade temperature varies from 98° to 105° F., the absolute minimum from 38° to 60° F., and the normal rainfall from 80 to 200 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless for a time in the hot season. The globose flower-heads appear in March–April, and the globose tuberculate fleshy fruits, 3–4 in. in diameter, ripen from June to early August. The fruits contain comparatively few seeds; these are oblong, 0·5–0·6 in. long, about 50 weighing 1 oz. (Fig. 325, *a*). The seeds quickly lose their vitality. The fruits are eaten by birds, monkeys, and other animals, as well as human beings, and the seeds are distributed by these agencies.

GERMINATION (Fig. 325, *b–f*). Hypogeous. The yellowish radicle emerges from one end of the seed, and simultaneously the cotyledonary petioles elongate, enabling the plumule to emerge; the young shoot is arched at first, but soon straightens. The fleshy cotyledons remain underground within the testa, and do not separate as in the case of *A. integrifolia*.

THE SEEDLING (Fig. 325).

Roots: primary root long, terete, tapering, flexuose, whitish and delicate in early stages, afterwards woody; lateral roots numerous, fibrous. *Hypocotyl* distinct from and thicker than root, 0·1 in. long, subterranean. *Cotyledons*: petiole 0·2 in. long, broad, flattened, somewhat fleshy, bent to one side of stem; lamina 0·5–0·6 in. by 0·3–0·35 in., thick, fleshy, elliptical, outer surface rounded, inner flat. *Stem* erect, terete or slightly compressed, green, tomentose. *Leaves* simple, first pair usually opposite, subsequent leaves alternate. Stipules 0·1 in. long, triangular acuminate, tomentose. Petiole 0·1 in. long, tomentose. Lamina 1–2·5 in. by 0·6–1·5 in., elliptical or ovate, dentate or serrate, tomentose.

The development of the seedling during the first season is somewhat slow, a height of a few inches being ordinarily attained. The seedling is sensitive to drought and frost; in its natural habitat it probably never experiences the latter, though a long dry season may affect it. It stands a fair amount of shade.

SILVICULTURAL CHARACTERS. The tree is shade-bearing in youth, but requires a fair amount of light for its best development. It is not ordinarily subjected to severe fires in the moist types of forest in which it grows, but when fires do take place it suffers considerably. The young plants are browsed by cattle and deer. The tree coppices well.

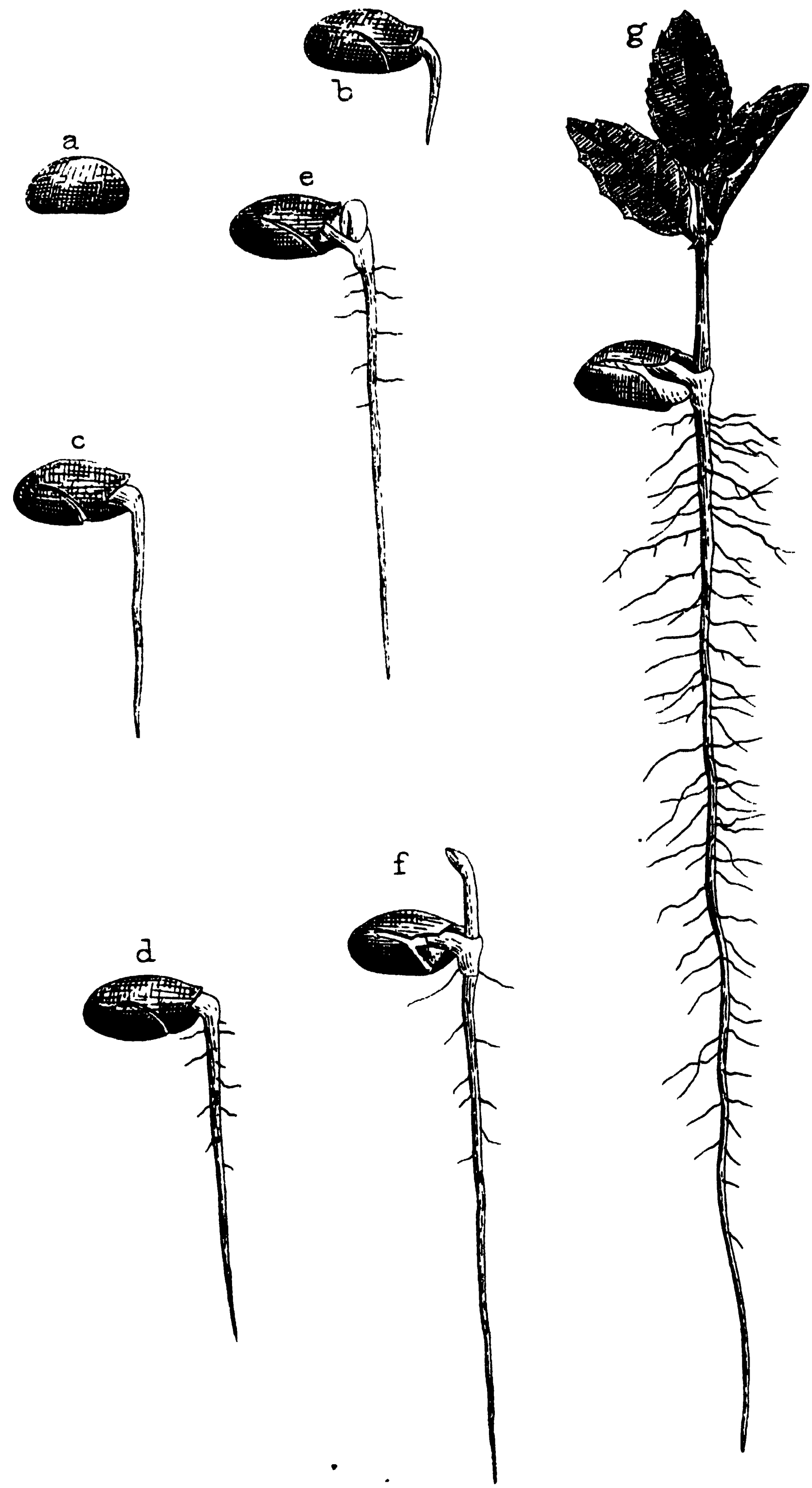


FIG. 325. *Artocarpus Chaplasha*. **Seedling × $\frac{7}{8}$.**
***a*, seed ; *b–f*, germination stages ; *g*, seedling in first season.**

NATURAL REPRODUCTION. Large quantities of seed fall to the ground under and around the trees when the fruits ripen early in the rainy season, some fruits falling whole and disintegrating on the ground and others being eaten on the trees by birds and monkeys and the seeds being dropped by them; a certain amount of seed is also removed by them and dropped at a distance from the trees. Germination commences soon after the seed falls, and takes place readily even if the seeds are not buried. Young seedlings may be found in large numbers during and shortly after the rainy season; the majority of these are killed off chiefly by dense undergrowth and heavy shade, but where sufficient light is obtained the young plants have little difficulty in making their way up, and in favourable localities natural reproduction is usually good.

ARTIFICIAL REPRODUCTION. The long delicate taproot renders the transplanting of seedlings difficult, and the most satisfactory method of raising young plants is to sow the seeds in long baskets as soon as they ripen and to plant out the seedlings in the baskets, when one year old, at the beginning of the following rainy season. Sowings *in situ* have not been tried. This species would probably prove a suitable one for underplanting or undersowing teak plantations which have been thinned out to afford sufficient light.

4. **Artocarpus incisa**, Linn. f. Breadfruit.

A native of the South Sea islands, cultivated for the sake of its fruit in most tropical countries, including the west coast of India and Burma. The leaves are deeply pinnatifid, up to 3 ft. in length. The tree requires a moist warm tropical climate, and does not thrive far from the sea. It is usually propagated either by carefully digging up and transplanting root-suckers, which are freely produced, or by planting sections of the surface roots about 1 to 2 in. in diameter and about 1½ ft. long. These sections are enclosed in a thick coating of fresh cowdung and clay and buried slightly in a shady bed, which is kept moist. This is done early in the cold season, about October. After the shoots have sprouted they are dug round and manured; they are finally transplanted at the commencement of the following rains.

For the first few years the plants grow best under slight shade, such as is afforded by partially cleared forest land. Later they require more light for their proper development, and the shade trees should be removed gradually.

5. **Artocarpus Lakoocha**, Roxb. Monkey jack. Vern. *Dheú*, *barhál*, *lakúch*, Hind.; *Dehua*, Beng.; *Wotomba*, *badhar*, Mar.; *Wontemara*, Kan.; *Naka-renu*, Tel.; *Myauklôk*, Burm.

A large deciduous tree with a spreading crown and large elliptical or ovate entire leaves up to 1 ft. long, softly tomentose beneath. Bark reddish brown, rough and scaly in old trees. Heartwood yellow turning brown, used for building, furniture, canoes, &c. The fruit is eaten, though it is somewhat insipid.

DISTRIBUTION AND HABITAT. The sub-Himalayan tract and outer hills from Kumaun eastwards, ascending to 4,000 ft., Assam, Burma; Chota Nagpur, truly wild in the Saranda hills, Singhbhum (Haines); Western Ghats from the Konkan southwards, Andamans. Much cultivated throughout the greater part of India and Burma as a shade or ornamental tree or for the sake of its fruit.

In its wild state it is found chiefly in moist or tropical forests, both deciduous and evergreen, often occurring along the banks of streams and along the sides of moist ravines. In its natural habitat the absolute maximum shade temperature varies from 95° to 115° F., the absolute minimum from 35° to 60° F., and the normal rainfall from 60 to 200 inches. It is, however, cultivated and grows well in northern India in places where greater extremes of temperature are experienced and where the rainfall is less than 60 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless or nearly so for a short time in the beginning of the hot season. In northern India the leaves fall during February–March, the new leaves appearing early in April, often before the old ones have all fallen. The flower-heads appear on the leafless branchlets in March–April, and the yellow, somewhat fleshy male heads, often partly eaten by birds, fall to the ground for some weeks after their first appearance. The fruiting period appears to be somewhat irregular. At Dehra Dun the fruits ripen chiefly in July–August, but some, probably a second crop, do not ripen till November. In Chota Nagpur the fruits ripen in May and again in October–November (Haines). The fruits (Fig. 326, *a*) are about 3–4 in. in diameter, irregularly lobed, soft, with a greyish velvety covering, containing an orange somewhat acid pulp, in which the seeds are embedded. The seeds (Fig. 326, *b*) are 0·4–0·5 in. long, white, oblong, rounded. About 65 to 85 weigh 1 oz. The seeds quickly lose their vitality. Fresh seed sown in nursery beds at Dehra Dun showed 81 per cent. of success.

The fruits are greedily eaten by monkeys and by parrots, minahs, and other birds. Throughout the fruiting season the trees are full of birds eating the pulp of the fruits and scattering the white seeds on the ground. The fragments of fruit pulp lying on the ground give out a strong fermenting odour.

GERMINATION (Fig. 326, *c–f*). Hypogeous. The bright yellow radicle emerges from one end of the seed, and simultaneously the cotyledonary petioles elongate, enabling the plumule to extricate itself from between the thick fleshy cotyledons and make its way up. The cotyledons remain underground within the testa, supplying the young plant with nutriment until they finally rot off.

THE SEEDLING (Fig. 326).

Roots: primary root long, thick, terete, tapering, woody, tomentose; lateral roots numerous, fibrous. *Hypocotyl* scarcely distinguishable, very short. *Cotyledons* subterranean; petiole 0·1–0·2 in. long, flattened, fleshy, white, minutely tomentose; lamina 0·4–0·5 in. by 0·35–0·4 in., thick, fleshy, orbicular or broadly elliptical or oblong, outer surface rounded, smooth, inner flat. *Stem* erect, terete, woody, green, tomentose; internodes 0·3–1 in. long. *Leaves* simple, alternate, the first two or three usually abortive and very small. Stipules 0·1 in. long, linear lanceolate, tomentose. Petiole 0·1–0·2 in. long, terete, tomentose. Lamina 0·4–2 in. by 0·2–1·2 in., elliptical or ovate, acute or acuminate, base rounded or cordate, irregularly serrate or dentate, dark green, woolly tomentose, venation prominently reticulate, lateral veins 4–8 pairs.

During the first season the growth of the seedling is somewhat slow, a height of 4–8 in. being attained; in the second year the growth is faster, a height of 2 ft. or more being attained under favourable conditions by the

Fig. 326. *Artocarpus Lakoocha*—Seedling

a—Fruit × ½ b—Seed × ¾ c - f—Germination stages × ¾

g - i—Development of seedling to end of first season × ¾

end of the season. The seedling requires a fair amount of soil moisture, and benefits in the early stages by slight shade. It is sensitive to drought and frost, though it is hardier in this respect than other species of this genus.

Silvicultural characters. The tree stands moderate shade in youth, but subsequently develops best with a liberal amount of overhead light. It is the hardiest of the Indian species of *Artocarpus*, but is somewhat frost-tender in the Punjab.

Natural reproduction. The seed, scattered round the trees in the manner already described, germinates during the rainy season, and after the end of the rains numerous seedlings may be found on the ground. Many of these perish during the ensuing dry season, but those which have germinated in a moist and fairly shady situation may survive. Seed lying on the surface of the ground in the open exposed to the sun usually fails to germinate ; it is an advantage, therefore, for the seed to become buried before germination takes place. This fact has been verified in the case of seed which has fallen naturally round trees, as well as by definite experiments carried out at Dehra Dun.

Artificial reproduction. There is little difficulty in raising seedlings in the nursery provided perfectly fresh seed is used. The seeds should be sown about 3 in. apart in drills 9 in. apart and covered with earth to a depth of about ½ in. The seedlings should be watered during dry weather, and will be ready for transplanting at the commencement of the following rainy season. Transplanting requires some care owing to the length of the taproot, though the young plants are not quite so sensitive to transplanting as those of other species of *Artocarpus*. The most successful method is to raise seedlings in baskets, to which they may be transferred from seed-beds when about 2 in. high, during the first rains, and to transplant them with the baskets early in the following rainy season.

Rate of growth. According to Gamble the rate of growth is three to four rings per inch of radius, giving a mean annual girth increment of 1·57 to 2·1 in., which is fast.

3. MORUS, Linn.

Six species of mulberry, possibly not all distinct, are cultivated in the Indian region ; three of these, *M. indica*, Linn., *M. serrata*, Roxb., and *M. laevigata*, Wall., are indigenous. The mulberries contain some interesting features, notably their great power of reproduction from cuttings and, in the case of *M. alba* at all events, the striking manner in which natural reproduction takes place, under favourable conditions, from seed spread by water and by birds.

Species 1. *M. alba*, Linn. ; 2. *M. indica*, Linn. ; 3. *M. serrata*, Roxb. ; 4. *M. laevigata*, Wall.

1. **Morus alba,** Linn. White mulberry. Vern. *Tút, tutri*, Hind.

A moderate-sized deciduous tree with shortly acuminate ovate, often lobed leaves and white or red fruits. The leaves are very variable, and there are many distinct varieties of the tree cultivated or run wild in different countries.

This is the chief mulberry used for silkworm rearing in the Punjab and

Kashmir; it is also grown for the sake of its fruit, which in cultivated varieties is sweet and succulent. It is grown as a roadside and avenue tree, but is not altogether satisfactory, as it does not live long and soon becomes ragged in the crown and unsightly. The wood is yellowish brown, of good quality, and is used for boats, furniture, turnery, hockey sticks, and other sporting requisites, and to some extent for buggy shafts.

DISTRIBUTION, HABITAT, AND SILVICULTURAL CHARACTERS. Cultivated in Europe, western and central Asia, China and Japan. Frequently cultivated in Baluchistan, Afghanistan, and Kashmir, and in northern India from the plains up to a considerable elevation in the Himalaya. It has run wild extensively in irrigated tracts on the Punjab plains. Henry [1] says that the tree is undoubtedly a native of China, where it is common in the wild state in the mountainous districts of the northern and central provinces, and that its cultivation and the rearing of silkworms can be traced back to the remotest days of Chinese civilization. Mayr [2] says it grows wild and attains a large size in the forests of central Yezo in Japan.

This is the mulberry which has become so invasive in the irrigated and riverain plantations of *Dalbergia Sissoo* in the Punjab plains (Vol. I, pp. 309, 311). In the early days of the Changa Manga plantation it was planted experimentally on a small scale, and since then has spread to a remarkable extent, and now constitutes probably about 80 per cent. of the growing stock. But for special cleaning operations to protect the sissoo, which is the principal species, the mulberry would doubtless quickly exterminate the sissoo. The plantation is worked as coppice-with-standards. Experiments in cutting back the mulberry to favour the sissoo in young coupes have shown that the crop has to be cut back as a rule at least five times in the first $2\frac{1}{2}$ years before the sissoo is safe from the mulberry. The latter produces seed at an early age, coppice-shoots four or five years old yielding quantities of fertile seed. The mulberry is more shade-bearing and faster growing in youth than the sissoo, coppicing with great vigour and often attaining a height of 15 ft. or more in the first two years; it has therefore a decided advantage over the sissoo in the struggle for supremacy.

In the Changa Manga plantation the mulberry was at one time regarded as a dangerous weed, but it is now looked on as an important adjunct to the sissoo. Its wood is of somewhat less value, but its growth is faster and its outturn greater, while its shade-bearing character enables it to occupy ground which would otherwise be wasted; it is a useful soil-protector, promotes straighter and cleaner growth in the sissoo, and materially increases the outturn of the plantation. Moreover the sissoo has for some time been seriously threatened by the fungus *Fomes lucidus*, which has killed the trees off in large numbers for some years past. An accessory species like the mulberry is therefore of great importance. So far the mulberry has been remarkably free from disease in Changa Manga. It is certainly attacked by *Fomes lucidus*, but the fungus appears to be purely saprophytic on it.

Fomes australis, Fr., is a fungus with grey sporophores fairly common on the mulberry in Changa Manga; it appears to be only a wound parasite not

[1] Elwes and Henry, The Trees of Great Britain and Ireland, vi. 1611.

[2] Fremdländische Wald- und Parkbäume für Europa, 1906, p. 485.

FIG. 327. *Morus alba*, irrigated plantation, 6 years old, thinned to a density of 1,200 stems per acre, Changa Manga, Punjab.

requiring special control measures at present. Dr. Butler [1] has published an account of the diseases to which this tree is subject.

Experience in Changa Manga has shown that the mulberry does best with a certain amount of shade or protection ; it is liable to be broken by wind when grown as pure coppice, and if suddenly exposed as a standard it also suffers from the sun. The mulberry, indeed, has not proved satisfactory as a standard ; it is short-lived, growing rapidly but soon becoming hollow, while trees left as standards, if they are not thrown by wind, tend to become branchy, and thus to interfere with the growth of the coppice. Experiments have accordingly been in progress to endeavour to find other suitable species to mix with the sissoo and mulberry, as it is not considered entirely safe to rely on these two species alone. The mulberry, it may be added, is ordinarily frost-hardy, but in Changa Manga it was affected to some extent during the abnormal frost of 1905. It is very liable to be thrown by wind in the Changa Manga plantation, owing largely to the dense state of the crop ; trees become so drawn up that they are unable to stand without the support of their neighbours, and when wind gets in extensive windfall results. It is hoped by periodic thinning to counteract this. Fig. 327 shows a mulberry crop in the Changa Manga plantation thinned to a density of 1,200 stems per acre.

Natural reproduction. The spread of the mulberry in the Changa Manga plantation is probably attributable mainly to water, though the seed is also scattered to a considerable extent by starlings (*Pastor roseus*). These birds visit the plantation in large numbers from the end of March to the end of April, when the fruits are ripe, and devour them, scattering the seeds, particularly in newly felled coupes, since the birds prefer the isolated standards as roosting-places. The seed is probably also spread to a small extent by jackals and by human beings. The distribution of the seed by water is demonstrated by the fact that seedlings are often found in abundance along the sides of the irrigation channels, while it has been noticed that in recently started irrigated plantations mulberry has made its appearance in some cases within three years under circumstances which leave no doubt that the seed was water-borne. Further evidence to show that the mulberry seed is freely distributed by water is to be found in riverain plantations. Thus in the Shadara plantation, situated on the low bank of the Ravi river and originally formed of pure sissoo, mulberry has appeared for many years past on the low-lying portions, subject to annual flooding when the river rises, and from there it has spread gradually into the higher parts. The seed has undoubtedly been transported down the Ravi during the flood season, which commences not long after the fruit ripens, from trees growing on the lower slopes of the Himalaya.

Artificial propagation and treatment. The tree is very easily raised, either from seed or from cuttings. The seed should be sown in June, either *in situ* or in nurseries. In the former case irrigated line sowings are to be recommended if the locality is dry. For transplanting purposes seedlings should be raised in seed-boxes under shade or in well-raised beds shaded from the sun and protected from drip during heavy rain. The fruits should be collected when thoroughly ripe, in April–May, and kneaded in several successive

[1] Mem. Dept. Agric. in India, Bot. Ser., vol. ii, No. 8, April 1909.

washings of water to separate the seeds, and the latter should then be spread out at once to dry in the shade. The seeds and seedlings are subject to insect attacks, and it is therefore sometimes the practice to soak the seeds in water mixed with camphor, and to sprinkle the seed-beds with a mixture of lime, ashes, and a small quantity of white arsenic. The seeds should be sown in June, pricked out about 18 in. apart in the nursery when about 4–6 in. high, and finally transplanted either in the cold season or early in the following rainy season. Before transplanting the lower branches should be pruned off and the upper branches stripped of all but one or two terminal leaves.

For the production of leaves for rearing silkworms the trees will be ready for working in four to five years from the time of transplanting. Meanwhile the stems should be kept free from branches up to 6 or 7 ft. from the ground, by pruning in the cold season. Before the collection of leaves is started the top should be cut off, leaving a total height of 10 to 12 ft., and the branches should be pruned down to promote the formation of pollard-shoots. Pollarding is thereafter carried out regularly, as a rule every second year after the gathering of the winter crop of leaves.

Superior cultivated varieties of mulberry may be budded on to seedlings of the common variety. Budding is carried out towards the end of the cold season on nursery-raised seedlings, one or two years old, cut off at about a foot from ground-level. The Bengal method of raising mulberry from cuttings is described under *M. indica*.

A full account of the methods adopted in Europe for the production of leaves for silk rearing has been published by Maillot and Lambert.[1] The essential operations are careful pruning for the production of pollard-shoots and succulent leaves, and the removal of dead wood and twigs. In France the leaves only are picked, while in Kashmir branches are lopped off, usually without care or system, so that jagged wounds are produced and dead wood is left, resulting in the admission of fungous diseases.[2]

Rate of growth and out-turn. The annual rings in the mulberry are distinct, and ring-countings can therefore be employed for ascertaining the rate of growth. Measurements made in 1913 in the Changa Manga plantation showed the following average rate of growth in girth of dominant coppice-shoots :

Morus alba : girth increment of coppice-shoots, Changa Manga.

Age. years.	Mean girth. in.	Age. years.	Mean girth. in.	Age. years.	Mean girth. in.	Age. years.	Mean girth. in.
1	2·5	7	12·9	13	21·9	19	29·0
2	4·5	8	14·4	14	23·3	20	30·0
3	6·5	9	15·9	15	24·6	21	31·0
4	8·2	10	17·4	16	25·8	22	32·0
5	9·8	11	18·9	17	26·9		
6	11·4	12	20·4	18	28·0		

These figures show a rapid rate of growth for the first six years, after which the growth is somewhat slower.

The following yield table for mulberry coppice in Changa Manga, based on numerous measurements, has been compiled by Mr. E. A. Greswell :

[1] Maillot et Lambert, Traité sur le Ver à Soie du Mûrier et sur le Mûrier, pub. Masson et Cie., Paris.

[2] Butler, *loc. cit.*

Morus alba : yield table for coppice, Changa Manga plantation.

Age.	Height.	Girth at 4½ ft.	Dominant trees. No. of trees per acre.	Dominant trees. Solid volume per acre.	Dominated trees, solid volume per acre.	Total solid volume per acre.	Mean annual increment, solid volume.
years.	ft.	in.		cub. ft.	cub. ft.	cub. ft.	cub. ft.
1	5	2·0	760	75	—	75	75
2	10	3·5	710	150	25	175	87
3	15	5·0	660	210	50	260	87
4	19	6·0	610	300	50	350	87
5	24	8·0	560	385	65	450	90
6	28	9·0	510	475	75	550	92
7	32	10·0	450	560	115	675	96
8	35	12·0	400	670	140	810	101
9	37	13·5	340	775	175	950	106
10	40	15·0	285	870	230	1,100	110
11	43	16·5	240	970	255	1,225	111
12	45	17·5	200	1,075	275	1,350	112
13	48	19·0	170	1,200	300	1,500	115
14	50	21·0	150	1,320	330	1,650	118
15	52	23·0	130	1,440	335	1,775	118
16	54	25·5	115	1,600	325	1,925	120
17	56	29·0	95	1,750	300	2,050	121
18	58	32·5	85	1,900	290	2,190	122
19	60	35·5	75	2,020	280	2,300	121
20	62	38·0	70	2,150	280	2,430	121

Factors of conversion from stacked to solid measure: Pieces over 2 in. diameter = ·54; brushwood = ·12.

These figures, it may be noted, refer to the growth in an irrigated plantation, which is no doubt faster than what might be expected under more normal conditions. Gamble mentions that a tree measured in Changa Manga had a girth of 5 ft. 11 in. at fifteen years of age, which is extremely fast.

2. **Morus indica,** Linn. Indian mulberry. Vern. *Tút*, *tutri*, *siah tút*, Hind. ; *Posa*, Burm.

A moderate-sized deciduous tree with caudate acuminate, ovate, often lobed leaves and dark purple fruits. This tree is closely allied to *M. alba*, and is sometimes regarded as a mere variety.

Wild in the sub-Himalayan tract in dry forest from the Sutlej eastwards, ascending to 5,000 ft. (Brandis). Extensively cultivated for rearing silkworms in Bengal, and also in Burma, southern India, and other localities. The wood resembles that of *M. alba*.

Artificial propagation and treatment. This species may be raised from seed in the manner described for *M. alba*. The fruits ripen in April–May. In Bengal and other localities where this mulberry is grown for the rearing of silkworms it is raised from cuttings and worked on a short coppice rotation with intensive cultivation and manuring. The system varies in detail, but the following, described by N. G. Mukerji in his *Handbook of Sericulture*, is a common system in Bengal :

Mature shoots not thicker than a man's thumb are cut into lengths of about 9 in., and planted in clumps of six or seven, the clumps being 18 to 27 in. apart in lines ; the cuttings, planted a few inches apart in each clump, are inserted slanting at an angle of about 60°, and buried except for about 1–2 in., or in dry soils completely buried. The ground is well dug up and repeatedly ploughed and harrowed for some months prior to the planting of the cuttings. The planting is carried out either in September–October, after the rains are over, or in January–February; the former is the rule in dry soils, and the latter in moist soils. After the cuttings sprout the ground is hoed up, care being taken not to shake or loosen the cuttings. About two to three months after planting, when the shoots ought to be about 20 to 30 in. high, they are cut down almost to ground-level, and ploughing is then done between the lines. The leaves from this first crop are considered bad for silkworms, and are generally used as cattle fodder. All subsequent crops are used for rearing silkworms. As a rule four crops of leaves are obtained, in November, March, June or July, and August. If irrigation is carried out, two extra crops, in January and May, are obtained. The shoots are cut back to ground-level annually in August or September. Intensive earthing, manuring, and tillage is carried out. The earthing consists of annually spreading in April or May fresh earth dug up from tanks or trenches. At the same time the ground is well manured; a dressing of saltpetre, 1½ maunds (about 125 lb.) per acre, applied after the stems are cut back in August or September, is also considered advantageous. A thorough digging is carried out in January, and ploughing or superficial digging is carried out in May, after manuring, September and November. Weeding is done during the rainy season. From two years after the plantation is formed a regular yield of 300 maunds (about 220 cwt.) of leaves per acre per annum should be obtained, from which 1,200 lb. of cocoons can be reared. In the Malda district yields of twice this amount are said to be not unusual.

Another Bengal method, pursued in the Burdwan district, by which cuttings already forced into sprouting are laid horizontally in the planting holes, is described in Sir George Watt's *Commercial Products of India* (1908), p. 785.

In Kollegal, Madras Presidency, most mulberry growers place two or three cuttings about 9 in. long, flat into holes dug 3 or 4 ft. apart, and cover them completely with earth; the shoots are cut back to ground-level annually about July, after which the ground is ploughed or hoed up and manured.

3. **Morus serrata**, Roxb. Himalayan mulberry. Vern. *Karún, kimu, himu, tút*, W. Him.

A moderate-sized or large deciduous tree with leaves usually cordate, often 3-lobed, thickly grey-tomentose beneath. Bark greyish or reddish brown, rough, with vertical fissures in old trees. Heartwood large, yellow or brown, an excellent wood for furniture or cabinet-work, and used for carving and other purposes. Under favourable conditions the tree reaches fairly large dimensions, a height of 60 to 70 ft. and a girth of 9 to 10 ft. being not uncommon. J. L. Stewart mentions several trees 20 ft. in girth, and one 28 ft. in girth at Barmaor in Chamba.

This is the common mulberry of the Himalaya from Kumaun westwards, both wild and cultivated, at 4,000–9,000 ft., occasionally descending lower. It is frequently cultivated in hill stations, and round villages, where it is lopped for cattle fodder.

The trees are leafless during the winter, the new leaves sprouting from March to May, at which time the greenish catkin-like inflorescences cover the tree, the male spikes being 1–2 in. long and the female spikes 0·5–1 in. long. The flowers are dioecious. The fruits are purple when ripe, and ripen in June–July, when they are greedily devoured by birds, which spread the seeds.

The tree is easily propagated from seed or from cuttings. Fresh seed should be sown in June or July in well-raised beds or in boxes, the seedlings being pricked out next spring and planted out either in the winter or early in the rainy season. It may be found advantageous to prune the stems down and to trim off some of the roots. Seedlings raised at Dehra Dun attained a height of 8 to 14 ft. by the end of the fifth season ; this practically represented four years' growth, as the growth during the first season amounted to 1–3 in. only.

Cuttings should be put down in the nursery during the rainy season and planted out when they have become thoroughly rooted. The tree coppices well, and produces root-suckers.

Gamble gives the rate of growth as usually 8 rings, but sometimes 4 rings per inch of radius, representing mean annual girth increments of 0·78 and 1·57 in. respectively.

4. **Morus laevigata**, Wall. Vern. *Kimbu*, Nep. ; *Bola*, Ass. ; *Tawpwèsa*, Burm.

A large tree of the outer Himalaya from Kumaun eastwards, ascending to 4,000 ft., Assam, Upper Burma (Shan hills), Martaban and Tenasserim (evergreen forests of Thaungyin, Brandis). Sometimes cultivated. In the eastern Himalaya the tree reaches a height of 100 ft. or more, with a girth of 15 ft. (Gamble). The wood is yellowish brown, very handsome, and is used for building, furniture, &c. In Assam it is much used for oars. The fruit, which ripens late in May or during June, is long cylindrical, rather dry, pale yellow when ripe. In the Duars it has been found that the seed is not always fertile ; it is possible that such seed may have been collected from dioecious female trees which have not been fertilized.

The growth, according to Gamble, is moderate, averaging 7 rings per inch of radius, which gives a mean annual girth increment of 0·9 in.

4. BROUSSONETIA, Vent.

Broussonetia papyrifera, Vent. Paper mulberry. Vern. *Malaing*, Burm.

A moderate-sized to large tree with somewhat variable mulberry-like leaves and smooth grey bark. Wood soft. The bast fibre is used for paper-making in Japan, Siam, and Burma ; in Burma it is made into cardboard blackened for use as slates for writing purposes in schools. The tree attains fairly large dimensions ; one over 7 ft. in girth was recently felled at Dehra Dun. Brandis says it is wild in the valley of the Maytharauk, Solo, and other tributaries of the Salween river south of the Karenni country. It is often cultivated, and although it thrives in tropical climates it is also hardy in Europe.

It has become established in some of the irrigated parts of the Punjab, where it has spread from seed and root-suckers. It was introduced many years ago into the Kaunli garden near Dehra Dun, and from there it has spread through the surrounding country. In the garden itself it has become a troublesome weed, spreading not only by seed (probably through the agency of birds), but also by means of root-suckers, which it sends up in great profusion from its superficial roots. It coppices vigorously. When once it takes possession of an area it is very difficult to eradicate, since if felled and uprooted it maintains its existence by means of the numerous suckers which spring from portions of roots left in the ground. It requires good moist soil to thrive in, and has not succeeded where tried on poor ground or where there is a heavy growth of grass. It is a brittle tree, the branches being easily broken by wind. The fruit, a reddish globose compound fruit in which the achenes hang on long fleshy stalks, ripens in the rainy season (Dehra Dun). The seeds are small and light.

The growth is extremely fast, and in the Kaunli garden this tree quickly outgrows other species. Gamble mentions a specimen from Kaunli averaging 4 rings per inch of radius, and one from Calcutta with one ring per inch of radius, giving mean annual girth increments of 1·57 and 6·28 in. respectively. A cross-section from Kaunli in the silvicultural museum at Dehra Dun showed 25 rings for a girth of 7 ft. 8 in., giving a mean annual girth increment of 3·7 in. Parker states that in Lahore it reaches a height of 60 ft. and a girth of 2–3 ft. in seven years.

The cultivation of this tree in suitable localities in India has been suggested for the purpose of paper manufacture. In Japan it is said to be grown from cuttings and worked on a short coppice rotation of about three years. The shoots are cut into short lengths and steamed, the bark being then stripped off and the outer dark portion scraped off for the coarser qualities of paper, and the inner and finer parts washed, kneaded, bleached in the sun, and then boiled in a lye and pounded into pulp. Mr. W. Raitt, cellulose expert, examined a sample of young coppice bark from Kaunli garden, but doubted if the material could be used for paper manufacture on a large scale unless some cheap process of getting rid of the outer bark could be evolved. Owing to the extremely rapid growth of the coppice-shoots and the high yield which may be expected, this question is worth pursuing farther.

5. CASTILLOA, Cerv.

Castilloa elastica, Cerv. Panama or Central American rubber.

This important rubber tree is indigenous to Mexico from N. lat. 21° southwards, through Central America, and probably also in the north-western portion of South America. In its native home it is a large tree, attaining a height of 180 ft. and a girth of 15 ft., and its growth is very rapid. It was introduced into the East in 1876, since when it has been cultivated to a certain extent in suitable localities in Ceylon and southern India. It has not, however, attained the importance which the Pará rubber has done ; not only does it give lower yields than the latter, but ordinarily it cannot be safely tapped under seven years of age, as against four or five years for Pará rubber.

The tree prefers a warm steamy climate and an elevation not much above sea-level, though it occasionally ascends to 1,500 ft. on the Pacific coast. It thrives best with a rainfall of 80 to 120 in. and an equable temperature averaging 77° to 85° F., and never falling below 60° F. It is exacting as to soil, requiring a deep fertile loam and avoiding marshy ground ; it is found most commonly along the banks of streams.

The leaves are large and oblong, and the fruit is a fleshy receptacle containing numerous seeds about ¼ in. in diameter. The seeds do not retain their germinative power long. The tree may be raised from seed or from cuttings; the latter, it is said, should be taken from the main shoots and not from the branches, as cuttings from these tend to grow more or less horizontally.

ORDER LV. PLATANACEAE

PLATANUS, Linn.

Platanus orientalis, Linn. Plane, eastern plane. Vern. *Chinar*, Pers., Hind.; *Buna, buin, bhunj*, Kashm.

A large deciduous tree with alternate palmi-nerved 5- to 7-lobed, rarely 3-lobed leaves, the bases of the petioles enclosing and concealing the buds. Bark smooth, thin, light grey or greenish, exfoliating in large thin scales, exposing the light yellow new bark in patches; bark at the base of old trees dark, thick, and furrowed. Wood yellowish or reddish white, used in Kashmir for boxes and small fancy lacquered articles; a good fuel.

The tree is indigenous to the eastern Mediterranean region, and is cultivated in Afghanistan, Baluchistan, and the western Himalaya from 2,000 to over 8,000 ft., particularly in the Kashmir valley. It grows fairly well in the Punjab plains if well supplied with moisture. It has been tried without success at Maymyo in Burma. Under favourable conditions it attains very large dimensions. Mr. J. C. McDonnell [1] records the girths of two large trees in Kashmir, (1) at Drogmula, 50 ft. girth, (2) at Jahama, 43 ft. girth (hollow). Mr. A. E. Wild [2] records a tree 36 ft. in girth measured in 1890 at Nilan Bhoto, Hazara. In 1918 I measured the same tree and found it to be 37 ft. 7 in. in girth; it was a spreading tree branching from near the base. The largest girth noted by Dr. Stewart at Srinagar was 28 ft. The tree grows best on moist deep well-drained soil. In Greece it grows wild along torrents in the mountainous districts. In the western Himalaya the leaves fall about October–November, and the new leaves appear in April. The flowers, which are monoecious in unisexual globose heads, appear in April–May, and the fruit ripens in June–July, remaining long on the tree. The seeds are very small and light, and for growing seedlings it is advisable to have well-raised seed-beds of finely pulverized soil containing a considerable percentage of sand; the seed should then be mixed with sand, loam, and water, and spread evenly over the surface of the beds. Careful watering is necessary, either by percolation or with a very fine spray, or the beds may be covered with straw and watered until germination commences. The seedlings grow slowly at first, and it is preferable not to plant them out until they are at least two years old. The plants can be transplanted without difficulty even when of a fair size. The tree can be raised successfully from layers and cuttings, even large thick stakes rooting successfully. It has been found that the best method of preparing cuttings is to tear off twigs about 1 ft. long so that a strip of the older branch to which they are attached remains at their base; the cuttings should then be planted several inches deep.

[1] Ind. Forester, xxix (1903), p. 152. [2] *Ibid.*, xxiii (1897), p. 206.

Elwes [1] states that in England the tree is always liable to be cut by frost at any age, and the branches and twigs assume a zigzag habit in consequence ; when of sufficient size it seems able to endure the severest winter frosts, but requires a fairly high summer temperature. He adds that it should not be planted on poor, stony land or in places exposed to cold winds, and that it is one of the few trees that will grow on strongly alkaline soil, and has been successfully planted on the alkaline lands of the San Joaquin valley in California.[2] In India it is quite frost-hardy.

The rate of growth is fairly fast. A specimen from Hazara, examined by Gamble, showed 6 rings per inch of radius, giving a mean annual girth increment of 1·05 in. Brandis mentions that the Nasim Bagh on the border of the great Kashmir lake is a large grove of plane trees planted by Akbar the Great soon after he had taken Kashmir in 1586. In 1838 Vigne found the average girth to be 13 ft., and supposed their age to be 248 years. The largest, close to the water, averaged 20 ft. in girth. Of two trees 170 years old at Brein in Kashmir Vigne found one 16 ft. 2 in., the other 20 ft. 10 in. in girth.

Var. *acerifolia*, Aiton (*P. acerifolia*, Willd.), is the London plane, so commonly planted in the squares and parks of London, and remarkable for its capacity for standing the smoky air of towns. The leaves are often 3-lobed. It has recently been tried in Baluchistan, but in March 1916 it suffered from late frost, having sprouted early owing to a mild winter.

ORDER LVI. JUGLANDACEAE

Genera 1. JUGLANS, Linn. ; 2. ENGELHARDTIA, Lesch.

1. JUGLANS, Linn.

Juglans regia, Linn. Walnut. Vern. *Akhor, khor, krot, akhrot, dún*, W. Him. ; *Thitcha*, Burm.

A large deciduous tree with imparipinnate leaves up to 15 in. long, fragrant when crushed, with 5 to 9, sometimes up to 13, leaflets. Twigs with chambered pith. Bark of young trees light grey, with vertical striations ; that of older trees light or dark grey, with deep vertical parallel fissures. Wood even-grained, greyish brown with dark brown streaks, often beautifully mottled, used for furniture, cabinet-making, carving, and gunstocks. The burrs are particularly valuable, and are used for veneer ; they have been extensively worked in the past in the forests of Kashmir, and within recent years have been exploited in Hazara. As a fruit-tree the walnut is well known.

When grown as a fruit-tree in the open it has a spreading crown and a comparatively short bole, but in the forest it is often a tall tree with a long clean stem, attaining a total height of 80–100 ft. or even more, with a girth of 10–15 ft. or more. Brandis mentions a tree of 22 ft. girth at Sali on the Chenab (8,200 ft.), and Stewart one of 28 ft. in Kulu. Mr. J. C. McDonnell [3] records two large trees in Kashmir, (1) girth 20 ft. 10 in. at Salkut, (2) 20 ft. 2 in. at Sogam.

[1] Elwes and Henry, The Trees of Great Britain and Ireland, iii. 621.

[2] Hilyard, Soils (1906), p. 480.

[3] Ind. Forester, xxix (1903), p. 152.

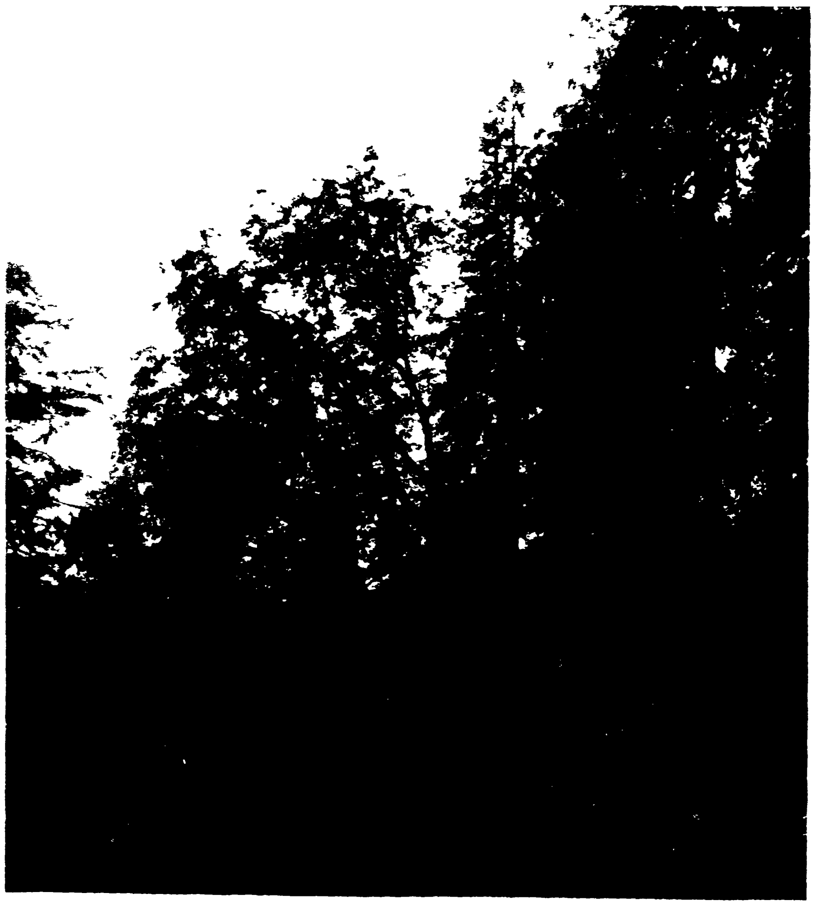


FIG. 328. *Juglans regia* in forest of silver fir (*Abies Pindrow*), Hazara.

FIG. 329. Typical area of pure walnut (*Juglans regia*), Kagan valley, Hazara.

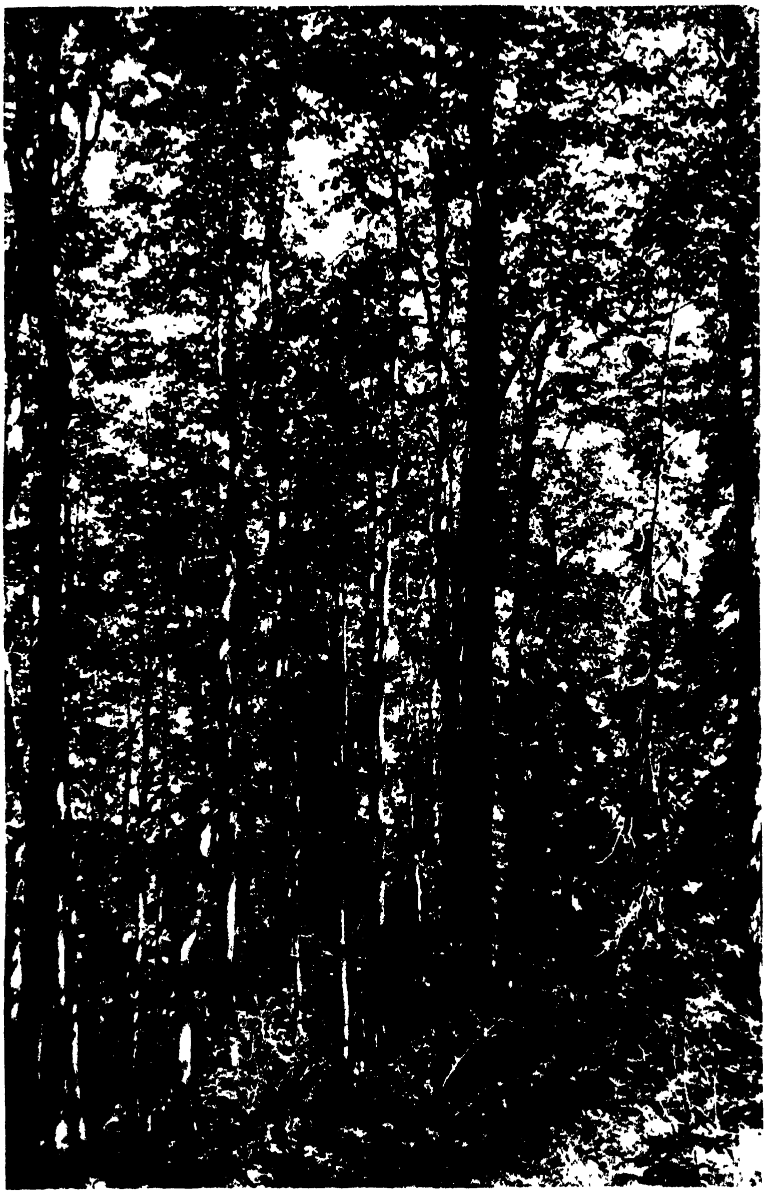


FIG. 330. Pure pole crop of walnut (*Juglans regia*), showing straight clean stems owing to dense growth Hazara.

The burrs sometimes attain a large size. In 1918 I measured one in the upper Siran valley, Hazara, which was 25 ft. in circumference and 2½ ft. thick; the girth of the tree above the burr, which was near its base, was 14 ft. 3 in.

There are numerous cultivated varieties of nut, the one most prized being the *kaghazi* (paper shelled) walnut of Kashmir, a large nut with a shell so thin as to be easily breakable between the finger and thumb of one hand.

Distribution and habitat. The walnut has a wide natural range, occurring wild in Greece, the Balkans, through Asia Minor, the Caucasus, Persia, Afghanistan, the Himalaya, the hills of Upper Burma, and possibly in north China and Japan. It is extensively cultivated in France and in southern Europe generally, also in the Himalaya and in China and Japan.

In the Himalaya it is indigenous usually at 4,500 to 11,000 ft., extending west to Afghanistan and east to Bhutan. In the west it grows either in pure groups or in mixture with other broad-leaved species such as maples, oaks, horse-chestnut, and bird-cherry, or with conifers, particularly spruce, silver fir, blue pine, and yew. It occurs chiefly on deep well-drained fertile soil, often containing boulders, in sheltered situations such as moist ravines or depressions on the hill-sides. It avoids stiff badly drained soil. When mixed with conifers it is commonest and grows best in fairly moist localities, often in association with silver fir (see Fig. 328); but it occurs sometimes mixed with blue pine on rather dry slopes on hot aspects, though here it is somewhat stunted. Pure crops of walnut are often found on the lower gentle slopes of well-drained cup-like depressions the upper parts of which are occupied by coniferous forest. It is a characteristic tree on the higher grazing grounds of Hazara, where it occurs often in pure groups.

The walnut is more abundant in Kashmir and Hazara than it is farther east, where, though common locally, it is not so widely distributed. In Hazara it is particularly common in the Kagan valley, often forming pure crops of considerable extent on the gentle slopes of basin-like ravines. Fig. 329 shows a typical pure crop in this locality, and Fig. 330 shows a pure pole crop in the upper Siran valley in Hazara.

In the eastern Himalaya it is found mixed with oaks, maples, laurels, magnolias, and other trees; natural trees, however, are rare in the Darjeeling hills, having been much cut out in former years.

The walnut is extensively cultivated for its fruit throughout the Himalaya and in the Khasi hills. It grows well at Mogôk in Upper Burma, but has not succeeded at Maymyo.

Leaf-shedding, flowering, and fruiting. In the Himalaya the walnut is one of the first species to lose its leaves. The leaves fall during September, some trees being almost leafless by the end of that month; others retain their leaves until well on in October, but by the latter half of November the trees are usually all leafless. The new leaves appear in March–April. The flowers appear with the new leaves. The male catkins are green, 2–5 in. long, arising singly or in pairs above the leaf-scars on the previous year's shoots. The female flowers, green with bifid styles, occur singly or up to four together at the apex of the young shoots. The fruits ripen chiefly in September, sometimes as early as July. The fruit is a green drupe, ovoid or nearly globular, about 2 in. long, with a very aromatic leathery pericarp, which splits irregularly when ripe. The enclosed nut (Fig. 331, *a*) is 2-valved, wrinkled and furrowed on the surface, and variable in size, shape and thickness of shell, usually 1–1·5 in. long : it is divided inside by two thin dissepiments into four incomplete cells, one dissepiment separating the two cotyledons, the other dividing them into two lobes. The wild walnuts have extremely thick, hard shells, and cannot be broken except by hard hammering. In the case of average-sized cultivated walnuts grown in hill villages in the western Himalaya about 45 to 50 were found to weigh 1 lb. ; actually the weight varies greatly with different varieties. Sound nuts have a high percentage of fertility.

In the forest the nuts are very subject to the attacks of monkeys, squirrels, rats, and birds, particularly nutcrackers. Quantities of wild walnuts may be found lying on the ground near the trees, every one with the thick shell bored through on one or both sides by rats. Bears also collect the nuts ; a case was recently recorded from Hazara in which the winter quarters of a black bear were found to be well stored with quantities of walnuts.

GERMINATION (Fig. 331, *b*, *c*). Hypogeous. The nut splits slightly at the suture and the radicle emerges from its basal end. The cotyledonary petioles elongate and the stout taproot attains a considerable length before the young shoot develops. The latter elongates first by arching, soon becoming erect.

THE SEEDLING (Fig. 331).

Roots : primary root long, thick, fleshy, becoming woody ; lateral roots numerous, long, fibrous, distributed down main root. *Hypocotyl* short, thick, not readily distinguishable. *Cotyledons* : petiole up to 0·5 in. long, thick, fleshy ; lamina 0·7–1·2 in. by 0·5–1 in., thick, fleshy, obovate, bilobed, much wrinkled. *Stem* erect, terete or obscurely angular, woody, glabrous, green to greenish brown, covered with lenticels ; internodes 0·4–2·5 in. long. *Leaves* exstipulate, first few scale-like, abortive, normal leaves alternate, imparipinnate, first three or four usually 5-foliate, sometimes 3-foliate, sometimes 6-foliate by division of terminal leaflet, subsequent leaves in first season chiefly 7-foliate, in second season usually 9-foliate, sometimes 7-foliate. Rachis 3–8 in. long, glabrous. Terminal leaflet larger than lateral ones, 3–8 in. by 2–4·5 in., elliptical or obovate, acuminate, irregularly dentate or serrate. Lateral leaflets sub-sessile, 1·5–5 in. by 1–2·5 in., unequally ovate acuminate, basal pair smaller than remainder. The leaves of seedlings, like those of the adult plant, have a characteristic fragrant odour when crushed.

The growth of the seedling is moderately fast. Nursery-raised plants at Dehra Dun reached a height of 1–1½ ft. by the end of the first season, 3–4 ft. by the end of the second season, and 7–8 ft. by the end of the third season. Seedlings raised from direct sowings in the Darjeeling hills attain a height of nearly 1 ft. by the end of the first rains and a height of about 3 ft. by the end of the second rains, and thereafter grow about 2 to 3 ft. annually. At Simla the growth is slower. Seedlings from direct sowings attained a height of only 3–6 in. by the end of the first season, while those raised in good soil in the nursery reached a height of 6–10 in. by the end of the first season, and 1–2 ft., after being planted out, by the end of the second season. Natural seedlings usually attain a height of 1–1½ ft. in three years. The seedling produces a long stout taproot, which may reach a length of 2 ft. and a diameter of 1 in. by the end of the first season. The young plants require a moist but well-drained soil ; they stand slight shade only, but benefit by side protection

Fig. 331. *Juglans regia* Seedling $\times \frac{5}{8}$

a—Fruit stone b-c—Germination stages d-Young seedling

from the sun in dry localities. They respond readily to cultivation, and are hindered by weed-growth. They are somewhat sensitive to drought and frost. In dry situations the seedlings die back from drought in the hot season, but unless severely affected they sprout again from the base. Young plants are much subject to damage from browsing by barking deer where these animals are present.

SILVICULTURAL CHARACTERS. The walnut is a light-demander, though it stands slight shade in youth ; in Europe it is usually considered to be similar to the oak (*Quercus Robur*) as regards light requirements. At the same time it requires to be grown in a close crop if straight clean timber is wanted, owing to its marked tendency to produce large spreading branches. The root-system is massive, spreading, largely superficial but also penetrating deep. The tree is wind-firm, though it does not thrive in exposed windy situations and is liable to be broken. Saplings in the Himalaya are liable to be barked by deer rubbing their horns. The bark is also frequently removed by the hill people, and is used for cleaning the teeth, for which purpose it has a commercial value. The walnut coppices well.

NATURAL REPRODUCTION. The fruits fall under and around the trees towards the end of the year, the pericarp cracking and rotting off. The nuts, however, are so subject to the attacks of birds and monkeys on the trees and of rodents on the ground, that large quantities are destroyed ; the noticeable scarcity of natural reproduction in the forest is usually attributed, probably rightly, to this fact. Some experiments to ascertain the factors influencing natural reproduction have been carried out at Dehra Dun, but these were not extensive enough to give complete results. So far as they go they indicate that for successful germination a fair degree of warmth combined with soil-moisture is necessary, and the nuts require a covering of earth or débris over them, failing which the radicle dries up and the germinating seedling dies. These conditions are ordinarily fulfilled in moist depressions so situated that they receive the sun's warmth for a part of the day, while the nuts roll into them and become mixed with and covered by earth and débris which is washed into the depressions. In the forest the best natural reproduction is found on moderate to gentle slopes on loose but deep fairly moist soil where boulders and rock fragments are plentiful ; the boulders appear to act as a protection to the nuts, which lodge behind them and become quickly covered with débris. Good crops of young walnut are often found on the recent detrital accumulations formed by the weathering of cliffs or the erosion of hill-sides, and on deep loose rubble on landslips in the open.

ARTIFICIAL REPRODUCTION. Cultivated varieties are best propagated by budding or grafting. For forest purposes the tree may be raised either by direct sowings, in which case the nuts should be covered to a depth of about 2 in., or by transplanting nursery-raised plants. The former method has proved the more successful in the Darjeeling hills, and is usually successful in places where the nuts are not liable to be destroyed by vermin, otherwise it is necessary to raise seedlings in the nursery and transplant them. In experiments carried out at Simla transplants from the nursery proved stronger and developed more rapidly than plants obtained by dibbling *in situ*. The chief difficulty connected with transplanting is the fact that the walnut seedling produces a very long stout taproot. This difficulty can be overcome at the time of transplanting by pruning the stem down to about 1 in. from ground-level and trimming the taproot down to a length of about 9 in.; transplanting is thereby facilitated. The seedlings stand this treatment well, and shoot up again from the base; in this case two or more shoots usually appear from one stump, and it is necessary at the end of the season to prune down all but the best shoot. Provided care is taken, however, the transplanting of seedlings during the first winter can be carried out quite successfully without any pruning of the stem and root, or with very slight trimming of the root, and such plants subsequently develop more rapidly than those which have been pruned down.

The nuts should be carefully stored from the time of ripening to the time of sowing, in order to protect them from vermin; this is best effected by hanging them up in bags or keeping them in covered earthenware jars. In sowing the nuts it is advisable to place them on their sides in order to promote germination in a natural position. In the nursery the nuts should be sown about 2 in. deep in prepared seed-beds of fine rich mould in a warm situation; the drills should be about 9 in. apart, the nuts being placed 3 to 4 in. apart in the drills. They are commonly sown in January or February, but where the snowfall is heavy they should be sown early in December, before the snow falls. Regular watering is necessary until the rainy season commences, and it is advisable to cover the beds with thorns to keep off vermin until germination is completed. Where rats are feared it is advisable also to fence the nursery with small-mesh wire netting, which should be buried several inches in the ground. The seedlings may be transplanted in the following cold season, after rain, the taproot being slightly trimmed if necessary and the planting holes being filled with rich soil. If larger plants are required the seedlings should be pricked out during the first winter with a spacing of about 1 ft. by 1½ ft., the taproots being trimmed, and finally transplanted during the second winter. Transplanting during the rains has proved fairly successful at Simla, but not so successful as winter planting.

Walnut requires to be planted somewhat closely in order to prevent branching. On gentle slopes or level ground a spacing of 6 ft. by 6 ft. is suitable, while on steeper slopes perhaps the best spacing would be 5 ft. apart in contour lines 8 or 9 ft. apart measured on the slope.

Dibblings *in situ* have been carried out with success in the Darjeeling hills. These dibblings are carried out in small groups to fill up blanks in the forest. The best situation is a damp depression; the sites of old charcoal kilns, which are usually in depressions, have given particularly good results, the mixture of earth and charcoal aiding germination and favouring growth. A spacing of about 6 ft. by 6 ft. is usually adopted. The soil at each stake is loosened to a depth of about 1 ft., and one nut is placed at each stake about 2 or 3 in. deep. The best time for sowing is January or February. Before germination takes place the sowings have to be carefully guarded from boys, who dig up the nuts to eat them; squirrels have also to be guarded against, and this is effected by placing thorny branches over the places where the nuts are sown. The young plantations have to be fenced against deer.

Silvicultural treatment. In the Himalaya natural reproduction cannot be relied on to a sufficient extent to employ any systematized treatment relying on reproduction by natural means. The only system which appears to be thoroughly applicable is that of clear-felling with artificial reproduction, and this is the system about to be introduced on a fairly large scale in Hazara. The growth of natural walnut in the western Himalaya indicates that it is well adapted for growing in dense pure even-aged crops, for natural crops answering this description are occasionally to be met with, and the trees produced are tall, straight, and clean boled (see Fig. 330). Although the walnut is often found mixed with conifers its presence under such conditions is not as a rule desirable, since it occupies much space with its spreading branches, and conifers do not come up readily beneath it; this is particularly the case with the blue pine (*Pinus excelsa*). Hence where the main object is to grow conifers it is advisable to cut out all branchy walnut trees from coniferous crops. On the other hand, walnut should be grown in separate crops by itself on favourable ground such as moist well-drained slopes and the sides of ravines at suitable elevations.

STATISTICAL. (1) *Bark thickness.* A limited number of measurements made in the Kagan valley, Hazara, gave the following average bark thickness for trees of different sizes:

Juglans regia: bark thickness, Kagan valley, Hazara.

Girth.	Average bark thickness.	Girth.	Average bark thickness.
2 ft.–2 ft. 11 in.	0·4 in.	5 ft.–5 ft. 11 in.	1·3 in.
3 ft.–3 ft. 11 in.	0·7 in.	6 ft.–6 ft. 11 in.	1·6 in.
4 ft.–4 ft. 11 in.	1·0 in.	7 ft. and over.	1·8 in.

(2) *Rate of growth.* Ring-countings on six stumps of naturally grown trees in the Kagan valley in 1918 gave the following mean rate of growth:

Juglans regia: rate of growth in girth, Kagan valley, Hazara.

Age.	Mean girth (including bark).		Age.	Mean girth (including bark).		Age.	Mean girth (including bark).	
years.	ft.	in.	years.	ft.	in.	years.	ft.	in.
10	0	5	70	3	10	130	6	4
20	0	11	80	4	3	140	6	9
30	1	6	90	4	8	150	7	1
40	2	1	100	5	1	160	7	5
50	2	9	110	5	6	170	7	9
60	3	4	120	5	11	180	8	1

According to Gamble the rate of growth is about 15 rings per inch of radius in the western Himalaya, 6 rings in the Sikkim Himalaya, and 3¼ rings for planted trees in the latter region; the corresponding mean annual girth increments are 0·42, 1·05, and 1·92 in. respectively. A cross-section 3 ft. 6 in. in girth from the western Himalaya in the silvicultural museum at Dehra Dun had 87 rings, giving a mean annual girth increment of 0·48 in. Walnut trees planted from 1880 to 1887 on the slopes of China, Naini Tal, commenced bearing about 1905, and in 1909 their average height and girth were 30 ft. and 2½ ft. respectively.

Measurements recorded by Forstmeister Rebmann[1] at Strassburg showed

[1] Allgemeine Forst- und Jagd-Zeitung, August, 1912, p. 257.

that trees eighty years old had an average diameter on poor sand of 16–17 in., on slate of 20–22 in., on better diluvial sand of 22–24 in., and on lime and loam soils of 26--28 in. .

2. ENGELHARDTIA, Lesch.

Engelhardtia spicata, Blume, including *E. Roxburghiana*, Lindl., *E. acerifolia*, Bl., *E. Colebrookiana*, Lindl., and *E. villosa*, Kurz. Vern. *Mowa, gadhmowa, gobar mowa*, Hind.; *Taung-tamasôk, petsut, thitsawbwa*, Burm.

A moderate-sized to large deciduous tree with grey bark and leaves usually paripinnate. Wood reddish grey, moderately hard, used for tea-boxes and carving. Common and sometimes almost gregarious in the outer Himalaya up to 6,000 ft., usually on rather dry situations; also in Assam, Manipur, Chittagong, and Burma, in the Shan hills and the hill *indaing* forests of Martaban and Tenasserim.

The tree is monoecious. In the outer Himalaya the spikes of ripe fruits are visible on the trees in May–June, and by the middle of June many of the fruits, with conspicuous light brown 3-lobed bracts, have fallen to the ground, often conveyed by wind to some distance from the tree. The nuts have irritant hairs.

This tree produces root-suckers in abundance, and is thus useful for binding unstable hill-sides. Gamble says that in some localities it forms a kind of coppice growth, as at Nagri in the Darjeeling hills; also that natural reproduction is excellent wherever the seedlings get sufficient light and are protected from cattle.

Growth, according to Gamble, 5 to 7 rings per inch of radius, giving a mean annual girth increment of 0·9 to 1·26 in. A cross-section 5 ft. 8 in. in girth in the silvicultural museum at Dehra Dun had 57 rings, giving a mean annual girth increment of 1·2 in.

ORDER LVII. CASUARINACEAE

CASUARINA, Forst.

Casuarina equisetifolia, Forst. Casuarina, beefwood (Australia). Vern. *Sura*, Mar.; *Chowku, saruku*, Tel.; *Cavukku*, Tam.; *Pinlè-kabwè, tinyu* (meaning 'pine'), Burm.

A large evergreen tree with a straight stem and feathery foliage consisting of numerous long, slender, drooping, jointed, 6–8 angled leafless branchlets arising from rough woody branches; the jointed branchlets, which are partly deciduous, are green, and fulfil the functions of leaves. Bark brown, rough, fibrous, exfoliating in longitudinal strips. Wood very hard, much liable to crack and split; used sometimes for poles and rafters, but chiefly for fuel, for which purpose it is excellent.

In general appearance the casuarina resembles a feathery conifer. It attains under favourable conditions a height of 100 ft. or more; trees up to 131 ft. in height have been measured in a plantation forty years old in North Kanara. It is particularly valuable for afforesting sandy beaches and shifting sand-dunes along the sea-coast; numerous stretches of sand along the Coromandel coast and parts of the west coast have been reclaimed and utilized by means of plantations of casuarina, under which it is eventually possible to introduce other species. The tree is not a long-lived one, probably seldom surviving more than fifty years even in favourable situations, and in less favourable localities scarcely reaching twenty-five years before becoming hollow and misshapen.

Distribution and habitat. Indigenous on sandy shores and dunes along the coast of Chittagong, Tenasserim, and the Andamans, particularly in the Little Andaman ; also in the Malay Archipelago, the Malay Peninsula, chiefly on the east coast, the Pacific islands, North Australia, and Queensland. It is cultivated throughout the greater part of India, not only in plantations along the coast, but also inland as an ornamental or avenue tree, and sometimes in plantations. It thrives best in close proximity to the sea on loose sand, growing sometimes to within a few yards of high-tide level, and even with its roots in the sea ; inland it tends to become dry topped and unsightly at a comparatively early age. In its natural state it is gregarious, forming pure crops with little or no undergrowth except grass and a few coastal shrubs. Although it thrives on pure loose sand or very sandy loam it has been grown with success on reclaimed mangrove soil in the Malay Peninsula. It is grown as an ornamental tree on various soils in India, but does not thrive on clay, preferring a sandy soil. On badly drained ground subject to inundation the trees become unhealthy and die off ; on sandy soils where the water-level sinks too low in the dry season they tend to become stunted and even bush-like. In the natural habitat of the tree on the coasts of Burma, Chittagong, and the Andamans the absolute maximum shade temperature varies from 98° to 101° F., the absolute minimum from 45° to 60° F., and the normal rainfall from 100 to 200 inches. On the coasts of the Indian Peninsula, where it thrives well, the absolute maximum shade temperature varies from 96° to 116° F., the absolute minimum from 45° to 63° F., and the normal rainfall from 35 to 150 inches. Inland it is grown in regions subject to greater extremes of temperature, but its growth, as already stated, is poorer than it is along the sea-coast.

Leaf-shedding, flowering, and fruiting. Pieces of the jointed branchlets are shed throughout the year, and in casuarina plantations form a thick layer on the surface of the ground. The tree ordinarily flowers twice a year, from February to April and in September–October, the fruits ripening in June and December. The flowers are unisexual, and are arranged in small spikes. The fruits are globose woody cones, 0·75 in. in diameter, containing a number of winged achenes, each enclosing a solitary seed. The achene (Fig. 332, *a*) is light brown, terminating in a membranous wing, the whole 0·2–0·3 in. long. The achenes are very light, about 20,000 weighing 1 oz. The seeds retain their vitality for a few months, and to some extent for a year ; tests at Dehra Dun gave a fertility of 5 per cent. for seed kept one year, but after eighteen months the fertility was nil. It is always desirable to use fresh seed. Trees on the coast commence bearing seed when about four or five years old. The seeds, both on the coast and inland, are very liable to the attacks of ants, which carry them off in large quantities from the nursery-beds.

Germination (Fig. 332, *b*–*i*). Epigeous. The radicle emerges towards the winged end of the achene. The hypocotyl elongates by pronounced arching, and in straightening raises the cotyledons above ground, the slender jointed scaly shoot soon appearing from their axil. The shell of the achene is usually carried up over the cotyledons, falling with their expansion.

THE SEEDLING (Fig. 332).

Roots: primary root moderately long, thin, wiry, flexuose; lateral roots numerous, fine, fibrous. *Hypocotyl* distinct from root, 0·5–0·8 in. long, cylindrical, slender, delicate at first, becoming wiry, yellow or green, turning red, then brown. *Cotyledons* sessile, 0·1 in. long, foliaceous, elliptical, entire, yellow turning green, then dark red. *Stem* erect, slender, entirely covered by the whorls of scale-like leaves, and appearing as if jointed. *Leaves* verticillate, scale-like, in whorls of 6 to 8, 0·1–0·2 in. long, decurrent round the stem except for the small acicular tips and forming ridges, the ridges of each whorl lying opposite the hollows of the next whorl, dark green or reddish green, later turning brown.

In the nurseries of the coastal regions the growth of the seedling is rapid, a height of 18 in. to 2 ft. or more being attained in the first season, with subsequent growth at the rate of 4 to 5 ft. per annum for a few years. Under less favourable conditions the growth is somewhat slower. At Dehra Dun seedlings reached the following heights during the first five seasons: (1) 6–10 in., (2) 3–4½ ft., (3) 8½–10 ft., (4) 11 ft., (5) 12½ ft.

The seedlings are very sensitive to drought and to excessive moisture. Seedlings of a tropical littoral species like casuarina might be expected to be frost-tender, but at Dehra Dun this was found not to be the case, the young plants remaining quite uninjured by frost when several indigenous species suffered. The seedlings have many enemies; hares, squirrels, and rats damage them, and on the coast they are subject to the attacks of crabs, which nip through the stems. They are very liable also to the attacks of crickets and other insects.

SILVICULTURAL CHARACTERS. The tree is a strong light-demander, suffering readily from suppression. Although the seedlings are very sensitive to drought the trees of the coast plantations have proved remarkably drought-resistant, though this may bo due to the fact that the subsoil water-level is not far from the surface. In the exposed position in which they stand the trees of the coast plantations are occasionally uprooted, or have their branches broken, by storms, although they appear to stand the force of the monsoon better than most species. The casuarina is very susceptible to damage by fire; the removal of the fallen twigs, a common practice in the coast plantations, considerably lessens the risk of fire, while in some plantations it is found necessary, for protective purposes, to remove grass in the young plantations.

Root-suckers sometimes appear in profusion in coast plantations, but this is not by any means universal; the trees also reproduce by natural layers from the lower branches. The roots produce nodules, which are sometimes present in large numbers. Mr. M. J. Narasimhan [1] found from a microscopic examination that the nodules contain bacterial cells, indicating that they probably perform a useful function; the production of root nodules appears to be characteristic of the genus, since they have been found also on other species of *Casuarina*. As a general rule the tree coppices badly, but if cut high the stools sometimes produce vigorous shoots. Mr. W. E. Copleston [2]

[1] Ind. Forester, xliv (1918), p. 265.

[2] Working Plan for the Casuarina Plantations near Honavar, 1910.

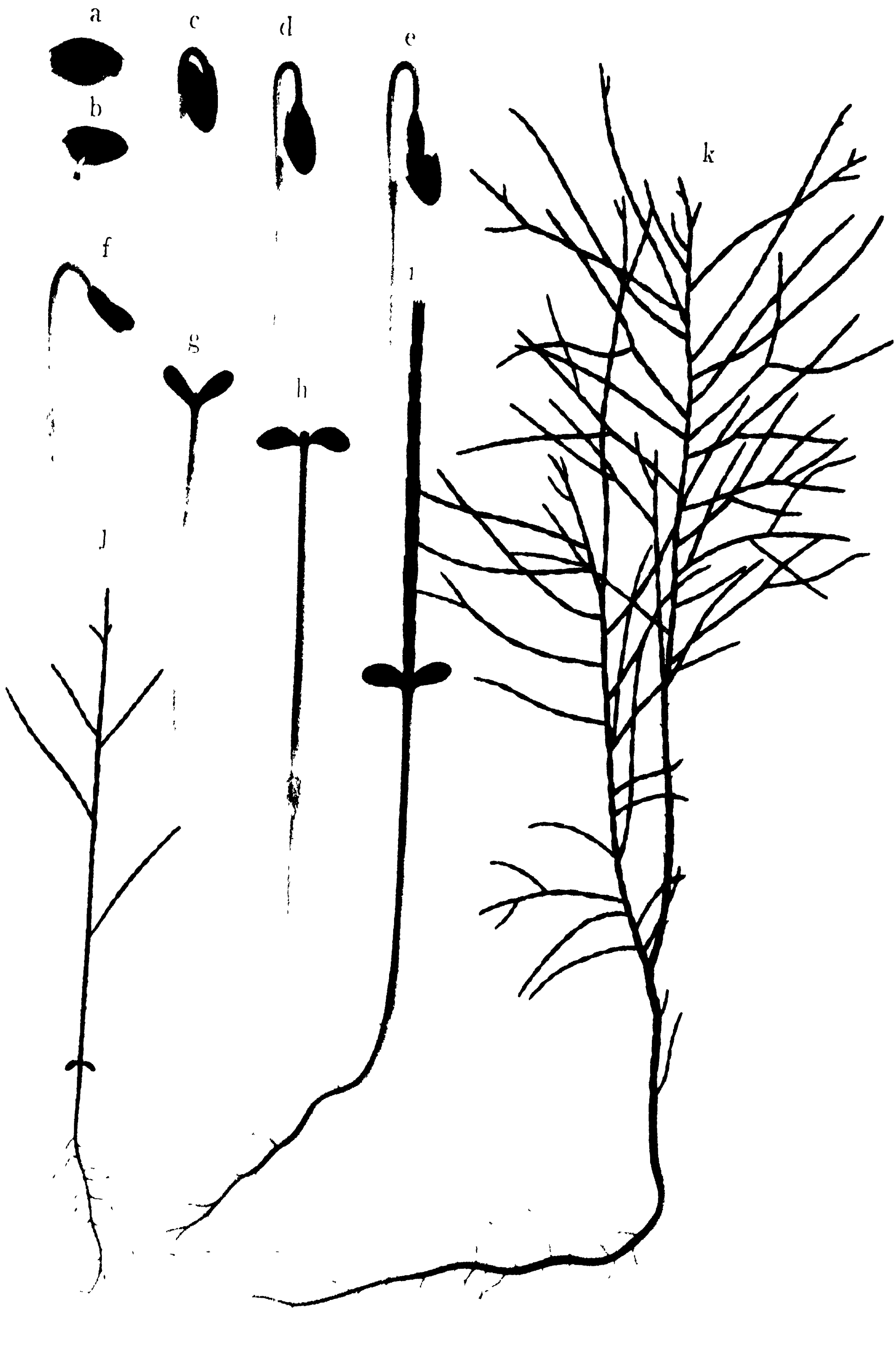


FIG. 332. *Casuarina equisetifolia* SEEDLING.

a Achene $\times 2$ b-i Germination stages $\times 2$ j Seedling towards end of first season $\times \frac{3}{4}$
k- Seedling towards end of second season $\times \frac{1}{4}$

mentions an exceptional case of coppicing in the Kasarkod plantation, North Kanara district, in which excellent coppice regrowth was obtained in a portion of the area close to the sea from trees which were ten or twelve years old when felled. Some of the coppice poles thirteen years old were 3 ft. in girth and over 80 ft. high. From some stumps as many as six strong shoots had developed, while from many stumps only one or two shoots were produced. Mr. P. M. Lushington[1] notes a case of vigorous layering and coppicing in a plantation in the Guntur district of Madras. Trees established from layers had a height of 15–20 ft. and a girth of 8½–18 in., although only two years old. An instance of vigorous coppicing was that of a stool about 2 ft. high and 30 in. in girth round the top, from a tree felled when about twelve years old ; the stool had produced five large poles which had a height of 30 to 35 ft. and a girth of 13–27 in. at an age of fourteen years. The casuarina is subject to various pests and diseases, the chief of which are mentioned below in connexion with plantations. Young plants suffer to some extent from browsing by cattle, especially buffaloes.

NATURAL REPRODUCTION. The distribution of seed is effected, to some extent at least, by the agency of wind. The seed is produced in large quantities, and it has been suggested that it has been carried by sea originally from Australia to Java, Borneo, and other islands and thence to the coast of the Malay Peninsula and Burma ; although this has not actually been proved, there seems to be nothing improbable in the suggestion.

As a general rule natural reproduction by seed is scanty or absent in the coast plantations of India, but in North Kanara natural seedlings appear in large quantities in open spaces along the edge of old plantations towards the end of the monsoon. The actual factors which influence natural reproduction require further study, but so far as experiments go, among conditions essential to success are (1) abundance of light, (2) porous sandy soil free from weed-growth, (3) absence of heavy rain during germination and the early life of the seedling, and (4) sufficient moisture in the soil to prevent mortality by drought during the first two or three years. Ants and other insects, as well as crabs, are no doubt responsible for a good deal of damage to seeds and seedlings under natural as under artificial conditions.

CASUARINA PLANTATIONS. All the most important casuarina plantations are situated along the sea-coast, both on the east and on the west side of the Indian Peninsula. There are some inland plantations, but the casuarina can hardly be regarded as a suitable plantation tree away from the coastal regions, though as a fast-growing and short-lived nurse for shade-bearing species it is sometimes useful.

The chief plantations formed by Government in the Madras Presidency are situated along the east coast, in the districts of Ganjam, Godavari, Kistna, Nellore, Chingleput, South Arcot, and Tanjore ; plantations have also been formed in North Arcot near Vellore, some distance from the sea. The most important of the east coast plantations are those of Nellore, which in 1910 aggregated over 3,600 acres. On the west coast of Madras plantations have been formed to a small extent in South Canara, the oldest, the Ullal plantation, dating from 1868. There are also many private plantations in the Madras

[1] Inspection Note, 1912.

Presidency, and within recent years the Local Government has adopted the policy of handing over the management of casuarina plantations to private enterprise, with the result that the Government plantations have for some years past been in process of disposal to private individuals.

In the Bombay Presidency the planting of casuarina was commenced in 1868–9 at Karwar in the North Kanara district, and in 1886 in the Kolaba district near Alibag. These plantations have since been increased considerably in both districts, and have proved highly remunerative, the produce, in the shape of fuel, being conveyed by sea to Bombay. There are plantations on a smaller scale in the Ratnagiri district. A strip of sand along the shore at Puri in Orissa has recently been acquired for the formation of a casuarina plantation.

The coast plantations have been formed on pure sand, on low dunes or flat shores, or in a few cases on sand mixed with river silt. The subsoil water-level is never at a great depth, the actual depth varying ordinarily from about 4 to 12 ft. in the dry season. Where the sand deposit covers rich alluvial arable land, as in parts of the Nellore plantations, the growth is particularly fine. Figs. 333 to 336 show plantations in different stages in the North Kanara district, Bombay.

The method almost universally adopted for establishing casuarina plantations is to transplant seedlings raised in the nursery, usually in beds, but sometimes in boxes. The total cost of formation ordinarily varies from Rs. 20 to Rs. 25 per acre. In North Kanara many of the plantations have been raised from natural seedlings collected from around the existing plantations in November and kept in the nursery until the following June, when they are planted out ; this method, however, is giving place to that of raising plants from seed in the nursery. Direct sowings do not answer, as the seedlings require special protection from heavy rain, drought, and insects. It may be mentioned that the casuarina makes a good hedge in sandy soil in coastal regions ; the seedlings should be planted out about 1 ft. apart and encouraged to form a bushy growth by repeated trimming commenced at an early age. In the nursery the seed-beds should be well raised and composed of pulverized light porous sandy soil mixed with well-sifted mould, dry cowdung, and ashes : the surface should be well smoothed and the seeds sown broadcast on the surface and lightly covered with a sifted mixture of mould, dry manure, and ashes. In the Godavari district it is reckoned that 200 lb. of fruits give 24 lb. of seed, which is sufficient for 75 beds each 2 ft. by 6 ft. A covering of palm leaves, straw, or reeds is placed on the beds until germination is completed ; germination ordinarily commences in about four to eight days, and the covering is removed in about ten to twenty days. Regular watering should be carried out. When the seedlings are about 2–4 in. high they are pricked out, the spacing adopted varying locally from 3 in. by 3 in. to 6 in. by 6 in. or even more. The age at which the seedlings are planted out varies locally from about six to eighteen months, but it is always advisable to keep the plants in the nursery as long as safety permits, in order to reduce the cost of subsequent watering in the plantation. The plants are transplanted into pits previously prepared, and often require to be supported for a year by stakes.

The dates of sowing, pricking out, and transplanting vary in different localities on the coast ; planting on the west coast depends on the south-west

Fig. 333. *Casuarina equisetifolia* plantations in North Kanara: (1) planting a cleared area at the beginning of the monsoon; old plantation on left.

Fig. 334. *Casuarina equisetifolia* plantations in North Kanara: (2) planted area at end of first monsoon.

FIG. 335. *Casuarina equisetifolia* plantations in North Kanara (3) plants one year in nursery, three years in plantation.

FIG. 336. *Casuarina equisetifolia* plantations in North Kanara. (4) felling a mature plantation.

monsoon, while on the east coast it depends in several localities on the north-east monsoon. The following dates apply approximately :

Locality.	Sowing.	Pricking out.	Transplanting.	Approximate age of plants when transplanted.
North Kanara	April	June	Commencement of SW. monsoon (June or beginning of July)	14 months.
Kolaba	Usually November (sometimes March–May)		Commencement of SW. monsoon (June or beginning of July)	18 months.
Madras east coast	February	May	Usually at commencement of NE. monsoon (October)	8 months.
			Sometimes in SW. monsoon (July)	5 months.

A system of making nursery-beds on raised platforms is in vogue in the Kolaba forest division of Bombay.[1] The seed-bed consists of a layer of soil 10 in. deep placed on a platform of latticed casuarina branchwood measuring 4½ ft. by 4½ ft., raised 2½ ft. above the ground on four stout posts. The advantages secured by this method are immunity from insect attacks, good drainage, and removal of the seedlings without damage to their roots, by loosening the platform. The seed is usually sown in November, and a bed of the dimensions given produces at the end of twelve to eighteen months 500 to 700 seedlings with an average height of 5 ft. The growth under this system is very rapid, an average height of 10 in. and 25 in. being attained after three and six months respectively. Planting is carried out at the commencement of the monsoon, the seedlings being about eighteen months old.

For inland planting the seed should be sown in the nursery between February and April, and the seed-beds should be protected by coverings of thatch from sun and heavy rain. The seedlings should be pricked out 6 in. by 6 in. when 4 to 6 in. high and transplanted early in the second rainy season, when about fourteen to sixteen months old. It is often preferable, however, to raise the seedlings in boxes.

In existing plantations various spacings have been adopted, but the general rule now is to plant 8 ft. by 8 ft., 9 ft. by 9 ft., or 10 ft. by 10 ft. In some of the Bombay plantations triangular planting with a spacing of 12 ft. is the rule. At one time the spacing in force was as close as 6 ft. by 6 ft., but experience has shown that such close spacing is not advisable, since the branches begin to interlace after about three years, and early thinnings are necessary to prevent insect and fungus damage. It is now generally held that a spacing of less than 9 ft. by 9 ft. is neither necessary nor advisable.

After the seedlings have been transplanted from the nursery they require to be watered at once. Regular watering is also necessary for one, two, or three years after transplanting, according to the locality. Supplies of water are obtained from wells previously dug at intervals through the area planted ; the depth down to the water-level is as a rule not many feet in the coast plantations. Watering is done as far as possible in the evening. The intervals between successive waterings and the length of time for which watering is carried out must depend largely on the locality, and even in the same locality more copious watering is necessary on the dunes than in the hollows. Excessive watering should be guarded against, as it is considered to be a contributory

[1] V. D. P. Rebeiro in Ind. Forester, xxxix (1913), p. 380.

cause of fungus attacks. In North Kanara it is usual to water daily during the first dry season, while weakly plants are also watered during the second dry season where the water-level is deep. On the east coast it is usual to water for three years. In the first year watering is usually carried out for about ten months at intervals of one, two, or three days, according to requirements; in the second year it is carried out for about six months (February–July), and in the third year for about four months (March–June), at similar intervals.

In the North Arcot plantations experiments carried out in 1909–10 showed that irrigation gave better results and proved cheaper than hand watering, although the plants were watered only once in five days instead of once in three days.

Pests and diseases in plantations. The artificial propagation of casuarina is attended with various difficulties in the shape of pests and diseases. Ants carry off the seeds from the seed-beds, and where this trouble is apprehended the seeds should be poisoned; copper sulphate might be tried. In the Malay States the seeds are treated with a decoction of the root of *Derris elliptica*. Spreading ashes over the beds has some effect in preventing the attacks of ants and other insects. Failing this the seedlings may have to be reared in boxes raised on platforms protected from insects; the platform system of Kolaba, described above, is said to prevent insect attacks. Seedlings in the nursery are much subject to the attacks of crickets, among which *Brachytrypes achatinus* has proved very destructive. They are guarded against in North Kanara by fencing the nursery round with a thick close fence 3 to 4 ft. high, and clearing all vegetation on a strip about 20 yds. wide outside the fence. The insects cannot as a rule hop over the fence; those which do gain admittance have to be dug out of their burrows and killed. In the nurseries of the coast plantations small crabs are often troublesome in destroying seedlings; where these are prevalent they have to be dug up daily in the nursery-beds and destroyed.

The plantations themselves are subject to various insect pests, of which *Arbela tetraonis*, the bark-eating caterpillar, and *Coelosterna scabrata*, a longicorn, are probably the worst. Young plants in some of the Madras plantations have been much damaged by the grubs of the rhinoceros beetle, *Oryctes rhinoceros*; burning all rubbish before planting has proved a check. More serious than any of these, perhaps, is the root-fungus *Trichosporium vesiculosum*, which appears to be favoured by excessive watering and congestion; thinnings commenced early and continued regularly have been found to check it to some extent. Insect and fungus attacks are dealt with by removing affected trees and grubbing up the stumps as soon as the attack reveals itself, but even this has in some cases failed to prevent the spread of the pests. In Nellore allowing a period of two years to elapse between felling and replanting is said to have had good results in the case of fungus attacks. A further expedient being tried in some of the Madras plantations is to plant other species of trees with the casuarina, either in regular mixture or in the form of belts between blocks of casuarina. The species most frequently planted are *Azadirachta indica*, *Eugenia Jambolana*, *Dalbergia Sissoo*, *Anacardium occidentale*, *Pongamia glabra*, *Pithecolobium dulce*, *Sapindus laurifolius*, and sometimes coco-nuts. These trees, besides assisting in segregation, are useful in attracting insectivorous birds, for in a dense casuarina plantation bird life is remarkably scarce.

Thinnings in plantations. Since the casuarina grows rapidly and is a strong light-demander, regular thinnings are necessary to ensure the proper development of the stems, which otherwise tend towards undue height-growth at the expense of volume production ; they are equally necessary in order to minimize the danger of insect and fungus attacks. Where planting is done as close as 6 ft. by 6 ft. the first thinning is usually necessary after four years, and may even be required at three years of age ; with wider spacing thinnings require to be commenced at an age of five to ten years, according to circumstances. In existing plantations the interval between thinnings is seldom more than ten years, and in some cases it has been as short as three years.

System of management and rotation. Casuarina plantations are worked under the clear-felling system with artificial reproduction by planting. An estimate of the rotation on correct financial lines was attempted in 1910 for the North Kanara plantations.[1] It was estimated from statistics of out-turn and price that the net rental at 4 per cent. culminated at twenty-seven years, while the greatest volume production was obtained with a rotation of thirty-three years ; accordingly a rotation of thirty years was adopted, and this has been followed in the case of the coast plantations of Bombay generally. The results of working under the North Kanara working plan of 1910, however, have led to doubts as to the accuracy of the estimate, and in August 1916 Mr. Marjoribanks, in a paper read at the annual conference of southern circle forest officers, came to the conclusion that a shorter rotation, say one of ten years, with a thinning after five or six years, would probably yield a larger profit than the one prescribed. The question was considered in 1917 by Mr. Hart, who advocated the immediate reduction of the rotation tentatively to fifteen years.[2] In Madras the plantations have always been worked on short rotations ; actually the rotations fixed at different times in various localities have varied from seven to fifteen years.

Rate of growth and out-turn. The growth is fast. The following estimates, from measurements in the North Kanara plantations, have been recorded in the appendix tables and curves of the working plan already alluded to :

Casuarina equisetifolia : rate of growth and out-turn, North Kanara plantations.

Age. years.	Mean basal diameter. in.	Corresponding mean girth. in.	Mean height of dominant stems. ft.	Volume per acre. cub. ft.	Mean annual volume increment per acre. cub. ft.	Current annual volume increment per acre for quinquennial periods. cub. ft.
5	2·8	8·8	20	200	40	
						40
10	5·3	16·6	35	400	40	
						70
15	7·2	22·6	51	750	50	
						120
20	8·9	28·0	74	1,350	67	
						130
25	10·2	32·0	94	2,000	80	
						130
30	11·4	35·8	105	2,650	88	
						100
35	12·2	38·3	109	3,150	90	
						50
40	12·7	40·0	112	3,400	85	

[1] Working Plan for the Casuarina Plantations in the West Division, Kanara, R. S. Pearson, 1910.

[2] Note on a Tour of Inspection in some of the Forests of the Central, Northern, and Southern Circles, Bombay Presidency, G. S. Hart, C.I.E., Inspector-General of Forests, April 1917, p. 28.

The following measurements have been recorded by Mr. V. D. P. Rebeiro in plantations in Kolaba :[1]

Casuarina equisetifolia : rate of growth, Kolaba plantations.

Approximate age (allowing for time in nursery).	Mean girth.	Mean height.
years.	in.	ft.
2–2½	3·5	11
3–3½	7	15
4–4½	8·5	17
5–5½	13·5	23
16–18	21	..
18–27	29	..
27–33	51	75

In the Madras plantations figures collected by Mr. E. P. Popert[2] in 1895 showed that the past yield varied from 50 tons per acre in Nellore to 28 tons in North Arcot, and he considered it safe to estimate a future out-turn of 40 tons per acre in coast plantations. More recent figures have shown that this estimate was over-sanguine, for in Nellore the actual average, under a ten-year rotation, for the ten years prior to 1910 was 25 tons per acre, and this from trees averaging a good deal more than ten years of age ; accordingly the estimated out-turn from 1910 onwards, under a rotation of eight years, was placed at 23 tons per acre, or nearly 2·9 tons per acre per annum over the whole area. If a ton be taken as equivalent to 50 cubic ft., the annual out-turn (i. e. the mean annual increment) per acre will be 144 cubic ft., which is greatly in excess of the estimate for North Kanara. Comparisons between the various records of out-turn given in working plans, however, are difficult to make, since they do not always state clearly whether yields from thinnings are taken into account.

Numerous statistics will be found in Mr. D. E. Hutchins's *Report on the Measurement of Rates of Growth of Casuarina in the Nellore District*, 1883.

ORDER LVIII. BETULACEAE

All the Indian trees of this order are Himalayan species, three, *Betula alnoides*, *Alnus nepalensis*, and *Carpinus viminea*, extending eastward to the hills of Burma. The most important Indian trees of this order are the birches and alders ; the hornbeams and hazels are represented by two species each, but none is sufficiently plentiful to be of much importance. The common hornbeam of the Himalaya is *Carpinus viminea*, Wall., which in general appearance much resembles the European hornbeam, *C. Betulus*, Linn. *C. faginea*, Lindl., is more local. The common Himalayan hazel is *Corylus Colurna*, Linn., which has a general resemblance to the European hazel, *C. Avellana*, Linn., and has an edible nut as good as that of the European species. *C. ferox*, Wall., is found in Nepal and Sikkim at 8,000–10,000 ft.

Genera 1. BETULA, Tourn. ; 2. ALNUS, Gaertn.

1. BETULA, Tourn.

There are three Indian birches, of which *B. cylindrostachys*, Gamble, is in all probability more than a mere variety of *B. alnoides*, Ham. All are hill

[1] Ind. Forester, xxxix (1913), p. 380.
[2] Note on Casuarina Planting, 1895.

species, *B. utilis*, Don, representing the highest limit of tree growth in the Himalaya. The fruits are small winged nuts arranged in catkins with deciduous scales, and a characteristic shared by all three species is their habit of springing up naturally on places where the soil has been exposed.

Species 1. *B. utilis*, Don; 2. *B. alnoides*, Ham.; 3. *B. cylindrostachys*, Gamble.

1. **Betula utilis**, Don. Syn. *B. Bhojpattra*, Wall.; *B. Jacquemontii*, Spach. Himalayan silver birch. Vern. *Bhuj*, *bhujpattra*, Hind.

A moderate-sized deciduous tree, usually with a somewhat irregular bole; sometimes a mere shrub. Leaves ovate acuminate, irregularly serrate, 2–3 in. long. Bark smooth, shining, reddish white or white, with white horizontal lenticels, the outer bark consisting of numerous thin papery layers exfoliating in broad horizontal rolls; inner cortex red, moist. In all but young trees the bark of the lower part of the stem becomes rough and dark coloured. Wood pinkish white, even-grained, used for building in the inner Himalaya. The bark is used as paper for writing, packing, roofing, covering umbrellas, and other purposes. The twigs are used for rope bridges and the leaves are lopped for cattle fodder.

Distribution, habitat, &c. This is the common birch of the higher levels of the inner Himalaya from Bhutan westwards, chiefly at 10,000–14,000 ft., but sometimes descending sporadically as low as 7,000 ft. and even to 6,000 ft. in the Kishenganga valley, Kashmir. It extends to China and western Tibet. At the higher elevations it is gregarious, occurring either in pure masses, often with an undergrowth of *Rhododendron campanulatum* or *R. Anthopogon*, or associated with the high-level silver fir (*Abies Webbiana*) and sometimes with juniper. In some localities, for example in Hazara, it is associated with the blue pine (*Pinus excelsa*), spruce (*Picea Morinda*), low-level silver fir (*Abies Pindrow*), brown oak (*Quercus semecarpifolia*), *Pyrus lanata*, *P. foliolosa*, and other trees, sometimes with an undergrowth of dwarf willow. In its gregarious state it marks the upper limit of tree vegetation on the uplands of the inner western Himalaya before the treeless snowy wastes begin (see Fig. 337). The birch forests occur on open exposed tracts which are under snow throughout the greater part of the winter. The tree is a strong light-demander. The young crops spring up on bare ground exposed by the scouring of snow or the accumulation of earth and rock débris. In such places natural reproduction is good, provided the young plants escape excessive grazing, which effectually prevents reproduction. The birch forests themselves are subject to constant erosion and scouring by snow, and the upper reaches of the snow-fed torrents are often piled up with the white trunks of the birch trees, which have been swept down by the sliding and melting snow. In some localities extensive damage is done to the birch forests by nomadic graziers, who lop and fell the trees for fodder and have been responsible for the clearance of whole tracts of forest. The excessive stripping of the bark for wrapping and other purposes also accounts for the death of many trees, and where the working of bark is to be carried out under control it should be insisted on that the outer bark should not be so completely removed as to expose the inner moist red cortex, and that a long enough interval should elapse between successive barkings to enable a sufficient thickness of outer papery bark to form again.

Leaf-shedding, flowering, and fruiting. The leaves fall about October, turning a beautiful golden yellow before falling. The trees remain leafless during the winter, and the new leaves appear in April–May, at which time the birch forests can be distinguished from a distance by the delicate green colouring of the young foliage. The flowers appear with the young leaves, the male catkins drooping, 3–5 in. long, and the female spikes stiff, 1–1·3 in. long. The fruit ripens from August to October; the fruiting spikes are 1–1·5 in. long, containing numerous small narrow-winged nuts subtended by deeply 3-lobed bracts. The winged nuts are dispersed by wind or by sliding or melting snow, finding a germinating bed on newly exposed ground.

Rate of growth. The growth is slow. Gamble gives the average at about 15 rings per inch of radius, representing a mean annual girth increment of 0·42 in. A cross-section in the silvicultural museum at Dehra Dun showed 69 rings for a girth of 2 ft. 2 in., giving a mean annual girth increment of 0·38 in.

2. **Betula alnoides**, Ham. Syn. *B. acuminata*, Wall. Alder birch. Vern. *Sheori*, *kath bhuj*, *ban utis*, W. Him.

A moderate-sized to large deciduous tree with ovate or ovate-lanceolate sharply acuminate irregularly and doubly serrate leaves, 3–6 in. long. Bark grey or greyish brown, shining, with horizontal oblong lenticels, peeling off in rather stiff narrow horizontal bands. Wood close-grained, whitish to light brown, not much used at present.

Distribution, habitat, &c. Himalaya from the Sutlej eastwards at 5,000–10,000 ft., Khasi hills, Manipur, and hills of Burma above 5,000 ft. This is the low-level birch of the Himalaya, its large leaves and somewhat sombre bark giving it the appearance of an alder. It often occurs sporadically in high forest mixed with oaks and other broad-leaved species as well as with conifers. It tends to become gregarious wherever conditions are favourable to its natural reproduction, that is, on landslips and other places where the soil has been newly exposed. Seedlings are frequently found on the sides of road-cuttings and similar places. Sporadic trees arise only from seedlings springing up on patches of new soil, since natural reproduction is incapable of appearing under a forest canopy or on weed-covered ground. This tree is not so pronounced a light-demander as *B. utilis*, and grows as a rule on more sheltered and moister situations than that species.

Leaf-shedding, flowering, and fruiting. The tree is leafless in winter. The flowers are fully developed in March–April, and perhaps also at other times; the male and female catkins are more or less the same size, 2–5 in. long. The fruiting spikes ripen in May–June; the nut has a wing broader than itself, and can be dispersed to a considerable distance, judging by the manner in which seedlings spring up a long way from any seed-bearer.

Rate of growth. Gamble gives the growth as 10 rings per inch of radius in the north-west and 6½ rings for Darjeeling wood; the corresponding mean annual girth increments are 0·63 and 0·96 in.

3. **Betula cylindrostachys**, Gamble. Low-level Darjeeling birch. Vern. *Saur*, Nep.; *Sunli*, Lepcha.

A tall deciduous tree, reaching over 120 ft. in height and 6 to 8 ft. in girth, with pink bark peeling off in large vertical flakes. Wood red, hard, heavy. Gamble gives this as a low-level species of the Darjeeling hills, probably distinct from *B. alnoides*. It ascends to 6,000 ft., and descends even to the *tarai* forests, where it grows along streams. The seed ripens in March. Like *B. alnoides*, it tends to become gregarious on landslips and other places where the soil has been exposed, and is a suitable tree for afforesting such places at the lower elevations by means of direct sowings. At times it forms dense crops. Measurements made by Mr. E. Marsden in two crops in the Darjeeling hills in 1917 gave the following results :

Betula cylindrostachys : sample plot measurements, Darjeeling hills.

Age.	Number of stems per acre.	Mean girth at 4½ ft. from ground.	Mean height.	Solid volume per acre.	Remarks.
years.		ft. in.	ft.	cub. ft.	
9	250	1 4	54	759	Open crop mixed with *Quercus semiserrata*
30	174	3 3·1	125	6,508	Unthinned.

These figures indicate a rapid rate of growth.

2. ALNUS, Gaertn.

The alders are readily distinguished from the birches by the persistent scales of the female spikes, which become woody in the cone-like fruit. The nuts are small and more or less winged. Both Indian species, like the birches, display the habit of springing up gregariously on new ground, *A. nitida* along the beds and banks of rivers and moist ravines, and *A. nepalensis* in similar places as well as on landslips and abandoned cultivation.

Species 1. *A. nepalensis*, Don ; 2. *A. nitida*, Endl.

1. **Alnus nepalensis,** Don. Nepalese alder. Vern. *Utis, kunis, kohi, kunsh,* W. Him. ; *Maibao,* Kachin hills.

A large deciduous tree, attaining a height of 80–100 ft. and a girth of 6 to 8 ft. Leaves 3–8 in. long, elliptical, entire or slightly denticulate. Bark silvery grey, darker in the forest. Wood pinkish, even-grained, soft, suitable for tea-boxes.

Distribution, habitat, &c. Throughout the Himalaya from the Ravi eastwards at 3,000–9,000 ft., sometimes lower, Khasi hills and the hills of Upper Burma. In the western Himalaya it affects moist, shady ravines near water, usually in gregarious strips, but it is not so strictly confined to the beds of streams as *A. nitida*. In the eastern Himalaya and the hills of Burma it comes up readily on landslips and newly exposed soil generally, and also affects moist ravines. In the Darjeeling hills it quickly takes possession of landslips, often along with *Bucklandia populnea*, the result being a pure crop of alder or an overwood of the fast-growing alder with a lower story of the more slow-growing *Bucklandia*. Abandoned cultivated lands also become quickly covered with a pure crop of alder, as is strikingly exemplified in abandoned *taungya* clearings in the hills of Upper Burma.

Flowering and fruiting. The flowers are fully developed from September to November ; male catkins 4–10 in. long, in large terminal drooping panicles, female 0·2–0·3 in. long, in axillary racemes, rarely solitary. Fruiting cones 0·5–1 in. long by 0·3 in. in diameter. Nuts with a narrow membranous wing. The fruits ripen in February–March, the empty cones remaining long on the tree.

ARTIFICIAL REPRODUCTION. The tree can be easily raised either by direct sowings on bare loose ground or by transplanting. Sowing should be done, *in situ* or in the nursery as the case may be, about February or March. Deer are found to be troublesome in young plantations, as they browse on the young plants as well as bark the saplings. In the Darjeeling hills the seed is sown broadcast on bare soil, and after the first year the seedlings grow rapidly, about 3 to 5 ft. a year. The tree is also occasionally planted in wet ravines where nothing else will grow, natural seedlings about 2 ft. high being usually transplanted. At Mongpoo great success is obtained by raising seedlings in the nursery and transplanting them when about 12 in. high. Seedlings can also be transplanted with success in June–July when 4–6 in. high and 3–4 months old. In the Darjeeling hills it has been found possible to transplant in the winter as well as in the rains.

In Burma this alder has been successfully established by line sowings in order to fill up grassy blanks in the forest reserves near Mogôk in the Ruby Mines district. An interesting system is in vogue among the *taungya*-cutting tribes in certain parts of the hills of the Bhamo and Myitkyina districts on the north-east frontier of Upper Burma. The crops raised in the temporary clearings are maize, cotton, or other hill crops. Alder seed is sown along with the crop or sown broadcast after it. A dense young crop of alder results ; it requires weeding for three years and fire-protection for four, after which it requires no further attention. The rotation for shifting cultivation is reduced by this system from twelve years to eight, while the soil is enriched and protected from erosion and desiccation. Experiments have been tried in other parts of Upper Burma in sowing up *taungyas* in this manner, but it has been found that the alder will not grow below 5,000 ft. elevation, and failure is attributed in some localities to suppression by dense weed-growth or to the depredations of deer.

RATE OF GROWTH AND OUT-TURN. Under favourable conditions the growth is very rapid. Mr. J. L. Baker informs me that up to 6,000 ft. in the Darjeeling hills the alder attains a height of 50 ft. and a girth of 3 ft. in ten years, giving a mean annual girth increment of 3·6 in.

Gamble's specimens showed 3·6 rings per inch of radius, and he mentions a round of Sikkim wood with 2·4 rings per inch. Manson's Darjeeling working plan gives 3–4 rings per inch as the average. These figures give a mean annual girth increment of about 1·5 to 2·5 in.

The following measurements were made by Mr. E. Marsden in a young crop below Rangirum in the Darjeeling hills : age, ten years ; stems per acre, 252 ; mean girth at 4½ ft. from ground, 1 ft. 4·1 in. ; mean height, 51 ft. ; solid volume per acre, 745 cubic ft. In a thinning carried out immediately before these measurements were made, 295 stems per acre, with a solid volume of 283 cubic ft., were removed.

2. **Alnus nitida**, Endl. West Himalayan alder. Vern. *Utis*, *kunis*, *kunsh*, *koish*, *sharol*, W. Him.

A large tree, attaining a height of 80–100 ft. and a girth of 6–12 ft. Leaves 4–5 in. long, elliptical ovate, acuminate, entire or obscurely crenate. Bark

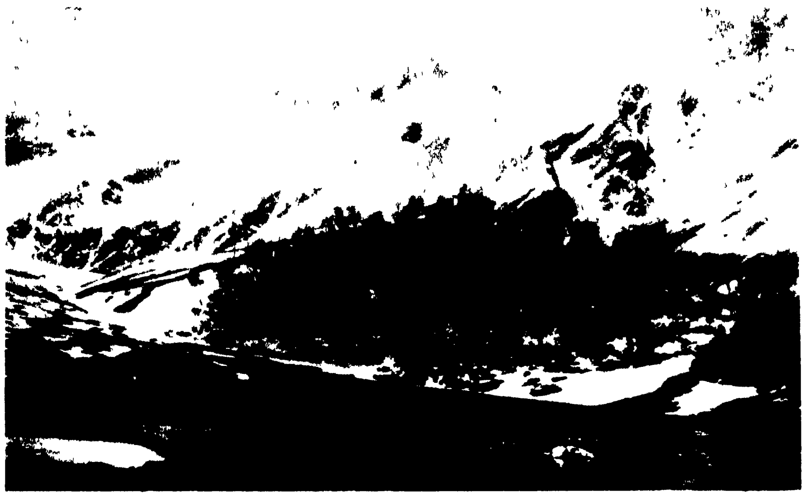


Fig. 337. *Betula utilis* towards upper limit of tree-growth, 12,000 ft. Tehri Garhwal.

Fig. 338. *Alnus nitida* in the bed of a stream in *Pinus longifolia* forest, Siran valley, Hazara

Fig. 339. Pure forest of *Quercus incana*, Kumaun hills.

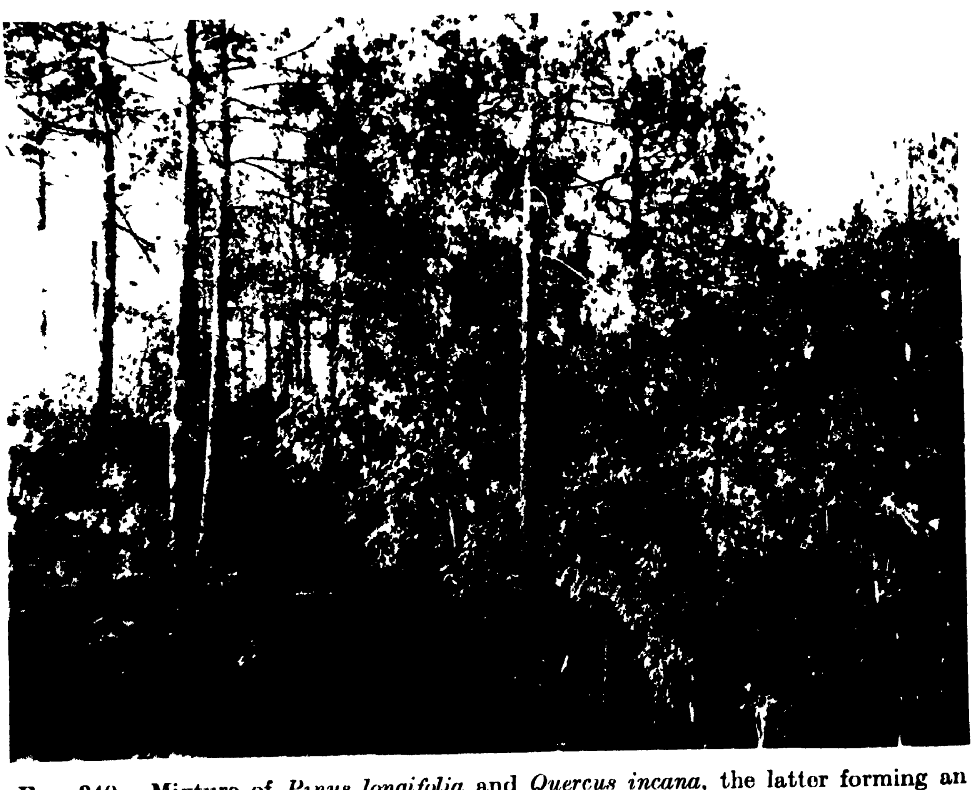


Fig. 340. Mixture of *Pinus longifolia* and *Quercus incana*, the latter forming an under story to the former, Kumaun hills.

dark brown, rough with deep furrows. Wood reddish white, soft, close-grained. The tree sometimes attains large dimensions ; Mr. J. C. McDonnell[1] records one of 15 ft. girth in Kashmir.

DISTRIBUTION AND HABITAT. Western Himalaya from the Jumna westwards, usually at low elevations, most commonly below 6,000 ft., but ascending occasionally to 9,000 ft. This alder is always found in moist situations, mainly along the beds and banks of streams and rivers. It springs up gregariously on new land thrown up in the beds of rivers, where it forms pure crops, sometimes of considerable extent. It also springs up in strips along the banks of moist ravines and torrents, often in *Pinus longifolia* forest (see Fig. 338).

Henry[2] says that this is one of the few Himalayan broad-leaved trees which have succeeded in England, and that three thriving specimens, raised from seed sent by Mr. R. E. Ellis of the Indian Forest Department in 1882, are growing near the lake in Kew Gardens, the largest of which was 40 ft. high and 2 ft. 3 in. in girth about 1906.

FLOWERING AND FRUITING. The flowers are fully developed from August to October. Male catkins 4–10 in. long, about 4–6 together in terminal racemes ; female spikes about 0·3 in. long. Fruiting cones 0·7–1·5 in. long by 0·5 in. in diameter, in erect lateral racemes. Nut with a narrow thickened edge. The fruits ripen in November–December, the empty cones remaining long on the tree.

ARTIFICIAL REPRODUCTION. The tree is easily propagated from seed sown in moist shady nursery-beds about February, the seedlings being transplanted in moist situations when two or three years old. Natural seedlings are often available in plenty for transplanting purposes. The tree can be raised from cuttings put down in nursery-beds of moist sandy soil at the commencement of the rainy season and transplanted, after they are well rooted, in the winter or in the rainy season.

RATE OF GROWTH. A cross-section 3 ft. 4 in. in girth in the silvicultural museum at Dehra Dun had 41 rings, giving a mean annual girth increment of about 1 in. The tree in Kew Gardens mentioned above showed somewhat faster growth.

ORDER LIX. FAGACEAE

The two Indian genera in this order are *Quercus* and *Castanopsis*, of which the former is large and important and the latter is of somewhat less importance. The Spanish chestnut, *Castanea sativa*, Miller, is cultivated in India.

Genera 1. QUERCUS, Linn. ; 2. CASTANOPSIS, Spach ; 3. CASTANEA, Tourn.

1. QUERCUS, Linn.

A large genus of great importance in forestry in Europe, North America, Japan, and elsewhere. There are between 30 and 40 known species of oak in the Indian region ; of these about 24 are Burmese, though several of these extend into Manipur or the hills of and adjacent to Assam or Chittagong,

[1] Ind. Forester, xxix (1903), p. 152.

[2] Elwes and Henry, The Trees of Great Britain and Ireland, iv. 954 (1906).

while a few extend to the eastern Himalaya. The great majority of the oaks are hill species, some extending to high elevations; one or two, however, occur also at low elevations in forests not of any hill type, for example *Q. velutina*, Lindl., and *Q. semiserrata*, Roxb., which are found in low-level *indaing* (dry dipterocarp) forest in Burma.

Of a total of about ten oaks in the eastern Himalaya the most important are *Q. lamellosa*, Sm., *Q. pachyphylla*, Kurz, *Q. lineata*, Bl., and *Q. spicata*, Sm. Of the five species of the western Himalaya the three most important are *Q. incana*, Roxb., *Q. dilatata*, Lindl., and *Q. semecarpifolia*, Sm.

Several of the oaks are markedly gregarious, their occurrence defining regular zones of elevation; these zones are particularly well defined in the case of the three west Himalayan species just mentioned, which succeed each other from the lower to the higher elevations in the order given.

The oaks are deciduous or evergreen. The flowers are unisexual, rarely bisexual, monoecious, the males in pendulous catkins or erect spikes, the females 3- to 5-celled and styled with two ovules in each cell, enclosed in an involucre of numerous scales. The fruit (acorn), which ripens in the first or second year, is a nut with its lower part surrounded by a coriaceous or woody cup resulting from the growth of the involucre. The nut is one-seeded, the remaining ovules being abortive; in the case of *Q. semecarpifolia*, however, cases have been noticed where more than one fertile seed is present. The cotyledons are thick and fleshy; there is no albumen. Germination is hypogeous, the radicle emerging from the apex of the nut and the plumule extricating itself by the elongation of the cotyledonary petioles. In *Q. semecarpifolia* this elongation is of an abnormal character, the petioles remaining united in the form of a tube which may reach a length of 4 in. or more; the tube serves as a protection to the minute plumule, while the abnormal elongation of the united petioles enables the young plant to reach the soil as rapidly as possible. The acorns of most of the better known Indian oaks are much subject to the attacks of insects, but a slight boring of the cotyledons, provided the embryo is not damaged, does not appear to affect the fertility of the seed to any extent. The acorns are also eagerly devoured by birds and by bears, squirrels, rats, and other animals. These agencies often have a very prejudicial effect on natural reproduction.

So far as they have been studied, those acorns which lie for some time on the ground before germinating benefit by protection from the direct heat of the sun, under whose influence they tend to crack and to deteriorate. In this respect their shape and weight assist them to find their way into hollows, behind boulders and into other places where they receive the necessary protection, while in some cases the leaf-fall, occurring in the early part of the hot season, affords the fallen acorns the benefit of a covering of dead leaves.

The Indian oaks are important both economically and silviculturally. Those of the western Himalaya are at present utilized, where accessible, mainly for fuel, and to a very small extent for timber; silviculturally, however, some of them are of great use as nurses to and companions of the more important conifers with which they are frequently associated. In the eastern Himalaya some of the oaks are much in request for timber.

Species 1. *Q. incana*, Roxb.; 2. *Q. dilatata*, Lindl.; 3. *Q. semecarpifolia*,

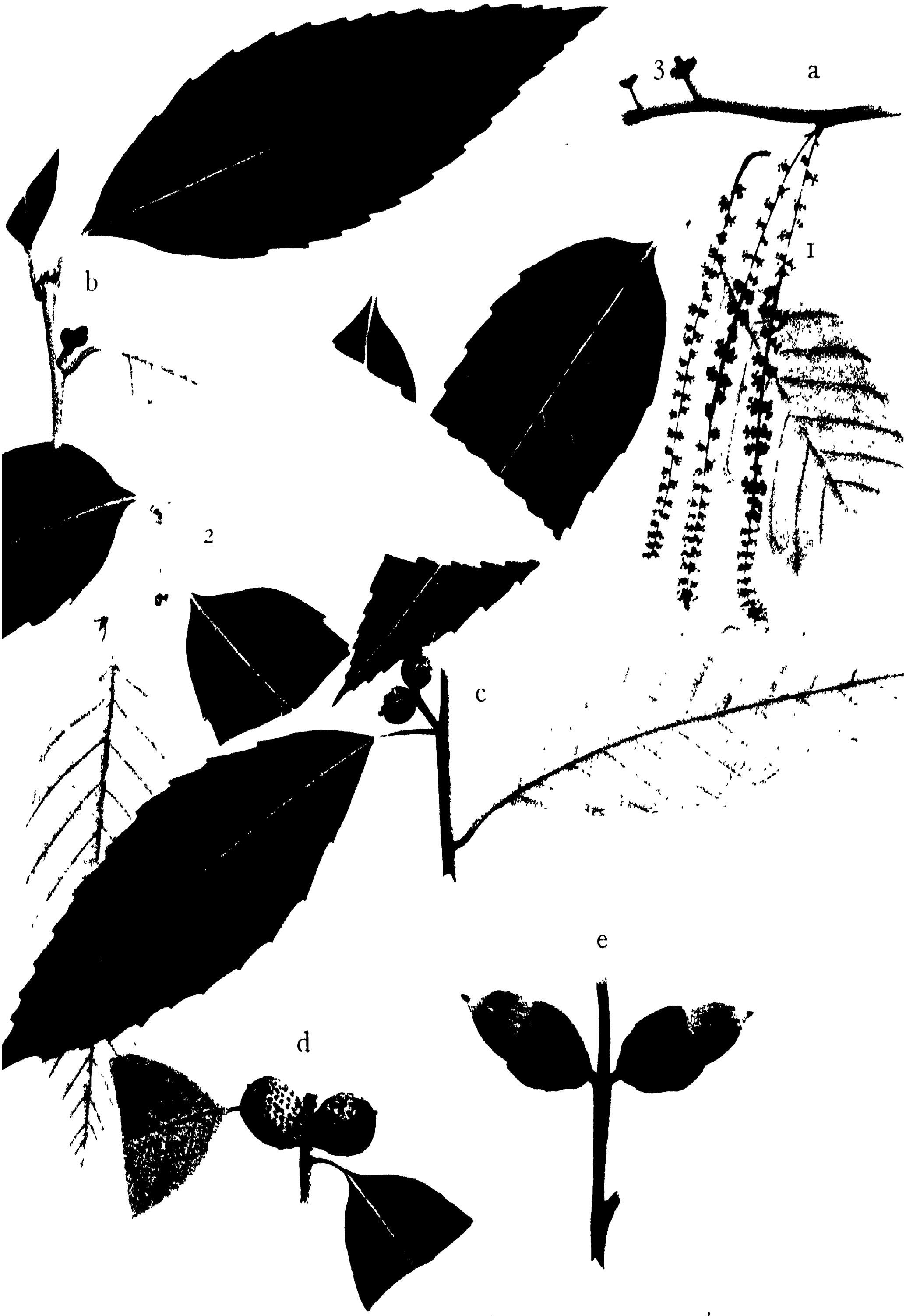


FIG. 341. *Quercus incana*—FLOWERS AND FRUIT × ¾

a—New shoots and leaves and portion of last year's shoot, with male catkins (1), young female flowers at time of pollination (2), and female spikes one year old (3), March-June

b—End of vigorous new shoot, showing slight development of young acorn in first season

c—Young acorns, June-July, second season

d—Young acorns, August, second season

e—Ripe acorns, December-January, second season

Smith; 4. *Q. lanuginosa*, Don; 5. *Q. Ilex*, Linn.; 6. *Q. serrata*, Thunb.; 7. *Q. Griffithii*, Hook. f. and Thoms.; 8. *Q. glauca*, Thunb.; 9. *Q. lamellosa*, Smith; 10. *Q. lineata*, Bl.; 11. *Q. spicata*, Smith; 12. *Q. pachyphylla*, Kurz.

1. **Quercus incana**, Roxb. Grey oak, ban oak. Vern. *Bán, bánj*, Pb., U.P.; *Rhin, rin, rinj*, Haz., Jhelum; *Shiddar*, Kashm.

A moderate-sized to large evergreen tree with massive gnarled branches and a rounded crown, ordinarily attaining a girth of 4–6 ft. and a height of 40–60 ft., but occasionally attaining a girth of 8–10 ft. and a height of 80 ft. or more. Leaves 3–6 in. long, oblong or ovate lanceolate, acuminate, sharply serrate, coriaceous, dull green and glabrous above, densely white or grey tomentose beneath. Bark grey to greyish brown, longitudinally and transversely cracked, exfoliating in irregular oblong, sometimes rectangular scales, often moss-covered. Wood very hard, apt to warp and split, much used for fuel and charcoal, and employed to some extent for building and agricultural implements. In moist ravines with deep fertile soil this oak is a tall tree with a long clear bole, but in less favourable situations the bole is short; on dry slopes with shallow rocky soil the tree is stunted and gnarled. When grown in a close crop on fertile ground it produces a long straight bole and a narrow crown.

This is the commonest oak in the hill stations of the western Himalaya, where it is the principal source of fuel supply.

Distribution and habitat. Western Himalaya, extending eastward to Nepal, chiefly in the outer ranges at 4,000–8,000 ft., but occasionally descending lower in moist situations. It occurs in the Mothronwala swamp, Dehra Dun, at 1,900 ft. In the Kangra valley it descends in moist ravines to about 2,300 ft. In Garhwal it is found at Ratwadab on the Mandal river at about 2,000 ft. In the Lower Beas valley in Kulu it descends to 3,000 ft. It is cultivated with success at low elevations, and with a plentiful supply of water it will grow on the plains. At Dehra Dun (2,000 ft.) planted trees grow well, seed freely, and regenerate naturally. This oak grows on a variety of geological formations, including shale, gneiss, mica schist, quartzite, and limestone; it is very frequently found on the clayey soil produced by the decomposition of the shales which are so common a feature of the outer Himalayan ranges. It grows well also on micaceous sandy soil, the result of the decomposition of mica schist. It grows on all aspects, but attains its largest dimensions on cool northerly aspects with deep moist soil; on hot aspects with shallow rocky soil it is stunted, though here it often forms purer crops than on cooler and more fertile situations.

The ban oak usually grows gregariously, sometimes forming pure forests of considerable extent (Fig. 339). Of broad-leaved trees, among its commoner companions are *Rhododendron arboreum, Pieris ovalifolia, Populus ciliata, Ilex dipyrena, Cornus macrophylla, C. oblonga, C. capitata, Pyrus Pashia, Euonymus pendulus, E. tingens, Myrica Nagi, Acer oblongum, A. pictum, Albizzia mollis, Cedrela serrata, Ulmus Wallichiana, Morus serrata, Ficus nemoralis, Carpinus viminea, Corylus Colurna, Alnus nepalensis*, and *Betula alnoides*, while in moist shady situations are found various Lauraceae, such as *Machilus Duthiei, M. odoratissima, Phoebe lanceolata, Litsaea umbrosa*, and others. It is frequently associated towards its upper limits with *Quercus dilatata*, and on moist ground at comparatively low elevations with *Q. glauca* ; in the Kumaun hills *Q. lanuginosa* occurs locally in mixture with it. The ban oak is also frequently found associated with conifers, namely deodar (*Cedrus Deodara*) and blue pine (*Pinus excelsa*) at the higher elevations, and chir pine (*Pinus longifolia*) towards its lower limits. It is a very useful nurse to the deodar on hot slopes. Mixed forests of ban oak and chir pine are particularly common ; here the oak either clings to the moister depressions, the pine occupying the spurs, or forms a lower story to the pine, which outgrows it. Fig. 340 shows oak forming an underwood to the pine.

On dry hot slopes where the crop is open the soil covering in ban oak forests usually consists of grass with occasional shrubs such as *Berberis*, *Indigofera*, *Desmodium*, and others. On more fertile ground there is usually a shrubby and herbaceous undergrowth : among the commoner shrubs are *Viburnum cotinifolium*, *V. stellulatum*, *Coriaria nepalensis*, *Berberis nepalensis*, *B. aristata*, *B. Lycium*, *Lonicera quinquelocularis*, *Jasminum humile*, *Maesa indica*, *Myrsine semiserrata*, *M. africana*, *Desmodium tiliaefolium*, *Rubus* spp., *Rosa macrophylla*, *R. moschata* (climber), *Prinsepia utilis*, *Daphne cannabina*, *Sarcococca pruniformis*, and the dwarf bamboo, *Arundinaria falcata*.

Where it descends to abnormally low elevations, *Quercus incana* is associated with typical low-level species. In the Dun it is found with *Eugenia Jambolana*, *Albizzia stipulata*, and other species of the local swamps. In the Kangra valley it is associated with *Dalbergia Sissoo*, *Acacia Catechu*, *Albizzia stipulata*, *Eugenia Jambolana*, *Ficus bengalensis*, and other low-level species, with an undergrowth of *Carissa spinarum*. In one locality it is found mixed with sal (*Shorea robusta*), the two forming an underwood to a crop of *Pinus longifolia*. In the Beas valley at 3,000 ft. it is found along with *Quercus glauca*, *Pistacia integerrima*, *Pyrus Pashia*, and *Olea cuspidata*.

In the normal habitat of this oak the climate is a temperate one ; the shade temperature probably seldom exceeds 95° F., while it occasionally descends to below 20° F. At abnormally low elevations it experiences temperatures well over 100° F., but here its existence is rendered possible owing to the presence of ample soil moisture and to a comparatively heavy rainfall. In its normal habitat it ascends into the region of winter snow and descends below that region ; the normal rainfall varies ordinarily from 40 to 95 inches, but at Dharmsala it is 117 inches. This oak does not extend into the inner arid valleys.

Leaf-shedding, flowering, and fruiting. The time of sprouting of the new shoots and of flowering and fruiting varies considerably with elevation and aspect, and may also vary from year to year in the same locality, probably owing to climatic causes. Within the usual habitat of the tree the young shoots appear from the beginning of April to the middle of June ; at Dehra Dun (about 2,000 ft.) they appear at the end of February or early in March. The young shoots and leaves are densely pubescent, and have a silvery grey or pale pink colour which gives the trees a conspicuous appearance at the season of sprouting. The growth of the young shoots is rapid, full length being attained as a rule in less than two months. In the second season the shoots become dark grey and woody, and gradually lose their pubescence. The old leaves fall for the most part from April to July or later, but leaf-

FIG. 342. *Quercus incana*—SEEDLING × ⅓

a -Acorn b -Nut of acorn c - e Germination stages f Seedling towards end of first season
g -Seedling in second season

shedding on a small scale may occur in the winter. The young leaves when fully developed can be readily distinguished from those of the previous year owing to the white or yellowish white tomentum on the under surface, which in the old leaves is a dirty grey colour (Fig. 341). The leaves have xerophytic characters in their stiff coriaceous texture and the tomentum on the under surface ; the tender young leaves, protected by a dense pubescence, are often seen hanging vertically in hot dry weather.

The male catkins and female spikes appear on the new shoots. The male catkins (Fig. 341, *a*, 1) are pendulous, up to 6 in. long, in clusters of a few to several at the base of the new shoots or singly along the lower part of them ; they ripen, and pollination takes place, from the end of March to the end of June, according to locality and season.

The female flowers (Fig. 341, *a*, 2) are small and inconspicuous, 0·1 in. in diameter more or less, single or two or more sessile on a common whitish tomentose peduncle, 0·3–0·6 in. long ; the spikes are axillary on the upper part of the new shoots. There is little or no growth in the young acorns for a whole year after pollination, and at the commencement of the second season they may be found on the previous year's shoots (Fig. 341, *a*, 3), their size being more or less the same as that of the young female flowers which have just appeared. In specially vigorous shoots, however, an appreciable development is apparent even in the first season (Fig. 341, *b*) ; this is particularly the case where lopping has stimulated the growth of the young shoots.

During the second season the growth of the young acorns is rapid. They commence growing about April–May, and during June–July are usually about 0·2–0·3 in. in diameter (Fig. 341, *c*), increasing in August to about 0·4–0·5 in. in diameter ; at this time the nut is still completely enclosed in the cup, which is greenish grey with brown-tipped imbricate scales (Fig. 341, *d*). The young acorns often remain abortive at this stage owing to insect attacks or other causes, and show no further development. The nuts commence to emerge from the cups from the end of August onwards, some becoming nearly full-sized, but still greenish grey, by the end of November or early December, though many have hardly emerged from the cup at that time. The acorns commence ripening in the latter half of December, and continue ripening during January. Many fall soon after ripening, but many remain some little time on the trees, falling gradually from February to May, though some remain even till June or July ; the majority fall from the trees during the storms or heavy rain showers which occur from time to time in the spring. The ripe acorns are solitary or in pairs or small clusters on the greyish brown woody shoots of two years previously (Figs. 341, *e*, and 342, *a*). The nut (Fig. 342, *b*), 0·7–0·9 in. long, conico-ovoid, brown with a grey pubescence towards the apex, is about half inserted in the cup, which is rough, brown, and woody. About 200–250 nuts weigh 1 lb.

The time taken from the pollination of the female flower to the ripening of the acorn is about 1 year 7 months to 1 year 9 months. It is sometimes stated that the flowers develop and ripen into acorns in the same season. I have never met with an undoubted case of this, and probably the idea has arisen from the fact that shoots bearing ripe acorns are often succeeded by new shoots bearing young female flowers. The explanation is that shoots which bear female spikes often produce no new growth the following year, though growth may be continued the year after, so that the successive shoots differ in age by two years, and not by one year, as might at first sight be supposed.

The acorns are greedily eaten by bears, monkeys, flying squirrels, rats, and birds, especially jays and nutcrackers. The squirrels and birds eat them both unripe and ripe. In 1916 the oaks in Simla gave promise of an abundant crop of acorns. Jays appeared in large numbers in November and remained throughout the winter devouring the unripe acorns; scarcely one was left to ripen, and those which did were all destroyed, and practically not a single acorn survived, the flying squirrels destroying those which escaped the attention of the jays.

In spite of the dangers to which the acorns are exposed good seed-years are fairly frequent. In Jaunsar in twelve consecutive years good seeding is recorded in five and poor seeding in seven years. In the Naini Tal forest division records exist regarding eight out of ten consecutive years, in which good seeding is recorded in four years and poor seeding in four years. In the Murree hills good seeding is recorded in four out of five consecutive years.

Fertile seed appears to be produced at a comparatively early age. The trees in a plantation in the Kaunli garden, Dehra Dun, although very crowded, seeded abundantly at twenty-six years of age, and produced plentiful reproduction; they have seeded regularly since. At Dharmsala in 1914 Khan Bahadur Imam-ud-din collected 48 sound seeds from coppice-shoots nine or ten years old and a similar number from a seedling tree of unknown age, and sowed them in two nursery beds; of the former, 26 germinated, and of the latter, 24.[1] If carefully stored in a cool, dry place and protected from insect attacks, the seed retains its fertility to a considerable extent for at least a year. Seed kept for one year at Dehra Dun was found to have a fertility of 60 per cent.

GERMINATION (Fig. 342, *c–e*). Hypogeous. The shell of the nut splits towards the apex and the radicle emerges, descending and forming a taproot. Meanwhile the cotyledonary petioles elongate to about 0·2–0·3 in., separating and enabling the plumule to emerge and the young shoot to ascend. The fleshy cotyledons remain within the shell on or under the ground; they remain for a considerable time attached to the young plant, supplying it with nutriment in its earlier stages.

THE SEEDLING (Fig. 342).

Roots: primary root long, stout, terete, tapering, brown, wiry, flexuose, pubescent when young; lateral roots fairly numerous, short to long, brown, fibrous, pubescent, distributed down main root. *Hypocotyl* distinct from root, 0·1–0·2 in. long, stout, yellowish, pubescent, subterranean. *Cotyledons* subterranean: petiole 0·2–0·3 in. long, fleshy, flattened, yellow, pubescent; lamina 0·8–1·1 in. by 0·3–0·5 in., thick, fleshy, conferruminate, elliptical, obovate, apex rounded, base auricled by the prolongation of the lamina behind the petiole, outer faces convex, inner flattened in contact. *Stem* erect, terete, wiry, lower part yellowish brown turning brown, glabrous or pubescent, upper part green, grey tomentose; internodes 0·2–0·8 in. long. *Leaves* simple, alternate, petiolate, the first two or three small (under 0·5 in. long) or abortive. Stipules 0·1 in. long or less, linear acuminate, brown. Petiole 0·1 in. long,

[1] Ind. Forester, xli (1915), p. 132.

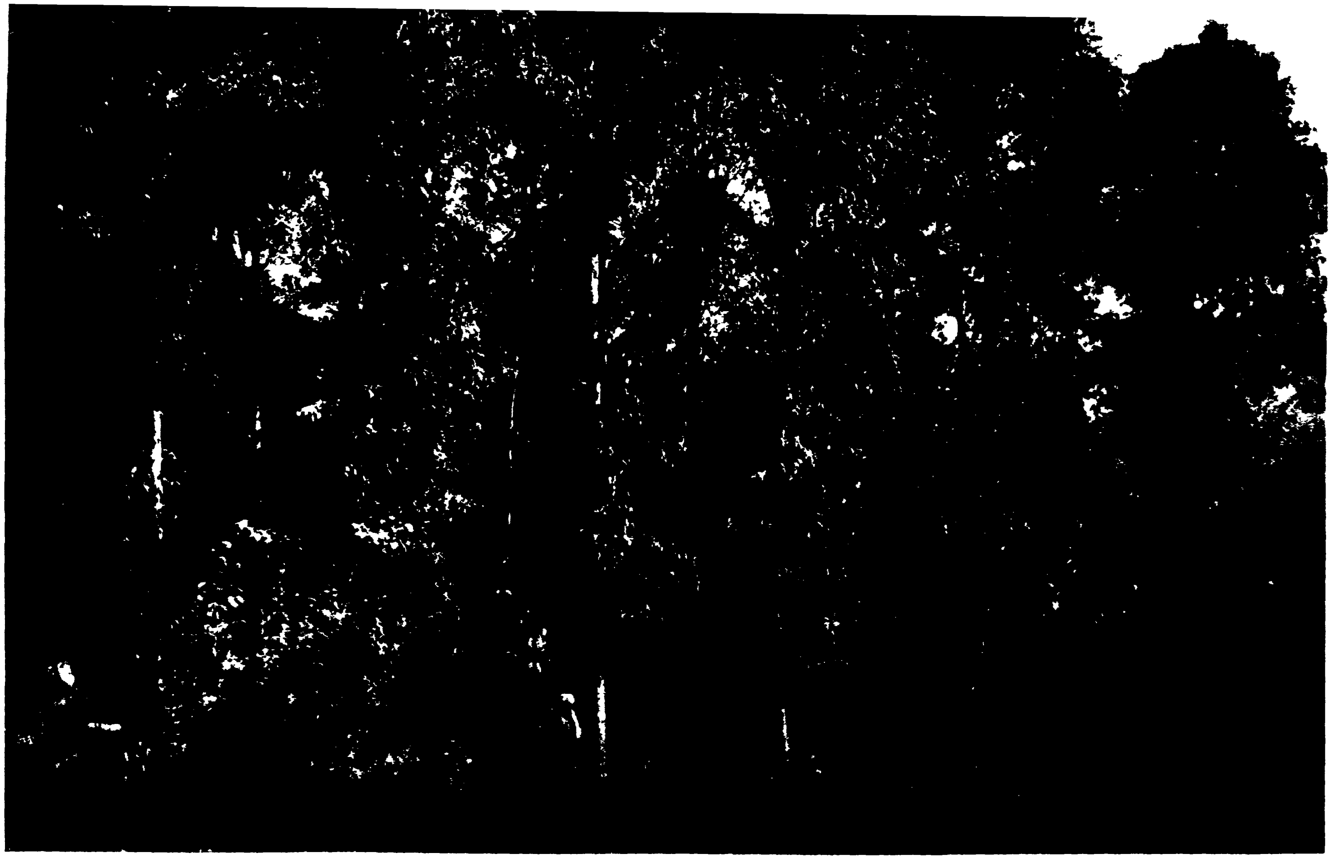


Fig 343 *Quercus incana*, plantation 34 years old, Kaunli, Dehra Dun

FIG. 344. *Quercus dilatata* tree, girth 16 ft. 4 in., height 144 ft., clear bole 72 ft., Jaunsar, United Provinces. Note man at base.

FIG. 345. *Quercus dilatata*, open crop of large trees, Hazara.

tomentose. Lamina (first season) 1·4–3 in. by 0·5–1 in., oblong or ovate lanceolate, acuminate, mucronate-serrate or dentate, coriaceous, green and glabrous or slightly pubescent above, densely whitish tomentose below; venation pinnate, lateral veins 6–10 pairs.

Under ordinary conditions the growth of the seedling is somewhat slow. During the first year natural seedlings attain a height of about 2 to 5 in. with 2–5 normal leaves. Plants raised from direct sowings in the forest in Jaunsar showed the following rate of growth:

Age in years .	4	6	8	10
Mean height .	0 ft. 11 in.	1 ft. 9 in.	2 ft. 8 in.	3 ft. 7 in.

Nursery seedlings grow somewhat faster, ordinarily attaining a height of 1 to 1½ ft. in three to four years. At Dehra Dun nursery seedlings constantly watered and weeded showed much more rapid growth, attaining a height of 2 to 3 ft. in two years and 5 ft. to 11 ft. 9 in. in four years; this exceptional growth, however, was due to constant attention combined with a climate warmer than this oak is accustomed to. Seedlings produce a stout taproot which attains a length of 6 to 12 in. in the first season. In their natural habitat seedlings commence the season's growth in May or early June.

For the first year or two seedlings stand a remarkable amount of shade, but thereafter they die off in excessive shade, and require moderate to full light for their best development. They are sensitive to drought, particularly during the first two years, when they die off in quantity in hot, dry situations. Seedlings are subject to the attacks of rats and crickets, which gnaw through the taproot. They grow well in grass and in moderate weed-growth, but develop best in clear hoed ground. Experiments at Dehra Dun showed that frequent weeding and loosening of the soil stimulates growth after the first year; during the first season its effect is not so marked, possibly because the seedlings obtain their nutriment to some extent from the fleshy cotyledons, and are not altogether dependent on the soil.

Silvicultural characters. The ban oak is a moderate light-demander. In this respect it stands between *Q. semecarpifolia*, which is more light-demanding, and *Q. dilatata*, which stands more shade. In the younger stages the ban oak stands a fair amount of shade, and even throughout its life it grows well under a light canopy of *Pinus longifolia* or *P. excelsa*. The root-system is massive, and on rocky ground is much gnarled and twisted; the tree is windfirm in consequence. This oak usually coppices well up to a girth of about 2 to 3 ft. and sometimes more, but large trees as a rule fail to coppice; in the Naini Tal hills it has been found that trees over 3½ ft. in girth cannot be relied on to produce stool-shoots. Enumerations carried out in these hills in young coppice coupes in 1911 showed one to twelve with an average of four shoots per stool. The rate of growth of coppice-shoots is somewhat slow.

In its younger stages this oak suffers much from goat browsing, and cattle also eat the young shoots. Perhaps the worst form of injury to which the tree is subjected, however, is that of lopping for fodder, which is usually carried out in the winter. Trees regularly lopped lose their normal rounded crowns and produce numerous small shoots along the main branches, the crowns gradually thin out, and in time the tree dies. In the neighbourhood of villages many tracts formerly clothed with oak forest have become entirely denuded of trees owing to the practice of lopping, and in many places the destruction can be observed in various stages of completeness.

In its natural home this oak resists ordinary frosts, but in the abnormal frost of 1905 it suffered considerably in some parts of the Himalaya, notably in the Murree hills. It is not hardy in England. It suffers severely from fire, particularly on steep slopes where there is a heavy inflammable undergrowth. The ban oak is subject to the attacks of certain loranthaceous parasites, particularly *Loranthus vestitus* and *Viscum japonicum* ; the latter has been observed to spread rapidly, probably through the agency of birds.

Natural reproduction. Under natural conditions germination takes place early in the rainy season or after the early showers immediately preceding the monsoon, that is, as a rule in June and early July. It has been observed that heavy showers in the spring fail to stimulate germination, the temperature probably being too low. Germination is capable of taking place under heavy shade, and the seedlings survive for a time under moderate shade. Drought is probably the most adverse factor which the natural seedling has to contend with. In dry seasons in May and June numerous seedlings which have germinated the previous year may be found dying off in places exposed to the sun, or even in shady places where the soil is shallow and dry. In dry seasons similar mortality takes place in the autumn among seedlings which germinated a few months previously. The influence of the sun is no less marked in its effect on germination, for seeds lying in the open exposed for any length of time to the sun almost invariably crack and fail to germinate. This has been demonstrated clearly by an experiment at Dehra Dun in which 50 seeds were placed on the ground in each of four separate plots : (1) exposed to the sun, the ground being covered with short grass; (2) exposed to the sun, on bare ground; (3) under light shade, but exposed to the sun for part ot the day; (4) under heavy shade. In plots (1), (2), and (3) not a single seed germinated, all being cracked by the sun. In plot (4) the percentage of success was 54, the best results being noticeable where the seed had become buried by the action of rain ; seed germinating on the surface of the ground was found to be liable to destruction through insects eating the radicle.

Under natural conditions seedlings are often found in some quantity in slight depressions in which the seed accumulates and becomes covered with dead leaves and débris, or under the shade of bushes, or in moist places such as sheltered banks. Grass is quite favourable to the germination of the seed and the establishment of the seedling, provided the soil is not too dry. Natural seedlings are often found in quantity amongst loose débris at the foot of cliffs or steep slopes, the seed becoming covered and the taproot developing well in such ground. Frequent showers in the hot season following the year of germination are beneficial in providing moisture in the soil sufficient to ensure the survival of the seedling ; a heavy snowfall probably has the same effect. It is probable also that the fact that the leaves are shed for the most part after the fall of the seeds and help to cover them and protect them from the sun assists in promoting successful germination ; this is particularly noticeable in slight depressions where leaves collect.

Apart from natural influences, grazing and grass-cutting are very adverse factors in the establishment of reproduction. In grazed areas where the oak

Fig 346. *Quercus dilatata*, dense young natural crop, Kumaun hills

FIG. 347. *Quercus dilatata* pole crop Kumaun hills, mean girth 13 in. mean height 31 ft., just thinned to 2,180 stems (containing 2,176 cub. ft.) per acre, by removal of 540 stems (containing 530 cub. ft.) per acre.

is mixed with conifers instances may often be observed in which the crop is becoming converted to a purely coniferous one owing to the establishment of natural reproduction of the conifer while that of the oak fails. Natural reproduction may also suffer through the destruction of the acorns by birds and mammals already referred to.

ARTIFICIAL REPRODUCTION. This oak may be raised artificially either by dibbling *in situ* or by transplanting seedlings raised in the nursery. In the Naini Tal hills the former has proved more successful and economical than the latter. The winter or early spring is the best season for direct sowing. In hot dry situations the seed should be sown under the shade of bushes, boulders, or clumps of grass, and should be covered with earth to a depth of ½ to 1 inch, not more ; sowings, however, often fail on dry hot slopes, and success depends largely on the season being a wet one.

For raising seedlings in the nursery the seed should be sown in early spring (February or March) in drills 9 in. to 1 ft. apart in soil which has been well dug up ; the seed should be covered to a depth of ½ to 1 inch. Watering is advisable during the dry season, and the beds should be kept clear of weeds, the soil being loosened periodically. The seedlings will be ready for planting out in the third or fourth year, when about 12–15 in. high. Pricking out in the nursery is not essential, but if desired it should be carried out in the rainy season the year after sowing, the roots being slightly trimmed if necessary. The rainy season has been found to be the best season for transplanting in the forest, the results of winter planting having proved to be on the whole less successful ; the latter, however, has been carried out quite successfully at Dehra Dun. Plantations require to be protected from grazing until the plants are out of reach of danger.

The ban oak has been raised artificially in many parts of the western Himalaya, usually in the form of sowings to restock small blanks. Fig. 343 shows a small plantation thirty-four years old at Kaunli, Dehra Dun ; this plantation, which was formed in 1882–3 on fertile alluvial ground, has shown remarkably good growth, as will be seen from the figures quoted below.

SILVICULTURAL TREATMENT. Hitherto the ban oak, where worked on its own account, has been treated under the selection system, the exploitable girth being usually fixed at 4½ or 5 ft., or under coppice-with-standards with a coppice rotation of twenty-five or thirty years. Often, however, the oak is worked as a secondary species to deodar or *Pinus longifolia*, and is cut or girdled in favour of the principal species. The coppice system is not successful unless the trees felled are of small size, say not more than 3 ft. in girth, and even then the proportion of failures is often considerable ; for this reason supplementary artificial restocking by seed is always advisable in coppice coupes.

The selection system is not altogether unsuitable so far as the silvicultural requirements of the tree go, though from the point of view of ensuring reproduction and proper tending, and providing for closure to grazing, the system of successive regeneration fellings is preferable. It should be remembered that the seedling is of slow growth, requires shelter from the sun in the earlier stages, and can stand fairly heavy shade for a time, though it requires more light for its subsequent growth. This indicates that the seeding fellings should be carried out with caution, care being taken not to open out the canopy severely until reproduction is well established. In most cases a fairly long regeneration period, say at least twenty-five years, is indicated. The case of the Kaunli plantation shows that under favourable conditions a crop of ban oak can be regenerated naturally with great success by a gradual opening of the canopy. The trees commenced seeding freely and regularly from an age of about twenty-six years, and the ground soon became carpeted with seedlings, although the canopy was dense ; subsequently the canopy has been gradually opened out, and a promising even-aged young oak crop is present under the old crop. The conditions here are particularly favourable. Seed is produced in abundance, its fertility is high, and it is little, if at all, subjected to the attacks of animals ; grazing is excluded, while the moist fertile soil under a complete canopy favours the establishment of the seedlings without risk of drought.

When the system of successive regeneration fellings is to be adopted in the irregular natural forests which exist at present it is probable that much supplementary artificial reproduction will be necessary. Closure to grazing and protection from fire will also be essential to success. Young even-aged crops are sometimes of considerable density, and in such crops thinnings form an important part of the tending operations necessary.

STATISTICAL. (1) *Coppice*. The mean height growth of coppice in Jaunsar, deduced from numerous measurements, chiefly in the Korwa forest, is estimated to be as follows :

Age in years . .	2	4	6	8	10	12	14	16
Mean height in ft. .	1·9	3·7	5·5	6·9	7·7	8·5	9·3	10·0

Measurements made in 1911 in a coppice coupe six years old at Bhowali near Naini Tal gave an average height of 4 ft. 3 in. and a maximum height of 6 ft. 2 in.

(2) *High forest*. Systematic measurements in permanent high forest sample plots in even-aged and more or less fully stocked natural crops were commenced by the Forest Research Institute, Dehra Dun, in 1910–11, and the first periodical remeasurement was carried out in 1915–16. The plots in question, which are situated in the Naini Tal and West Almora forest divisions of the United Provinces, are 11 in number—7 unthinned, involving 442 measurements, and 4 thinned, involving 212 measurements. The following results have been compiled from these measurements :

Quercus incana : rate of growth in girth, Naini Tal and West Almora sample plots.

	Mean girth.					
	Thinned plots.			Unthinned plots.		
Age.	Fastest.	Slowest.	Mean of all plots.	Fastest.	Slowest.	Mean of all plots.
years.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
30	1 0¼	0 6	0 7¾	0 10	0 6	0 8
40	1 5¼	0 9	0 11	1 2½	0 9½	1 0¼
50	1 10¼	1 0	1 2½	1 7¼	1 1	1 4½
60	2 3¼	1 3	1 6½	2 0½	1 4¾	1 9
70	2 8½	1 6	1 10¾	2 5¼	1 8¾	2 1½
80	..	1 9¼	2 3½	2 10½	2 0¾	2 6½
90		2 0¾	2 8½	..	2 4¾	2 11½
100		2 4½	..	..	..	3 4½
110		2 8¼	..	.	..	3 9½
120		..	..	..	..	4 2½

FIG. 348. *Quercus dilatata*—FLOWERS AND FRUIT × $\frac{3}{4}$

a New shoot and leaves, and portion of last year's shoot, with male catkins (1), young female spike (2) and female spike of previous year (3) April–May b–d Young acorns, showing successive stages of development, June–July, second season e Ripe acorns, August–October, second season

Volume figures in respect of these plots are recorded in *Indian Forest Records*, vol. vi, pt. ii, but these are not yet extensive enough to form the basis for general averages. In the above girth measurements the effect of thinnings has not yet become apparent. These measurements indicate that the growth of *Quercus incana* is slower than that of *Q. dilatata*.

The plantation at Kaunli, Dehra Dun, already referred to, has been measured twice with the following results : [1]

Quercus incana : measurements in Kaunli plantation, Dehra Dun.

Age.	Number of stems per acre after thinning.	Mean girth.	Mean height.	Solid volume per acre.	Intermediate yields per acre, from thinnings, solid volume. Periodic.	Total to date.
years.		ft. in.	ft.	cub. ft.	cub. ft.	cub. ft.
32	525	1 8·6	56	3,208	950	950
36	356	2 2·6	65	3,827	658	1,608

The growth in this plot is considerably faster than anything recorded in the normal habitat of this oak, and the volume production is also abnormally high.

The following estimated rate of growth, based on ring countings, applies to natural trees in Jaunsar : [2]

Quercus incana : rate of growth, Jaunsar.

Age.	Mean girth.	Mean height.
years.	ft. in.	ft.
20	..	5
40	1 1	14
60	2 1	22
80	3 2	30
100	3 11	38
120	4 9	47
140	5 7	56
160	6 3	65

2. **Quercus dilatata,** Lindl. Green oak, moru oak. Vern. *Moru*, W. Him. ; *Tilonj*, Kumaun, Garhwal ; *Barungi*, Haz.

A large evergreen tree with a dense crown of shining green foliage ; leaves 1·5–3 in. long, entire or spinous serrate, green on both surfaces. Bark of young trees smooth, grey to greyish brown, that of older trees dark grey or nearly black, scaly, with vertical and horizontal cracks, and exfoliating in rectangular or irregular scales. Wood very hard, used for building, agricultural implements, &c., as well as for fuel and charcoal.

The moru oak is the largest of the western Himalayan oaks, and under favourable conditions attains very large dimensions and produces a long straight bole. I measured the following trees in 1909 in the Siari block near Konain, Jaunsar :

[1] Statistics compiled in the Silviculturist's Office, 1916–17, Ind. For. Rec., vol. vi, pt. v, 1918.

[2] Working Plan for the Jaunsar-Bawar Forests, P. H. Clutterbuck, 1901. (Girth measurements converted from diameter measurements recorded in the plan.)

No.	Girth at 4½ ft. from ground.		Total height.	Length of bole.	
	ft.	in.	ft.	ft.	
1	16	4	144	72	Height and length of bole measured with clinometer.
2	16	3	144	75	
3	14	3	144	..	
4	13	2	127	..	
5	12	0	125	..	Wind-fallen trees.
6	10	2	125	..	
7	10	0	122	61	

The lower part of tree No. 1 is shown in Fig. 344. Other girths of standing trees measured in the same locality were 17 ft. 8 in., 16 ft. 5 in., 16 ft. 3 in., 15 ft. 6 in., 14 ft. 9 in., 14 ft., 13 ft. 9 in., 12 ft., and 11 ft. 11 in. Mr. Gleadow [1] mentions a tree near Mundali in Jaunsar measuring 151 ft. in height and 17 ft. in girth.

Distribution and habitat. Western Himalaya from Nepal westwards, chiefly at 7,000–9,000 ft., but descending in some localities to about 5,500 ft., particularly in cool moist situations. It is very common in the Kumaun hills and from Jaunsar to Kulu. On the Dharmsala side of the Kangra hills it is absent except for a few scattered trees in Chota Bangahal. In the Murree hills it does not occur south of the Murree Dewal spur, though common on and north of that spur. The Burban forest near Murree affords a fine example of *Quercus dilatata* high forest extending over an area of about 56 acres ; the soil is deep, moist, and fertile, and the trees are tall and of large girth. In Hazara this oak is common locally at about 6,000 to 8,500 ft. In Dir and Chitral it occurs locally in cool moist situations. It extends west into Afghanistan.

Although found on all aspects, the moru oak avoids very dry situations and favours moist, cool localities and northerly aspects. It attains its best development on deep rich, moist, well-drained soil. It often tends to regenerate in dense pure patches (see Fig. 346), and to grow gregariously in crops of varying extent. It is, however, also frequently found scattered in mixture with other trees, both coniferous and broad-leaved. Perhaps its commonest companion is the spruce (*Picea Morinda*), and the mixture is an excellent one, the oak being drawn up by the spruce and producing a long clean bole. The large oak shown in Fig. 344 is mixed with spruce, and the measurements of large trees given above were made in a mixed spruce and oak forest. Other coniferous trees associated with the oak are the blue pine (*Pinus excelsa*), the deodar (*Cedrus Deodara*), and the silver fir (*Abies Pindrow*), while there is often an undergrowth of yew (*Taxus baccata*). Among broad-leaved trees the commoner associates are *Aesculus indica*. *Acer Caesium*, *A. pictum*, and other maples, *Ulmus Wallichiana*, *Prunus Padus*, *Cornus macrophylla*, *C. capitata*, *Euonymus pendulus*, *E. tingens*, *Juglans regia*, *Corylus Colurna*, *Betula alnoides*, and *Populus ciliata* ; at its lower limits it mixes freely with *Quercus incana*. In moru oak forests there is often a rich undergrowth of herbaceous plants and shrubs, such as *Viburnum*, *Lonicera*, *Rubus*, *Rosa*, *Daphne cannabina*, *Indigofera*, *Desmodium*, *Strobilanthes*, and various ferns, with the dwarf bamboos *Arundinaria falcata* or *A. spathiflora*. Fig. 345 shows a typical though somewhat open crop of oak with a shrubby undergrowth ; a few saplings of *Pinus excelsa* may be seen making their way up in a gap on the right.

[1] Forest School Tour in Jaunsar, 1898–9, p. 49.

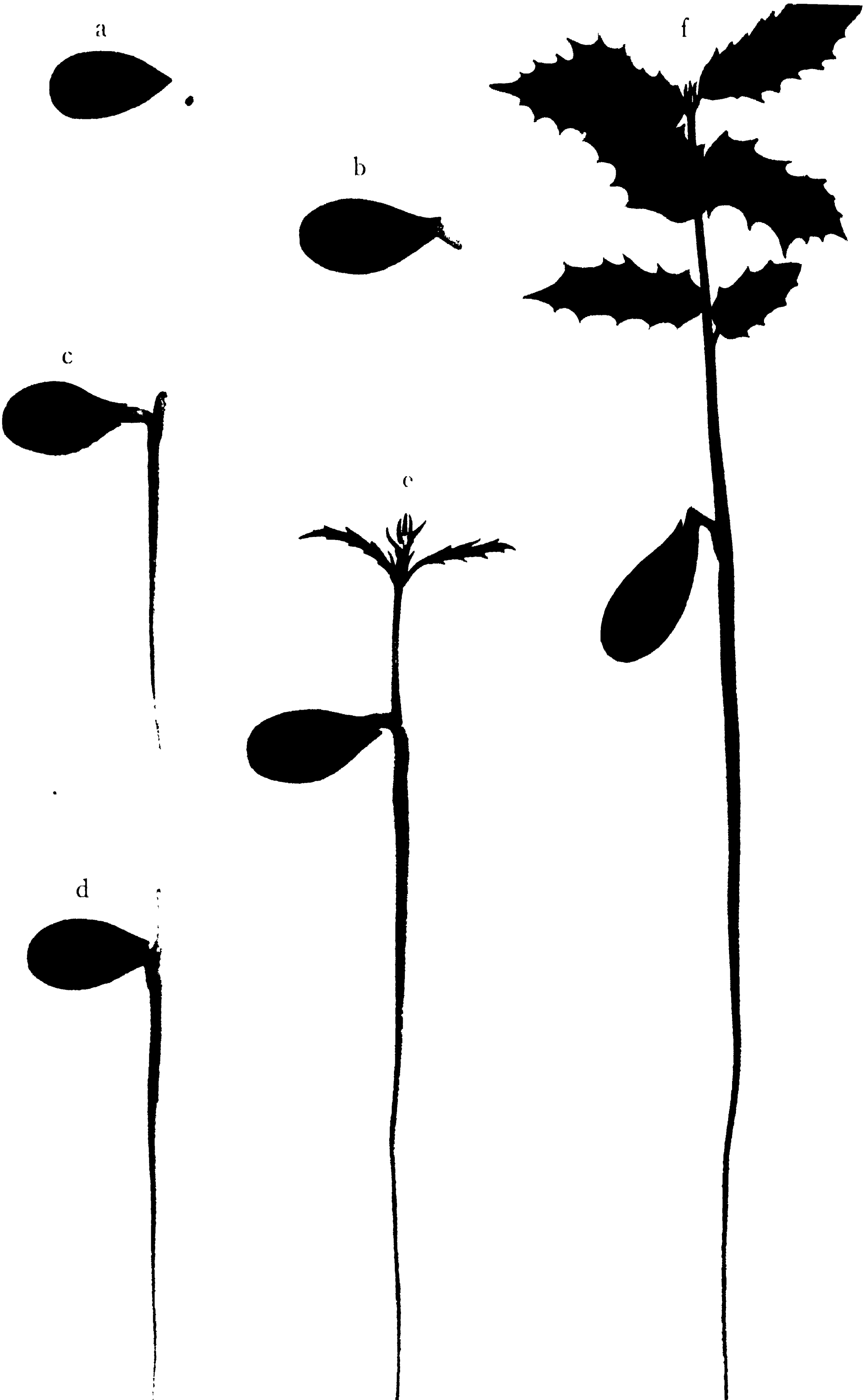


FIG. 349. *Quercus dilatata*.—SEEDLING × $\frac{3}{4}$

a. Nut of acorn. b–d. Germination stages. e, f—Development of seedling during first season.

The home of this oak is in temperate regions, where there is usually a fairly heavy winter snowfall. The maximum shade temperature probably seldom exceeds 90° F., and the minimum is often below 20° F. The normal rainfall, including equivalent snowfall, varies for the most part from 45 to 95 in.

Leaf-shedding, flowering, and fruiting. The old leaves fall principally during May and June, but some may commence falling earlier, while some may persist later. The new green shoots appear late in March to early in May, according to elevation; they grow rapidly, attaining full size within two months.

The male catkins and female spikes appear on the new shoots, the former maturing and pollination taking place in April–May. The male catkins (Fig. 348, *a*, 1) are in pendulous clusters 2–3 in. long at the base of the new shoots. The small female flowers, usually several in number, are sessile on a common pendunele 0·5–1·5 in. long, the spikes being axillary in the upper parts of the new shoots (Fig. 348, *a*, 2). The shoots which bear female spikes often produce no new growth the following year.

There is little or no growth in the young acorns during the first season; about a year after the appearance of the flowers they may be found on the previous year's shoots, only just commencing to grow (Fig. 348, *a*, 3). From that time onwards their growth is rapid. The nut remains enclosed in the cup until June–July, when it commences to emerge (Fig. 348, *b*, *c*, *d*); at this time the nut is bright green and the cup is pale green or greyish green with prominent imbricate scales.

The acorns (Fig. 348, *e*) are solitary or two or more together on the previous year's shoots. They commence ripening in August, and by October most of them have fallen and many have germinated; at the higher elevations they often do not ripen until well on in October, germination taking place at the end of that month or even later. The nuts (Fig. 349, *a*) are 0·6–1·3 in. long by 0·4–0·7 in. in diameter, ovoid or oblong, brown to dark greenish brown, glabrous and shining; the cups are 0·4–0·8 in. in diameter, grey, woody, with closely adpressed scales, and enclose about one-third to nearly one-half of the nut. The time taken from the pollination of the female flower to the ripening of the acorn is thus about 15–17 months.

The acorns are subject to insect attacks. They are also devoured by animals and birds, but as they ripen before the winter and germinate at once, they do not suffer nearly so much as do acorns, like those of *Q. incana* and various other species, which ripen in the winter when food is scarce and germinate some time after ripening. Good seed-years are fairly frequent. In Jaunsar records for fourteen years out of seventeen consecutive years showed good seeding in six and poor to moderate seeding in eight years.

Germination (Fig. 349, *b*–*d*). Hypogeous. The nut splits towards the apex and the radicle emerges, descending and forming a long stout taproot. Meanwhile the cotyledonary petioles elongate to 0·3–0·5 in., sometimes longer, and separate, enabling the plumule to emerge and the young shoot to ascend. The fleshy cotyledons remain within the shell on or under the ground; they remain attached to the young plant for a considerable time, providing it in its earlier stages with nutriment.

The germination of this oak shows a transition stage between that of the lower-level oaks (*Q. incana*, *Q. glauca*, and *Q. lanuginosa*) and that of the high-level oak (*Q. semecarpifolia*) ; thus it tends to form cotyledonary petioles long enough to indicate an effort to push the embryo plant down towards the soil, but in a lesser degree than in the case of *Q. semecarpifolia*, while moreover the cotyledonary petioles are separate and not united into a tube as in the case of the latter.

THE SEEDLING (Fig. 349).

Roots: primary root long, thick, terete, tapering, woody ; lateral roots few to moderate in number, fibrous, distributed down main root. *Hypocotyl* scarcely distinguishable. *Cotyledons* subterranean, remaining within the nut. Petiole 0·4–0·6 in. long, inner surface flattened, slightly pubescent to glabrescent. Lamina 0·7–1·1 in. by 0·4–0·6 in., thick, fleshy, obovate or oblong, apex rounded, base prolonged in one or two points, outer surface rounded, grooved or wrinkled, inner flattened in contact. *Stem* erect, terete, woody, green turning brown, tomentose; internodes 0·2–1·4 in. long. *Leaves* simple, alternate, or earlier ones sub-opposite. Petiole 0·1–0·2 in. long, tomentose. Lamina 0·7–2·2 in. by 0·4–1·2 in., oblong or oblong lanceolate, acuminate, spinous serrate; young leaves tender, yellowish green to reddish brown, stellate pubescent ; older leaves stiff, glabrous, green above and beneath.

During the first season seedlings ordinarily attain a height of 2–4 in., with about three to ten leaves and a stout taproot 6–10 in. long. Subsequent growth is somewhat faster, a height of 1½–2 ft. being attained in five years. Seedlings stand much shade ; they establish themselves well under a moderate growth of shrubby weeds, but are apt to damp off under dense herbaceous weed-growth and on badly drained ground. Seedlings are sensitive to drought. They are subject to the attacks of an insect, believed to be a cricket, which bites through the root collum and kills the seedlings during the first two seasons.

SILVICULTURAL CHARACTERS. The moru oak stands more shade than either *Quercus incana* or *Q. semecarpifolia*. Its root-system is less massive than in the case of those species, and trees are not infrequently thrown by wind. Its coppicing power is uncertain. In some localities trees coppice well up to about 3 ft. in girth, but larger trees often fail to produce stool-shoots. In the Murree hills even trees under 3 ft. in girth seldom produce coppice-shoots ; since many of the trees in that locality are of coppice origin it has been suggested that this oak does not coppice more than once. The moru oak, like *Q. incana*, is much subjected to lopping, and in village lands it suffers much from this practice. Young plants and coppice-shoots are readily browsed, particularly by goats.

NATURAL REPRODUCTION. Under natural conditions the seed germinates soon after falling during and at the end of the rainy season, from August to October. The ground is then moist and conditions for germination are favourable ; in dry places exposed to the sun, however, the seed may fail to germinate. In a good seed-year the ground in the neighbourhood of seed-bearers at this time is thickly carpeted with young seedlings in various stages of germination and development, although a good deal of the seed may be destroyed by insects before reaching the ground. In places exposed to the sun many of these seedlings die off in the ensuing dry season, but in moist shady places the majority survive, and the young oak crops establish themselves in dense thickets. Such thickets are found not only under shade but also on open grassy slopes, chiefly on the downhill side of the seed-bearers, provided the

FIG. 350. *Quercus semecarpifolia* trees on ridge at 9,000 ft., Jaunsar.

FIG. 351. *Quercus semecarpifolia* forest of good quality, opened out several years previously and containing much natural reproduction, Jaunsar.

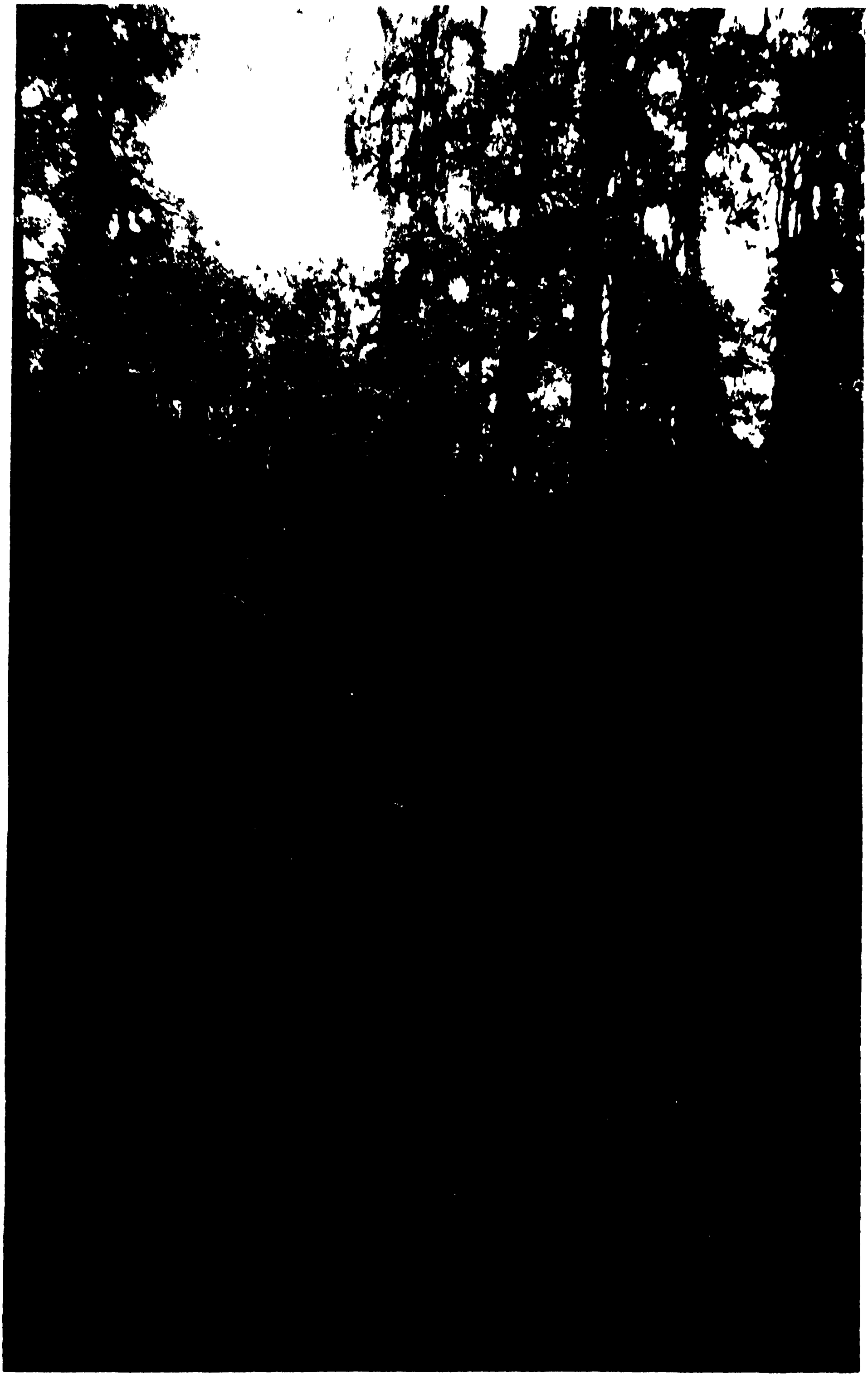


FIG. 352. *Quercus semecarpifolia*, dense natural reproduction established as a result of a heavy opening of the canopy, Jaunsar.

aspect and situation are not too dry. Although thickets of young oak appear under fairly heavy shade, these establish themselves most freely where there are moderate to wide gaps in the canopy. Seedlings are not as a rule found at any great distance from seed-bearers, the reason being not only that the seed is heavy, but also that it germinates soon after falling, and therefore has less chance of being transported to any distance, by rainwater or otherwise, than in the case of seeds which lie on the ground some time before germinating. Reproduction is not as a rule good where there is a heavy growth of herbaceous weeds, although a moderate shrubby weed-growth does not appear to retard it to any great extent. Exclusion of grazing is necessary in order to ensure good natural reproduction.

ARTIFICIAL REPRODUCTION. This oak can be cultivated successfully either by direct sowing or by transplanting from the nursery. In either case the seed should be sown as soon as it ripens, about August and September. For transplanting purposes nursery-raised seedlings two years old are usually employed, the planting being done in the rainy season. Good results, however, can be attained by transplanting natural seedlings, which are often available in quantity.

Experience in Jaunsar has shown that sowing and planting on hot, dry slopes result in failure, but that if carried out on moist loamy soil in cool situations, they can be accomplished with complete success ; the usual spacing adopted has been 5 ft. by 5 ft., which is probably not too close if clean-stemmed poles are required.

SILVICULTURAL TREATMENT. Hitherto this oak has been worked, along with its associates, either as coppice-with-standards or under selection fellings. Coppice fellings, as already noted, are uncertain. Selection fellings are not unsuitable, but in view of the natural tendency of this oak to regenerate in even-aged masses, which owing to their density require special tending, the concentrated working and attention afforded by the system of successive regeneration fellings would appear to be preferable to the more diffuse working under the selection system, except perhaps on very limited areas. In carrying out regeneration fellings every opportunity should be taken to free the groups of young oak as soon as they establish themselves, since they develop best with abundant overhead light. Thinnings in these dense thickets require to be commenced fairly early and repeated at regular intervals. Fig. 347 shows a young pole crop which has just been thinned.

RATE OF GROWTH. The following statement gives the mean rate of growth of transplants in plantations at Matkangra and Bodyar in Jaunsar, as well as of plants left to grow up in the nursery in the form of thickets :

Quercus dilatata : rate of growth in plantations, Jaunsar.

Age. (from seed).	Mean height.				Mean girth.			
	Matkangra.		Bodyar.		Matkangra.		Bodyar.	
	Plantation.	Nursery.	Plantation.	Nursery.	Plantation.	Nursery.	Plantation.	Nursery.
years.	ft.	ft.	ft.	ft.	in.	in.	in.	in.
5	2	3·5	2	3				
10	5·5	8·5	4	6·5				
15	9·5	14·5	7·5	11·5		12		
20	14	20·5	..	..				
25	18·5	26·5	..	..				
30	23	..	..	..				

The Bodyar plantation was formed in a somewhat unfavourable locality on a rocky slope. The plants left in the nurseries formed dense thickets, those in the Matkangra nursery being particularly vigorous.

Systematic measurements in permanent high forest sample plots in the Naini Tal forest division were commenced in 1911–12 by the Forest Research Institute, Dehra Dun. The first quinquennial remeasurement was carried out in 1915–16, and the average growth in five unthinned sample plots in even-aged and more or less fully stocked natural crops involving 253 measurements was found to be as follows :

Quercus dilatata : rate of growth in high forest sample plots, Naini Tal.

Age.	Mean girth.		Age.	Mean girth.	
years.	ft.	in.	years.	ft.	in.
30	1	0	60	2	6·2
40	1	5·5	70	3	2
50	1	11·2	80	3	9·5

A more rapid rate of growth would doubtless be attained in the case of regularly thinned crops. Subsequent remeasurements will produce more reliable results, but in the meantime the increments deduced for one quinquennial period are sufficient for a rough estimate of the growth. These measurements indicate that the growth of *Q. dilatata* is more rapid than that of *Q. incana*.

The Jaunsar working plan [1] gives the following estimated rate of growth, based on ring countings :

Quercus dilatata : rate of growth, Jaunsar.

Age.	Mean girth.		Mean height.	Age.	Mean girth.		Mean height.
years.	ft.	in.	ft.	years.	ft.	in.	ft.
20	..		5	100	3	11	47
40	1	1	15	120	4	9	58
60	2	1	25	140	5	7	69
80	3	2	36	160	6	3	80

3. **Quercus semecarpifolia,** Smith. Brown oak, kharshu oak. Vern. *Kharshu*, *banjar*, *kreu*, *khor*, W. Him. ; *Khusra*, Bhut.

A large tree, evergreen or nearly so, forming in favourable localities a long clean bole, but at its upper limit and on exposed ridges often stunted and gnarled. Leaves 2–4 in. long, elliptical or oblong, spinous-toothed in young trees and coppice-shoots, often entire on older trees, stiffly coriaceous, glabrous and dark green above, brown tomentose (in young leaves nearly white tomentose) beneath. Bark dark grey, rough, with small quadrangular or irregular scales. The branches are often festooned with mosses and lichens. Wood very hard, of good quality but not much used as timber, though locally employed for building and agricultural implements ; an excellent fuel and charcoal wood.

In favourable situations this oak ordinarily reaches a height of 80–90 ft. and a girth of 7 ft. or more, but larger trees are occasionally met with. In the Mohna forest near Chakrata, Mr. A. Smythies measured a tree 117 ft. high

[1] Working Plan for the Jaunsar-Bawar Forests, P. H. Clutterbuck, 1901. (Girth measurements converted from diameter measurements recorded in the plan.)

FIG. 353. *Quercus semecarpifolia*.—FLOWERS AND FRUIT × $\frac{3}{4}$

a New shoot and leaves and portion of last year's shoot and leaves, with male catkins (1), young female spike (2), and female spike of previous year (3), end of May - June
b Half-grown acorns June second season c Ripe acorns, end of June - July, second season

and an old stump 15 ft. in girth.[1] In the same forest I measured in 1909 two trees 101 and 102 ft. in height and a third 13 ft. 7 in. in girth and 74 ft. high; the last was quite hollow. On the ridge above Deota in Tehri Garhwal, Mr. Gleadow[2] records trees with girths of 12, 13½, 14¼, and 16¼ ft., the last a dead tree. Mr. E. M. Coventry[3] records two trees in the Muril forest, Jubal state, 13 ft. 5 in. and 13 ft. 10 in. in girth. In 1918 I measured a tree 16 ft. 8 in. in girth near Lohar Baik in Hazara; this tree, however, was hollow.

The kharshu oak promises to be an important yielder of tannin. In 1918 Mr. Pilgrim found as much as 23·65 per cent. of tannin in samples of branch bark, although stem bark yielded only 11·63 per cent. English oak bark seldom gives more than 14 per cent., so that the tannin content of kharshu branch bark is remarkable; in addition the ratio of soluble non-tannin to tannin was found to be only 1·9, which is very low.

Distribution and habitat. This oak is found throughout the Himalaya from Bhutan westwards, chiefly at 8,000–12,000 ft., on the Burma-Manipur frontier at 8,000–10,000 ft., and in China. It is the high-level oak of the western Himalaya, often ascending to the upper limit of tree growth except in places where the silver birch (*Betula utilis*) occurs above it. It descends occasionally to 6,500 ft., but is seldom found in abundance below 8,000 ft. Within its well-marked zone it is typically gregarious, forming pure forests along the tops and upper slopes of ridges. In Fig. 350 a belt of this oak is seen along the ridge in the foreground, and the far ridges are for the most part capped with it. It is frequently mixed with spruce (*Picea Morinda*), silver fir (*Abies Pindrow* or *A. Webbiana*), or yew (*Taxus baccata*), and in some localities with blue pine (*Pinus excelsa*). Among broad-leaved species occasionally associated with it are *Pyrus lanata*, *Prunus Padus*, *Acer caesium*, *Juglans regia*, and at the higher elevations *Betula utilis*. It is found both on deep rich moist soil in more or less sheltered localities and on poor rocky ground on the crests of ridges, where, however, it is usually stunted.

There is often a luxuriant herbaceous and shrubby undergrowth in the kharshu oak forests. Among the commoner shrubs are *Rosa macrophylla*, *Rubus niveus*, and other species, *Salix elegans*, *Viburnum stellulatum*, *V. cotinifolium*, *V. foetens*, *Lonicera angustifolia*, and the dwarf bamboo *Arundinaria spathiflora*. In some localities *Strobilanthes Wallichii* forms a dense soil-covering.

The kharshu oak forests occur in regions of heavy snowfall and at least moderate rainfall; they do not extend into the driest parts of the inner Himalaya.

A typical but somewhat open crop of kharshu oak of first-class quality is shown in Fig. 351. This crop is in the Mohna block, Deoban, near Chakrata, at an elevation of 9,000 ft., on a north-easterly aspect; the underlying rock is limestone and the soil is deep and rich. An enumeration on a representative 1-acre plot showed 54 trees, of which 24 were 1 to 5 ft. in girth, and 30 were 5 to 9 ft. in girth. The mean height was 79 ft. and the mean girth 5 ft. 9 in. The crop had been heavily opened out some years previously, and the density was little more than one-half, indicating that a fully stocked crop of this type

[1] Journ. For. School Tour, 1888.
[2] *Ibid.*, 1898–9.
[3] Jubal State Working Plan, 1905.

would contain about 100 trees per acre. The young crops frequently grow up in extremely dense thickets.

LEAF-SHEDDING, FLOWERING, AND FRUITING. At the lower elevations the new shoots first appear early in May, and by the end of June the new leaves are fully developed and the shoots have almost attained full length; at the higher elevations the new shoots do not commence to appear until June. As a rule the old leaves begin to fall in May–June, and do not all fall until the new leaves are well out; sometimes, however, most of them fall before the new leaves are fully developed, and the trees are somewhat bare for a short time. The new shoots are tender, green, covered with a whitish tomentum, the previous year's shoots being greenish brown, shining, and lenticellate. The new leaves, subtended by brown deciduous stipules, are bright green above, with a felty light brown, nearly white, tomentum beneath; the old leaves are dark green above, turning brown before falling, with a brown tomentum beneath (Fig. 353, *a*).

The male catkins and female spikes appear with the new shoots, the former ripening and pollination taking place in the end of May or in June. The male catkins (Fig. 353, *a*, 1), 2–5 in. long or more, are found in sparse or dense pendulous clusters at the base of the new shoots, or a few are distributed singly along the lower parts of these shoots. The female spikes (Fig. 353, *a*, 2), up to 0·8 in. long, with 3–12 small sessile flowers, are axillary in the upper part of the new shoots; the flowers have three, sometimes four, recurved styles.

There is little or no growth in the young acorns until the following spring, when they commence growing rapidly as soon as the new shoots begin to appear, and by June they may be of any size up to 1 in. in diameter or even more; their growth is very uneven, a single spike at this time often containing young acorns of all sizes from about 0·3 in. in diameter upwards. These young acorns occur solitary or in pairs, or in clusters of 3–6 or more (Fig. 353, *a*, 3, and *b*). Their colour is dark green, intermingled with rich reddish brown, the base within the cup being pale greenish yellow; the cup is soft and leathery, the scales green with reddish brown tips.

The acorns (Figs. 353, *c*, and 354, *a*) commence ripening towards the end of June, and continue ripening during July, and at the higher elevations even into August; the period between the pollination of the female flower and the ripening of the acorn is therefore about thirteen months.

The ripe nuts are globose, inserted in a shallow grey leathery cup formed of small imbricate pointed scales, and vary much in size and colour. They average about 0·8–1 in. in diameter, and about 60 weigh 1 lb. Many fall green, turning brown on the ground, while others turn dark brown before falling. The nuts fall as soon as they ripen and germinate immediately, some even showing signs of germination before falling. Many have insect holes through them, but this does not prevent germination if the embryo is uninjured. The acorns are eagerly devoured by bears, langur monkeys, squirrels, and birds, but in a good seed-year they are produced in great abundance, and there is no lack of seed. Records of seeding are available for twelve consecutive years in Jaunsar; during this period good to abundant seeding was recorded in four years, and poor to moderate seeding in eight years.

FIG. 354. *Quercus semecarpifolia* SEEDLING × ½

a—Acorn b - f— Germination stages g, h Development of seedling during first season

The seeds retain their vitality for a very short time, but the percentage of fertility of fresh seed is high. Tests showed a fertility of 95 to 100 per cent. I carefully examined a quantity of fallen acorns in the Jaunsar forests in the middle of July 1912; 90 per cent. had germinated, and of the remaining 10 per cent. about half were bad and the remainder were good but had not commenced germination.

Occasionally 2- to 4-seeded acorns are found, a corresponding number of taproots emerging from a single acorn.

GERMINATION (Fig. 354, *b–f*). Hypogeous. Germination commences with the emergence of the radicle from the apex of the nut. Elongation quickly takes place of what appears to be the young taproot, but what consists in reality of two parts, (1) the cotyledonary petioles united into a tube, and (2) the young taproot at the base of and in continuation of this tube. If the petiolar tube be cut through longitudinally the minute plumule will be found at its junction with the taproot, and completely enclosed within the tube. The elongation of the petiolar tube continues until the young taproot is safely conveyed into the soil; the tube may thus attain a length of as much as 4 in. or even more. From this stage onwards the taproot elongates and thickens considerably, sending out numerous fibrous lateral rootlets. Meanwhile the petiolar tube splits near its base, and through the opening formed the young shoot emerges and ascends; sometimes more than one shoot emerges.

Germination under natural conditions takes place early in the rainy season when a thick growth of new grass or other herbaceous plants, in addition to dead leaves, covers the ground. Thus the object of this abnormal elongation of the cotyledonary petioles, in this case in the form of a tube, is evidently to transfer the embryo seedling, with its delicate young taproot, as rapidly as possible through this soil-covering, and to enable it to establish a connexion with the soil. This accomplished, the seedling continues for some time to receive nutriment from the fleshy cotyledons through their petiolar tube, and the remains of the cotyledons and of their long petiolar tube may still be found during the second season.

This abnormal elongation of the cotyledonary petioles is seen also in the case of *Shorea robusta*, where, however, the petioles are not united into a tube. The seed of both species is quickly perishable, and this may account for the special means necessary for bringing the germinating seedling quickly into contact with the soil. The tubular form of the cotyledonary petioles in the case of *Quercus semecarpifolia* is no doubt a protective device for guarding the plumule from injury.

THE SEEDLING (Fig. 354).

Roots: primary root long, terete, very thick in upper part, tapering rapidly downwards, brown, woody, rough and striate by cracking of the epidermis, younger parts minutely tomentose; lateral roots numerous, moderately long, fibrous, minutely tomentose, distributed down main root. *Hypocotyl* hardly distinguishable, subterranean. *Cotyledons* subterranean. Petioles united in a terete slightly arched tube 1–4 in. or more in length, which completely encloses the plumule and splits near the base to allow the young shoot to emerge; petiolar tube stiff, becoming somewhat woody, tomentose. Lamina 0·8–1 in. in diameter, thick, fleshy, outer surface rounded and much wrinkled, inner surface irregularly wavy and depressed, the two cotyledons in close contact, base produced into a rough thick point behind the petiole. *Stem* erect or somewhat straggling, grooved, wiry, pale green or reddish, tomentose; internodes 0·3–1 in. long. *Leaves* simple, alternate. Stipules 0·1–0·2 in. long, linear acuminate, tomentose, pale green when young, turning dark brown, deciduous. Petiole 0·1 in. long, tomentose. Lamina 1·5–2 in. by 0·8–1·2 in., elliptical or oblong, spinous dentate, apex obtuse, mucronate, base rounded or cordate, sub-coriaceous, pubescent on both surfaces with a tomentose fringe round the margin.

Under natural conditions the seedling as a rule produces in the first season nothing more than a small leafless stem 2 to 3 in. high, on which normal foliage leaves are replaced by mere scales with buds in their axils, and normal leaves are produced for the first time only in the second season ; under favourable conditions, however, normal leaves are produced during the first season, as shown in Fig. 354. Although the development of the stem is small the taproot grows rapidly in length and thickness, enabling the seedling to establish itself successfully. Many seedlings die down towards the end of the first season and often for a few years subsequently, sending up new and stronger shoots each year from dormant collum buds until they finally commence upward growth ; only under favourable conditions do they grow steadily from the commencement without dying back. The leafless form of the first season's shoot is an interesting adaptation for withstanding the climatic rigours at the high elevations at which this oak grows. The growing season is a short one, and is followed by a period of autumn drought and a severe winter ; after germination the young plant therefore at once assumes a leafless winter form in preparation for the adverse conditions with which it has to contend. It may be noted that when young plants are artificially grown below their natural elevation and are specially tended they produce normal foliage leaves in the first season and do not die back. The rate of growth of seedlings is very slow, averaging only about 2 to 4 in. a year in height in the case of those grown under natural conditions, though the growth is somewhat faster in the case of plants raised in the nursery.

Silvicultural characters. This oak is a light-demander, and fails to establish itself under shade which is at all heavy (see under 'natural reproduction', below). It coppices and pollards fairly well, though coppice and pollard shoots are liable to be bent or broken by snow ; the latter in particular are so liable to snow-break that pollarding is not a system to be recommended. Coppiced stools often send up a large number of shoots, of which a few eventually survive and suppress the remainder. The growth of coppice-shoots is slow. What appears to be natural coppice is sometimes met with ; this is known to be due in some cases to fire. The leaves, particularly when young, are readily eaten by goats and sheep. The root-system of this oak is massive, and the tree is not so liable to be thrown by wind as *Q. dilatata*, although in exposed situations windfalls are occasionally met with. It grows in the region of heavy snow, and sometimes suffers from snow-break, particularly in dense pole crops. Regular thinnings should tend to minimize this damage. At the higher levels the trees not only have their branches broken by the masses of snow which accumulate on the crowns during the winter, but are also uprooted and piled up in heaps by sliding snow.

Natural reproduction. Under natural conditions germination, as

FIG. 355. *Quercus lanuginosa* FLOWERS AND FRUIT $\times \frac{1}{1}$

a—Young shoot, April - May, with male catkins (1) and female spikes (2) b Young acorns, half grown, about five months old, end of September c Ripe acorns, end of December

already noted, takes place as soon as the seed falls, between June and August, that is, early in the rainy season. Conditions for germination therefore are good, since the seed does not lie exposed to the attacks of animals, and the young seedling obtains the full benefit of the rainy season in which to push its long taproot down into the soil and to become established. After a good seed-year young seedlings may be found in large quantities. In 1909 I demarcated a plot of natural seedlings 22 ft. square, that is, 53·8 square yds. in area, in the Mohna block at Deoban in Jaunsar. The seedlings were chiefly under 1 ft. in height, but a few were more, the maximum height being 2 ft. 3 in. The seedlings in this plot were carefully counted that year and for five years subsequently, with the following result :

Quercus semecarpifolia : enumeration of natural seedlings in demarcated plot.

year.	Number of seedlings in plot.	Equivalent number. per square yard.	per acre.	Height of largest seedlings.
1909	651	12·1	58,590	27 in. (maximum).
1910	1,320	24·5	118,800	
1911	1,560	29·0	140,400	
1912	2,441	45·4	219,690	36 in. (maximum), 35 in., 34 in., 33 in., 32 in., 31 in.
1913	2,392	44·5	215,280	38 in. (maximum), 37 in., 36½ in., 36½ in., 36 in., 36 in.
1914	1,687	31·4	151,830	39 in., 39 in. (maximum), 38 in.

These figures indicate the profusion with which natural seedlings are capable of springing up, and they also demonstrate the extremely slow growth of even the most vigorous of them. The marked increase in the number of seedlings between 1909 and 1912 was due mainly to fresh germination ; it is quite possible, however, that many seedlings may have escaped notice for one year owing to their leafless stems or owing possibly to their having died back. The decrease in the number after 1912 was apparently due to the suppression of the smaller and less vigorous seedlings.

For the establishment of natural reproduction abundant overhead light is essential, and if this is ensured and the other conditions are favourable, thickets of great density establish themselves in the neighbourhood of seed-bearers. Frequently along the edge of an oak wood a mass of sapling reproduction resembling a thick hedge springs up, while in the interior of the wood nothing beyond the seedling stage is to be found. Similarly where the canopy of an oak wood has been heavily opened out dense thickets of young oak appear in the gaps. Fig. 352 gives some idea of this. Where trees are standing in the open there are often dense thickets of young growth on the downhill side of them, and it is noticeable how isolated seed-bearers crowning a ridge will produce such thickets extending for some distance down the slopes on either side.

Heavy grazing prevents oak reproduction, but instances have been observed where light grazing has not had any appreciable effect on its establishment. Natural reproduction is often prevented from establishing itself by a dense growth of weeds and heavy undergrowth, particularly in moist depressions. Among the most troublesome weeds is *Strobilanthes*

Wallichii, which produces a dense matted growth preventing oak reproduction. This plant, an account of which is given in Vol. II, pp. 695–6, flowers and dies at intervals of twelve years. In Jaunsar numerous oak seedlings have been observed to establish themselves immediately after the periodic flowering. Experiments have also shown that the *Strobilanthes* can be eradicated successfully by cutting it down in the year of flowering immediately before the ripening of the fruit, that is in September; this eradication has been found to result in the establishment of many oak seedlings which could not otherwise have survived.

On the upper slopes of China hill at Naini Tal, where this oak occurs naturally, reproduction persistently fails, but the cause of this has not yet been ascertained.

ARTIFICIAL REPRODUCTION. This oak has on several occasions been raised successfully in Jaunsar by sowing in contour lines or by dibbling. It is necessary to have the contour lines prepared in advance and to sow the seed as soon as it ripens; fairly open places should be chosen. Transplanting from the nursery was also carried out at one time in Jaunsar, but no details are available, direct sowing having been more usual.

SILVICULTURAL TREATMENT. The kharshu oak is sometimes worked as coppice, but this system is not always satisfactory as the coppice-shoots are liable to be bent or broken by snow; their growth, too, is very slow. From what has already been noted under 'natural reproduction' it will be seen that this oak is well adapted for working as high forest under the system of successive regeneration fellings, a somewhat open seeding felling being made, followed by a further opening of the canopy as soon as natural reproduction begins to appear in the gaps. A heavy opening of the canopy several years ago in the Mohna block, Jaunsar, was followed by promising masses of reproduction wherever there was sufficient light and the growth of weeds was not too heavy; owing to the slow growth of the seedlings, however, it was a long time before there were any visible results. Judging from the tendency of the oak to regenerate in fringes in the open along the edges of the woods, clear fellings in narrow strips would probably give good results. Owing to the density of the young crops thinnings should be commenced in the thicket or young pole stage.

RATE OF GROWTH. (1) *Coppice.* Periodical measurements in coppice coupes near Deoban in Jaunsar show the following mean rate of growth:

Quercus semecarpifolia: rate of growth of coppice, Jaunsar.

Age.	Mean girth.	Mean height.
years.	in.	ft.
5	3·0	3·7
10	4·9	6·5
15	6·3	9·2
20	7·7	11·7
25	9·0	14·0
30	10·0	16·2
35	11·0	18·4

(2) *High forest.* Periodical measurements in young plantations in Jaunsar gave the following results:

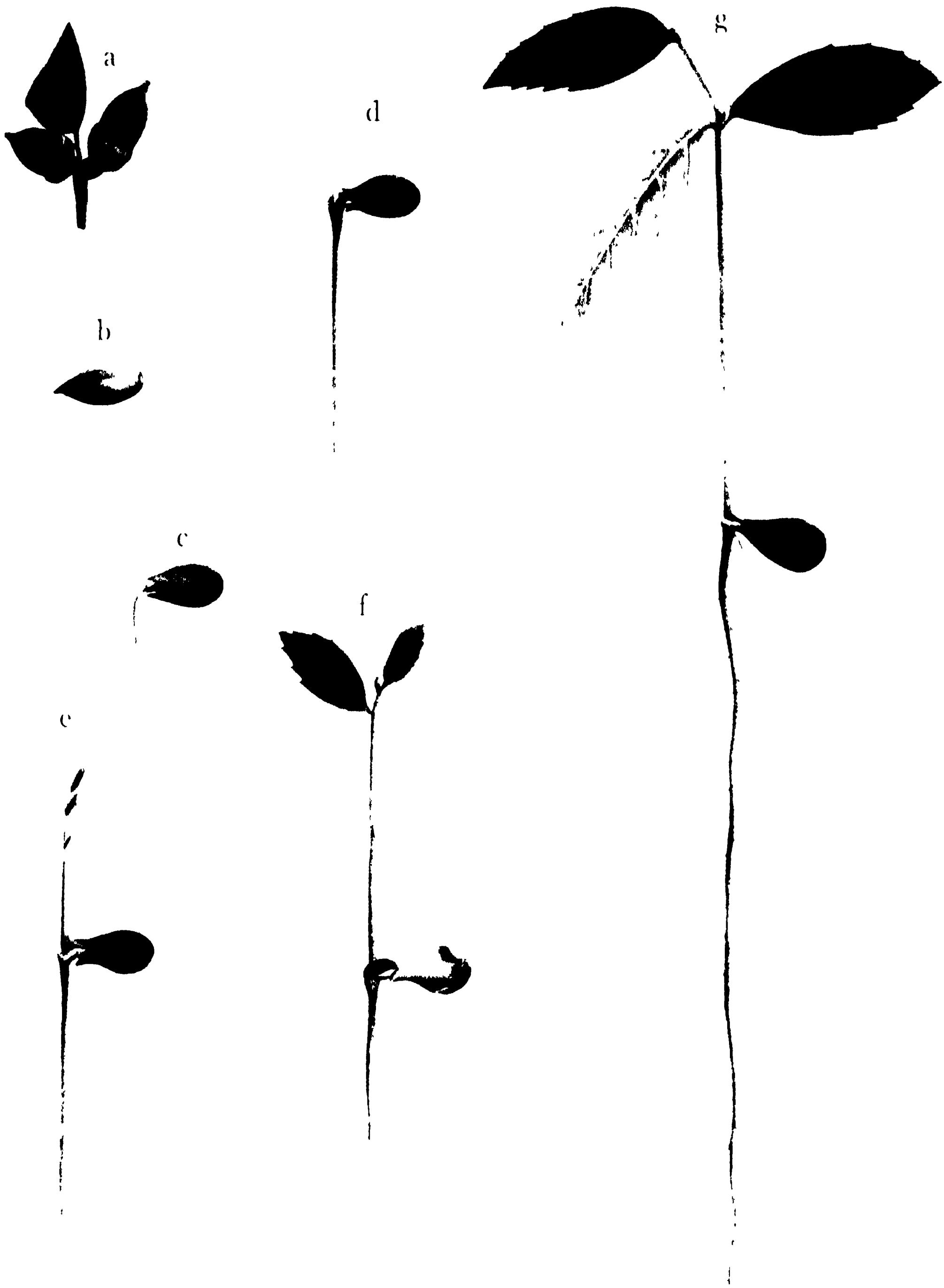


FIG. 356. *Quercus lanuginosa*—SEEDLING × $\frac{3}{4}$

a—Acorns b Nut of acorn c-e Germination stages f, g—Development of seedling during first season

Quercus semecarpifolia : rate of growth in young plantations, Jaunsar.

Age (from seed).	Mean girth.	Mean height.
years.	in.	ft.
5	1·4	1·8
10	2·7	3·7
15	4·2	5·5
20	5·6	7·3

The rate of growth in girth, deduced from measurements in four Research Institute sample plots, in natural crops at Deoban in Jaunsar, of which two were thinned and two were not thinned, is as follows : [1]

Quercus semecarpifolia : rate of growth in girth in natural crops, Jaunsar.

	Mean girth.			Mean girth.	
Age.	Thinned plots.	Unthinned plots.	Age.	Thinned plots.	Unthinned plots.
years.	ft. in.	ft. in.	years.	ft. in.	ft. in.
10	0 2¼	0 1	70	2 2¾	1 8
20	0 5¾	0 4¼	80	2 7¾	1 11½
30	0 9¾	0 7¼	90	3 1¼	2 3
40	1 2	0 10½	100	3 7½	2 6¾
50	1 6	1 1	110	.	2 10¾
60	1 10	1 4¾	120	..	3 3

These results are based on measurements for one quinquennial period only, and are therefore only tentative.

The Jaunsar working plan of 1901 gives the following estimated rate of growth, based on ring-countings : [2]

Quercus semecarpifolia : rate of growth, Jaunsar.

Age.	Mean girth.	Mean height.
years.	ft. in.	ft.
20	..	5
40	0 8	15
60	1 7	24
80	2 3	33
100	2 11	43
120	3 7	54
140	4 4	65
160	5 0	76

4. **Quercus lanuginosa,** Don. Woolly oak. Vern. *Rianj,* Kumaun ; *Banga,* Nep.

A large evergreen tree, somewhat resembling *Quercus incana,* but the leaves are broader and densely whitish to rusty tomentose on the lower surface, while the young shoots are more woolly. Bark grey, either smooth and shining, with numerous small lenticellate excrescences and exfoliating in rather large irregular sheets, or rough by exfoliation in numerous rectangular scales of smaller size. On old trees the bark often forms horizontal raised rings at intervals up the bole. Wood very hard, used as fuel along with other associate oaks.

In the open the tree tends to branch low and to form a short bole, but when grown in a close crop a straight clean bole is formed. I have measured trees up to 70 ft. in height and 11 ft. in girth.

[1] Statistics compiled in the Silviculturist's Office, 1916–17, Ind. For. Rec., vol. vi, pt. v, 1918.

[2] Working Plan for the Jaunsar-Bawar Forests, P. H. Clutterbuck, 1901. (Girth measurements converted from diameter measurements recorded in the plan.)

DISTRIBUTION AND HABITAT. The distribution of this tree is very local. It occurs in patches, sometimes of small extent, in the Garhwal and Kumaun Himalaya, extending eastward to Bhutan, at 4,000–8,000 ft. Mr. Jacob[1] says that in Bhutan it occurs chiefly in the inner valleys with *Quercus Griffithii* at 6,000–8,000 ft. Mr. A. E. Osmaston informs me that he found a gregarious patch about 30 to 40 acres in extent, containing some large trees, in the Divadanda block in Garhwal. There are some patches in the hills of the Naini Tal district at elevations of 6,000 to 7,500 ft. In this district it is perhaps commonest round Kilberry, where it is found on limestone and shale, and may be seen clinging to limestone rocks on precipitous ground. It is associated with *Quercus incana* and *Rhododendron arboreum*, and at its upper and lower elevations with *Quercus dilatata* and *Pinus longifolia* respectively. The tree is typically gregarious, often occurring in dense pure patches (Fig. 357). It may be found along the tops of shaly ridges on poor soil, but in such places it is stunted. It is often found on sunny slopes. In the Naini Tal hills *Quercus dilatata* is tending to supplant it in cool sheltered places.

In those parts of the Naini Tal hills where this oak occurs the rainfall is about 90 in.; the absolute maximum shade temperature is probably slightly over 90° F., and the absolute minimum is between 20° and 25° F.

Seedlings recently planted in the Forest Research Institute grounds at Dehra Dun promise well.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The young shoots appear in March or early April; they are covered with a dense woolly tomentum of a pale tawny or rusty colour which persists throughout the season, becoming a dirty grey colour by the end of the year, but disappears in the second season, the shoots becoming dark grey or brown. The young leaves (Fig. 355, *a*), subtended by downy brown deciduous stipules, are woolly tomentose on both surfaces, but the tomentum soon disappears from the upper surface, which becomes dark green, glabrous, and shining, with a yellow midrib (Fig. 355, *b*). The time of shedding of the old leaves has not been accurately recorded, but they have been observed to be still on the trees in October.

The male catkins and the female spikes appear with the young shoots, the former maturing and pollination taking place towards the end of April and during May. The male catkins (Fig. 355, *a*, 1), arranged in pendulous clusters at the base of the young shoots or singly along the lower part of those shoots, are usually 4–8 in. long, but have been measured up to 14 in. in length, the flowers in this case being widely separated. The female spikes (Fig. 355, *a*, 2) are axillary in the upper parts of the new shoots; the flowers, usually 2–5 in number, sometimes more, are sessile on the common peduncle, the woolly tomentum on which almost hides them.

After pollination the young acorns commence to develop, and by September are usually about 0·2–0·5 in. long by 0·2–0·4 in. in diameter, the nuts for the most part well out of the cup, green with a thick covering of short light grey woolly hairs (Fig. 355, *b*). From then onwards they grow rapidly, and ripen in the latter half of December and in January, that is, about eight months from the time the female flower is pollinated. They fall to the ground by degrees from the time of ripening onwards.

[1] Report on the Forests of Bhutan, 1912.

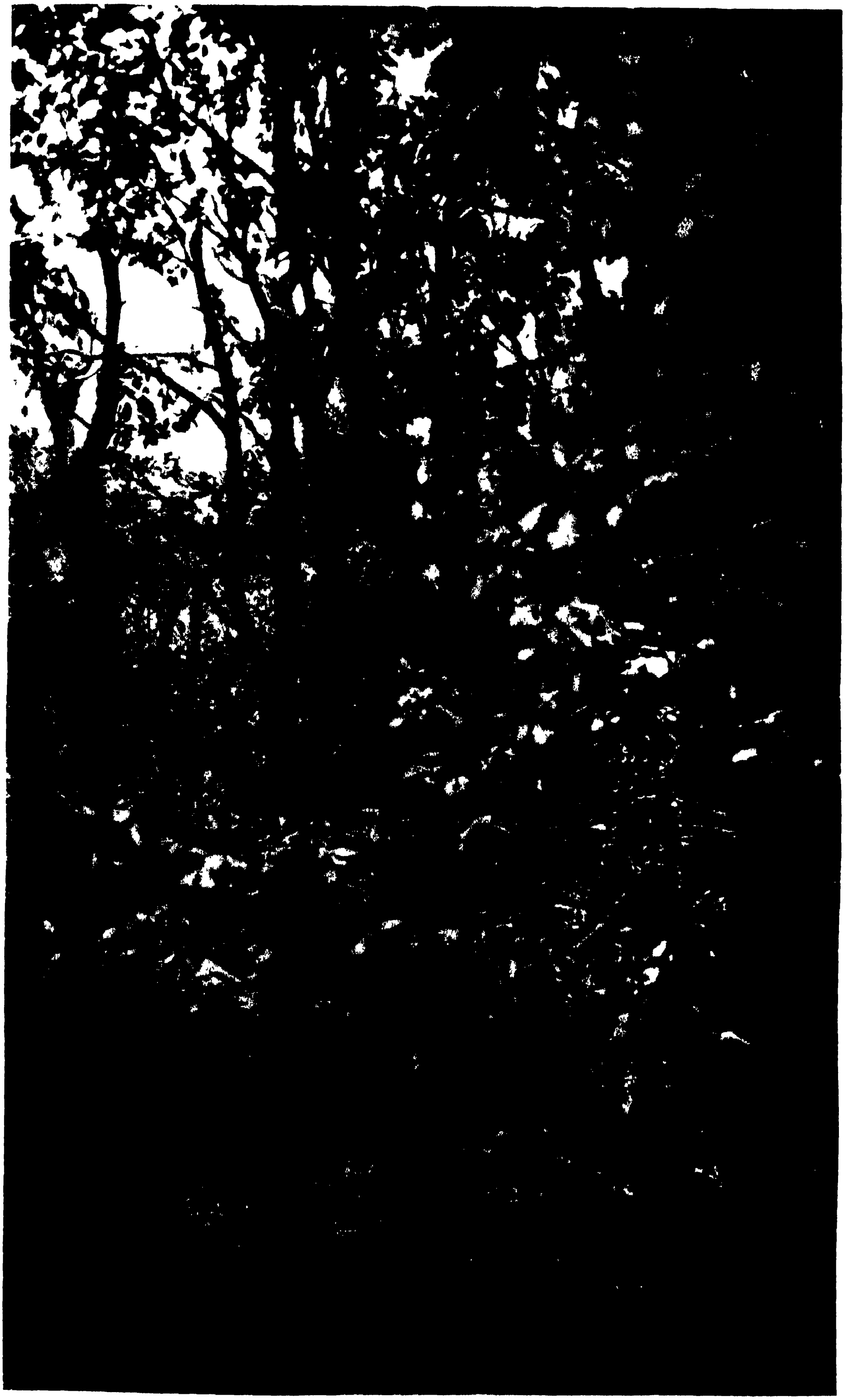


FIG. 357. *Quercus lanuginosa*, pole crop. Kumaun hills.

FIG. 358. *Quercus Ilex* growing gregariously on a dry rocky slope at 5,000 ft., Kagan valley, Hazara. *Cedrus Deodara* on left.

FIG. 359. *Quercus serrata*, plantation 30 years old, Kaunli, Dehra Dun.

The acorns (Figs. 355, *c*, and 356, *a*) are sessile, usually in clusters of 2–5. The cup is 0·4–0·5 in. in diameter, with closely adpressed woolly tomentose imbricate scales, shallow, enclosing the nut for less than one-quarter of its length to nearly one-half. Nut (Fig. 356, *b*), 0·5–0·7 in. long by 0·3–0·45 in. in diameter, ovoid, light brown, smooth, shining, covered with light grey, woolly hairs for some distance from the apex.

The acorns are eagerly devoured by bears, and, as in the case of most Himalayan oaks, are much subject to the attacks of boring caterpillars.

GERMINATION (Fig. 356, *c–e*). Hypogeous. The shell of the nut splits towards the apex and the radicle emerges, descending rapidly and forming a taproot. Meanwhile the cotyledonary petioles elongate to about 0·1–0·2 in., enabling the plumule to emerge and the young shoot to ascend. The fleshy cotyledons remain within the shell on or under the ground; they remain attached for some time to the young plant, supplying it with nutriment in its earlier stages.

THE SEEDLING (Fig. 356).

Roots: primary root long, fairly stout, terete, tapering, wiry, tomentose; lateral roots fairly numerous, moderately long, fibrous, distributed down main root. *Hypocotyl* more or less distinct from root, 0·1 in. long or less, thick, tomentose, subterranean. *Cotyledons* subterranean. Petiole 0·1–0·2 in. long, flattened, tomentose. Lamina 0·4–0·6 in. by 0·25–0·4 in., thick, fleshy, apex rounded, base prolonged behind petiole, outer surface convex, inner flattened in contact. *Stem* erect, terete, woody, woolly tomentose; internodes 0·2–2·5 in. *Leaves*, first pair usually abortive, opposite, sub-opposite or alternate, subsequent leaves normal, alternate or sometimes sub-opposite. Stipules 0·1 in. long, linear falcate. Petiole 0·1 in. long, or less, woolly tomentose. Lamina 1·2–3 in. by 0·6–1·5 in., elliptical ovate, acute, serrate, woolly tomentose.

The growth of the seedling is slow. By the end of the first season a height of 2 to 5 in., with two to four leaves, is ordinarily attained, and subsequent growth is at the rate of only a few inches a year. Seedlings raised at Dehra Dun attained an average height of 1 ft. 7 in. in four years.

SILVICULTURAL CHARACTERS. This oak is more light-demanding, but less exacting as to soil and exposure, than *Quercus dilatata*. It coppices well. It has a massive root-system, and appears to be wind-firm.

NATURAL REPRODUCTION. Under natural conditions the seed lies on the ground during a portion or the whole of the hot season, and germinates during the rainy season. This oak appears to resemble *Quercus incana* so far as conditions for successful natural reproduction are concerned, but if anything reproduction seems to be capable of establishing itself on somewhat drier localities than in the case of *Q. incana*. Natural seedlings are found most plentifully on open grassy slopes and spurs, often along with seedlings of *Pinus longifolia*. In sheltered localities in the Naini Tal hills, seedlings of *Quercus dilatata* may sometimes be found springing up in quantity under an overwood of *Q. lanuginosa*, indicating that the former species is tending to supplant the latter in such places.

ARTIFICIAL REPRODUCTION. Experiments at Dehra Dun have shown that this oak can be grown successfully either by direct sowing or by transplanting from the nursery as in the case of *Quercus incana*. Care is necessary not to expose the roots too much during transplanting.

Rate of growth. Measurements of four trees in a mixed unthinned oak sample plot at Kilberry near Naini Tal showed an average girth increment of 2·8 in. in four years, or 0·7 in. in a year. Measurements of one tree in a thinned sample plot in the same locality showed a mean annual girth increment for the period of 1·2 in., which indicates that in thinned crops the growth may be fairly fast. The trees in question varied from 15 to 25 in. in girth at the first measurement.

5. **Quercus Ilex,** Linn. Syn. *Q. Baloot,* Griff. Holm oak. Vern. *Balút, charrei,* Afg.; *Pargái, kharanja,* trans-Indus; *Banj,* Chitral; *Chúr, bré, irri,* Pb.

A small or moderate-sized evergreen tree, often little more than a shrub. Leaves coriaceous, upper surface dark green, lower surface softly whitish or greyish tomentose, very variable in size and shape, 1–3 in. long, elliptical or oblong, entire or with large spinescent teeth, both forms sometimes on the same branch. Bark dark grey, divided into small scaly plates. Wood very hard, used in India for agricultural implements and tool-handles and much cut for fuel. The branches are lopped for cattle fodder. In Europe the bark is considered a good tanning material.

In the Himalayan region the tree sometimes reaches 5–6 ft. in girth, but is often kept in the condition of scrub by cutting and lopping. In the Kurram valley, Mr. Bagshawe measured eight trees averaging 7 ft. 1 in. in girth.

Distribution and habitat. This tree has a wide distribution, occurring in different soils and climates and showing considerable variation in different localities. It extends westward to southern France, Spain, and Portugal, often occurring in arid situations and on dry hill-sides. It is widely distributed in the Mediterranean region, from France and Spain eastward through Italy, the southern Tyrol, Corsica, Sicily, Greece, the coast region of Syria, and in other Mediterranean countries including Morocco, Algeria, and Tunis. It is often cultivated in England, where it reaches large dimensions.

In the Indian region it is found in the inner arid tracts of the Himalaya from the Sutlej valley, westward to Afghanistan. It is common on the eastern slopes of the Suliman range at 5,000–6,000 ft., in the Kurram valley at 6,500–9,000 ft., in the hills north of the Peshawar valley at 3,500 ft., in Chitral at 6,000–8,500 ft., and in the arid valleys of the upper Jhelum, Chenab, Ravi, and Sutlej at 4,000–8,500 ft. In the Kagan valley it is common and gregarious at 4,500–6,000 ft., usually associated with *Fraxinus xanthoxyloides* and *Daphne oleoides,* and in places with deodar (see Fig. 358). In Kashmir it is common on the hot southerly slopes in the lower part of the valley of the Kishanganga and its two tributaries, the Karna and the Jagran, at 3,500–7,000 ft.

In the dry regions which it frequents it is often found associated with *Pinus Gerardiana,* growing on dry, rocky, hot slopes. In Chitral it is a common companion of the deodar, especially at the lower elevations of the latter, and is sometimes associated with the blue pine.[1]

Leaf-shedding, flowering, and fruiting. In England the leaves persist for two or three years (Henry); in India they persist as a rule for less than 1½ years. The following remarks apply to trees in the Indian region:

The young shoots, which are covered with a pale grey stellate pubescence,

[1] Report on the Chitral Forests, Imam-ud-din, 1908.

FIG. 360. *Quercus Ilex* FLOWERS AND FRUIT × $\frac{7}{8}$

a -Male catkins, April, May b—New shoot and portion of previous year's shoot, with female flowers at time of pollination (1) and young acorns one year older (2), April, May

c—Ripe acorns, October of second season

appear in March–April (Fig. 360); the young leaves on the under side are pale grey stellate tomentose, on the upper side pubescent with stellate hairs, afterwards becoming glabrate. The male catkins (Fig. 360, *a*), in drooping clusters, up to 3 in. long, appear at the base of the new shoots and ripen in April–May, when pollination takes place. The minute female flowers (Fig. 360, *b*, 1), usually two or three, are sessile on slender peduncles up to 1·5 in. long, axillary on the upper part of the new shoots.

There is little or no growth in the young acorns during the first season, and they remain small until April–May of the second season (Fig. 360, *b*, 2), after which the acorns develop rapidly. By the end of June they are about 0·3 in. in diameter, with the nut completely enclosed in the cup of imbricate pale greyish green scales. The acorns (Fig. 360, *c*) ripen about October, and are usually two or three in number on a common peduncle. The nuts are 0·8–1·2 in. long by 0·4–0·6 in. in diameter, oblong conical, light brown, glabrous, shining; the woody cup is greyish brown with closely adpressed scales, and encloses about one-quarter to one-third of the nut.

In the Himalayan region a period of about a year and a half thus elapses from the time of pollination of the female flower until the ripening of the acorn.

SILVICULTURAL CHARACTERS. This is a typically xerophytic species, often forming low scrubby growth with spinous leaves and growing on dry stony or rocky ground and hot slopes. Its xerophytic habit is further exhibited by its capacity for producing root-suckers, unlike most oaks, especially when the stumps of felled trees are dug out or split, as is done in Provence to stimulate reproduction by suckers. The tree coppices well, and in the Mediterranean region is frequently worked as coppice for the production of tanning bark.

RATE OF GROWTH. According to Gamble the growth is slow and the rings uncertain. Ring-countings by Mr. Bagshawe on the eight trees in the Kurram valley referred to above gave an average of 270 rings for a mean girth of 7 ft. 1 in. or a mean annual girth increment of 0·31 in. Khan Bahadur Imam-ud-din estimated the rate of growth of coppice-shoots in Chitral at about 10 in. in height per annum.

6. **Quercus serrata,** Thunb.

A moderate-sized or large handsome deciduous tree, forming a full rounded crown when grown in the open and a straight clean bole when grown in a close crop. Leaves lanceolate or elliptical lanceolate, 5–7 in. long, sharply serrate, glabrous when mature and green on both sides. Bark dark greyish brown, rough, with deep irregular vertical fissures. Wood very hard, dark greyish brown, used for building. A fast-growing tree suitable for plantations and for ornamental and shade purposes. It reaches fairly large dimensions. A tree about 7 ft. in girth was recently felled at Dehra Dun, where also there is a cross-section 8 ft. 1½ in. in girth in the silvicultural museum.

DISTRIBUTION. Eastern Himalaya at 3,000–8,000 ft., Khasi hills, Manipur, hills of Upper Burma at 3,500 ft. and over, China, and Japan. This is one of the common oaks at Maymyo, where it occurs at 3,500 ft. with *Quercus Griffithii*, *Schima Wallichii*, *Castanopsis*, and various other trees, with an undergrowth often consisting of bracken. Here it is most common on the more fertile soils, particularly on red clayey loam, and often becomes gregarious in moist situations. In the Chin hills it is common along with *Pinus Khasya*, *Rhododendron arboreum*, *Alnus nepalensis*, and other oaks. It has been much planted in the cinchona plantations of the Darjeeling hills. It grows well at Dehra Dun, where it has been planted for ornament; there is a small plantation of it in the Kaunli garden at that place (Fig. 359).

LEAF-SHEDDING, FLOWERING, AND FRUITING. The dates given here refer to Dehra Dun only. The leaves turn yellow and brown and commence falling in November, and by January the trees are leafless. The new delicate green leaves appear in February. The male catkins are first visible in October or early November, and are to be seen, up to about 1 in. in length, at the ends of the leafless branches in January; with the sprouting of the new shoots in February they elongate rapidly, attaining a length of 4–6 in. Pollination takes place in February or March. The small green 3-styled female flowers appear on the new shoots in February, and hardly develop for a whole year, remaining about 0·1 in. in diameter, and brown in colour, through the ensuing winter. In the second year they commence increasing in size in March and develop rapidly, ripening and falling in September and October. The acorn (Fig. 361, *a*) varies much in size. The nut is broadly ovoid to globose, 0·8–1·2 in. long by 0·6–1 in. in diameter, with an obtuse apex, brown, glabrous and shining; its base is enclosed about one-third to one-half in a woody cup with spreading recurved scales. About 70 to 120 nuts weigh 1 lb. Fertile seed commences to be produced fairly early. The trees in the plantation at Kaunli, Dehra Dun, produced fertile seed in abundance at twenty-two years of age. At Dehra Dun the immature seed-crop is sometimes destroyed by storms.

GERMINATION (Fig. 361, *b–e*). Hypogeous. The radicle emerges from the apex of the nut and descends rapidly, forming a long stout taproot. Meanwhile, the cotyledonary petioles elongate to about 0·3 in., enabling the plumule to emerge and the young shoot to ascend. The fleshy cotyledons remain within the nut on or under the ground; they remain attached to the young plant for a considerable time, supplying it with nutriment in its earlier stages.

THE SEEDLING (Fig. 361).

Roots: primary root long, thick, terete, tapering, brown, woody, longitudinally wrinkled; lateral roots numerous, moderately long, fibrous, distributed down main root. *Hypocotyl* fairly distinct, about 0·1 in. long, thick, subterranean. *Cotyledons* subterranean. Petiole 0·3 in. long, flattened. Lamina 0·8–1 in. by 0·6–0·7 in., thick, fleshy, obovate, apex more or less truncate, base slightly prolonged over the petiole, outer surface rounded, longitudinally wrinkled, inner flattened in contact. *Stem* erect, terete, green, tomentose; internodes in first season 0·4–1 in. long. *Leaves*, first pair opposite, sub-opposite or alternate, subsequent leaves alternate, first few leaves often scaly and rudimentary. Stipules 0·1–0·15 in. long, linear falcate, tomentose. Petiole 0·1 in. long. Lamina 1–2·8 in. by 0·4–0·7 in., oblong or elliptical lanceolate, acuminate, base rounded, sharply serrate, pubescent when young; lateral veins 8–12 pairs.

The growth of the seedling is fast. At Dehra Dun nursery plants kept weeded and watered attained by the end of the first season a height of 3 ft. 10 in., with a strong taproot 2 ft. 9 in. long. In the case of direct sowings, where

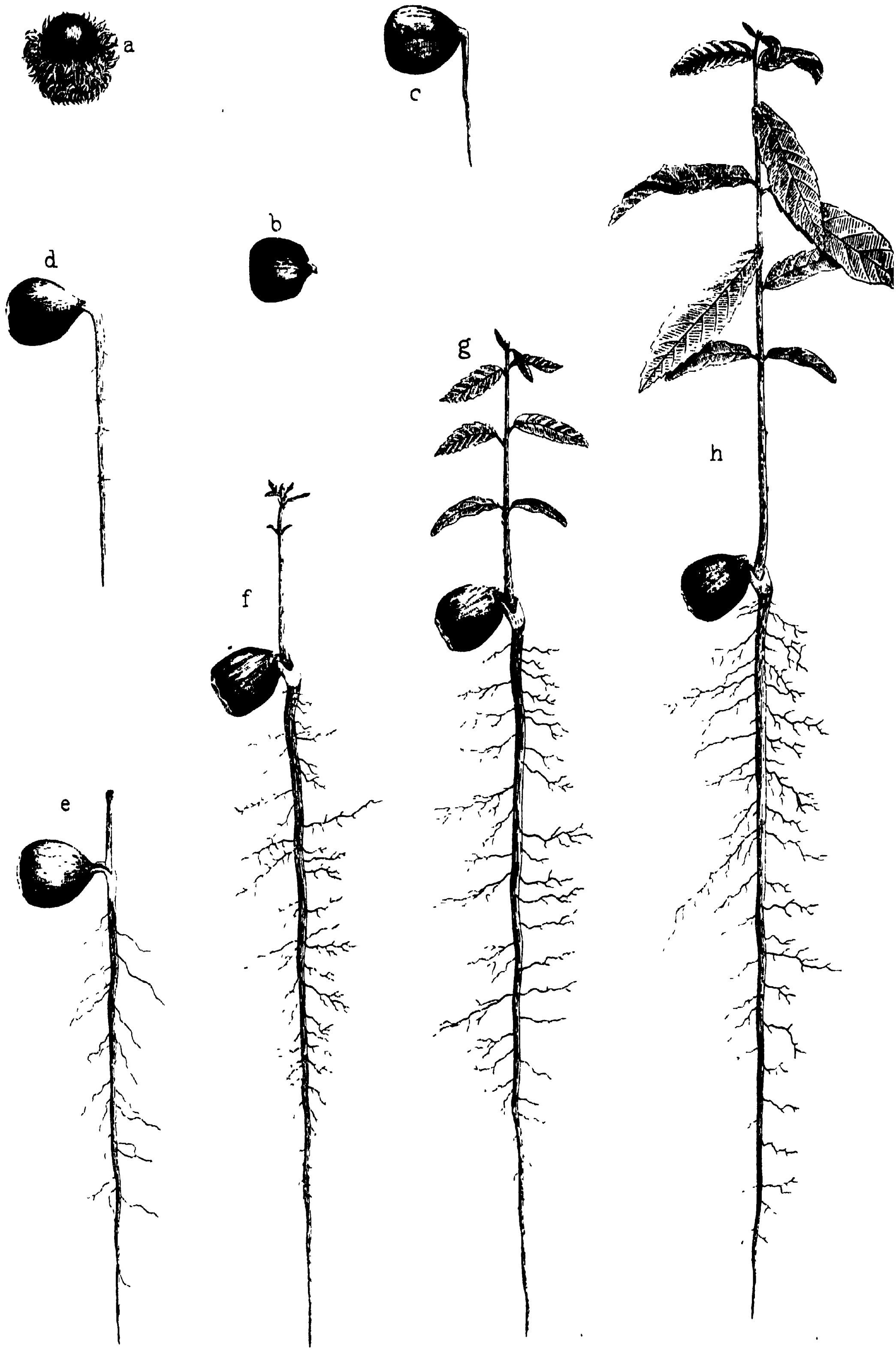


FIG. 361. *Quercus serrata*. Seedling × ½.

a, acorn ; *b–e*, germination stages ; *f–h*, development of seedling to end of first season.

no weeding or watering was done, seedlings attained a height of 10 in. by the end of the first season and 4 ft. by the end of the second season. Transplants from the nursery reached a height of 7 to 7½ ft. in three years.

SILVICULTURAL CHARACTERS. This oak is a moderate light-demander, saplings establishing themselves readily in gaps, but not under cover which is at all heavy. At Dehra Dun it is frost-hardy. It coppices well up to a moderate size.

NATURAL REPRODUCTION. Experiments at Dehra Dun showed that seeds lying uncovered in the open tend to split, and fail to germinate, and that for successful germination under natural conditions they require either to become covered soon after falling or to lie shaded from the sun. In the Kaunli plantation natural seedlings appear in quantity under fairly dense shade, but these do not survive long except round the edges of the plantation where they have abundant light. In the Maymyo forests this oak regenerates freely in gaps and open spaces, where seedlings and saplings may often be found springing up in abundance.

ARTIFICIAL REPRODUCTION. For forest purposes direct sowing is usually preferable to transplanting, owing to the length of the taproot. Experiments at Dehra Dun, however, have shown that transplanting can be carried out quite successfully during the first rainy season by pruning down the taproot to a length of about 9 in. and cutting down the stem or stripping off the leaves; the seed should be sown in February, the beds being regularly watered and weeded, and by July or August the seedlings will have attained a height of 1–2 ft. with a taproot up to 2 ft. or more in length. The Kaunli plantation at Dehra Dun was formed in 1895 by transplants spaced 6 ft. by 6 ft. Successful results have been attained in the Maymyo fuel reserve by sowing in ploughed lines.

SILVICULTURAL TREATMENT. This oak is suitable for treatment under successive regeneration fellings, light being admitted early to the young crop; unregenerated gaps are easily filled up artificially by dibbling or by sowing in ploughed lines. Thinnings require to be commenced early, as the young crops are sometimes dense. The Kaunli plantation has suffered much from want of thinning.

RATE OF GROWTH. The growth under favourable conditions is rapid. A cross-section 8 ft. 1½ in. in girth in the silvicultural museum at Dehra Dun, cut from a tree grown in that place, had 45 annual rings, giving a mean annual girth increment of 2·17 in. The Kaunli plantation at an age of twenty-three years (from seed) had a mean girth of 23·6 in. and mean and maximum heights of 50 ft. and 69 ft. respectively; these measurements were made immediately after thinning. The plantation had not previously received attention in the way of thinning, otherwise the mean girth would probably have been greater. A thinning made at twenty-three years of age removed 673 stems per acre with a solid volume of 1,178 cubic ft., leaving 365 stems per acre with an estimated volume of 2,231 cubic ft.

7. **Quercus Griffithii**, Hook. f. Vern. *Dingim*, Khasi hills; *Metlein, thitcha*, Burm.

A large deciduous tree with coriaceous leaves 6–9 in. long, usually pubescent beneath. Wood very hard, of good quality. Bhutan, very common in the

FIG. 363 *Quercus glauca*—FLOWERS AND FRUIT × $\frac{3}{4}$

a—Young shoot and leaves with male catkins (1) and female flowers (2), March-April
b—Young acorns June   c—Half-grown acorn, August-September
d—Ripe acorn October-November, seven months after first appearance of female flower

inner valleys at 4,000–8,000 ft. from the Raidak valley eastwards (Jacob), Khasi and Naga hills, Manipur, hills of Burma east of the Irrawaddy and Sittang. A gregarious tree which, as Gamble remarks, deserves more attention owing to its excellent wood, which resembles that of *Q. Robur* of Europe. It has been successfully cultivated along with *Q. serrata* in the cinchona plantations near Darjeeling, and has shown fast growth.

This is one of the common oaks of Maymyo in Burma, where it grows at 3,500 ft. and upwards along with *Quercus serrata*, *Schima Wallichii*, *Castanopsis*, and many other trees, often with an undergrowth of bracken fern. It is a moderate light-demander, and regenerates freely in gaps and open spaces. At Maymyo it has been raised successfully by line sowings in blanks.

8. **Quercus glauca**, Thunb. Syn. *Q. annulata*, Smith. Vern. *Barin*, *báni*, *inái*, *phanát*, W. Him.; *Phalat*, Nep. (Fig. 365.)

A handsome evergreen tree with a dense rounded crown and a clean, cylindrical, though not very long bole. Leaves 3–6 in. long, oblong or ovate-lanceolate, upper part serrate, base entire, green, glabrous above, glaucous beneath. Bark thin, grey, smooth. Wood very hard, not much used except for fuel. A handsome tree worth cultivating for shade and ornament in moist situations. In the western Himalaya I have never seen any trees of large size, the largest found being about 5 ft. in girth and 50 ft. in height.

DISTRIBUTION AND HABITAT. Generally distributed throughout the outer Himalaya, ascending to 6,000 ft., also in the Khasi hills. The tree is found typically in moist situations in valleys, on the sides of ravines and along streams. In the Kangra valley it occurs at 3,000 ft. near Shahpur, mixed with *Quercus incana* and associated with *Albizzia stipulata* and other low-level trees. It is not as a rule gregarious except along the banks of streams; in moist localities in the western Himalaya it is often associated with *Machilus odoratissima* and other evergreen laurels, while *Quercus incana* is also one of its commonest companions. In the *Pinus longifolia* forests of the Kumaun hills it grows plentifully along some of the streams in the valleys, for example below Ranikhet. There is an interesting patch of forest between Baijnath and Dhelu in the Mandi state, at 4,000–5,000 ft. on a northerly aspect, where the rock is sandstone and shale, and the soil is a deep moist clayey loam; here *Quercus glauca* forms the great bulk of the crop, and in places is almost pure, its chief associates being *Quercus incana*, with a little *Pinus longifolia*, *Rhododendron arboreum*, and *Pieris ovalifolia*. In the Beas valley in lower Kulu it occurs at 3,000 ft., associated with *Quercus incana*, *Pistacia integerrima*, *Pyrus Pashia*, *Olea cuspidata*, and other trees. In Hazara it occurs in moist ravines in the *Pinus longifolia* forests of Khanpur and Siran at 4,000–5,000 ft.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The new green shoots and the delicate copper-coloured young leaves, with fine silky hairs on the under surface and subtended by light brown deciduous stipules, appear in March or early April. The old leaves commence turning yellow and falling soon after the young shoots appear, but are not all shed until the new leaves are fully out. The male catkins and female flowers appear with the new shoots. The male catkins (Fig. 362, *a*, 1), 2–3 in. long, are in dense pendulous clusters at the base of the new shoots, and the female flowers (Fig. 362, *a*, 2), usually in twos or threes, are sessile on common axillary peduncles 0·25–0·5 in. in length on the new shoots. After pollination the development of the young acorn is rapid. By the end of May or June the annulations are already distinct on the cup, which is 0·1–0·2 in. in diameter, and still encloses the nut (Fig. 362, *b*). The nut commences to protrude soon after, and by August or September the acorn is half grown but still green (Fig. 362, *c*). It ripens in October–November, that is in the short period of seven months from the time of first appearance of the female flower. The cup is shallow, greyish and annulate with several velvety belts of connate scales, and the nut (Fig. 363, *b*) is 0·6–0·9 in. long by 0·3–0·4 in. in diameter, pointed, light brown, smooth, shining and glabrous (Figs. 362, *d*, and 363, *a*). About 330–350 nuts weigh 1 lb. The nuts fall soon after ripening, separating readily from the shallow cups, which may remain for some months on the tree. The seed retains its vitality for some months at least ; seed kept for eight months and tested at Dehra Dun showed a fertility of 90 per cent.

GERMINATION (Fig. 363, *c–e*). Hypogeous. The shell of the nut splits towards the apex and the radicle emerges, at once descending and forming a taproot. Meanwhile the cotyledonary petioles elongate to about 0·2–0·3 in., enabling the plumule to emerge and the young shoot to ascend. The fleshy cotyledons remain within the shell attached for a considerable time to the young plant and providing it with nutriment in its earlier stages.

THE SEEDLING (Fig. 363).

Roots : primary root long, moderately thick, terete, tapering, woody ; lateral roots numerous, moderately long, fibrous, distributed down main root. *Hypocotyl* more or less distinct from the root, about 0·1 in. long, thick, subterranean. *Cotyledons* subterranean. Petiole 0·2–0·3 in. long, inner surface flattened. Lamina 0·7–0·8 in. by 0·35–0·4 in., thick, fleshy, elliptical oblong, apex rounded, base sagittate, forming a prolongation behind the petiole, outer surface rounded, inner flattened in contact. *Stem* erect, terete, green, glabrous ; first internode (above cotyledons) 2·5–3·5 in., subsequent internodes 0·2–1·8 in. long. *Leaves* simple, first pair usually opposite, subsequent leaves alternate. Stipules 0·2 in. long, linear acuminate. Petiole 0·2–0·3 in. long, flattened above. Lamina, first pair 0·9–2·3 in. by 0·5–1·5 in., elliptical, ovate or obovate, acuminate, subsequent leaves 1·5–4·5 in. by 0·5–1·3 in., elliptical lanceolate, acuminate, base tapering, sharply serrate, green, glabrous and shining above, glaucous beneath ; lateral veins prominent, parallel, 8–12 pairs.

Natural seedlings attain a height of about 5–7 in. during the first season, and nursery-raised seedlings ordinarily attain a height of 6–10 in. by the end of the first and 1–2 ft. or more by the end of the second season. Seedlings eight years old, the result of direct sowings in the Korwa forest, Jaunsar, had a mean height of 3 ft., but this growth is probably below the average, as the locality in which the sowings were made was a somewhat dry one. Experiments at Dehra Dun have shown that seedlings stand a fair amount of shade, but that they die off under heavy shade. The seedlings are rather sensitive to drought, and require a moist soil for their best development.

SILVICULTURAL CHARACTERS. This oak stands a considerable amount of shade, thrives best on moist rich soil, and does not grow well in dry situations. It coppices freely.

NATURAL REPRODUCTION. Under natural conditions germination commences early in the rainy season, about July, but in moist places germinating

FIG. 364. *Quercus glauca*— SEEDLING × $\frac{3}{8}$

a—Acorn b—Nut of acorn c-e—Germination stages f-i—Development of seedling to end of first season

seed has been observed early in May. Experiments carried out at Dehra Dun have shown that seed lying in the open exposed to the sun for any length of time invariably cracks and becomes infertile. For successful germination it is essential that the seed should either become buried soon after falling, or lie on very moist ground or under shade. Natural reproduction establishes itself under moderate shade, but after the young plants are well established they benefit by complete light overhead. In very moist almost swampy ground thickets of natural reproduction are sometimes met with.

ARTIFICIAL REPRODUCTION. This oak can be raised successfully either by direct sowing or by transplanting from the nursery. The best time for sowing, both direct and in the nursery, is the early spring, and transplanting from the nursery can best be carried out in the rainy season the year after sowing. Plantations should be made as far as possible in moist ravines and similar places, and not on dry ground.

9. **Quercus lamellosa,** Smith. Buk oak. Vern. *Búk*, Lepcha; *Bujrat, shalshi*, Nep. (Fig. 366.)

A large evergreen tree forming in the open a massive spreading crown and a short, often crooked bole, but producing in a close crop a tall clean straight bole. Leaves up to 18 in. long, elliptical-lanceolate, acute at both ends, sharply serrate, glabrous above, glaucous beneath. Bark grey and granular, often with a pinkish tinge in old trees. The stem and branches are almost invariably covered with a thick layer of moss. Wood very hard, durable under cover, used for building; an excellent fuel. This is the most important oak of the Darjeeling hills.

The tree attains a very large size, reaching under favourable conditions a height of 100–120 ft. and a girth of 15–20 ft., while girths up to 40 ft. have been recorded. The largest tree measured recently in the Kurseong forests was 24 ft. 2 in. in girth (H. S. Gibson). Large trees are, however, almost invariably hollow, and it is doubtful if trees much over 7 ft. in girth can be relied on to be thoroughly sound, though sound trees up to 10 ft. in girth or even more are occasionally met with.

DISTRIBUTION AND HABITAT. Eastern Himalaya from Nepal eastwards at 6,000–9,000 ft., Manipur at 7,000–9,000 ft. In the Darjeeling hills the tree is commonest between 6,000 and 8,000 ft. in mixed forest along with maples, laurels, *Michelia excelsa*, *Quercus lineata*, and other trees. It grows on any aspect, as well as on ridges, but thrives best on northerly slopes with deep, well-drained, fairly moist soil. On somewhat clayey loam it tends to become more or less gregarious, while in some old grazed areas the crop in places consists almost entirely of old misshapen buk trees. The climate of the Darjeeling hills is decidedly humid, with a rainfall of over 100 in.

FLOWERING AND FRUITING. The flowers appear in April–May, and the acorns ripen in November–December in the second year, falling soon after. The acorns are very large, broader than long, the cup up to 3 in. in diameter, woody, with a number of lamellae, enclosing the greater part of the nut. The nuts (Fig. 364, *a*) are 0·7–1·1 in. long by 0·9–1·5 in. in diameter, light brown, smooth, shining, with a broad base and a thick prominent, laminated, finely tomentose apiculum; about 45–50 weigh 1 lb. They are very subject to insect attacks, and a great deal of seed is destroyed in this way. The acorns

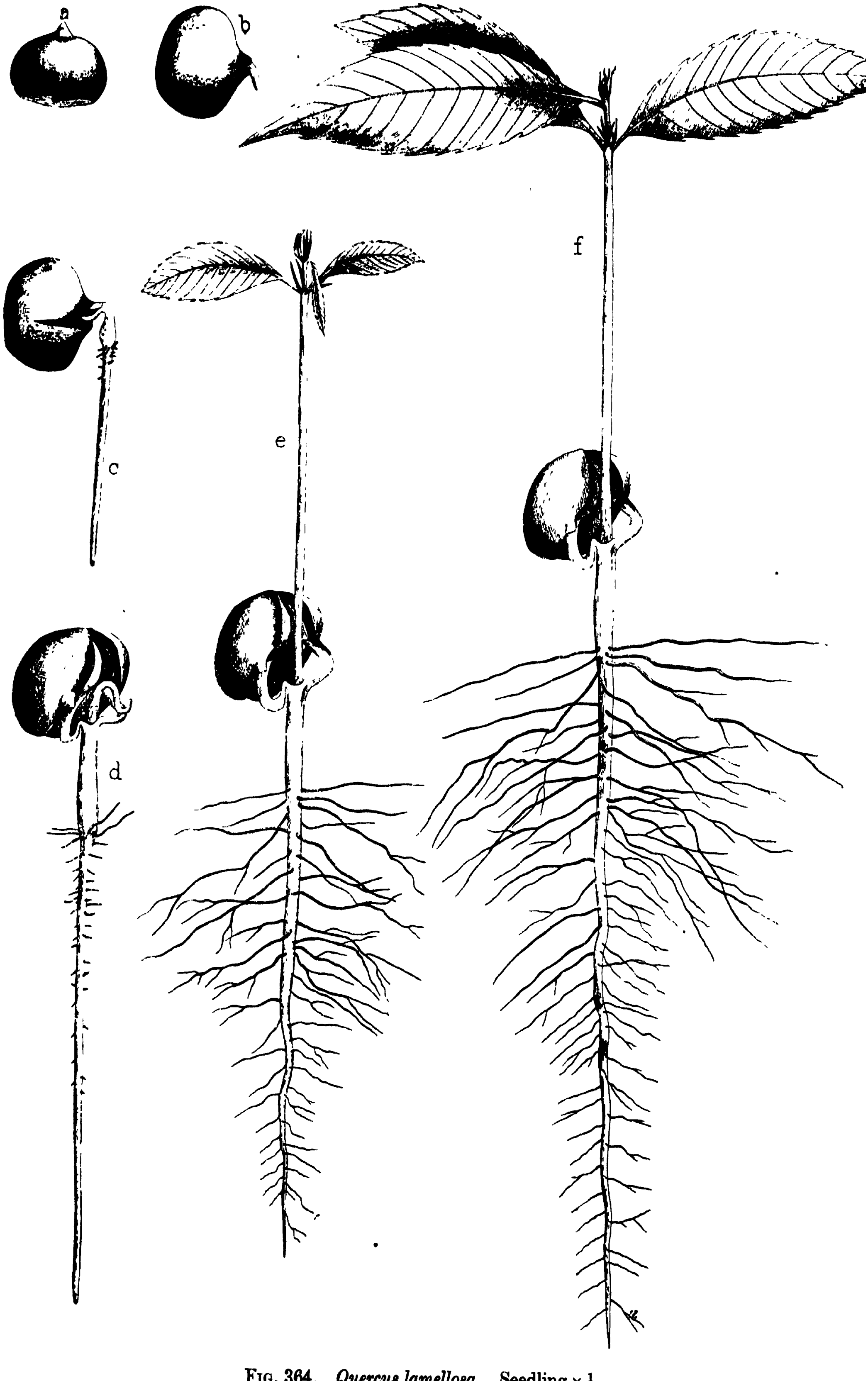


Fig. 364. *Quercus lamellosa.* Seedling × ½.
a, Nut of acorn ; b–e, germination stages ; f, seedling six weeks old.

are also greedily eaten by almost all wild animals, including bears, pigs, deer, monkeys, squirrels, and rats, and a considerable portion of the seed-crop is destroyed by them. Records of seed-years show that in the Darjeeling forests out of eight consecutive years the seeding was good in three years, fair in two years, and bad in three years. Ordinarily a good seed-year is expected about once in three years.

GERMINATION (Fig. 364, *b–e*). Hypogeous. The radicle emerges from the apex of the seed, the thick shell of which splits, and the taproot attains some length before the plumule emerges. The emergence of the young shoot is effected by the elongation of the cotyledonary petioles. The young shoot appears from between these petioles and arches during elongation, afterwards straightening. The taproot may attain a length of several inches before the young shoot appears above ground.

THE SEEDLING (Fig. 364).

Roots: primary root long, thick, terete, tapering, somewhat fleshy in young stages, soon turning woody, glabrous; lateral roots numerous, moderately long, fibrous, distributed down main root. *Hypocotyl* distinct from root, 0·8–1·2 in. long, thick, fleshy, somewhat compressed, tapering slightly upwards, glabrous. *Cotyledons*: petiole 0·9–1·2 in. long, flattened, somewhat fleshy, curved; lamina thick, fleshy, 0·7–1 in. long by 1–1·2 in. broad, outer surface rounded, rugose, inner flat, base prolonged to a blunt point. *Stem* erect, tapering slightly upwards from base to first node, somewhat compressed below that node, elsewhere terete, young parts woolly tomentose; internodes, first, from base to first node, 4–6 in., next few 0·4–1 in., in second year up to 2 in. long. *Leaves* simple, first pair opposite, subsequent leaves alternate. Stipules 0·3–0·5 in. long, linear acuminate, pubescent. Petiole 0·5–0·6 in. long, flattened or channelled above, pubescent. Lamina 4–6·5 in. by 1·5–2·5 in., elliptical lanceolate, acuminate, serrate, sub-coriaceous, bright green above, glaucous beneath, minutely pubescent or glabrescent when young, afterwards glabrous, lateral veins 9–12 pairs, often slightly depressed above, prominent beneath.

The growth of the seedling is moderate, an average height-growth of about 1 ft. per annum being usual during the first few years. A long stout taproot is formed from the commencement. Seedlings stand a fair amount of shade, but after their earlier stages they develop best with full overhead light; they have a tendency to produce numerous side branches, and require to be grown in a close crop for the production of clean stems. Seedlings are frost-hardy, but are sensitive to fire; they are damaged by grazing, but suffer to a less extent than most species in their habitat.

SILVICULTURAL CHARACTERS. Although shade-bearing in its younger stages, from the sapling stage onwards the tree develops best with full overhead light, but it requires much side shade to prevent the formation of side branches and promote a straight clean bole. It is hardy to frost and drought, but is very susceptible to damage by fire, large trees being sometimes killed outright. It coppices very well, even large trees throwing up healthy shoots. It does not produce root-suckers.

NATURAL REPRODUCTION. Owing to the quantity of acorns destroyed by insects and animals natural reproduction is not so good as it might be, although it is sometimes fairly good in areas which have been closed to grazing for some time. Clean bare ground does not appear to be necessary for germination as in the case of light seeds, the acorns germinating well on a carpet of undecayed leaves. A canopy sufficiently shady to prevent a dense undergrowth is beneficial, though after the seedlings have established themselves they require more overhead light; where the undergrowth is dense seedlings are scanty or absent. Mr. Manson[1] states that reproduction is most satisfactory where the soil is rich and light and where there is no grazing, and especially on ridges or where the forest is open or the cover particularly lofty; he adds that the *maling* bamboo (*Arundinaria racemosa*), which generally grows best on ridges where there is abundant light, and of which the haulms retain the fallen leaves, seems to assist the reproduction of the oak in places where the bamboo itself is protected from cattle. He mentions also that the young plants seem to require protection, and may be found under the shelter of a boulder, stump, or fallen tree, having possibly sprung from acorns which have been left by squirrels or have escaped their notice. Hoeing the soil or clearing the undergrowth round seed-bearers is said to be ineffective, as this only attracts animals and enables them to find the acorns.

Artificial reproduction. Direct sowings have been found to give much better results than transplanting unpruned nursery-raised seedlings, as the long taproot renders transplanting somewhat difficult. Mr. J. R. P. Gent, however, informs me that he has transplanted in the rains with complete success nursery seedlings four years old with stems about 1 in. in diameter, after pruning off the taproot and cutting off the stem immediately above the lowest side branch; this system would probably be found useful for filling up blanks in young plantations. Whatever method is employed, the seed should be sown as soon after ripening as possible, and certainly not later than January, owing to its liability to insect attacks if kept any time. The seeds require to be sorted carefully, those which are badly worm-eaten being discarded; seeds which float in water are usually considered unsuitable. In the Kurseong forest division the method usually followed in the case of direct sowings is to loosen the soil to a depth of about 18 in. in patches 1 ft. square and to bury the seeds 3 or 4 in. below the surface; as a rule two or three seeds are sown in each patch, as germination is somewhat uncertain and the seeds, even in the ground, are liable to destruction by animals. The seedlings ordinarily appear in May, and require to be kept free from weeds and climbers for three or four years. In some places the loosening of the soil prior to sowing is considered unsuitable, as it attracts animals.

For transplanting purposes the seeds are sown in seed-beds in December or January at intervals of about 3 in. and at a depth of about 3 in.; they are usually pricked out about 1 ft. apart in the nursery when one year old and transplanted when about three years old and 2–3 ft. in height. Transplanting is best carried out in February or March, before the season's growth commences; it may also be carried out towards the end of the rainy season, about August, after the new leaves have hardened.

Rate of growth. The annual rings are usually indistinct, but Gamble estimates the growth at about 8 to 12 rings per inch of radius, giving a mean annual girth increment of about 0·5 to 0·8 in.

[1] Darjeeling Working Plan, 1893.

FIG. 365. *Quercus glauca*, girth 3 ft. 4 in., height 40 ft., Kumaun hills.

FIG. 366. *Quercus lamellosa*, girth 10 ft., height about 100 ft., bole about 50 ft., Darjeeling hills.

FIG. 367. *Populus ciliata* on island in Kunhar river, Kagan valley, Hazara.

Mr. H. S. Gibson says a girth of 6 ft. is reached in about 120 years, and gives the average growth up to twenty years as follows :

Quercus lamellosa : rate of growth of young trees, Darjeeling hills.

	Mean height.		Mean girth.	
Age.	Natural.	Artificial (planted).	Natural.	Artificial (planted).
years.	ft.	ft.	in.	in.
1	1	1		
2	2	2		
3	3	3		
4	4	3·5		
5	7	4		
6	10	5		
10	18	8		
15	30	14		
20	40	22	18	10

Mr. J. L. Baker says that measurements recently made in abandoned nursery-beds in the Darjeeling hills indicate that under such favourable conditions trees grown in dense crops might, at the rate of growth exhibited, be expected to attain a girth of 6 ft. in about sixty-two years, at all events at the lower elevations.

10. **Quercus lineata,** Blume. Vern. *Phalat*, Nep.

A large evergreen tree with thick brown rough bark. Eastern Himalaya at 6,000–9,000 ft., Khasi and Naga hills, Arakan, hills of Upper Burma. This is an important tree of the Darjeeling hills ; it is a common companion of the buk (*Q. lamellosa*), and the wood of the two is used almost indiscriminately, though that of the buk is considered somewhat the better. The nut of the acorn is depressed, often broader than long, in a broad shallow cup. The acorns are much subject to the attacks of insects and animals, and natural reproduction suffers in consequence. The treatment of this tree is similar to that of *Q. lamellosa*, and the two are often grown together artificially. Flowers April–May ; fruits September–October (Manson, Darjeeling).

11. **Quercus spicata,** Sm. Syn. *Q. squamata*, Roxb. Vern. *Arkaula*, Nep.; *Bara chakma*, Beng.; *Thitcha, sagat*, Burm.

A moderate-sized to large tree with large but very variable leaves, and acorns several close together on spikes. Eastern Himalaya from Nepal eastwards, ascending to 5,000 ft., common in moist *jhoras* or depressions in the Duars ; Assam, Manipur, and dry hills of Burma. Gamble says it is often gregarious, and forms in the Darjeeling hills a sort of coppice wood, preferring somewhat dry exposed ridges, and usually associated with *Engelhardtia spicata* and *Schima Wallichii*. It coppices profusely. Flowers March–April; fruits September–October of second year (Manson, Darjeeling).

12. **Quercus pachyphylla,** Kurz. Vern. *Bara katús, singori katús*, Nep.

A large evergreen tree attaining a height of 80–100 ft. or more and a girth of 15 ft. Var. *fruticosa*, Manipur, is a shrub or small tree. Leaves 5–8 in. long, smooth and greyish. Acorns crowded together into compact masses with cups confluent. Wood of good quality, used for planking, shingles, &c. Sikkim, in the inner hills at 6,000–10,000 ft., usually at higher elevations than *Q. lamellosa*, and common on the Singalila ridge. Manipur at 7,000–9,000 ft. The acorns, which ripen about November, are much subject to the attacks of insects and animals, and reproduction suffers in consequence. Manson[1] says seedlings are fairly numerous in the neighbourhood of the parent trees. He gives the rate of growth as 8 to 10 rings per inch of radius, representing a mean annual girth increment of 0·63 to 0·78 in.

2. CASTANOPSIS, Spach.

Evergreen trees with erect male catkins and nuts of the fruit wholly enclosed in the involucre, which is covered with spines or tubercles. Twelve Indian species, of which eleven are found in Burma.

Species 1. *C. indica*, A. DC.; 2. *C. Hystrix*, A. DC.; 3. *C. tribuloides*, A. DC.

1. **Castanopsis indica,** A. DC. Syn. *Castanea indica*, Roxb. Vern. *Banj katús*, Nep.; *Thitè*, Burm.

A moderate-sized to large evergreen tree with elliptical oblong sharply serrate leaves and silvery grey bark. Wood fissile and largely used for shingles, as well as for building. Eastern Himalaya from Nepal eastwards, ascending to 6,000 ft.; in Bhutan all along the outer hills up to 4,000 ft. (Jacob); Assam, Chittagong, hills of Upper Burma east of the Irrawaddy. Common in the Darjeeling hills, especially on dry slopes and on abandoned cultivation. Flowers November–December: fruits September–October (Darjeeling). The nut, which is edible, is enclosed in a very prickly involucre. The tree coppices and pollards well. Gamble gives the rate of growth at about 4 to 6 rings per inch of radius, representing a mean annual girth increment of about 1 to 1·6 in., which is fast.

2. **Castanopsis Hystrix,** A. DC. Syn. *C. rufescens*, Hook. f. and Th. Vern. *Katús, bara katús*, Nep.; *Hingori*, Ass.

A large evergreen tree, reaching a height of 100–120 ft. and a girth of 15 ft. or more. Leaves lanceolate, with a fine rusty tomentum beneath. Wood much used for shingles and planking in the Darjeeling hills. Sikkim and Bhutan at 6,000–8,000 ft. (common in the Takdah forest, Darjeeling hills); Assam, hills of Upper Burma east of the Irrawaddy and of Martaban. Flowers May; fruits September–October (Darjeeling). The nut, which is edible, is enclosed in an involucre with stellately branched spines. Natural reproduction is fairly good in the Darjeeling hills, and the seedlings stand a good deal of shade for some years. Artificial reproduction is best secured by dibblings *in situ*, the ground being disturbed as little as possible to prevent attracting squirrels, rats, and other animals, which devour the nuts. Transplanting from nurseries has been found difficult. The tree coppices well. Gamble gives the growth at about 8 rings per inch of radius, representing a mean annual girth increment of 0·78 in.

3. **Castanopsis tribuloides,** A. DC. Syn. *Castanea tribuloides*, Wall.; *Quercus ferox*, Roxb. Vern. *Tumari, katonj*, Kumaun; *Musre katús*, Nep.; *Thitegyin, kyansa*, Burm.

A moderate-sized evergreen tree with lanceolate acuminate leaves, green above and pale beneath. A variable tree with a wide distribution. Outer Himalaya from the Ganges eastwards, ascending to 6,000 ft., evergreen forests of the Duars, Assam, Manipur, Chittagong, hills of Burma. Flowers March; fruits May (Duars). Nut edible, enclosed in an involucre armed with stout, often clustered spines. The tree coppices very well.

[1] Darjeeling Working Plan, 1893.

3. CASTANEA, Tourn.

Castanea sativa, Miller. Syn. *C. vulgaris*, Lam.; *C. vesca*, Gaertn. Spanish or sweet chestnut.

A native of southern Europe. Cultivated in the Himalaya for the sake of its fruit. It succeeds fairly well up to about 6,000 ft., and grows well at Dehra Dun (2,000 ft.); it tends to branch low, however, and does not produce the height-growth attained in Europe. The fruit ripens well, but it is not of such large size or such good quality as in Europe. In some parts of the Himalaya the trees tend to reproduce naturally. It has succeeded best at fairly low elevations, about 3,000–5,000 ft., on northern aspects, moderately dry regions, and fertile but somewhat sandy soil. In Europe it does not do well in soils containing much lime or in clayey soils, requiring a sandy but deep and fertile soil for its best development. The tree is grown from seed. In Europe it is usual to keep the nuts in dry sand over the winter, as a protection against mice, and to sow them in the nursery in the spring, pricking them out with somewhat close spacing when one year old, and planting them out when two years old. In India the nuts do not keep well, and it is sometimes found advisable to sow them when they ripen, about August or September. The tree is a moderate light-demander; it coppices well, and in Europe is frequently grown as coppice for the supply of poles of different sizes. In Europe it is sensitive to late and early frosts, but in those localities in which it has been cultivated in India it withstands all ordinary frosts.

ORDER LX. SALICACEAE

This order, which comprises the willows (*Salix*) and the poplars (*Populus*), is of somewhat secondary importance in India; with few exceptions its members are confined to the Himalaya. The trees are deciduous, and the flowers are dioecious, in catkins similar in both sexes.

Genera 1. SALIX, Linn.; 2. POPULUS, Linn.

1. SALIX, Linn.

There are 27 known indigenous willows, of which 24 are purely Himalayan, some of them little known, two non-Himalayan, and one (*S. tetrasperma*, Roxb.) extending throughout the greater part of India and Burma, including the outer Himalaya. In addition there are four introduced species, namely *S. alba*, *S. fragilis*, *S. babylonica*, and *S. Caprea*. Another species which has recently been tried on a small scale in Kashmir is *S. coerulea*, the chief willow used in England for cricket bats.

The willows are shrubs or trees, often fast-growing, with soft white or light red even-grained wood. They pollard and coppice vigorously, grow readily from cuttings, and are very useful for planting along river-banks or on unstable hill-sides to fix the soil. The twigs of most willows are used for basket-work, and there is scope for the cultivation of suitable species for the manufacture of baskets for the Himalayan fruit trade.

In raising willows from cuttings straight shoots 2–3 ft. long and 2–4 years old, with well-matured wood, should be selected from pollarded or coppiced trees ; the cuttings should have a slanting cut at each end. In moist ground thick shoots up to 10 ft. or more in length strike readily, though under ordinary conditions shoots 3 or 4 ft. long and about ½ to 1 in. in diameter are suitable. The cuttings are planted *in situ* in the rainy season, or, if watering or irrigation is possible, in January or early February, before sprouting commences. Where the ground is too dry for the direct planting of the cuttings it may be necessary to plant them in the nursery, watering them and keeping them there until they are well rooted, when they are planted out. Cuttings so treated may be planted in the nursery early in February, before sprouting commences, or in the rainy season.

The Himalayan willows are leafless in the winter, and sprout early in the spring, the flowers appearing with or before the new leaves. The flowers are dioecious, in catkins bearing numerous flowers on a slender axis. The fruit, a small capsule dehiscing into two recurved valves, ripens as a rule 2–3 months after flowering. The seeds are minute, with long silky hairs enabling them to be carried a long distance by the wind. In the Himalaya seedling reproduction springs up readily on newly exposed ground on landslips, in cuttings, on depressions scoured by snow, and similar places ; here willow seedlings may often be found in quantity, and they perform a useful function in fixing unstable hill-sides and preparing the way for the establishment of other trees.

Species 1. *S. tetrasperma*, Roxb. ; 2. *S. Wallichiana*, And. ; 3. *S. elegans*, Wall. ; 4. *S. daphnoides*, Vill. ; 5. *S. alba*, Linn. ; 6. *S. coerulea*, Sm. ; 7. *S. fragilis*, Linn. ; 8. *S. babylonica*, Linn. ; 9. *S. Caprea*, Linn.

1. **Salix tetrasperma**, Roxb. Indian willow. Vern. *Bed, bains, bilsa, laila*, Hind. ; *Bocha, bitasa*, Mar. ; *Niranji*, Kan. ; *Momaka, yenè*, Burm.

A small or moderate-sized, sometimes large deciduous tree, often evergreen in Burma, very variable, with silky pubescent shoots and lanceolate or ovate-lanceolate acuminate leaves. Bark rough, with deep vertical fissures. Wood red, soft, even-grained, used for planking and well-construction, and has been successfully tried for match-manufacture. The twigs are used for basket-work, and the branches are lopped for fodder. It is a useful tree for planting along rivers and streams to support their banks, and for growing on wet ground.

This is the common willow of India, and is found, often growing gregariously along the banks of rivers and streams and in wet swampy places generally, throughout the greater part of India and Burma, ascending to 6,000 ft. in the Himalaya and 7,000 ft. in the Nilgiri hills. The season of flowering and fruiting seems to vary. In northern India the tree is leafless in the cold season, the leaves falling after the end of the rainy season ; the new leaves and the catkins appear in February–March, and the fruit ripens about April, but in some localities flowering takes place in the autumn. Haines[1] says the tree in Chota Nagpur is deciduous in September, the flowers appearing on the new shoots in October and the fruits ripening in December–January ; he adds that in some districts of Bengal it flowers in the hot season. Talbot says in Bombay it flowers in October–November.

The tree grows well from cuttings planted in moist places, and stands flooding, often sending out small rootlets near the base of the stem when

[1] For. Flora Chota Nagpur, p. 402.

subject to inundation. It coppices and pollards well. It is decidedly frost-hardy, and in the great frost of 1905 in northern India it was almost the only tree which escaped injury. In the abnormal drought of 1907 and 1908 in the forests of Oudh it suffered to some extent when the streams and swamps dried up.

The rate of growth is fast. Gamble's specimens gave 2 to 7 rings per inch of radius, representing a mean annual girth increment of 0·9 to 3·14 in. In the Delhi Bela plantation Mr. Minniken found the growth to be 2 to 2½ rings per inch of radius, giving a mean annual girth increment of 2·52 to 3·14 in.

2. **Salix Wallichiana,** And. Vern. *Bhains, bhainshra,* W. Him.

A large deciduous shrub or small tree, with young parts silky and leaves lanceolate acuminate, usually entire, when young silvery pubescent on both surfaces or on the under surface. Bark greenish grey. A common species in the Himalaya, extending eastward to Bhutan, chiefly at 7,000–8,000 ft. but ascending to 9,000 ft. and descending almost to the plains. Kurram valley at 10,000–12,000 ft. Flowers March–May, with or before the new leaves. The branches are used for basket-making.

3. **Salix elegans,** Wall. Vern. *Bed, báshal, bail,* W. Him.

A deciduous shrub. Leaves 1–3 in. long, ovate or oblong, obtuse, rarely acute. Bark greenish grey. The commonest species of the western Himalaya, at 6,000–11,000 ft., growing gregariously and often forming dense, almost impenetrable thickets of some extent. It is a very useful shrub for reclothing new ground and for preventing erosion. It is also a useful nurse for more valuable species, which establish themselves under its cover. The twigs are cut for cattle and goat fodder.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves fall about November–December. The new leaves and flowers appear in March–April, and the fruits ripen in May–June. The seeds (Fig. 368, *a*) are 0·06 in. long, green, pointed at one end, blunt at the other, with numerous long white silky hairs attached to the blunt end.

GERMINATION (Fig. 368, *b–e*). Epigeous. The minute seed swells up, becoming bright green. The thin delicate papery testa at first encloses the unopened cotyledons like a pointed cap, but soon falls and the cotyledons expand. The apex of the radicle is enveloped for a time in the silky hairs of the seed until the young root pushes its way down through them.

THE SEEDLING (Fig. 368).

Roots: primary root long, terete, wiry, flexuose, giving place in second year to a large bushy mass of long fibrous roots; lateral roots in first year moderate in number and length, distributed down main root. *Hypocotyl* distinct from root, about 0·1 in. long, tapering upwards, glabrous, often slightly curved. *Cotyledons* shortly petiolate, 0·1–0·15 in. by 0·05 in., foliaceous, slightly fleshy, ovate oblong, entire, green, glabrous, apex rounded. *Stem* erect, terete, green and minutely pubescent in first season, previous year's stem greyish green in second season; internodes up to 0·2 in. in first year, up to 1 in. in second year; winter buds reddish. *Leaves* simple, alternate. Stipules minute. Petiole up to 0·15 in. long in first two years, flattened or channelled above. Lamina in first year 0·15–1·2 in. by 0·05–0·4 in., in second year 1–2·5 in. by 0·3–0·8 in., ovate- or oblong-lanceolate, acute or acuminate, serrate, bright green above, paler beneath, young leaves pubescent, older leaves glabrous.

During the first season the growth of the seedling is slow; by the end of the season a height of 0·5 to 2 in. is attained, the number of leaves varying from 5 to 15. During the second season the growth is much faster, the average height at the end of the season being 1½ ft. The seedling requires an abundance of light, soon becoming suppressed under shade; it is very sensitive to drought, and requires a good deal of moisture in the soil. The seedlings are leafless during the winter, the new leaves appearing as a rule in March. Before falling the leaves are often shrivelled up by frost, which does not affect the stem.

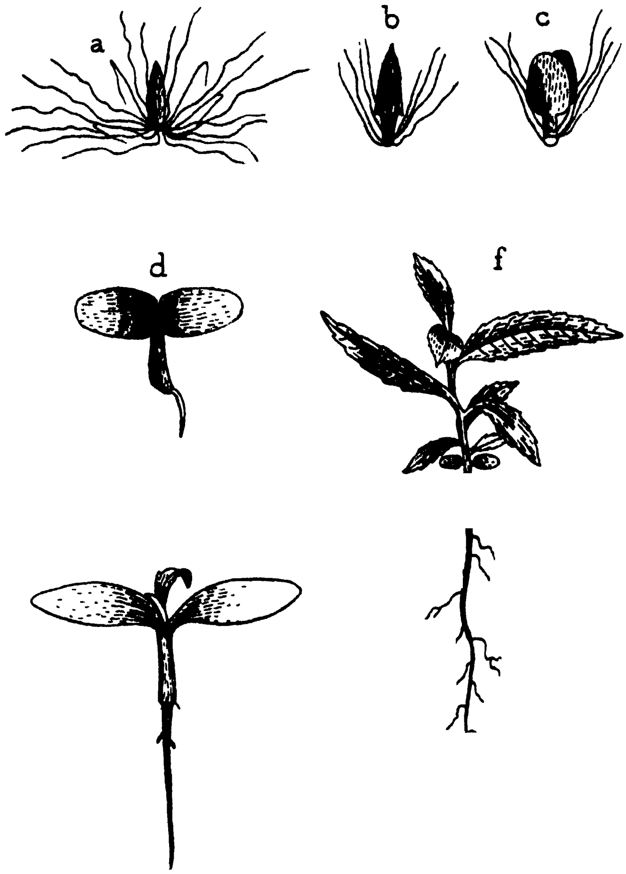


FIG. 368. *Salix elegans*. Seedling.

a, seed × 5; *b–e*, germination stages × 5; *f*, seedling 2½ months old ½.

NATURAL REPRODUCTION. Under natural conditions germination takes place early in the rainy season. This willow, like many others, springs up in abundance on ground newly exposed by landslips, or on depressions scoured by snow sliding down the hill-sides.

ARTIFICIAL REPRODUCTION. This species can be grown readily from cuttings in the manner described in the introduction to this genus. It is also easily raised from seed. Fresh seed should be sown in light soil in boxes during June, the boxes being sheltered from heavy rain and regularly watered. Germination commences in a few days. Where they are congested the seedlings should be pricked out towards the end of the rainy season. They will usually be large enough to plant out in the following rainy season, though if large plants are required they may be pricked out in the nursery when a year old and finally planted out the following February, before they sprout, or in the ensuing rainy season.

4. **Salix daphnoides**, Vill. Vern. *Bed, bail, bhashli, bashroi*, W. Him.

A large deciduous shrub or small tree. Branches dark green or nearly black, often with a glaucous bloom. Leaves 3–5 in. long, elliptical lanceolate, acuminate, serrate. Bark greenish grey, smooth. Western Himalaya at 2,500–15,000 ft., extending to the inner arid zone. A common species, especially at about 7,000–9,000 ft. Brandis says it attains 60 ft. with a straight erect trunk, 6–7 ft. and at times 9–12 ft. in girth. According to Stewart it is much grown from cuttings in Lahoul between 8,500 and 11,000 ft., generally near water. Flowers March–April, before the new leaves ; fruits May–June. The wood is used in the inner arid tracts for building and utensils. The twigs are used for baskets and wattle-work, and the branches are lopped for fodder, the trees in the inner Himalaya being pollarded on a rotation of 3–5 years. It has been employed largely in north Germany for fixing the ground on railway embankments and cuttings and on dry sand-hills, for which its strong long-spreading roots render it particularly suitable (Brandis).

5. **Salix alba**, Linn. White willow.

A large deciduous tree with ascending branches, the branchlets spreading or pendulous. Leaves lanceolate acuminate, upper surface greyish green with silky pubescence, lower surface whitish with dense silky pubescence. Bark light brown, fissured.

Indigenous to Europe, western and northern Asia. Frequently cultivated in the western Himalaya up to 7,000 ft., growing best along water-courses. Flowers March–April.

There is a demand for the wood in the Punjab for making cricket bats. In England, however, the wood of this species is considered of less value for the purpose than that of *S. coerulea*, Sm., and is used only for inferior bats.

6. **Salix coerulea**, Sm. Cricket-bat willow.

This willow is of special importance as being the species whose wood furnishes the best cricket bats. Its introduction into India has recently been attempted, 1,000 cuttings having been imported from England in 1916–17 and planted in the Kitriteng plantation in Kashmir. The experiment did not prove very successful, but in view of the probable demand for the wood it is worth repeating in other localities. The following brief account of this willow is based entirely on the description given by Elwes and Henry.[1]

A large tree with ascending branches making a narrow angle with the stem and forming a pyramidal crown. Terminal branchlets erect, not spreading or drooping. Bark smoother than in *S. alba*. Leaves similar to those of *S. alba*, but thinner in texture, more translucent and less densely pubescent, lower surface not white but bluish grey. Most botanists consider this tree a variety of *S. alba*. No male trees are known to exist, and Henry considers it possible that it is a first cross between *S. alba* and *S. fragilis*, with most of the characters of the former dominant. Its growth is much faster than that of *S. alba*, and it produces a wood light in weight, very

[1] The Trees of Great Britain and Ireland, vii. 1763.

elastic and tough and eminently suitable for the manufacture of cricket bats of the best quality.

The tree appears to be confined to the eastern counties of England, where it has been known for over a century. It thrives best on rich light alluvial soil by the side of running streams, and grows well also on moist fertile loam; clay and gravel soils or badly drained marshy ground are unsuitable for it.

The following interesting account by Henry of the cultivation of this willow may be quoted:

'At the present time it is the invariable custom amongst expert growers of cricket-bat willow to use large sets, up to 20 ft. long and 3 in. in diameter, and scarcely smaller than 6 to 10 ft. long by 2 in. in diameter. The sets are best obtained from young trees that have been felled for sale or that have been specially pollarded for the purpose, and should never be taken from the tops of old trees, as these are seldom straight, and require trimming. A young tree, about ten years old, gives the best sets when pollarded, and can be again pollarded every five or six years for six or seven times until decay sets in. The sets should be cut in early spring. Mr. Pratt, after trimming them for four-fifths of their length, has them tied up in bundles of ten and kept in water for a month, after which they are planted out.

'As the willow is a light-demanding tree, and the grower's object is to produce, as quickly as possible, a short stem clean of branches for about 12 to 15 ft., a good crown of foliage must be preserved from the start, and the trees should be planted so wide apart that they do not interfere with each other by lateral shade. If closely planted, they grow more slowly, and often develop an elliptical instead of a circular stem. The distance apart along the side of a stream should not be less than 10 yards. Close planting to kill undergrowth or grass is a mistake, as the latter, if necessary, can be removed by cultivation, though this is seldom done.

'Holes may be made for the sets by driving in a stake two or three feet deep, which can afterwards be levered out. The sharpened end of the set is then dropped into the hole, and tightly rammed in position. It is very important to insert the set deeply and firmly, so that it may not be shaken by the wind. The after care consists in rubbing off in the first three years, with the gloved hand, as high up as possible, the buds which appear on the stem, so as to prevent the development of side shoots. Mr. Pratt advocates the pruning of the stem afterwards to a height of 25 ft., but this is seldom if ever done in Herts. or Essex, where growers are content with a stem clear of branches to 12 or 15 ft.

'Willow trees become saleable to bat-makers when about 15 in. in diameter at six feet from the ground, or about 13 in. at twelve or fifteen feet up. The original set remains as a useless core in the centre of the stem. As the width of a bat is about 5½ in. and the clefts are taken radially, the minimum diameter should be 5½ in. + 5½ in. + 2 or 3 in. (the diameter of the set) = 13 or 14 in. The trees may of course be allowed to grow for another period of years, until a second ring of clefts is formed around the first ring, or even for a further period; but it is usually most profitable to dispose of the trees when they are young.

'The trees are generally sold standing, and are deemed of first quality when the stem is straight, clear of knots or branches, and covered with a smooth scaly bark, which is indicative of rapid growth. As the length of a bat is about 28 in., the trees as soon as felled, which is done in winter, are cross-cut into lengths of 28 to 30 in., and these in turn are split into clefts. The clefts are split up along the radii, so that the annual rings run from the front to the back of the bat. The best clefts come from the lower part of the tree, which is far tougher than the upper portion. In the best bats I have counted from seven to nine annual growths.'

FIG. 369. *Populus ciliata* in ravine running through forest of *Pinus excelsa*. Hazara.

7. **Salix fragilis,** Linn. Crack willow.

A moderate-sized deciduous tree with lanceolate serrate leaves terminating in a long oblique acuminate apex, and each serration terminating in a reddish brown gland. Branchlets easily breaking off at their insertion, especially in spring. Bark rough, with prominent ridges alternating with deep broad fissures.

Believed to be indigenous throughout the greater part of Europe and in western Asia. Cultivated in the Kurram valley, Gilgit, Ladak, Lahoul, and Baluchistan. It requires more moisture than *S. alba*, growing chiefly along the banks of rivers, streams, and lakes. In Europe the growth is moderately fast, but a specimen from Lahoul showed 11 rings per inch of radius (Gamble), giving a mean annual girth increment of 0·57 in., which is rather slow.

8. **Salix babylonica,** Linn. Weeping willow.

A small or moderate-sized picturesque deciduous tree with spreading branches and long pendulous branchlets. Bark rough, with fissures and ridges.

The original home of this willow is believed to be central and southern China, where it occurs along the banks of rivers and water-courses. It is extensively cultivated in Europe and in other parts of the world. It is frequently seen in cultivation in northern India, from the plains up to 9,000 ft., and in Baluchistan ; it thrives best at comparatively low elevations, up to about 5,000 ft. It is grown to a small extent along irrigation channels in the Changa Manga plantation in the Lahore district, where there is a limited demand for the wood for cricket bats, though the price received is small ; it is found, however, to be short-lived, and when the trees die they decay rapidly. In India the new leaves and catkins appear in February–March, and the fruit ripens about two months later. The male tree is much commoner than the female.

In Europe the young shoots are very liable to be killed by frost, as the tree sprouts early. It thrives best in comparatively warm climates and in moist soil beside running water. It strikes readily from cuttings and grows rapidly in suitable localities. A cross-section in the silvicultural museum at Dehra Dun showed 27 rings for a girth of 3 ft. 3 in., giving a mean annual girth increment of 1·44 in. According to Gamble the growth is usually about 4 to 5 rings per inch of radius, giving a mean annual girth increment of 1·26 to 1·57 in.

9. **Salix Caprea,** Linn. Sallow, goat willow.

A small tree with oval or elliptical leaves with an undulate or crenulate, rarely entire margin ; stipules large and reniform. Bark smooth and greenish in young trees, afterwards fissured.

Indigenous to Europe and northern Asia. Cultivated in the Punjab, chiefly along river banks. It is less exacting than most willows as regards soil, growing on dry and even rocky ground, as well as in swampy localities. It grows readily from cuttings, and is useful for fixing shifting soil and river-banks. It is often little more than a shrub. Flowers February–March, before the leaves.

2. POPULUS, Linn.

There are six species of poplar in India, either indigenous or introduced, of which *P. ciliata*, Wall., and *P. euphratica*, Olivier, are the most important ; the others either are planted for shade or ornament or are quite local. The poplars are soft-wooded, usually fast-growing trees. Most of them produce root-suckers in great abundance, pollard well, and grow readily from cuttings. The coppicing power appears to vary. The minute seeds, enveloped in tufts of long white silky hairs, are distributed by the wind, and seedlings spring up on newly exposed or recently formed ground (see under *P. ciliata* and *P. euphratica*). Much of the seed is infertile, and germination appears to be successful only under special conditions (see under *P. ciliata*).

Species 1. *P. ciliata*, Wall.; 2. *P. nigra*, Linn.; 3. *P. alba*, Linn.; 4. *P. euphratica*, Olivier.

1. **Populus ciliata,** Wall. Himalayan poplar. Vern. *Safeda, piplás, pahari pipal, chelaun, chalni, ban pipal, bagnu,* W. Him.

A large deciduous tree with a tall clean straight bole. Leaves broadly ovate acuminate, usually with a cordate base; margins serrulate-crenate and ciliate. Buds viscid and resinous. Bark of young trees and branches smooth greenish grey, that of old trees dark brown, rough, with deep vertical fissures. Wood whitish to greyish brown, sometimes yellowish brown in the centre, soft. It is not much used in the Himalaya owing to the presence of coniferous woods which are more in demand; it has, however, been pronounced excellent for match manufacture. This is a useful tree for afforestation purposes on unstable hill-sides. Under favourable conditions it reaches large dimensions. In 1918 I measured three trees in Hazara with girths of 9 ft. 8 in., 11 ft. 1 in., and 12 ft. 9 in., with estimated lengths of clear bole of 50 ft., 70 ft., and 50 ft. respectively, and estimated heights of 100 to 120 ft.

Distribution and habitat. Himalaya from Kashmir to Bhutan, at 4,000–10,000 ft. In the western Himalaya it is a common and conspicuous tree in mixed broad-leaved, oak, and coniferous forests. It is capable of growing on dry hill-sides, where it sends up numerous suckers; in such places it does not attain large dimensions. In coniferous forests it is perhaps most frequently associated with blue pine, and trees of large size are often found in ravines running through blue pine forests (Fig. 369); it is also frequently found with deodar, spruce, or silver fir. In the upper Siran valley there are some very fine specimens, with tall straight boles, growing in forests of spruce and silver fir. As a rule the poplar reaches its largest dimensions in ravines in mixed broad-leaved forests, associated with *Aesculus indica, Prunus Padus, Cedrela serrata, Ulmus Wallichiana*, maples, and oaks. In places it is found, usually in pure patches, on islands in the beds of streams, as along the Kunhar river in the Kagan valley, Hazara (see Fig. 367), and in the Kishanganga valley, Kashmir. It thrives best on a well-drained porous soil.

Leaf-shedding, flowering, and fruiting. Some trees commence shedding their leaves early in September and are almost leafless by the end of that month. Others shed them later, but all are leafless as a rule by the end of November. The new leaves appear towards the end of March or early in April, the catkins appearing immediately before the young leaves. The male catkins are 3–6 in. long, yellow, pendulous; the female, on separate trees, are also pendulous, but are somewhat stiffer and greener. The female tree is much commoner than the male. The fruits ripen in June, the catkins elongating to 6–12 in. and the 3- or 4-valved capsules opening and permitting the minute seeds, enveloped in silky down, to escape. During June the air in the neighbourhood of poplar trees is full of flecks of down floating about in the breeze. This is objected to in some hill stations, and the tree is discouraged in consequence, and ruthlessly lopped or cut. A more sensible arrangement would be to plant cuttings of male trees and to encourage the growth of what is a decidedly handsome and interesting tree.

The seeds (Fig. 370, *a*) are about 0·05 in. long, light brown, covered with minute bristles by means of which they cling to the masses of silky down. The fine white silky hairs attached to the seeds are 0·25–0·35 in. long; these hairs are easily separated from the seeds, and are then found to be attached together at their bases in threes. A large proportion of the seeds are infertile; the maximum I have obtained in various tests is 23 per cent. of success. Possibly the scarcity of male trees may account for the want of fertility of much of the seed.

GERMINATION (Fig. 370, *b–f*). Epigeous. The testa splits longitudinally down one edge like a follicle and the radicle emerges. There is slight arching of the hypocotyl, and the cotyledons, enclosed in the testa, are raised above ground by the elongation of the hypocotyl; the testa falls to the ground with the expansion of the cotyledons.

THE SEEDLING (Fig. 370).

Roots: primary root moderately long, terete, tapering, thick after first season; in first season a taproot often not developed; lateral roots numerous, long, fibrous. *Hypocotyl* distinct from root, 0·2–0·4 in. long, terete, white turning pale green to reddish green. *Cotyledons*: petiole 0·06–0·08 in. long; lamina 0·08–0·12 in. by 0·08–0·12 in., foliaceous, broadly ovate, sometimes broader than long, apex rounded, base rounded or truncate or broadly cordate, entire, green, glabrous. *Stem* erect, terete; in first year glabrous, usually reddish, internodes up to 0·3 in. long, terminal bud red; in second year reddish green marked with whitish lenticels, young parts minutely pubescent, older parts woody, glabrous, internodes up to 1 in. long, terminal bud red; in third year new season's shoot reddish green with whitish lenticels, previous year's shoot greenish grey, smooth, marked with pale-coloured lenticels. *Leaves* simple, alternate. Stipules triangular or falcate acuminate, up to 0·15 in. long in first three years. Petiole slightly flattened above or channelled, usually red, minutely pubescent, in first year up to 0·15 in., in second year up to 0·6 in., in third year up to 1·3 in. long. Lamina in first year 0·3–1·2 in. by 0·15–0·5 in., oblong or ovate lanceolate, apex and base acute, first one or two leaves distantly serrulate, subsequent leaves serrate, green, glabrous, or in young leaves pubescent beneath, veins and tips of serrations usually reddish; in second year 0·5–5 in. by 0·3–1·7 in., oblong lanceolate, acuminate, base acute or rounded, serrate, green and glabrescent above, whitish and pubescent beneath, venation reticulate, veins slightly depressed on upper surface, principal veins on upper surface and tips of serratures reddish; in third year up to 5 in. by 2·5 in., ovate, acute or acuminate, base cordate or rounded, serrate, upper surface green and glabrescent or in young leaves minutely pubescent, lower surface whitish and pubescent, venation reticulate, veins slightly depressed on upper surface, principal veins on upper surface and tips of serratures reddish.

During the first season the growth of the seedling is slow; by the end of the season it attains a height of 0·5–1·3 in., with 4–7 small leaves and a bushy fibrous root-system up to 2 in. long. Subsequent growth is faster. Artificially raised plants were found to attain a height of about 1 ft., with 15–20 leaves, by the end of the second season, and 2½ ft. by the end of the third season.

Natural seedlings grow more slowly. Of several examined the mean height during the first five years was: first year, 1·4 in.; second year, 3·7 in.; third year, 5·1 in.; fourth year, 7 in.; fifth year, 16 in., with a taproot 1 ft. long.

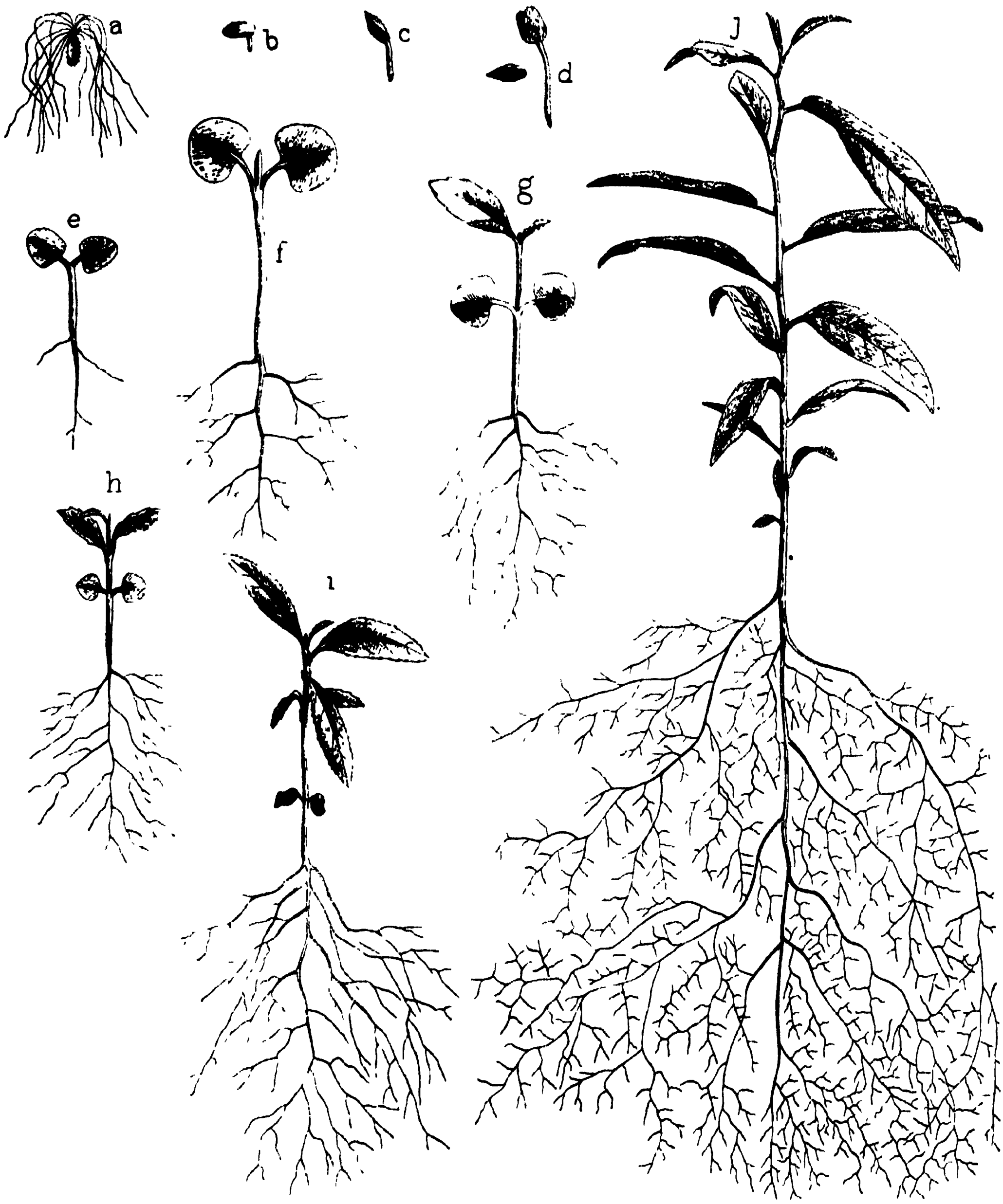


FIG. 370. *Populus ciliata*. Seedling.

a, seed × 2½; *b–f*, germination stages × 2½; *g–i*, development of seedling during first season, *g* × 1½; *h*, *i* ¾; *j*, seedling towards end of second season × ½.

The leaves of seedlings fall in November–December, that is, later than those of adult trees; those of young seedlings often turn a deep red colour before falling. New growth starts in March–April. The seedling requires a light porous soil, and tends to damp off in water-logged ground. The leaves of seedlings are sometimes touched by early frosts before falling and by late frosts after sprouting ; in frosty localities the stems may be killed down during the winter, but new shoots are readily produced from the base.

Silvicultural characters. This tree is a light-demander ; it springs up chiefly on open ground, and stands little shade even in youth. It pollards vigorously, but its coppicing power appears to be poor except in the case of young trees. It has an extraordinary capacity for producing root-suckers, and parent trees may often be found sending up quantities of suckers within a considerable radius. On hill-sides where the soil is exposed, or on rocky ground, suckers often appear in great profusion even from roots of large size. Natural layers are sometimes produced, when young branches lying along the ground become covered with earth and send out roots. The tree stands drought well.

Natural reproduction. Under natural conditions the seed, which reaches the ground shortly before the rainy season, germinates a few days after the commencement of the rains. The silky down round the minute seed seems to form a protective covering, preventing the seed from being washed away and retaining moisture during germination. Many of the minute seedlings must be washed away by heavy rain in the earlier stages, but some survive, since natural seedlings are occasionally met with, as a rule in crevices of rocks or on newly exposed ground. Seedling reproduction never springs up on ground covered with grass or weeds or under cover, but only on exposed rocks or in places where the soil has been recently exposed, such as landslips and cuttings, and on alluvial boulder deposits in the beds of streams. By far the commonest form of natural reproduction is by root-suckers.

Artificial reproduction. Owing to the minute size of the seed and the seedling in its earlier stages direct sowings are out of the question, while the usual methods of raising nursery plants are also inapplicable. The only method by which I have been able to raise seedlings with success is to sow the seed in June, soon after collection, on the surface of powdered brick or fine sand in pots or boxes kept under cover but well exposed to the light. Frequent and regular watering is required, and germination takes place in a few days. Care is necessary, during watering, not to wash the minute seedlings out of the ground. The soil should never be allowed to cake, and weeds should be removed wherever they appear. By October the seedlings will average about 1 in. in height, and they should then be pricked out 3 or 4 in. apart in boxes of light sandy soil. These boxes should be protected from frost during the winter by means of a thick covering of thatch or by being placed under the cover of a shed. In the early spring the boxes should be placed in the open, but where late frosts are to be feared it is advisable to protect them at night by a covering of thatch ; water should be given regularly but sparingly during the dry season. About August, after the rainy season has well started, the seedlings, now several inches high, should be pricked out about 18 in. apart in well-raised nursery-beds of light sandy loam and kept there through the winter. Next February, before sprouting commences, they should be finally planted out ; by this time they are about 1 ft. high. Planting can also be carried out successfully during the rainy season, but the risk of failure is greater. If large plants are required, for instance for roadside planting, the seedlings may be kept for another year in the nursery.

The more usual method of raising poplar is by means of cuttings. These may be either planted *in situ* during the rainy season or kept in the nursery until well rooted before being planted out. I have found the latter the more successful method, very good results having been attained in the following manner. The cuttings should be selected from straight vigorous pollard or coppice shoots or root-suckers. The best results are obtained with wood of the previous year, the cuttings being about $\frac{1}{3}$ to $\frac{2}{3}$ in. in diameter at the thick end ; for upright planting a length of about 12–18 in. is convenient, the cut being a slanting one at either end, while for horizontal planting a length of about 9 in. suffices. The cuttings should be taken in February, before sprouting commences, and planted about 6 in. apart in nursery-beds of light porous soil. They may be either put in the ground upright with a slant in the usual way, or completely buried horizontally about an inch below the surface ; the former method has been found somewhat more successful than the latter. Regular watering and weeding should be carried out throughout the hot season, but no further watering is necessary or advisable after the rainy season commences, by which time the cuttings will have become well rooted. The rooted cuttings can, if desired, be planted out during the rainy season, but this is not advisable, since the chances of failure are much greater than if they are kept in the nursery until the following spring. The best results have been attained by planting out in February before sprouting commences, that is, a year from the time of taking the cuttings.

RATE OF GROWTH. The growth is fairly fast, especially in the case of young trees. A cross-section in the silvicultural museum at Dehra Dun showed 33 rings for a girth of 2 ft. 11 in., giving a mean annual girth increment of 1·06 in. The bark thickness was 0·75 in. Gamble gives the average as about 8 to 9 rings per inch of radius, representing a mean annual girth increment of 0·7 to 0·78 in. Rooted cuttings raised in the nursery and transplanted in the early spring when a year old put on a height-growth of 3 to 5 ft. during the first season.

2. **Populus nigra,** Linn. Black poplar.

A large tree with viscid buds and branchlets and almost triangular acuminate leaves, though these vary greatly. Bark grey or greyish black, rough, deeply furrowed in old trees. The typical form is widely distributed in Europe, but is not cultivated in India. The fastigiate form, the Lombardy or pyramidal poplar (var. *italica,* Du Roi ; var. *pyramidalis,* Spach), is frequently planted in the western Himalaya up to 12,500 ft., particularly in Kashmir ; it is readily recognized from its numerous small branches growing upwards in brush-like form close to and covering the stem, forming a long narrow cylindrical crown. It rarely flowers in India. It is easily raised from cuttings or from root-cuttings, and pollards well. Root-suckers are not often produced while the tree is living, but when it is cut down numerous suckers spring from the roots. The tree will grow on comparatively dry ground, and is useful for fixing unstable slopes. The growth is rapid.

3. **Populus alba,** Linn. White poplar. Vern. *Chitta bagun, safeda,* W. Him.

A large deciduous tree with young branches and buds densely white tomentose. Leaves very variable in size and shape; petioles and under surface densely white tomentose. Bark on young stems smooth, light grey or whitish; on old trees dark, rough, and furrowed, especially near the base. In Afghanistan the wood is used for making grape-boxes.

The white poplar is wild and cultivated in the western Himalaya at 4,000–10,000 ft., extending west to Europe, especially in the Mediterranean region, and north to Siberia; it is also planted in the Punjab plains, Sind, Baluchistan, and elsewhere, but does not do well in the plains. It occurs to a limited extent in the Murree hills with *Populus ciliata*, maple, horse-chestnut, and other trees. It is common in parts of the Kagan valley on hill-sides from 6,000 ft. upwards, where it is wild and possibly indigenous; here it is associated with *Populus ciliata*, *Pinus excelsa*, *Cedrus Deodara*, and other trees, and is similar in habit to *Populus ciliata*, springing up on newly exposed ground and on recently formed alluvial deposits in the beds of streams. It is sometimes found on steep slopes with shallow soil on hot aspects, and as it stands a dry climate it should be useful for afforesting dry slopes. It requires deep moist soil, however, to attain a large size. It produces suckers freely, and can be propagated by transplanting suckers or root-cuttings. It also grows readily from cuttings. In Europe it is considered inferior in pollarding power to *P. nigra*. The growth is fast.

4. **Populus euphratica**, Olivier. Sind poplar. Vern. *Báhan*, *bhán*, Sind, Pb.; *Padar*, Bal.

A moderate-sized or large tree with very variable leaves, those of young plants and coppice and pollard shoots linear, 3–6 in. long, shortly petioled, usually entire, those of older trees on normal branches usually broadly ovate, rhomboid or cordate, long petioled, dentate or variously lobed. Bark thick, with irregular vertical furrows. Wood moderately hard, with red heartwood, used mainly for building and turnery, the lacquered articles in Sind being made as a rule from this wood; it has been pronounced suitable for match manufacture.

In Sind the tree reaches a height of about 40–50 ft., with a girth of 5–8 ft. and occasionally up to 10–12 ft.; at high elevations it is a smaller tree. It produces a clean bole up to 20 or 25 ft. in length, but the bole is seldom perfectly straight.

Distribution and habitat. This tree furnishes a remarkable example of a species which extends in elevation almost to the upper limits of tree-growth, and is yet indigenous and thrives in the hottest climate of the Indian plains under the mitigating influence of river inundations.

In India the chief home of the tree is in the forest belt along the Indus in Sind, particularly in the upper and middle parts of the province. It is also found in the southern Punjab along the Sutlej river below Ferozepore, in the valleys of the Suliman range up to 3,000 ft., and in Baluchistan on tributaries of the Indus river. In the upper reaches of that river and its feeders it is found in Ladak and Tibet, especially along the Shayok river at 10,500 ft., ascending to 13,500 ft. Westward it is indigenous on riverain areas in Afghanistan, Turkestan, Persia, Mesopotamia, and Palestine. Parker[1] mentions that it is common in the Jhok forest on the Ravi, and stray specimens

[1] For. Flora Punjab, p. 509.

occur near Baloki, but that as neither Stewart nor Brandis mentions the bahan on the Ravi it is possible that these trees are not wild, but have spread from trees planted in Shahdara plantation.

The tree is typically gregarious, occurring pure or associated with a few other species on the alluvial ground of riverain tracts. The riverain forests along the Indus in Sind have already been described under *Acacia arabica* (Vol. II, p. 421) and under *Tamarix* (Vol. I, p. 16). In these tracts the poplar springs up in abundance on new alluvial deposits along with *Acacia arabica*, *Tamarix dioica*, and *T. Troupii*, and to a lesser extent with *Prosopis spicigera*, which, however, appears more commonly on land which has become elevated above the reach of all ordinary floods. Often the poplar occurs as a standard over an underwood of tamarisk.

In Sind and the southern Punjab the tree experiences a very dry climate which becomes excessively hot in the hot season. The absolute maximum shade temperature varies from about 120° to nearly 125° F., and the absolute minimum from 29° to 35° F., while the normal rainfall varies from 3 to 8 in. It is able to survive in this excessively hot, dry climate only by reason of the annual river inundations. At the higher elevations of its natural habitat the rainfall is also scanty, while extremely low minimum temperatures have to be endured.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless or nearly so from January to March. Before falling the leaves assume a rich golden colour, and a poplar forest in upper Sind at this time presents beautiful colouring. The flowers, in lax catkins, the male 1–2 in. and the female 2–3 in. long, appear in January–February, when the trees are leafless or have only a few old leaves on. The fruits ripen from April to June, the small capsules opening into three, rarely two valves, and the minute seeds, surrounded by silky hairs, being disseminated by the wind.

SILVICULTURAL CHARACTERS. This tree is a decided light-demander. The root-system is mainly superficial, and the tree produces root-suckers in abundance to a considerable distance from the parent tree, the production of suckers being stimulated in areas overrun by fire. Owing to the superficial root-system the trees, particularly large ones, are liable to be blown down when the ground becomes softened by inundations. The tree stands flooding for a time only, and does not survive on low-lying ground liable to prolonged inundation; it survives longer than *Acacia arabica* in the absence of water. It is frost-hardy in its natural habitat. In its earlier stages it suffers much from browsing by cattle and goats. It coppices well up to a large size, and stands pollarding for a long time.

NATURAL REPRODUCTION. Natural seedlings often spring up in quantity on newly formed riverain alluvial ground after the annual floods subside; for its successful establishment it is necessary to exclude grazing and to protect from fire. Much of the reproduction in the poplar forests consists of root-suckers.

ARTIFICIAL REPRODUCTION. Artificial reproduction by seed has been tried in Sind without success. Possibly the method of raising seedlings in pots or boxes, as described for *Populus ciliata*, might prove successful. The tree can be propagated from cuttings, but this method has not been resorted to with any great success for regular planting operations.

Silvicultural treatment. In the riverain forests of Sind the principal species is *Acacia arabica*, and the system of management is adapted mainly to the requirements of that species ; this consists of clear-felling with natural combined with artificial reproduction, the rotation being as a rule thirty years. Under this system the poplar reproduces freely by coppice-shoots and root-suckers, while on newly formed alluvium seedling reproduction springs up. In order to attain the best results it is necessary to exclude grazing from areas bearing young crops. The tree is well adapted for treatment under coppice or coppice-with-standards, reproduction being obtained from root-suckers as well as from coppice-shoots.

Rate of growth. The growth is rapid. Brandis gives 3 to 4 rings per inch of radius, representing a mean annual girth increment of 1·57 to 2·1 in. Figures received from Sind show that a height of 50 ft. is attained in about thirty years, and a girth of 8 ft. may be reached in fifty years.

ORDER LXI. PALMAE

The palms are among the most interesting and important, as well as the most beautiful, of all the woody members of the vegetable kingdom. The most important, from an economic point of view, are those, such as the coconut, date, palmyra, betel-nut, and other palms, which are cultivated for the production of oils, fibres, and edible and other products ; these as a general rule are not of special importance in Indian forestry. On the other hand, there are certain forest species which have an extensive local use for thatching and other purposes, while several of the rattan canes are regularly exploited ; other forest species, again, like *Caryota urens* and *Corypha umbraculifera*, yield edible and other products, while the palmyra (*Borassus flabellifer*) and the wild date palm (*Phoenix sylvestris*) are forest trees in some localities. Nevertheless, the importance of the cultivated palms, from an economic point of view, far outweighs that of the forest species, most of which are of botanical rather than of economic interest. Hence, since the cultivation of the more important palms belongs to the realm of agriculture rather than of forestry, our treatment of this order must necessarily be brief and confined to a few species which are of economic importance or are particularly common.

The adult palm usually has an erect woody, cylindrical, unbranched stem bearing a crown of leaves at its summit. In many species, however, the stem does not rise above ground, and the visible portion of the plant has the form of a tuft of leaves rising straight from the ground ; *Phoenix acaulis* is the commonest species of this type. In the canes and rattans (*Calamus*) the internodes are long and the slender stems are often scandent, climbing to a considerable height through the tree-growth. In some palms the stem is quite smooth, while in others it is covered with annulations, the scars of former leaves ; in several species the stem is surrounded with a fibrous covering, while in some it is armed with formidable spines. Branching is rare, and is confined mainly to a few species of the genus *Hyphoene*.

The stems of palms consist normally of an outer hard zone of numerous thick-walled fibro-vascular bundles with intervening parenchymatous tissue and an inner soft portion occupying the centre of the stem and consisting mainly of parenchymatous tissue. The fibro-vascular bundles from the leaves, when they join the stem, first bend inwards towards the centre and then outwards and downwards near the periphery, where they are closely packed together and form the hard outer zone of the stem. Growth in thickness does not, as in the case of dicotyledonous trees, take place by the addition of new external layers of wood produced from the cambium zone, but by general growth within the stem, causing it to increase in thickness until it attains its full size, when further increase in diameter ceases.

The leaves, which form a graceful tufted crown, are often of very large size. They are of two main types, the palmate and the pinnate, whence the popular terms fan-palm and feather-palm respectively. The leaf is entire in the bud, but splits or tears into strips or segments as expansion takes place. The petiole has a broad sheathing base. Leaf-shedding does not take place with regularity as in the dicotyledons. When the leaf has reached the end of its life-cycle it gradually dies, falls over and decays, the basal sheath in some species persisting for a considerable time on the stem. The leaves of seedlings are usually undivided.

The inflorescence is generally lateral, or in a few species terminal; it consists of a much-branched panicle or sometimes a simple or compound spike on a common, often thick peduncle (spadix), and is enclosed in the bud by sheathing bracts (spathes). Where the inflorescence is terminal, as in *Corypha umbraculifera*, the palm flowers once after many years, and then dies after fruiting. Where the inflorescence is lateral the plant may flower year after year, the spadix dying and falling off after fruiting.

The flowers are monoecious, dioecious, or polygamous, rarely bisexual. The male and female flowers often occupy different portions of the same spadix, the female below and the male above, or in some species the male and female may be intermingled on the spadix. The flowers are 3-merous, usually with three sepals, petals and carpels, and six stamens. In the fruit two of the carpels may become abortive, only one seed resulting, as in the coco-nut. The fruit is a drupe or a berry. The seed has a small embryo and a large endosperm, which is sometimes oily, sometimes hard and horny, and occasionally mucilaginous.

The palms are essentially characteristic of the tropical regions of the globe, the number of species being richest where the humidity is greatest; this applies likewise to the Indian region, where the species are most numerous in the moister parts of Burma, the Andamans, the eastern Himalaya, and the west coast, including the Nilgiri and other hills of southern India. Among the commoner palms of the drier but not arid regions of India, indigenous or cultivated, are *Phoenix acaulis*, *P. humilis*, *P. sylvestris*, and *Borassus flabellifer*. Perhaps the best Indian example of an arid region palm is *Nannorhops Ritchieana*, which grows gregariously in the dry tracts of the trans-Indus country.

Genera 1. PHOENIX, Linn.; 2. ARECA, Linn.; 3. COCOS, Linn.; 4. NIPA, Wurmb.; 5. CALAMUS, Linn.; 6. CARYOTA, Linn.; 7. NANNORHOPS, H. Wendl.; 8. LICUALA, Rumph.; 9. BORASSUS, Linn.; 10. CORYPHA, Linn.

1. PHOENIX, Linn.

Species 1. *P. sylvestris*, Roxb.; 2. *P. acaulis*, Buch.-Ham.; 3. *P. humilis*, Royle; 4. *P. paludosa*, Roxb.; 5. *P. dactylifera*, Linn.

1. **Phoenix sylvestris**, Roxb. Wild date palm. Vern. *Khajur*, *khaji*, *salma*, *sendi*, *thakil*, Hind.

An erect palm 30–50 ft. high, with a rounded crown of large greyish green pinnate leaves 7–15 ft. long. Stem covered with the persistent bases of the petioles. The leaves are used for mats and baskets, but the chief importance of the tree lies in the sugary sap which it yields, and which is boiled down into raw sugar or used for the manufacture of fermented liquor. The sap is obtained by cutting a notch into the soft wood at the base of the lowest living leaves and freshening the wound at frequent intervals by paring off a thin slice, the sap exuded being collected in a vessel or section of bamboo (Fig. 371). By the end of the season a large notch is formed, and each successive year the notch is cut on alternate sides of the tree, so that the stem acquires a curious zigzag appearance. Tapping commences in October and ends in March. The wood is used for pegs for tent-pegging.

This palm is common and gregarious in many parts of India, either cultivated or wild. In parts of the sub-Himalayan tract and the Peninsula it occurs gregariously, and apparently wild, on low alluvial land along rivers.

It is accommodating as to soil, but prefers moist alluvial ground provided it is not too heavy and clayey. In such places it regenerates freely from seed, and the young plants are little subject to browsing. So far as is known it does not produce suckers.

Its artificial propagation in Bengal, according to Kanjilal,[1] is carried out by collecting the ripe seeds in May and sowing them in the nursery, which is kept weeded. The seedlings are transplanted in the third rainy season with a spacing of 7 ft. by 9 ft., giving 585 trees to the acre, on ground previously hoed up or ploughed. When the plants are five years old the green upper leaves are tied up like a bouquet, the lower yellow ones being cut away with a sharp knife; this is repeated annually, the ground being well ploughed meanwhile. In the seventh year, when the stem above ground is about 1½ ft. high, tapping can commence, though it is preferable to wait until the eighth or ninth year, when the stem reaches a height of about 3 ft.

2. **Phoenix acaulis**, Buch.-Ham. Dwarf date palm. Vern. *Thakal*, *jangli khajur*, *pind khajur*, Hind.; *Thinbaung*, Burm.

A low almost stemless palm with pinnate leaves and a thick bulbous stem densely covered with the persistent bases of the petioles. The leaves are used for mat-making. The fruit is eaten, and a sago is made from the interior of the stem. This palm is common and gregarious in open grassy types of sal forest and in grass-lands, particularly on clayey ground, both in the sub-Himalayan tract and in the Peninsula, also on dry hill slopes. In the outer Himalaya it ascends into the forests of *Pinus longifolia*. It is a common undergrowth species in open *indaing* forest in Burma. The fruits ripen towards the end of the hot season, and are a favourite food of peafowl.

[1] Ind. Forester, xviii (1892), p. 451.

3. **Phoenix humilis,** Royle. Vern. *Khajur*, Hind.

An erect, somewhat variable palm, sometimes attaining a height of 10 ft., with pinnate leaves, the stems densely covered with the bases of the fallen petioles or marked with the scars left by them. Found throughout the greater part of India in hilly country, often on dry ridges, ascending the outer Himalaya to 5,000 ft., and the Nilgiris to 6,000 ft.; also in Burma. It produces root-suckers, particularly if the stem has been damaged by fire or otherwise. The fruit ripens in the hot season. Fig. 58 shows this palm as an undergrowth in forest of *Shorea Tumbuggaia* (see Vol. I, p. 132).

4. **Phoenix paludosa,** Roxb. Vern. *Hintal*, Beng.; *Thinbaung*, Burm.

A densely tufted palm with slender stems 6 to 20 ft. in height or sometimes more, which forms impenetrable thickets in the tidal forests of Bengal, the Andamans, and Burma. The leaves are used for thatching, the smaller stems for walking-sticks and the larger ones for rafters. The fruit ripens during the rainy season or early cold season.

5. **Phoenix dactylifera,** Linn. Date palm. Vern. *Khajur*, *khaji*, Hind.; *Thinbaw thinbaung*, Burm.

A tall tree, attaining a height of 100–120 ft., the stem covered with the persistent bases of the petioles. Leaves pinnate, grey, up to 15 ft. long. Flowers dioecious. The fruits are the well-known dates of commerce, of which there are numerous varieties in cultivation; the leaves are extensively used for mats and bag-like baskets, and the wood of male trees and trees past yielding fruit is used for building and other purposes. The stem yields a sugary sap.

Distribution and habitat. The date palm is believed to be indigenous to Mesopotamia and the oases of the Sahara desert. Brandis says it was probably first introduced into India in the eighth century, at the time of the first Mohammedan conquest of Sind, and is now found cultivated and run wild in Sind and the southern Punjab, particularly near Multan and Muzaffargarh. It has also been planted in many other parts of India, chiefly as a result of continued efforts to introduce it during the past half-century. Some of the Punjab dates are of very fair quality, but the tree does not appear to thrive in India except in the drier regions.

In northern Africa and western Asia the date forms a staple article of food, and the tree is extensively cultivated. In these regions it thrives in an arid climate, where it is exposed to great heat in the daytime and often to frost at night. It grows and fruits best, however, with large and continuous supplies of water in the soil, on land which is constantly irrigated. In this connexion an Arab proverb aptly says: 'The date palm, the queen of trees, must have her feet in running water and her head in the burning sky.' In Egypt well irrigation is frequently practised, while round Basra there are immense irrigated plantations which receive copious supplies of water every twelve hours. As regards soil the tree does not appear to be exacting, though it grows best in a sandy loam. On heavy soils prolonged inundation, causing water-logging, is injurious and may kill the trees. In Egypt there are some varieties capable of growing on unirrigated land, and others which grow on low-lying ground subject to frequent inundation. The tree responds readily to manuring.

FIG 371. *Phoenix sylvestris*

FIG. 372. *Borassus flabellifer.*

Characters and requirements. Unlike *Phoenix sylvestris*, the date palm produces suckers in quantity round its base. It resists frost well, and when not flowering and fruiting stands a temperature as low as 20° F. For ripening its fruit, however, it requires dry hot weather. It is a strong light-demander, and will not grow under shade even in youth; young transplants, however, require protection from hot winds. In India it flowers in March–April, and the fruits ripen in September–October. Under favourable conditions the tree commences flowering and fruiting at an age of six to ten years; in Egypt it is said to take ten years to come into full bearing.

Propagation. The tree can be propagated from seed or by planting offsets (suckers). The latter method is preferable to the former; it ensures the propagation of good varieties, while offsets can be taken mainly from female trees, with only so many male plants as are required for pollination. A ratio of three or four male trees to 100 female trees is considered sufficient for purposes of pollination, and this includes a safeguard against loss of male trees. The offsets are usually planted with a spacing of 20 ft. by 20 ft. to 25 ft. by 25 ft. from April to August, freely watered for at least a year, and protected where necessary from hot winds by means of thatch, or, as is the custom in Egypt, with umbrella-like coverings of maize stalks.

Pollination. Wind pollination is too uncertain to effect the ripening of the fruit, and artificial pollination has therefore been in vogue since the earliest historical times. The male inflorescence with its spathe is removed as soon as mature, the spathe is slit open, and the flowers are placed in a basket for about twenty-four hours. The cultivator then climbs the female trees on which the spathes have burst and ties sprigs of male flowers among the female flowers, pollination being thus effected. The pollen remains fertile a long time if kept dry, and in some localities it is kept from year to year. Experiments at the Mecca experimental station have shown that it may remain fertile for seven years.

2. ARECA, Linn.

Areca Catechu, Linn. Areca palm, betel-nut palm. Vern. *Supari*, Hind.; *Gua*, Beng.; *Adike*, Kan.; *Kamuga*, Tam.; *Poka-vakka*, Tel.; *Kun*, Burm.

A tall erect palm, 40–80 ft. high, with a straight smooth annulate stem and pinnate leaves, 4–6 in. long. The seeds are the betel-nuts used for chewing and in medicine. This palm is largely cultivated in the moist tropical regions of India and Burma, thriving on deep rich moist loam. Seedlings are raised in shady nurseries and transplanted at an age of two or three years. In Bengal they are planted under the shade of lines of *Erythrina indica*, 12–15 ft. apart, put in as cuttings. When the palms come into bearing the *Erythrina* trees are cut down and a second supply of palm seedlings is planted between the original rows. In Ceylon direct sowing is frequently carried out, the seeds being dibbled in holes about 6–8 ft. apart.

The trees are monoecious, the flowers being unisexual. The fruit is orange or scarlet, 1·5–2 in. long, ovoid; the seed (betel-nut) is about 0·7 in. in diameter. The flowers usually appear from January to March, the fruits ripening from October to January. The usual crop is about 150–300 nuts per tree. Isolated trees may fruit in about seven years, but in plantations fruiting does not usually take place until the tenth or twelfth year, while the plantation does not come into full bearing until it is twenty to thirty years old. Fruiting is said to continue for about 30–60 years.

3. COCOS, Linn.

Cocos nucifera, Linn. Coco-nut palm. Vern. *Narel, nariyal*, Hind.; *Narikel*, Beng.; *Narela*, Mar.; *Thenpinna, tengina*, Kan.; *Tenkaya, nari-kadam*, Tel.; *Tennai, tenkai*, Tam.; *On*, Burm.

A tall erect palm with a straight or curved stem 40–80 ft. high, with somewhat indistinctly annulate leaf-scars; base swollen and covered with rootlets. Leaves pinnate, 6–12 ft. long. This palm yields the coco-nut of commerce, largely used as an article of food and as a producer of oil or vegetable fat, which is expressed from the dried kernel known as copra. The fibrous husk of the fruit is used for ropes, mats, &c., the cut flowering stalks are tapped for toddy, and the wood is used for walking-sticks, furniture, and various ornamental purposes as well as for building.

Distribution and habitat. The original home of the coco-nut is a matter of some speculation. Some authorities maintain that its original home was in the tropical regions of America, probably on the west coast of Central America, and that it was introduced into the Polynesian islands at an early date, and spread to other islands and mainland coasts. Others maintain that it is a native of the East Indian islands, including Ceylon, and that it spread by means of ocean currents to the Pacific islands. Wherever its original home may have been, it has long been cultivated in the coastal regions of India, Burma, and Ceylon, and is plentiful on the Coco and Nicobar islands in the Bay of Bengal. Germination is not injured by long immersion in sea water, and the fruit is undoubtedly capable of being transported by sea currents, while the coco-nut palm is found on the coasts of uninhabited islands. Nevertheless some authors maintain that it cannot exist permanently in a littoral environment, that it has everywhere been planted by man, that there are no wild coco-nut palms in the Pacific islands, that it does not long survive human neglect, and that from the nature of its fruit it must have originally been a native of a comparatively dry climate, where it could grow to a fairly large size by its own water before having to draw water from the soil. The structure of the fruit, however, might equally well denote that of a littoral species, since halophytes are known to possess xerophytic adaptations such as those exhibited by plants in dry regions. The fact remains that the coco-nut palm thrives best in coastal regions with a warm tropical climate in which the mean temperature does not fall much below 80° F. It is, however, frequently cultivated inland, and thrives and ripens its fruit in Burma as far as lat. 24° or even farther north. In northern India it is occasionally seen as far north as the Gangetic plain. Although the tree thrives in regions of fairly heavy rainfall, excess of moisture in the air is said to be injurious to the formation of fruit, and provided there is sufficient soil moisture to counteract the effect of excessive transpiration a moderately dry climate is said to be preferable to a very moist one. Some fruitful coco-nut districts have rainfalls of only 50 to 70 in. In the dry zone of Upper Burma coco-nut palms thrive on irrigated land with a rainfall of not much over 30 in. On the other hand, coco-nuts are also grown successfully in regions where the rainfall amounts to 200 in. or more.

The coco-nut palm requires a porous soil with an abundance of soil-moisture. It thrives best on a deep fertile sandy loam along rivers and estuaries. Its roots can endure salt water, but do not require it, and its capacity for thriving on sandy soil along the sea-shore is due largely to the presence of fresh or nearly fresh water not far from the surface. Stiff or water-logged soils and dry porous soils deficient in moisture are unsuitable. The coco-nut palm prefers much lime in the soil, but can flourish in soils with little lime.

LEAF-FORMATION, FLOWERING, AND FRUITING. New leaves arise from the centre of the apical cluster from a bud known as the 'cabbage'. Copeland[1] found, from experiments at the College of Agriculture, Philippines, that leaves took 1½ years from their first appearance until their full development, and that another 1½ years were required for the fruits to mature in their axils. Flowering and fruiting take place throughout the greater part of the year; in India the fruit ordinarily takes 9–12 months to mature. The spadix, which bears both male and female flowers, is about 4–6 ft. long. The fruit is a three-sided obovoid or sub-globose drupe with rounded angles and a fibrous mesocarp. The true seed lies within the hard woody endocarp or shell of the so-called 'nut', which is not a true nut. The seed has a large solid endosperm and a small embryo beneath the largest 'eye' in the shell. Under the most favourable conditions fruiting commences from the fifth to the seventh year, otherwise it commences a good deal later.

SILVICULTURAL CHARACTERS. The coco-nut palm is intolerant of shade, and develops best when fully exposed to the sun; young plants, however, do best under slight shade. It withstands gales very well, sound trees being seldom snapped or uprooted by strong winds; young fruits, however, are sometimes blown down during storms. The root-system consists of a large number of roots radiating outwards to a distance of several yards from the underground portion of the stem and numbers of lateral roots issuing almost at right angles to the main roots. The whole system forms a very firm anchorage.

PESTS AND DISEASES. Bud-rot is an infectious disease which rots the terminal bud and may cause high mortality; diseased trees should be felled and the diseased bud burnt. A stem-bleeding disease has been fully described by Petch,[2] who has also described a root disease caused by the fungus *Fomes lucidus*.[3] Among insect pests the two most serious are *Oryctes rhinoceros*, the rhinoceros beetle, and *Rhynchophorus ferrugineus*, the red beetle, both of which tunnel into the stems and the young tissue at the apex. The former is found in decaying tissues, and there is some doubt whether it is directly injurious. The latter attacks unhealthy trees only, but is more harmful than the rhinoceros beetle.

CULTIVATION. Coco-nuts required for seed purposes should be selected from trees which are prolific bearers. Nuts ripened on the trees are employed, and these are as a rule collected in the hot season. It is not usual to plant

[1] E. B. Copeland, Philippine Agriculturist and Forester, vol. i, No. 3, March 1911.

[2] T. Petch, Cir. and Agr. Journ. Roy. Bot. Gardens, Ceylon, iv. 22.

[3] *Ibid.*, p. 24, March 1910.

the nuts *in situ*, the common practice being first to cause them to germinate and then to plant them out. Various methods of effecting germination are practised, the husk being always left on the nut. In very moist climates the nuts are sometimes hung on a horizontal pole or round the posts of a house and occasionally watered until germination is well advanced, when they are transplanted. Sometimes the nuts, after hanging for a time, are thrown into a well and left to germinate while floating. Some advocate placing the nuts in heaps of ten or twelve and planting them out as soon as they germinate. A commoner practice is to prepare nursery-beds in sandy soil well dug up and to place the nuts on their sides and almost in contact in shallow trenches in the beds, covering them wholly or to about two-thirds of their depth with soil. The seed-beds are kept moist but not saturated. Germination ordinarily takes place in three to six months, and transplanting is carried out as a rule with seedlings 1–2 years old, or occasionally younger, the season of planting being early in the rains. The most usual spacing is 18 ft. by 18 ft. to 30 ft. by 30 ft. The young plants are usually shaded with thatch, and are kept watered in dry weather. Weeding, shallow ploughing, and manuring are now generally considered advisable throughout the life of the plantation, while irrigation may be necessary in dry localities. It has been found advantageous to cultivate leguminous crops under the palms; these are partly dug in for manure and partly grazed. The coco-nut palm responds in a marked degree to cultivation and manuring. In Ceylon it is generally estimated that the cost of formation and tending of a fair-sized coco-nut plantation up to the tenth year amounts to somewhat over £30 per acre, with interest at 8 per cent. and deducting yields in the eighth, ninth, and tenth years.

RATE OF GROWTH AND YIELD. The rate of growth and the yield vary enormously according to the locality and the amount of manuring and cultivation. Mr. A. W. Lushington [1] says that of a large number of plants put down in a garden in Vizagapatam five to six years previously only one or two were beginning to form a definite stem, while by far the greater number had not a semblance of a stem. Other records show much better growth than this. Woodrow mentions trees which reached a height of 60 to 70 ft. in eighteen years in the Bombay Presidency. In Ceylon under the most favourable conditions fruit commences to form in the fifth year, but crops of any size are not produced until the ninth or tenth year, after which there is a rapid increase until the twentieth year, the yield, with careful manuring and cultivation, being maintained until the seventieth year. In native plantations in Ceylon 30 to 40 nuts per tree per year is considered a fair average yield, but 70 to 150 nuts a year are not uncommonly produced. In a well-managed plantation it is estimated that about 3,750 nuts per acre are produced in the fifteenth year, and about 5,000 per acre in the twentieth year. A ton of copra is produced by 4,000–5,000 large nuts, 5,000–8,000 medium nuts, or 8,000–10,000 small nuts.

4. NIPA, Wurmb.

Nipa fruticans, Wurmb. Vern. *Gulga*, *gabna*, *golphal* (fruits), *golpatta* (leaves), Beng.; *Dani*, Burm.

A gregarious palm with numerous large pinnate leaves, 15–30 ft. long,

[1] Ind. Forester, xxxv (1909), p. 152.

arising in tufts from a stout creeping rhizome. This palm is a very characteristic species along tidal estuaries and creeks in the Sundarbans and on the coasts of Chittagong, Burma, the Andamans, the Malay Peninsula and Archipelago, and south to the coast of Queensland; also in the Philippines. It occurs sparingly in Ceylon, but is not found in the Indian Peninsula. It is at times very plentiful, both in the mangrove swamp and in the drier tidal forest behind it, where it occurs in fringes along the banks of creeks.

The leaves are extensively used for thatch and the leaf-stalks are used as fishing floats. The young fruit is edible, and toddy can be obtained from the spathe.

The flowers are monoecious, on a spadix 4–7 ft. long. The fruit is a large head about 1 ft. in diameter, with numerous crowded one-seeded drupes, the seed as large as a hen's egg. The fruits are disseminated by water.

5. CALAMUS, Linn.

This genus contains over 30 Indian species of armed, usually climbing palms, commonly known as canes or rattans, which are characteristic of moist evergreen or swampy ground. Nothing appears to be known regarding the time required for different kinds of canes to reach maturity. In Coorg the time required is believed to be about five years, and in the *ghat* forests a cutting cycle of six years has been adopted in the latest working plan.

6. CARYOTA, Linn.

Caryota urens, Linn. Indian sago palm, fish-tail palm. Vern. *Mari*, Hind.; *Birli*, Mar.; *Baini*, Kan.; *Mhar, jilugu*, Tel.; *Konda panna*, Tam.; *Minbaw*, Burm.

An erect palm attaining 40–60 ft. in height under favourable conditions. Leaves bipinnate, of large size, sometimes as much as 20 ft. in length, the ultimate leaflets shaped somewhat like the tail of a fish. The wood is strong and is used for building and other purposes. The inner tissues of the stem yield a starchy substance used as food. The leaves yield a strong fibre known as *kitul*. The flowering peduncles are tapped for liquor.

This handsome palm is distributed throughout the moister forest regions of India, usually in cool, shady valleys, and is often cultivated in gardens. It is said to attain full size in about 10–15 years, and produces flowers for some years afterwards. The tree is monoecious, and the spadices are axillary. The first and longest spadix, 10–12 ft. long, is formed in the upper part of the tree. Subsequent spadices, which are successively of smaller size, are in turn formed lower down, until eventually, when the fruiting is finally over, the tree becomes exhausted and dies.

7. NANNORHOPS, H. Wendl.

Nannorhops Ritchieana, H. Wendl. Syn. *Chamaerops Ritchieana*, Griff. Vern. *Mazari*, trans-Indus; *Kilu*, Salt Range.

A low shrubby palm with much-divided palmate leaves usually arising in tufts from a branched underground rhizome, sometimes from an erect branching stem. The leaves are used for mats, fans, baskets, &c., the petioles are used for ropes, and the seeds are strung in necklaces.

This palm is found in arid regions along the North-West Frontier, in the Peshawar valley, Kohat, Kyber Pass, Salt Range, trans-Indus hills of Sind, and Baluchistan up to 5,000 ft. It grows gregariously, covering considerable stretches of dry stony ground. It can be propagated from seed or from offsets.

8. LICUALA, Rumph.

Licuala peltata, Roxb. Vern. *Kurnd,* Beng.; *Patti,* Ass.; *Salu,* Burm.

A palm attaining 10 ft. or more in height, with orbicular peltate deeply partite leaves which are largely used for thatching. Found, often gregariously, in tropical forest and moist ravines in Sikkim, Assam, Chittagong, Burma, and the Andamans. Flowers cold season; fruits hot season.

9. BORASSUS, Linn.

Borassus flabellifer, Linn. Syn. *B. flabelliformis,* Roxb. Palmyra or toddy palm. Vern. *Tál, tár,* Hind.; *Tád, tamar,* Mar.; *Tadi,* Tel.; *Panam, panai,* Tam.; *Tan,* Burm. (Fig. 372.)

A tall, erect palm, attaining 70 ft., and under specially favourable circumstances 100 ft. in height, with a black stem bearing narrow annulate leaf-scars; stems of younger trees covered with dead leaves or the bases of the petioles. Base of stem bearing masses of rootlets. Leaves palmate, multifid, 3–5 ft. in diameter, with somewhat short petioles.

This palm is extensively tapped for toddy, the sweet sap exuding from the cut flowering spadices being fermented into spirit or boiled down into raw sugar. The leaves are used for writing upon and for thatching, mats, fans, &c. The pulp of the fruit, the unripe seeds, and the young seedlings are eaten. The outer hard wood is used for building, particularly for posts and rafters, and the stems hollowed out are used for water-pipes.

DISTRIBUTION AND HABITAT. This palm is believed to be a native of tropical Africa; it is largely cultivated or has run wild in many parts of India, chiefly south of the Indo-Gangetic plain, and in Burma, particularly in the dry zone, where there are numerous extensive groves. It is also largely cultivated in portions of the Madras and Bombay Presidencies. This palm is essentially a tropical species. It prefers regions of only moderate rainfall, and thrives best on a sandy soil; it is not suited to very moist climates or stiff soils. Natural seedlings spring up readily, but require protection from grazing.

LEAF-PRODUCTION, FLOWERING, AND FRUITING. The bases of the petioles partially encircle the stem, fitting closely one above another. The immature leaves at the top are pressed tightly together in various stages of development, protecting the growing-point, which is some distance down through the mass of immature leaves. As the leaves become older the base of the petiole splits open longitudinally, leaving a gap of some extent in the centre. Mr. A. W. Lushington[1] has noted that three leaf-bases form a spiral annulation, twelve leaves are developed in the course of a year, and consequently four annulations correspond to a year's growth. Messrs. A. B. Jackson[2] and J. Donald[3] made independent examinations of palmyras and found that each annulation was a quite separate ring, that each ring supported but one leaf,

[1] Ind. Forester, xxxv (1909), p. 148. [2] *Ibid.*, p. 394. [3] *Ibid.*, p. 521.

and that the annulations were not spiral. Examinations by Messrs. Hole [1] and McCrie [2] have confirmed the conclusions of Messrs. Jackson and Donald that each leaf forms a separate and distinct annular scar.

As regards leaf production, Mr. W. McRae has described an experiment carried out at the Central Agricultural Station, Coimbatore, over periods of 6½ and 4½ years in the case of ten and three palmyras respectively, in which the young leaves were marked with zinc labels. This experiment showed that the number of leaves which expanded each year varied from 12 to 16·5 and averaged 14. The mean annual rainfall during the period of the experiment was 25·76 in.

The palmyra palm is dioecious, the male and female flowers being borne on branched spadices on different trees. The fruit is sub-globose, 4–5 in. in diameter, smooth, reddish black when ripe, containing 1–3 hard-shelled seeds (pyrenes) embedded in soft yellowish fibrous pulp. Mr. C. E. C. Fischer [3] collected evidence in Malabar, with a moist climate, and Erode, with a dry climate, indicating that fruits are first formed at an age of nineteen years in the former and thirty-five years in the latter.

DISEASES. The most serious disease of the palmyra is that known as bud-rot, caused by the fungus *Pythium palmivorum*, which attacks the bud, eating into the growing-point and eventually killing the tree. Dr. Butler [4] has described this disease in detail, with measures for controlling it.

PROPAGATION. The palmyra is propagated by direct sowings, owing to the difficulty of transplanting the seedlings.

RATE OF GROWTH. Several years elapse before any upward growth takes place, the underground portion of the stem increasing meanwhile in diameter. Actual instances are on record of the time taken from the sowing of the seed to the commencement of upward growth. Mr. A. W. Lushington [5] quotes two instances in the Kistna district in 1910: (1) plants nineteen years old were only just beginning to form a stem above ground, (2) seedlings six years old had only a few leaves and no properly developed underground stem.

Mr. J. Donald [6] recorded in 1910 a case in which seedlings sprung from seed sown in 1892 commenced upward growth when eighteen years old, one or two having commenced a year earlier; subsequent growth was at the rate of 12 to 15 in. a year.

From these recorded instances it would appear to be necessary to add about eighteen to twenty years to the age of a palmyra tree as estimated from its actual rate of growth after upward growth commences. Mr. A. W. Lushington [7] records an instance of a palmyra grove in Repalli *taluk*, raised from seed sown in 1829, in which the trees had attained a height of 30 to 36 ft. in 1895, when they were estimated to be one-half to two-thirds grown. Assuming that twenty years were spent in the seedling stage the actual period of upward growth would be forty-six years, and the growth in height would be about 6½ to 8 in. a year.

[1] Ind. Forester, xxxv (1909), p. 632. [2] *Ibid.*, xxxvi (1910), p. 575.
[3] *Ibid.*, xxxviii (1912), p. 51.
[4] E. J. Butler, Mem. Dept. Agri. India, Bot. Ser., vol. iii, No. v, September 1910.
[5] Ind. Forester, xxxvi (1910), p. 364.
[6] *Ibid.*, xxxvi (1910), p. 688. [7] *Ibid.*, xxi (1895), p. 10.

10. CORYPHA, Linn.

Corypha umbraculifera, Linn. Talipot, tali or fan palm. Vern. *Tali*, Kan.; *Condapana*, Tam.

A large erect palm with a cylindrical annulate stem and large palmate leaves, attaining a height of 80 ft. and a diameter of 2 ft. or more. The starchy pith is converted into flour, the leaves are used for thatching, umbrellas, mats, fans, &c., and the hard seeds are made into beads and buttons.

DISTRIBUTION AND HABITAT. Indigenous to the Andamans and the forests of the Kunta and Honawar *talukas* of North Kanara. Cultivated in the tropical parts of India and in Burma. In the working plan for the Honawar tali palm forests, 1908, Mr. P. E. Aitchison gives a detailed description of the occurrence and working of this palm in the tract in question. Here it occurs on the spurs and slopes of the Western Ghats on light stony soil up to 2,200 ft., thriving best on schist and quartzite on the steep and stony slopes rather than on the lower slopes or the laterite at their base. The rainfall is probably over 200 in. The tops of the hills are clothed with evergreen forest, below which is the tali palm area. The palms are gregarious, being found in patches of a few acres to large belts extending along the whole length of the hill-side, either pure or mixed with *Albizzia stipulata*, *A. odoratissima*, *Lagerstroemia lanceolata*, *Terminalia paniculata*, *Holigarna Arnottiana*, and a few other species. On the lower slopes the forest is deciduous and only occasionally contains full-grown palms, though seedlings are abundant throughout the whole forest.

FLOWERING AND FRUITING. The tali palm is monocarpic, that is, it flowers and fruits but once in its life, on attaining maturity, and then dies. The flowers are bisexual. Flowering takes place from November to January, a huge pyramidal spadix of whitish flowers, 10 to 20 ft. high, appearing at the apex of the tree above the crown of leaves. Meanwhile the leaves commence to wither and droop. After the fruit ripens and falls, that is, in the ensuing hot season, the tree dies and the spadix eventually falls over and decays. The fruit is a globose drupe about 1·5 in. in diameter, with a very hard globose seed. The quantity of seed produced by one tree is very large, averaging, it is said, more than 560 lb. in weight. Sporadic flowering takes place more or less every year, a gregarious flowering taking place at long intervals; the last general flowering in the Honawar forests is said to have taken place in the early eighties of last century.

NATURAL REPRODUCTION. Natural seedlings appear in great profusion, sporadic flowering being sufficient to ensure natural reproduction in abundance owing to the large quantity of seed produced. The seed is disseminated by the agency of birds, squirrels, and porcupines and by the action of rain, which washes it down the hill-sides.

METHOD OF WORKING. The method of working prescribed in Mr. Aitchison's working plan for the Honawar forests is an adaptation of the selection system. The palms are worked for the flour obtained from the stem; this substance is yielded after the tree has reached a certain size, when the stem becomes bulbous towards the middle and the inner tissue of the central third of it becomes utilizable. Only palms containing edible pith are exploited, and for this purpose the trees are divided into four classes: (1) palms containing at least eight head-loads of edible pith (these are usually bulged towards the centre of the stem); (2) full-grown palms with less than eight head-loads of edible pith; (3) half-grown palms; (4) palms which have not yet formed a stem, but which have passed the seedling stage. In fixing the yield the essential point is to know the period occupied from the time when the tree enters class 1 until it flowers and dies. This is not accurately known, but is estimated at twenty years, while the time taken to pass through class 2 is also estimated at twenty years; the yield is fixed by number of trees on this basis.

RATE OF GROWTH. Diameter is no criterion of age. After the stem has reached a certain size it increases no farther in thickness, though it usually swells out in the central portion. Mr. Aitchison has made an estimate of the rate of growth from measurements of palms growing on old *kumri* areas (shifting cultivation). Assuming that the palms started with the regrowth, and estimating their age from that of surrounding trees whose annual rings could be counted, the approximate age of palms of different sizes was found to be as follows: class 1, 70–85 years; class 2, 50–70 years; class 3, 30–50 years; class 4, up to 30 years. Mr. Butterworth[1] describes experiments made since this estimate was formed, which indicate that class 3 and 4 trees put on five new leaves in two years; from this he assumes that a class 2 tree with 160 annulations on the stem shows about sixty-four years' growth from the time when it commenced forming a regular stem above ground, and allowing for the initial period up to this stage he puts the flowering age at about eighty-eight years.

ORDER LXII. GRAMINEAE (tribe Bambuseae)

The bamboos are of such importance in Indian forestry that some account of the silvicultural characters of the tribe as a whole and of the principal members of it must necessarily find a place in this work. It must be admitted, however, that our knowledge of the habits and requirements of the various bamboos is as yet very incomplete, and that a great deal remains to be done in the way of their study. So far experimental work of a silvicultural nature has been confined almost entirely to the commonest of Indian bamboos, *Dendrocalamus strictus*, and the results up to date are given in this introductory note on the bamboos as a whole. Gamble's standard work on this tribe, *The Bambuseae of British India*,[2] contains not only a comprehensive systematic account of all the species known at the time of its publication, including several new ones, totalling 151, but also gives much information regarding their habits.

DISTRIBUTION AND HABITAT. As Gamble remarks, the distribution of bamboos in India naturally follows the distribution of the rainfall. Temperature is also an important factor in determining the distribution in zones of altitude. Gamble classifies the indigenous distribution of the bamboos described in his work as follows:

[1] Ind. Forester, xli (1915), p. 3.
[2] Ann. Roy. Bot. Garden, Calcutta, vol. vii, 1896.

Region.	Number of species.
North-western India	7
Central India and Deccan	6
Western Ghats and coast	15
Ceylon	9
Bengal, north-eastern Himalaya and Assam	46
Burma	39
Malaya with lower Tenasserim and the Andamans	29

The Burma region had, however, been insufficiently explored when he published his *Bambuseae*, and when all the bamboos of that region have been described the number of species will probably prove to be greater.

The habitat of the different bamboos varies greatly, but that of each is so well defined that these plants form excellent indicators of different types of forest. For instance, in the Pegu Yoma forests of Burma *Bambusa polymorpha*, which requires a moist fertile well-drained soil, indicates the moist type of upper mixed forest, while *Dendrocalamus strictus* is characteristic of the driest type; *Cephalostachyum pergracile* indicating types midway between the two or verging on the moister types. Again, *Bambusa Tulda* is common on alluvial flats along streams, *Oxytenanthera albociliata* is more typical of low plateaux or hills on sandy or lateritic soil, while the sides of the damper ravines are fringed with the moisture-loving *Dendrocalamus longispathus*; and, lastly, in the dampest valleys of all, where the forest becomes evergreen, *Teinostachyum Helferi* with its long straggling culms forms impenetrable thickets. Similarly, in other localities where various species occur each species can usually be allocated to its particular terrain and type of forest. The commonest Indian bamboo, *Dendrocalamus strictus*, thrives in somewhat open types of mixed deciduous tree forest, or where trees are almost absent, on well-drained light, often stony soil on hill-sides, and extends into drier regions than any other species. The other common bamboo of the Indian Peninsula, *Bambusa arundinacea*, is found on richer and moister soil, often on alluvial ground along the sides of streams. The most important genus of the higher altitudes is *Arundinaria*, comprising nearly thirty species, which are most largely represented in the eastern Himalaya.

As a general rule the bamboos are markedly gregarious. In some cases they form the only second growth on abandoned clearings where shifting cultivation is practised; on such ground they may cover extensive tracts to the exclusion of tree-growth. This is particularly the case with the single-stemmed bamboo, *Melocanna bambusoides*, whose rhizomes show great vitality and power of spreading. In the Arakan hills the effects of shifting cultivation are marked over extensive tracts by the occurrence of pure forests of this bamboo. Regarding a single-stemmed bamboo (*Melocanna* sp.?) in the Karen hills, Brandis[1] noted in 1881 that *taungya* clearings had mostly grown up in bamboos, and that the period allowed for the bamboo forest to grow up before it was cut again varied from seven to fifteen years. In the case of the tufted bamboos this effect of shifting cultivation, in producing large tracts of pure bamboo, is not generally so marked, since the new culms produced after the clump is cut down are smaller and less vigorous for the first few years than in the case of the single-stemmed species. Nevertheless cases are

[1] Suggestions regarding Forest Administration in British Burma, 1881, p. 141.

not uncommon in which the temporary clearing of forest results in a regrowth of pure bamboo of tufted species. Instances of this may be seen in parts of Burma in the case of *Dendrocalamus strictus*, and in the Shan States in the case of *Oxytenanthera albociliata*, which forms the entire regrowth over large areas.

GENERAL CHARACTERISTICS. The bamboos are perennial grasses in which the woody stems (culms) arise from woody rhizomes. In the majority of cases the rhizomes are more or less densely clustered together, and the culms accordingly arise in clumps or tufts, producing the caespitose type of bamboo. In some cases the culms arise at intervals from a long creeping rhizome, either singly, as in *Melocanna*, or in tufts of a few stems together, as in several species of *Phyllostachys*. Between the single-stemmed and the densely clumped forms there are intermediate types forming somewhat open clumps, such as *Dendrocalamus membranaceus* and *Arundinaria jaunsarensis*. The culms are hollow, with walls which vary much in thickness according to species; in some cases, as in *Dendrocalamus strictus* in dry localities, the cavities are small or even absent, solid culms being the result. The culms are divided at intervals, at the nodes, by solid transverse septa. In some species, such as *Thyrsostachys Oliveri*, *T. siamensis*, and *Melocanna bambusoides*, the culms for a considerable distance from the base are devoid of branches, or have only very small branchlets. Some species, for example *Oxytenanthera albociliata* and *Dendrocalamus Hamiltonii*, have large prominent branches, while others, such as *Bambusa arundinacea* and *B. Tulda*, have dense clusters of branchlets at the nodes all the way up the stem, these clusters being almost invariably arranged alternately. In *B. arundinacea* the branchlets are thorny, bearing spinescent buds. In many species aerial roots are produced at the nodes, these occurring in some cases up to about two-thirds the height of the culm and in others only on the lowest few nodes, where they sometimes lengthen and penetrate the soil.

In stature and form the bamboos are very variable. They comprise all degrees of size from the lofty forms of tropical regions, attaining a height of 100 ft. or more, to mere undershrubs, chiefly species of *Arundinaria*, which are found at high altitudes. Most species are erect, but some, like *Teinostachyum Helferi*, are straggling or semi-scandent, while others, like *Dinochloa* spp., are truly scandent, climbing into the crowns of tall trees. Bamboos may be deciduous or evergreen, the former being characteristic of dry and the latter of damp or shady localities. Some species, like *Dendrocalamus strictus*, which are usually deciduous, may be evergreen in damp climates or moist situations, while others, for example *Bambusa polymorpha*, which are ordinarily evergreen, may become deciduous in dry climates and localities and in abnormally dry seasons.

The new culms are produced from the rhizomes in the chief rainy season of the locality in which they grow, appearing above ground in the form of tender pointed cones covered with imbricate sheaths inserted at the nodes. The culms elongate rapidly, reaching full height as a rule in two to four months; the branches develop only after the upward growth of the culm is completed, and the nodal sheaths fall in whole or in part after the culm matures, their period of persistence varying with different species. The number of new culms produced varies greatly with the species and the size and vigour of the clump, while in years of good rainfall the number produced has been observed to be greater than in years of deficient rainfall. In well-developed vigorous clumps of many arborescent species, ten to twenty new culms a year is not an unusual number, while in some of the shrubby species as many as 50 to 100 or more may be produced under favourable conditions.

Mr. B. B. Osmaston [1] has recorded some interesting observations made in 1917 on the growth of bamboos at Dehra Dun. He notes in the first place that in the case of the various species cultivated there the young culms appeared early in August, that is, more than a month after the beginning of the rainy season, and growth in height was not completed until the end of November. The growth was at first very slow; it quickened gradually for four to six weeks until the culms were some 12 ft. or so in height, when a maximum rate of growth was attained, and this was maintained fairly uniformly for several weeks, after which the rate gradually decreased until the end of November, when growth ceased. Detailed measurements were made of a single new culm in a large clump of *Dendrocalamus giganteus*, these measurements being recorded regularly twice a day, namely at 6 a.m. and 6 p.m., in order to observe the night's growth as well as that of the day. In a few instances measurements were taken at shorter intervals in order to ascertain the effect, if any, on the rate of growth produced by rainfall and a saturated atmosphere or sunshine and a reduced relative humidity. These measurements showed that the growth during the night was usually nearly double of that during the day. This striking difference, however, had apparently nothing to do with light, nor was it directly connected with temperature, for measurements taken at short intervals showed that rapid growth is induced by high relative humidity, irrespective of the time of day or night. Thus measurements taken before and after periods of steady drizzle or rain during the day showed that under these conditions growth was as rapid as it was during the night, whereas in the absence of drizzle and rain during the day the growth was found to slow down, the explanation being that the evaporation which commences with a fall in the relative humidity reduces turgescence, a condition essential for growth. The most rapid growth recorded in a single day was on September 1, when the culm grew nearly 13 in. in twenty-four hours, a rate of growth which was maintained for the next nine days at least, during which period the culm grew 9·18 ft.; it had then attained a height of 23 ft., and measurements, becoming difficult, were discontinued. The culm in question first appeared in the beginning of August, and reached its full height (71 ft.) in the middle of November, so that it took altogether 3½ months to develop, during which time it grew an average of 8 in. in twenty-four hours.

FLOWERING AND FRUITING. The inflorescence, which is made up of spikelets in which the flowers vary in number and arrangement, shows much variation in different species. The fruit is a caryopsis, usually of grain-like form, but sometimes large and fleshy, as in *Melocanna bambusoides*. When flowering takes place the culms as a rule remain in leaf during the early part of the flowering and gradually lose their leaves as it proceeds, although in a few cases the leaves are present throughout its duration. At times some of the culms of a clump flower and die, while the remaining culms do not; this is often observed in the case of *Dendrocalamus strictus*, and may possibly be due

[1] Ind. Forester, xliv (1918), p. 52.

to the fact that the clump has developed from more than one seedling. Some species flower annually without dying, the same clump bearing leafy and flowering culms. This appears to be a common characteristic in the bamboos of America, but is rare in those of India, where it is exemplified in *Arundinaria Wightiana* of the Nilgiris, *Bambusa lineata* of the Andamans, and *Ochlandra Rheedii* of southern India. Kurz says that *Schizostachyum elegantissimum*, a Java species, flowers and dies every third year, reaching a height of 20–25 ft. Bamboos have sometimes been observed to flower without dying, even when flowering takes place at long intervals. This is seen in certain species of *Arundinaria*, and has been observed in the case of imported specimens grown in Europe ; in such cases the flowering culms are said to have died, and the rhizomes were much weakened, but with special tending were kept alive and eventually recovered. In a general flowering of *Arundinaria falcata* at Simla in 1916 certain clumps were cut down after flowering ; in the following year it was noticed that some of them had died completely, but others had sent up new whippy flowering shoots from the rhizome, showing that the latter still retained some vitality after the first flowering. It is possible, however, that the clump arose from more than one seedling, and that part of it would have flowered in the second year in any case, as was actually observed in other clumps that had not been cut down. Various cases have been recorded in India of bamboos of different species recovering after flowering, and the phenomenon is perhaps not so uncommon as is generally supposed. Such cases, however, appear to be exceptions to the almost universal rule in the case of Indian bamboos in general, namely that these flower at long intervals, and having flowered and fruited they die, reproduction being effected by the numerous seedlings which spring up in the ensuing rainy season and take some years to mature into full-sized clumps.

Some interesting facts have been recorded from time to time in connexion with the flowering of bamboos, but our knowledge of the subject is as yet very incomplete, and the matter well deserves more detailed study. The absence of new culms is generally held to be a reliable sign of prospective flowering in the following year, but systematic observations are required in order to ascertain whether or not this is a universal rule. It has actually been observed not only in the case of bamboos which form clumps, but also in the case of the single-stemmed bamboo, *Melocanna bambusoides*. Offsets taken from clumps which subsequently flowered have themselves been found to flower. Yet a writer in the *Indian Forester*, vol. ii, p. 311, states that in the plantations of *Dendrocalamus giganteus* near Myanaung in the Irrawaddy delta the villagers are in the habit of planting offsets in gaps in the plantation, and that these offsets flower long after the parent clumps, the plantation being thus maintained perpetually. If this be so there may be exceptions to the usual rule in the case of some species or under certain conditions. Cutting down a clump which is about to flower does not prevent flowering ; in such a case a profuse mass of flowers appears on the stumps of the cut culms and on the small shoots issuing from the base of the clump. This has been frequently observed in areas cleared for temporary cultivation, particularly in the case of *Bambusa Tulda*, *Dendrocalamus strictus*, and *Cephalostachyum pergracile*. Kurz, however, mentions that in the case of some bamboo plantations it is customary to cut down all the culms the year before flowering is expected, in order to prevent flowering, and here again there may be exceptions to the general rule. Gamble [1] mentions cases of clumps of *Bambusa Tulda* and *B. nutans* producing flowers before their time when injured by cutting or partial uprooting ; it is possible, therefore, that mutilation may, as in the case of fruit trees, stimulate flowering.

Perhaps the most interesting phenomenon relating to the flowering of bamboos is that of gregarious flowering, with which is closely related the question of the life-cycle of the bamboo and the cause of flowering. So far as is known the vast majority of Indian bamboos flower gregariously and die over tracts of varying extent at comparatively long intervals of time. In addition many species flower sporadically, isolated clumps or small groups of clumps flowering and dying here and there. It is impossible always to draw a sharp distinction between gregarious flowering on a small scale and sporadic flowering on a large scale, since the two merge into each other. Similarly, although certain species show a marked tendency to flower gregariously and seldom flower sporadically, while others flower sporadically almost every year and may on occasion also flower gregariously, yet a definite line between the two classes cannot always be drawn. Among species which show a marked tendency towards gregarious flowering at long intervals of time may be mentioned *Bambusa arundinacea*, *B. polymorpha*, *Melocanna bambusoides*, and *Teinostachyum Helferi*. To the other class, namely those which often flower sporadically and may also flower gregariously, belong *Dendrocalamus strictus*, *D. Hamiltonii*, *D. longispathus*, *Cephalostachyum pergracile*, *Bambusa Tulda*, *Oxytenanthera albociliata*, and *Arundinaria falcata*. The seed from sporadically flowering clumps is said to be not always so fertile as that produced at the time of gregarious flowering ; this, however, does not appear to be a general rule, since seedlings of several species have been raised from seed obtained from solitary flowering clumps, and natural seedlings have been observed in plenty round such clumps in the forest.

Gregarious flowering usually takes place in three stages : (1) preliminary sporadic flowering, (2) gregarious flowering, and (3) final sporadic flowering of the remaining clumps. The length of each stage may vary considerably, and the first and third stages may be so prolonged as to include the second, which may not be very marked. Gregarious flowering may take place over a comparatively small area or may extend over hundreds of square miles. In many cases it has been observed to commence in one locality and to spread like a wave in a definite direction, taking a few years to extend over the whole flowering area. A general seeding of bamboo attracts to the locality numerous birds, particularly jungle-fowl and pheasants, which as a rule are exceptionally numerous in such areas. The fleshy fruits of *Melocanna bambusoides* similarly attract bison, deer, pig, and other animals. In Burma it has been noticed that in years of gregarious seeding of bamboos rats multiply freely, and when the seeding is over these pests commit great havoc among the neighbouring agricultural crops. For a few years after a general bamboo seeding the forests are littered with a mass of dead culms which are often bound together with herbaceous climbers and form a dense impenetrable tangle, blocking paths

[1] Bambuseae, pp. 31 and 33.

and floating-streams. In such places fires of great intensity rage, but while they do severe damage to the tree-growth they are not without their use in helping to clear the ground and make way for natural reproduction.

The factors which determine the life-cycle of bamboos and the occurrence of general flowering are not yet clearly understood. Certain evidence points to the probability that abnormally dry seasons stimulate flowering. Kurz mentions that in two abnormally hot dry seasons in Burma the number of flowering species collected by him was remarkably large; also that in the Calcutta Botanical Gardens an exceptionally large number flowered in 1874, a year of exceptional drought. Other instances of plentiful flowering in hot dry seasons have been recorded from time to time in different forest tracts. The influences which stimulate flowering, however, must act some time beforehand, while gregarious flowering repeatedly occurs in seasons which are not abnormal and in localities where drought is unknown. Further, the flowering of those bamboos which flower annually or at short regular intervals cannot be explained on climatic grounds. But perhaps the strongest evidence against the climatic theory is the fact that bamboos raised artificially by offsets or from seed may flower simultaneously with clumps of the parent stock, or with others raised artificially from the same stock, in different localities under different climatic conditions. Thus *Melocanna bambusoides* flowered in the Bamonpokri plantation, Kurseong, in 1912–13, simultaneously with the general flowering of natural plants in Chittagong. *Dendrocalamus Hamiltonii* planted at Dehra Dun flowered in 1894, simultaneously with a general flowering in the forests of Sikkim. *Arundinaria falcata* planted in Simla flowered freely in 1916, and in the same year this species flowered gregariously in the forests of Jaunsar. MM. A. and C. Rivière [1] mention that in 1867 or 1868 *Arundinaria japonica* flowered almost simultaneously in the Bois de Boulogne, at Sceaux, at Marseilles, and at Hamma in Algiers. These plants were all offsets from a parent plant introduced from Japan in 1850. Again, M. Carrière [2] says that *Arundinaria falcata* (*A. Falconeri* ?) flowered in 1875–6 in Brittany, Normandy, Angers, Nantes, Algiers, and the garden of the Luxembourg. In the same year it flowered at Fota Island, Co. Cork.[3] So far as evidence goes, therefore, although it is not unlikely that hot, dry seasons may stimulate flowering to the extent of accelerating it by a short time, it is difficult to conceive how they can do so except in the case of clumps which have almost reached the end of their life-cycle, and would have flowered before long in any case.

It may be assumed then that the period between successive flowerings of any bamboo represents its physiological life-cycle; it is possible, moreover, that this cycle may be influenced to a slight extent by climatic or other causes, but primarily it is determined by physiological causes inherent in the plant. That this period varies with different species is certain; whether or not it varies for the same species in different localities is not known. Certain species flowering annually or at short intervals have been mentioned. In the case of those species which flower at long intervals it is very difficult to determine accurately, owing to the incompleteness of past records, if the period is constant even in the same locality, but on the analogy of the annual or short-period

[1] Les Bambous. [2] Revue Horticole.

[3] A. B. Freeman-Mitford, The Bamboo Garden, 1896, p. 8.

species and of other plants like some species of *Strobilanthes*, whose life-cycle is known to be constant, it is reasonable to suppose that the cycle of the long-period bamboos may be at least approximately constant. So far as incomplete records show, the life-cycles of some of the commoner Indian bamboos appear to be approximately as follows : *Arundinaria falcata*, 28–30 years ; *Bambusa arundinacea*, 32–34 years ; *Dendrocalamus strictus*, between 30 and 40 years ; *Melocanna bambusoides*, about 45 years (Chittagong and Arakan). *Bambusa polymorpha* flowered gregariously along the western side of the Pegu Yoma about 1859 and 1860 ; signs of another general flowering have been in evidence since 1918, so that its life-cycle may prove to be 60 years or a little more.

The extraordinary phenomenon of the gregarious flowering of bamboos at long intervals, with their subsequent death and regeneration from seed, is a source of wonderment to those who have witnessed it, and interesting speculation is possible as to its origin. If the constancy of the life-cycle be accepted as a fact the phenomenon admits of a possible explanation. In the case of species like *Dendrocalamus strictus*, *Cephalostachyum pergracile*, and *Bambusa Tulda*, which frequently flower sporadically, the flowering may be observed in single clumps, or in patches of a few clumps together, which have apparently sprung from a solitary flowering clump of the previous generation, or in small groups of less than an acre, apparently the result of the spread of the seed from one or a few flowering clumps of the previous generation, or in larger groups. And so the progress can be traced from small to large groups of varying size and thence to general flowering over restricted areas and finally to gregarious flowering over considerable tracts of country. This would lead to the conclusion that gregarious flowering is the result of the gradual spread of the species, through successive and more or less constant life-cycles, over a wide area from one or a limited number of original flowering individuals. If this be so, then in the case of those species like *Bambusa polymorpha*, which flower at long intervals with a marked tendency to gregariousness over extensive tracts, the process of taking possession of the ground must have occupied a considerable period of time, and the life-cycles of the various individuals of the crop must have been remarkably constant.

This theory, however, is discounted by the fact that in certain cases of gregarious flowering young plants only a few years old have been found to flower along with the mature clumps. Mr. A. Smythies,[1] describing the gregarious flowering of *Dendrocalamus strictus* in the Chanda district, Central Provinces, says that clumps of all ages flowered—not only mature clumps, but also young plants of six or seven years' growth or even less. Mr. E. V. Ellis [2] describes a gregarious flowering of *Cephalostachyum pergracile* in Toungoo, Burma, in which young plants, some estimated at about three to six years old and others at about ten years old, had flowered freely. The writer, however, makes an interesting statement with regard to the plants estimated to be about ten years old, namely that the culms had for some reason died, only their bases remaining on the rhizomes, while from dormant buds on these bases numerous 5-foot shoots had come up and flowered. The rhizomes of these young flowering shoots did not appear to be in any way mature. This certainly suggests that it may be easy to confound seedling growth with shoots

[1] Ind. Forester, xxvii (1901), p. 126.
[2] *Ibid.*, xxxiii (1907), p. 323.

springing from rhizomes which may be connected with those of the mature plants. A fact which I, and no doubt others, have observed in forest of *Bambusa polymorpha* and *Cephalostachyum pergracile* is that a dense growth of whippy shoots often springs up between the clumps, particularly in fire-protected areas, where such growth is encouraged ; these shoots do not consist of seedling growth, since they are found in areas where no recent flowering has taken place, and since they spring from the rhizomes originating from the mature clumps they would naturally be expected to flower when the latter flower. It is reasonable to assume, in the absence of more detailed investigation, that *Dendrocalamus strictus* and other species may under certain conditions similarly produce small shoots of a seedling-like appearance from rhizomes originating from older clumps. It is also possible that suppressed clumps and culms, which have not been able to develop normally, may sometimes be mistaken for seedling growth owing to their small size, although in age they may be equal to the rest of the bamboo crop.

Instances of the undoubted flowering of young bamboo seedlings have been observed from time to time, but these are mere abnormalities. Mr. Sunder Lal Pathak [1] records an instance of the flowering in April 1896 of five seedlings of *Dendrocalamus strictus* raised from seed sown a year previously in a nursery at Pinjour near Kalka ; these died within three or four months of flowering.

GROWTH OF SEEDLINGS AND DEVELOPMENT OF CULMS AND CLUMPS. In the normal caespitose types of bamboos with grain-like seeds, when germination takes place the plumule emerges in the form of a pointed conical bud with sheathing scale-like leaves, which rapidly develops into a thin, wiry stem bearing single foliage leaves arising alternately at the nodes, the bases of the leaves sheathing the stem. Meanwhile fibrous roots develop from the base of the young shoot. The tufted form of the young plant commences to show itself at an early stage. This is effected by the production on the rhizome of successive pointed buds, from which are developed short rhizomes which curve upwards and form aerial shoots. The buds and rhizomes, and the shoots arising from them, become successively larger and larger. The earlier shoots are thin, wiry, and grass-like, but subsequently a time comes when woody culms are produced, which bear some resemblance to the adult culms in form, in the shape of the sheaths, and in other particulars. The transition between the grass-like and the woody culms is gradual ; the latter are at first thin and whip-like, and only at a later stage do culms in any way approaching in size or appearance those of the normal adult clump commence to form. The rate of development of the clump depends very largely, even in the same species, on the conditions under which it has been grown ; this will be referred to below.

A tufted growth may commence to form at an early age. Fig. 373 shows successive stages in the development of a seedling of *Arundinaria falcata*. Fig. 374 shows the germination and early seedling stages of *Dendrocalamus strictus*. In this species the new rhizomes of seedlings take a decided bend downwards before curving upwards to form aerial shoots ; thus the successive shoots, besides being larger than the preceding ones, arise from rhizomes

[1] Ind. Forester, xxv (1899), p. 22.

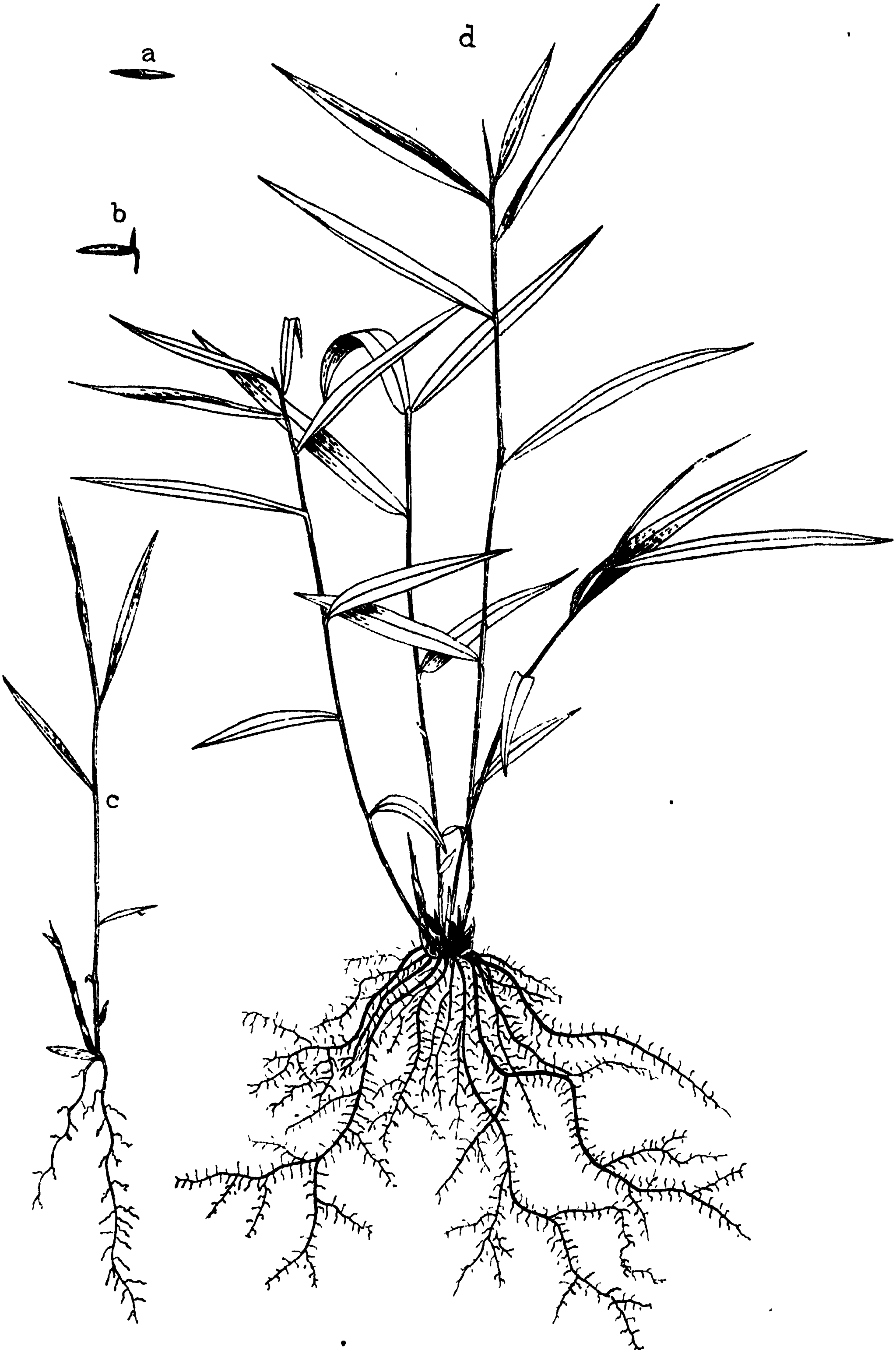


FIG. 373. *Arundinaria falcata.* Seedling × ¾.

a, seed; *b*, germinating seed; *c*, seedling one month old with seed still attached, showing commencement of formation of tufted stems; no rhizome yet formed; *d*, seedling four months old, end of October.

deeper in the ground. This can be seen in Fig. 376, in which the shoots formed earliest are seen on the left and the one formed latest is seen on the right. In vigorous nursery-grown seedlings of *Dendrocalamus strictus* as many as ten shoots have been counted on seedlings at the end of the first season. Fig. 375 represents a nursery-raised seedling fourteen months old, in August, with six consecutive shoots including the original one. It shows the increase in size of the successive rhizomes and shoots and the manner in which the former push their way deeper and deeper into the ground.

Under unfavourable conditions the shoots of bamboo seedlings may die back for some years in succession before the plant finally establishes itself; this is particularly common in the case of *Dendrocalamus strictus* in dry situations. Even under more or less favourable conditions the first shoot of the seedling may die off at the end of the first season (see Fig. 374, *h*). Under normal conditions the earlier shoots die off sooner or later, on being supplanted by the larger and more vigorous shoots formed subsequently.

The gradual development of the normal clump from the seedling has been carefully observed in the case of *Dendrocalamus strictus*. The formation of clumps in the case of single plants is normally effected by the gradual spread of the plant from the centre outwards by the formation of new rhizomes from which spring new shoots. Under natural conditions, in which the ground may be covered with innumerable seedlings, the formation of clumps is the result of a thinning-out process in which the more vigorous individuals survive. Natural clumps may consist of more than one original seedling.

The time taken to form clumps and to produce normal culms depends greatly on the conditions under which the plants have grown. In the case of artificially raised plants, regularly weeded and watered, whippy culms commence to be produced in the second season, these issuing from amongst a mass of wiry stems previously formed (see Fig. 377). In the third season fair-sized culms, beginning to have the appearance of adult culms, may be formed (Fig. 378). The statement on page 988 shows the rate of development of artificially raised seedlings in some of the experimental plots at Dehra Dun.

In the weeded line sowings the bamboos were large enough to commence working in the sixth year and to yield an average of one to two culms per clump.

Natural seedlings develop much more slowly than those grown artificially under favourable conditions. In January 1911 two plots about half a mile apart were carefully fenced off in the fire-protected sub-Himalayan forests near Kotdwara at the base of the Lansdowne hills in an area where *Dendrocalamus strictus* had recently flowered gregariously, the ground being carpeted with seedlings one year old; a few older seedlings were present, but these have been omitted in the measurements recorded below. The statement on page 990 gives the height and condition of these natural seedlings each year up to an age of eight years.

Dendrocalamus strictus: development of artificially grown seedlings at Dehra Dun.

	No.	Conditions under which grown.	Height and other particulars at the end of season. 1st season.	2nd season.	3rd season.	4th season.	5th season.	6th season.
	1	Direct sowing, watered and weeded	Maximum 1 ft.	Maximum 8 ft. 6 in.: vigorous	9 ft. 8 in.–12 ft.	Maximum 14 ft.: several stout culms		
Adjacent.	2	Line sowings, irrigated, weeded, thinned	Maximum 4 ft.: vigorous.	Maximum 14 ft.	5 ft.–14 ft. 4 in. Maximum diameter 0·5 in.		Mean 24 ft. Maximum 30 ft. Mean diameter 2·1 in.	Maximum 38 ft. (35 clumps).
	3	Line sowings, irrigated, weeded, unthinned	Maximum 4 ft.: vigorous.	Maximum 6 ft.	2 ft. 3 in.–12 ft. 5 in.: culms thin.			
	4	Line sowings, irrigated, unweeded	Maximum 2 ft. 6 in.	Maximum 4 ft.: thin, suppressed	2 ft. 2 in.–11 ft.: few surviving.		Maximum 19 ft.	Maximum 30 ft. (only 3 clumps surviving).
	5	Line sowings, unirrigated, weeded	Maximum 3 ft. 6 in.	1 ft. 6 in.–11 ft.: vigorous, with strong culms	Maximum 16 ft. Maximum diameter 1 in.: vigorous		Mean 28 ft. Maximum diameter of new culms 2·1 in.; 5–11 new culms per clump	Mean 32 ft. Maximum 38 ft. Average 8 new culms per clump, maximum diameter 2·2 in.
	6	Line sowings, unirrigated, unweeded	Maximum 2 ft. 7 in.	1 ft. 4 in.–5 ft.: thin, suppressed	Maximum 7 ft. 6 in.: condition poor			
	7	Line sowings, unirrigated, weeded, raised with field crops	Maximum 2 ft. 8 in.	Maximum 12 ft.: average 4 ft. 6 in.				
	8	Nursery transplants, two months old, not watered or weeded after transplanting	Maximum 2 ft. 1 in.	Maximum 5 ft. 2 in.	3 ft. 10 in.–13 ft. 3 in.			
	9	Nursery transplants, two months old, not watered or weeded after transplanting	Maximum 3 ft.	Maximum 7 ft.	4 ft. 8 in.–12 ft. 6 in.			
	10	Nursery transplants, two months old, not watered or weeded after transplanting	Maximum 1 ft. 5 in.	Maximum 5 ft. 2 in.	3 ft. 2 in.–13 ft.			
	11	Nursery transplants, one year old, not watered or weeded after transplanting	..	3 ft.–4 ft.	Maximum 15 ft.	Well-formed clumps, maximum height 9 ft. 9 in. to 21 ft.: maximum diameter 1 in.: largest clump with eight well-developed culms.		

Fig. 374. *Dendrocalamus strictus*. Seedling.

a, seed $\times \frac{3}{2}$; *b–g*, germination and development of seedling during first season $\frac{1}{3}$; *h*, seedling early in second season $\times \frac{1}{3}$. The original shoot (on right) has died down; the leafy shoot is the new season's first shoot.

Dendrocalamus strictus: development of natural forest seedlings, Kotdwara.

Year.	Age. years.	Height and condition. Plot 1.	Plot 2.
1911–12	2	2–2½ ft.	1½–2½ ft.
1912–13	3	Maximum 4½ ft.: average 3–3½ ft. Stems wiry and grass-like.	2–4 ft.
1913–14	4	Chiefly 4½–5 ft. A few whippy culms commencing to form: otherwise stems for the most part thin and wiry.	Chiefly 3–5 ft.
1914–15	5	Chiefly 7–9 ft. Small culms formed.	Chiefly 5–7 ft.
1915–16	6	Clumps commencing to form. Many seedlings thin and wiry, suppressed by the more vigorous individuals.	
1916–17	7	Dense mass of small clumps. Mean height 10 ft. Diameter chiefly about ½ in., maximum 1½ in.	Clumps somewhat scattered, height 8–9 ft.
1917–18	8	Dense mass of small clumps. Average about 5 culms per clump. Mean height 15 ft.: mean diameter 0·8 in. Best clump with mean height 24 ft., mean diameter 1·4 in., with 7 new culms averaging 28 ft. in height	Average about 4 culms per clump. Mean height 18 ft.: mean height of new year's culms 25 ft. Best clump with 15 old culms of mean height 24 ft. and 6 culms with mean height 28 ft., mean diameter 1·2 in.

Figs. 379 and 380 show the appearance of plot 1 at three years and seven years of age respectively. Judging from the size of the culms and clumps at the last time of recording they might be expected to reach exploitable size at an age of about twelve or thirteen years, that is, in about twice the time required for plants raised artificially and carefully tended.

The season in which new culms are produced appears to be more irregular in the case of young plants than in the case of adult plants. Thus at Dehra Dun seedlings of *Dendrocalamus strictus*, even when not watered, produce new culms at different times from May to October, whereas adult plants produce them normally only in the rainy season from July to September.

Bamboo seedlings in general benefit by a certain amount of protection from the sun, the amount depending on the species and locality. Even in the case of *Dendrocalamus strictus*, which is found naturally in dry hot localities, this early shade is beneficial. In an experiment in the Jubbulpore district in 1910–11, of 200 seedlings of this species transplanted at the commencement of the rains half were planted under cover and the other half in the open; of the former the whole, and of the latter only 60 per cent., survived. Dense shade and heavy weed-growth, however, are detrimental, and cause wholesale mortality. Bamboo seedlings have many natural enemies. Rats kill them by gnawing through the rhizomes and the base of the stems, squirrels gnaw the shoots, pigs and porcupines dig up young plants in quantity to eat the rhizomes and young shoots, while the seedlings are readily browsed by hares, deer, goats, and cattle.

Hitherto we have dealt mainly with seedlings and young clumps. A clump may be said to have attained maturity when it commences to produce full-sized culms. Thereafter it continues to enlarge by the formation of new branches to the mass of rhizomes, and the number of new culms produced annually continues to increase up to a point. The size of the clump, however,

FIG. 375. *Dendrocalamus strictus*—SEEDLING × ¼

Nursery-raised seedling 14 months old, August, showing successive shoots, marked a to f

depends more on its vigour, that is, on favourable conditions of soil, climate, &c., than on its age. The older culms in time die off, but the time during which a culm normally survives in the case of different species and under different conditions has not yet been determined. Mr. R. S. Pearson [1] found the following average ratio of new to old culms in clumps of the three species named :

Bambusa arundinacea (W. Coast) . . .	1 new to 3·42 old
Cephalostachyum pergracile (Burma) . . .	1 new to 2·93 old
Bambusa polymorpha (Burma)	1 new to 4·22 old

Unless it is certain, however, that the number of old culms is limited by natural death and not by felling, that is, unless countings are made in areas where no felling has taken place, an estimate based on the ratio of new to old culms might be misleading.

Mr. W. H. Lovegrove [2] has recorded some observations on the growth of clumps of *Dendrocalamus strictus* which bear on the correct method of working bamboos. He notes that whereas during the development of the clump the rhizomes tend to spread outwards from the centre, with advancing age the clump tends to advance in certain directions only, that is, in the directions most favourable to the development of the rhizomes. On a slope the tendency is to advance up the slope. Injury, such as the cutting of culms on one side of the clump only, causing the death of the rhizomes, or obstructions such as rocks or hard ground, prevent the spread of the clumps in the direction where the injury takes place or the obstruction occurs and cause the clump to extend in another direction. He further traces the cause of the formation of congested clumps to injury round the periphery, and this is further supported by observations recorded later by Mr. B. A. Rebsch.[3]

The formation of congested clumps, in which the culms are packed tightly together and are often much bent and twisted, is frequently seen under certain conditions, especially in village lands and on the outskirts of the forest where the clumps suffer injury, and in places where the soil is poor, dry, or hardened. It is particularly common in the case of *Dendrocalamus strictus* (see Fig. 381). The correct explanation of this abnormal growth, in most cases at all events, is no doubt the one advanced by Messrs. Lovegrove and Rebsch, namely that the clumps have been reduced to this condition by ill treatment, such as unrestricted cutting round the periphery, browsing of the young shoots round the edge of the clump by cattle, the ground simultaneously becoming hardened, continual removal of the young tender shoots for food, and digging up culms with rhizomes attached for sticks. This constant injury to the periphery of the culm causes the death of the rhizomes, and in time a dense mass of dead rhizomes prevents the living rhizomes from spreading outwards. The latter accordingly develop within the clump, where also the new culms are produced year after year, with the result that congestion takes place and the new culms may bend in all directions in their efforts to penetrate the dense mass of older culms.

In the case of the single-stemmed bamboos, in which the rhizomes instead of being massed together spread laterally to a considerable distance and send up single culms at intervals, the development is abnormal. This, at all events, is the case with *Melocanna bambusoides*, the most important Indian species

[1] Ind. For. Records, vol. iv, pt. v, 1913, p. 18. [2] Ind. Forester, xxvi (1900), p. 433.
[3] *Ibid.*, xxxvi (1910), p. 202.

and the only species of *Melocanna* whose flowers and fruits are at present known. The fruits are large and fleshy, and the seedlings grow vigorously and produce strong culms from the time of germination ; these attain a height of several feet by the end of the first season and reach exploitable size within a few years.

Natural reproduction. Under natural conditions the seed germinates at the commencement of the rainy season, and the ground in the neighbourhood of the seedling clumps becomes carpeted with young seedlings. These spring up and survive in greatest abundance on bare ground, and particularly on newly exposed soil. Where there is a heavy growth of weeds the seedlings are apt to be killed off. Although bamboo seedlings have great power of recovery after being burnt, protection from fire encourages their growth to a remarkable degree, as may be seen in the case of young growth of *Cephalostachyum pergracile* and other species in the moist mixed forests of Burma ; if this seedling growth is fire-protected it grows up in the densest masses, choking the natural reproduction of teak and other trees.

Grazing is the greatest enemy of natural reproduction. In some of the heavily grazed forests of the sub-Himalayan tract, where *Dendrocalamus strictus* flowered gregariously from 1908 to 1913, the bamboo has been exterminated by grazing in areas where timely steps were not taken to protect the young growth. Some remarkable instances were noticed in the neighbourhood of Kotdwara. Here the seedlings which sprang up in abundance were in certain areas grazed to such an extent that the ground by January appeared to be devoid of any bamboo seedling growth. Seedlings, however, survived in the middle of the dead bamboo clumps where they were out of reach of cattle, and some of these eventually established themselves. In one of these heavily grazed areas two plots, which have already been alluded to, were fenced off the year seeding took place. Within the plots young bamboo growth established itself in dense masses, whereas outside the fence, where constant grazing took place, the bamboo was exterminated. Fig. 382 shows the edge of one of the protected plots seven years after fencing ; the dense growth of young bamboos within the fence, on the left, may be contrasted with the complete absence of bamboo growth outside it, on the right.

In spite of the damage done by grazing, however, bamboo seedlings for a time have great power of recovery. An area near Kotdwara was fenced off two years after the seeding of the bamboo, and in the meantime heavy grazing had kept the ground bare of seedlings ; nevertheless after fencing was carried out seedlings sprang up in quantity from the rhizomes which had not been destroyed. Where fencing could not be carried out owing to grazing rights, the expedient was resorted to of overturning the dead bamboo clumps in the rainy season with the aid of elephants ; numerous seedlings made their way through the fallen clumps and were thus saved.

Artificial reproduction. Bamboos may be propagated artificially by seed, by division, by offsets, by stem or rhizome cuttings, or by layers.

Propagation by division is usually carried out in the case of the dwarf bamboos, which are easy to handle and transport bodily. This consists in dividing up the mass of rhizomes and transplanting the culms in small clumps of two or three with rhizomes attached ; transplanting is best carried out

FIG. 376. *Dendrocalamus strictus*, artificially raised seedling in second season, showing root-system and rhizomes.

FIG. 377. *Dendrocalamus strictus*, artificially raised seedling in second season, showing development of culms. Staff shows feet.

Fig 378 *Dendrocalamus strictus*, artificially raised plants, end of third season, Dehra Dun.

immediately before the growing season commences, and as much earth as possible should be kept round the rhizomes.

The commonest method of propagation by cuttings is that usually termed planting offsets. Culms one year old are cut through with a slanting cut about 3 to 4 ft. from the ground, and the rhizomes to which they are attached are dug up with the roots intact and cut off to a length sufficient to include a well-developed bud. These offsets are planted out sufficiently deep to cover the first two or three nodes, which are usually found close together at the base of the culm. The transplanting of offsets should be carried out immediately before the beginning of the rainy season, and watering should be done in dry weather. A new shoot is produced sometimes in the first year, sometimes not until the second year.

Stem cuttings without rhizomes attached are very uncertain. Vertical stem cuttings are usually taken by cutting the culm down as low as possible, where it joins the rhizome, so as to include the lowest nodes, which tend to produce rootlets. Culms one year old should be employed. In the case of dwarf species the whole culm may be planted, but in the case of the larger bamboos the cutting should be about 2 to 3 ft. long. These cuttings are planted vertically or nearly so, the group of nodes at the base being completely buried. It is preferable to keep cuttings in the nursery until they are well rooted, watering being carried out regularly in dry weather. In the case of some species cuttings, consisting of two nodes with the intervening internode, half buried more or less vertically in manured soil in nursery beds, and well watered, will strike successfully; they require regular watering for some time after transplanting. Another method is to place stem cuttings, consisting of one internode with a node at either end, horizontally in the ground so as almost to cover them with earth, leaving only their upper surface exposed; in that surface a notch may be cut large enough to allow water to enter the hollow internode. Sprouting and rooting eventually takes place at the nodes. This method was tried with several species at Dehra Dun, but the only one which gave much success was *Dendrocalamus Brandisii*, though even with this species the resulting growth was slow.

Rhizome cuttings, that is, sections of fresh living rhizomes of the preceding year about 6 to 12 in. long, containing at least one bud, form a successful means of propagating certain species, particularly *Melocanna bambusoides*, which sprouts readily from such cuttings. These cuttings should be well watered in dry weather.

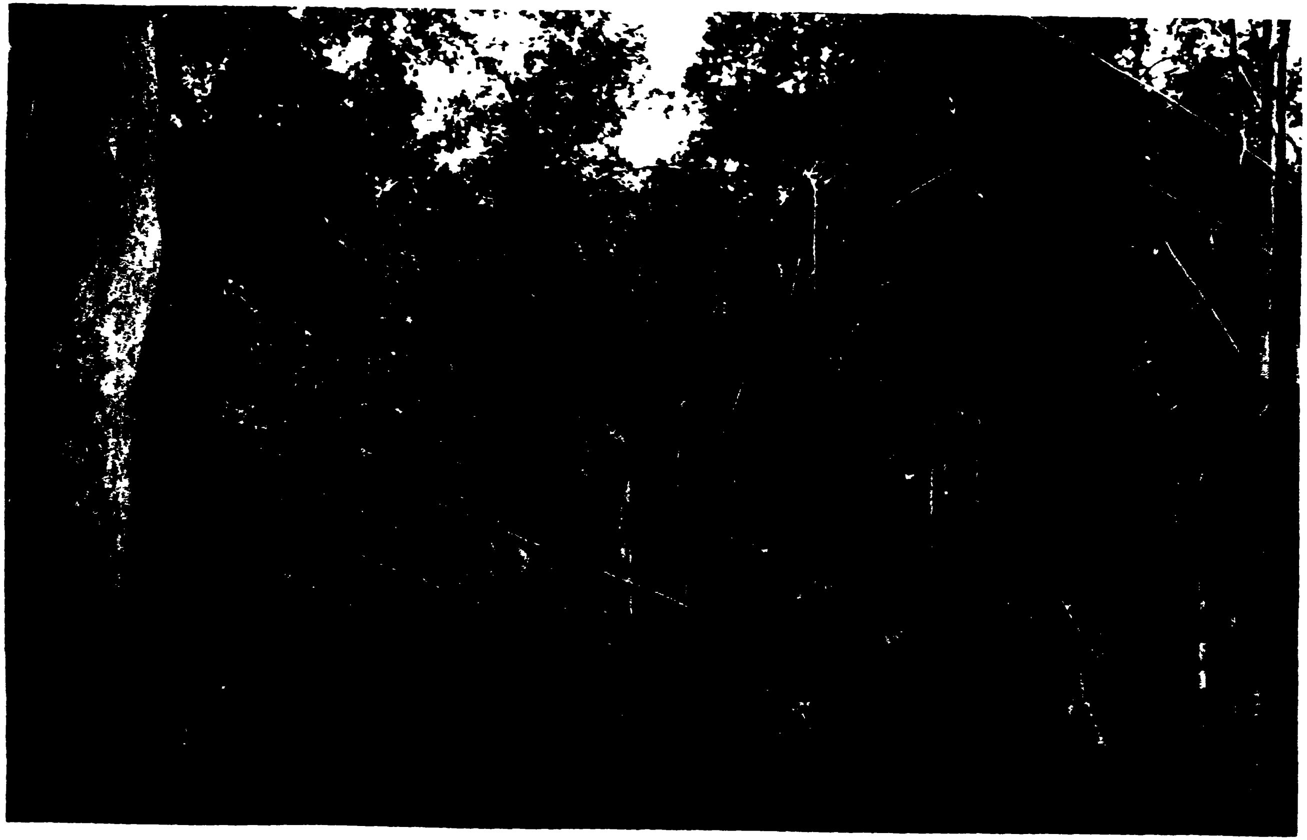
Some species, such as *Bambusa vulgaris*, are propagated by layers, the culm being partly cut through near the base, bent over and pegged down below the ground. Roots eventually develop and shoots are produced at the nodes: the internodes are then cut through and the resulting plants are separated and planted out.

Where bamboos are propagated from cuttings or by other vegetative methods of reproduction some years are required for a normal clump of full-sized culms to form. Under such methods of propagation the resulting clumps are liable to flower when the parent clumps flower, and their life may be short or uncertain. For forest purposes propagation from seed is certainly the most satisfactory method wherever seed is obtainable, but in the case of species which flower at long intervals it cannot be resorted to regularly. Propagation from seed may be effected either by direct sowing or by transplanting seedlings raised in the nursery.

Direct sowings of *Dendrocalamus strictus* in lines have been carried out experimentally at Dehra Dun with great success. The experimental lines were 10 ft. apart, and were thoroughly dug up to a width of 3 ft. In actual practice the distance between lines would vary with the species of bamboo; for *Dendrocalamus strictus* 18 to 20 ft. would probably suffice. Seed was sown early in June along the centre of each line and lightly covered with earth, one pound of seed sufficing for 600 ft. of line. Subsequent weeding was found to be essential. Where weeding was not carried out the seedlings soon became suppressed and were eventually killed out, whereas weeding accompanied by loosening of the soil along the lines stimulated growth to such an extent that the culms of the fourth year attained a height of 20 to 24 ft. and a diameter of 1·5 to 1·8 in. No watering or irrigation was carried out at any time. It was found advantageous to thin out seedlings, where too crowded, at the end of the first season, to an interval of 3 to 4 ft.; this had a great effect on the growth of the plants left. A second thinning was found to be beneficial about the third or fourth year, after clumps and thick culms had begun to form, the thin whippy shoots being cut out and the clumps separated as far as possible. Fig. 383 shows an unirrigated line sowing after the third rainy season, and Fig. 384 a portion of a line with plants four years old, in which a thinning has recently been carried out. A further series of experiments consisted in raising the same species in unirrigated line sowings with the aid of field crops. The crop employed was the lesser millet, *Eleusine coracana* (vern. *mandwa*), which was sown in the latter half of May and reaped in October, when it was about 4 ft. high. The lines were prepared as before and the bamboo seed was sown early in June. It was found necessary to leave a width of 2 to 3 ft. along the line clear of crops, since the latter if sown continuously over the area tended to suppress the bamboo seedlings. Weeding and thinning were carried out as before, and the results were even better than in ordinary line sowings without field crops, while the expenditure on weeding was considerably less, since the cultivator was responsible for carrying it out while the crops were on the ground. Fig. 385 shows a line in the first season before the crop was reaped.

Irrigated line sowings proved equally successful where weeding was carried out regularly, but so far as the growth of the bamboo and the general results were concerned there was little difference between the irrigated and the unirrigated lines. For moisture-loving species or in dry climates, however, irrigated line sowings would no doubt justify the extra expenditure on irrigation. The water-channels are dug about 1 ft. deep and 1 ft. in mean width, the earth being heaped up in a ridge running along one side of the channel. The seed is sown along the base of the ridge on the side facing the channel. Irrigation by percolation was found to be preferable to flooding in the case of *Dendrocalamus strictus*.

Transplanting from the nursery is frequently resorted to. The seed should be sown in prepared seed-beds shortly after it ripens, or in the case of the hill species in early spring. The seed may be sown either in drills or broadcast,



'*rocalamus strictus*, establishment of natural 'eproduction. Ko ara. Un Pı
dense mass of natural seedlings of 3 rain seasons (other s of fenc

FIG 380 *Dendrocalamus strictus*, establishment of natural reproduction. Kotdwara United Provinces: (2) same plot after 7 rainy seasons.

the latter being preferable if rats are to be feared, and the seed-beds should be watered and weeded regularly. In the case of most species the plants are ready for final transplanting during the first rainy season. Sometimes they are pricked out in the nursery when a few inches high, but this is not always necessary. Great care is required in planting out, since bamboo seedlings are liable to wither if the roots are exposed to the sun, for which reason the roots should be kept surrounded with earth. In order to guard against failure two or three seedlings are sometimes planted in each pit. In dry localities it may be necessary to water the young plants for some time after transplanting. It is sometimes customary to transfer the seedlings, when two to three months old, from the seed-bed to bamboo baskets, where they are kept until ready for transplanting in the rainy season. The transplanting of natural forest seedlings of *Dendrocalamus strictus* about a foot high has been found to be very successful and cheap. In dry regions it has been found of great advantage to plant out bamboo seedlings under the shade of bushes and low trees ; if this is done it may be possible to dispense with watering.

Experiments carried out at Dehra Dun with *Dendrocalamus strictus* showed that transplanting was far less successful in the dry season than in the rainy season ; in the former case, although 80 per cent. of the plants survived, the subsequent growth was not good. In these experiments transplanting in the second rainy season was found to be not only more expensive, owing to the large size of the plants, but also less successful than in the first season, a large proportion of the plants dying in the former case. An attempt was also made to transplant in the second rains after cutting the culms down to two nodes from the ground, but this proved to be a failure.

Experiments with *Arundinaria falcata* at Simla showed that good results can be attained by sowing the seed in the nursery in February or March and transplanting in the ensuing rainy season or in February the next year. Care is required not to expose the roots during transplanting.

The formation of bamboo plantations is not unattended with risks. Young plants, both in the nursery and after transplanting, suffer from the depredations of rats, hares, porcupines, pigs, deer, and cattle, and careful fencing may be necessary until the plantation is out of danger. Where successful, bamboo plantations are a source of considerable profit where natural bamboos are absent or insufficient to meet demands. A plantation of *Bambusa arundinacea* near the village of Yeota in the Akola district, Berar, was commenced in 1887 and completed about ten years later. Nursery plants a year old and 1½ to 4 ft. high were planted out 10 ft. by 10 ft., two plants in each pit, and watered for two years after planting. In 1913 the plantation had an area of 25 acres, and contained nearly 3,000 clumps. The total cost of formation and upkeep amounted to Rs. 399 and Rs. 1,032 respectively. The first exploitation was made in 1902–3, and the total number of bamboos extracted up to 1911–12 was 50,053, the cost of exploitation being Rs. 1,163. The gross revenue derived was Rs. 4,875, which gives, after deducting all expenditure, a net return of Rs. 91 per acre in twenty-five years, or Rs. 3–10–0 per acre per annum from the commencement. This does not take into account the value of the land or interest on capital, but as an example of what is possible in a dry region the results are not unfavourable.

EXPLOITATION. The correct method of exploiting bamboos with the view of obtaining the maximum out-turn without impairing the vigour of the clump is one in which our knowledge is as yet far from complete. Methods of working ordinarily resolve themselves into the removal, at definite intervals of years, of either all the old culms, that is, culms more than one year old, or a certain number or proportion of them. The tract to be worked is divided into a number of equiproductive blocks corresponding to the interval of years in question, and the blocks are worked in rotation. When working is carried out on a large scale it is often considered impracticable to supervise any system of cutting out only a portion of the old culms, though this is actually provided for in some working plans, which prescribe the retention of a fixed number of culms per clump, usually eight or ten, and prohibit cutting from any clump unless it contains a larger number of culms than this. Ordinarily no culm less than one year old should be cut, but where young culms are required for basket-manufacture it is customary to permit the removal of a small proportion of these under careful supervision. As regards the rotation, it was formerly the practice to adopt one of two years only, that is, to divide the tract into two blocks and to work them alternately. It has, however, since been ascertained that the clumps deteriorate under such a short rotation, and one of three years is now commonly adopted, though it has by no means been proved that this is not also too short. In some localities longer rotations, up to six years, are in force.

The height at which the culms should be cut is another matter of importance. Bamboo cutters, unless controlled, are apt to cut them several feet above ground, and in time the clump becomes choked up with dead and dying lengths of culms which render cutting difficult. In the Siwaliks systematic thinnings had at one time to be carried out for a series of years, at considerable expense, in order to remove the masses of culm remnants from within the clumps. On the other hand, it has been held by some that cutting low down near ground-level is injurious in that culms when cut die down at the rate of one internode a year, and hence if low cutting is carried out the rhizomes quickly die. The experiments mentioned below have shown that the view that cut culms die at the rate of one internode a year is not correct ; that they die down in many cases is true, but the rate of dying appears to depend mainly on the vigour of the culm, some dying down rapidly and others not dying at all for a few years at least. Nevertheless as the point is still in doubt it is now usually customary to prescribe cutting at a definite height, say between 1 and 2 ft. from the base, thus effecting a compromise between high and low cutting. The judicious thinning out of dead culm remnants and twisted culms from within the clumps has been found most beneficial in the case of *Dendrocalamus strictus* in the Siwalik hills, where also the use of the saw in preference to the axe has been found to minimize the damage to the stumps of felled culms. Nevertheless, the drastic removal of quantities of culm remnants from within a clump may do more harm than good. Mr. A. Wimbush[1] records a case in South Malabar of an experimental cutting out of culms and dead lengths of culms cut high in former fellings, the species being *Bambusa arundinacea*. From four clumps 99 green bamboos and 109 dead lengths were

[1] Ind. Forester, xxxix (1913), p. 155.

FIG. 381. *Dendrocalamus strictus*, congested clump; note dead rhizomes on periphery.

Exploitation. The correct method of exploiting bamboos with the view of obtaining the maximum out-turn without impairing the vigour of the clump is one in which our knowledge is as yet far from complete. Methods of working ordinarily resolve themselves into the removal, at definite intervals of years, of either all the old culms, that is, culms more than one year old, or a certain number or proportion of them. The tract to be worked is divided into a number of equiproductive blocks corresponding to the interval of years in question, and the blocks are worked in rotation. When working is carried out on a large scale it is often considered impracticable to supervise any system of cutting out only a portion of the old culms, though this is actually provided for in some working plans, which prescribe the retention of a fixed number of culms per clump, usually eight or ten, and prohibit cutting from any clump unless it contains a larger number of culms than this. Ordinarily no culm less than one year old should be cut, but where young culms are required for basket-manufacture it is customary to permit the removal of a small proportion of these under careful supervision. As regards the rotation, it was formerly the practice to adopt one of two years only, that is, to divide the tract into two blocks and to work them alternately. It has, however, since been ascertained that the clumps deteriorate under such a short rotation, and one of three years is now commonly adopted, though it has by no means been proved that this is not also too short. In some localities longer rotations, up to six years, are in force.

The height at which the culms should be cut is another matter of importance. Bamboo cutters, unless controlled, are apt to cut them several feet above ground, and in time the clump becomes choked up with dead and dying lengths of culms which render cutting difficult. In the Siwaliks systematic thinnings had at one time to be carried out for a series of years, at considerable expense, in order to remove the masses of culm remnants from within the clumps. On the other hand, it has been held by some that cutting low down near ground-level is injurious in that culms when cut die down at the rate of one internode a year, and hence if low cutting is carried out the rhizomes quickly die. The experiments mentioned below have shown that the view that cut culms die at the rate of one internode a year is not correct ; that they die down in many cases is true, but the rate of dying appears to depend mainly on the vigour of the culm, some dying down rapidly and others not dying at all for a few years at least. Nevertheless as the point is still in doubt it is now usually customary to prescribe cutting at a definite height, say between 1 and 2 ft. from the base, thus effecting a compromise between high and low cutting. The judicious thinning out of dead culm remnants and twisted culms from within the clumps has been found most beneficial in the case of *Dendrocalamus strictus* in the Siwalik hills, where also the use of the saw in preference to the axe has been found to minimize the damage to the stumps of felled culms. Nevertheless, the drastic removal of quantities of culm remnants from within a clump may do more harm than good. Mr. A. Wimbush[1] records a case in South Malabar of an experimental cutting out of culms and dead lengths of culms cut high in former fellings, the species being *Bambusa arundinacea*. From four clumps 99 green bamboos and 109 dead lengths were

[1] Ind. Forester, xxxix (1913), p. 155.

FIG. 381. *Dendrocalamus strictus*, congested clump; note dead rhizomes on periphery.

Fig 382. *Dendrocalamus strictus*, natural reproduction 7 years old, showing adverse effect of grazing, Kotdwara, United Provinces: portion to left of fence protected from grazing, with dense young growth of bamboos about 8 ft high, portion to right open to grazing and devoid of young bamboos.

cut, leaving 35 sound culms, or about nine in each clump, evenly scattered through the clump. The result was that every culm was blown over during the succeeding monsoon and was either broken or bent over until it leant against an adjoining clump. In three clumps examined next season two had produced no new culms and the third had sent up two very thin culms, both of which had been broken. *Bambusa arundinacea*, however, is a species in which it is hardly possible to test satisfactorily the effect of judicious thinnings. The dense mass of interlacing thorny branchlets renders it difficult to remove individual culms so as to leave the remainder moderately and evenly spaced, while the culms of this species are soft and weak for their size and are easily bent or broken by wind. Fig. 386 shows the effect of a heavy thinning in the case of this species.

Mr. W. H. Lovegrove,[1] in describing his observations on the growth of *Dendrocalamus strictus* in the submontane forests east of the Ganges, which have been alluded to above, concludes (*a*) that a clump should be encouraged to grow in the directions chosen by itself, which can be determined by observing where the youngest culms are; (*b*) that the culms should not be cut over the whole periphery of a clump; and (*c*) that care should be taken not to clean out too large areas in a clump, thereby causing the accumulation of a large mass of dead rhizomes.

Much experimental work of a systematic kind remains to be done in order to study the development and growth of the various important species and to ascertain the best method of working them. In this connexion a series of experiments was commenced by me in 1910–11, the species dealt with being *Dendrocalamus strictus*. Two experimental plots were laid out, one in a somewhat dry locality (rainfall 50 in.) at Ranipur in the Saharanpur Siwaliks, dealing with 57 clumps, and one in a fairly moist locality (rainfall probably about 70 in.) near Kotdwara, in the submontane forests of the United Provinces, dealing with 98 clumps. The main objects of the experiments were to ascertain the effect (1) of cutting culms at different heights above ground, (2) of working under different rotations, and (3) of cutting all or only a portion of the old culms (that is, culms more than one year old) at one time. These experiments have been continued regularly since their commencement, Mr. Marsden taking over control of them in 1915. Although the experiments have not yet been in progress long enough to produce final and definite conclusions on all points, the tentative conclusions arrived at after eight years have been summarized thus by Mr. Marsden:[2]

'1. Annual working, whether cutting high or cutting low, whether removing all old culms or only half of them, leads to more or less rapid reduction in size of clump, in number of new shoots, and in girth of culms.

'2. When all the culms except those of the current year are cut, the clump deteriorates. This is true for 1-year, 2-year, and 3-year rotations, and for cutting at a height of one node, three nodes, or five nodes. When the rotation is four years, the result is not so obvious.

'3. When the rotation is one year and only half the number of old culms is cut, the results are better than when all old culms are cut. Height of cutting

[1] Ind. Forester, xxvi (1900), p. 433.

[2] *Ibid.*, xliv (1918), p. 147. It should be noted that the conclusions refer only to *Dendrocalamus strictus* in the United Provinces.

makes no difference. Of fifteen clumps treated thus, only two were in good condition, and this method cannot be recommended. When only half the old culms were cut, the clumps under a 2-year rotation were in much better condition than those under a year rotation.

'4. Whatever the rotation, some old culms should be left. Old culms are wanted both for the mechanical support of new shoots and to maintain the rhizomes in full vigour.

'5. The effect of difference in height of cutting upon the health of the clump is either nil, or so slight as to be negligible. Cutting high produces a number of twigs at the top of the stumps which impedes working.

'Production of new shoots is not affected by height of cutting. But removing half the old culms gives more shoots than clear-felling all old culms, and 2-year rotation more than 1-year rotation. Of the methods under experiment, most new shoots were yielded by the clumps worked under a 2-year rotation when half of the number of old culms were felled. Felling all the old culms fails to produce many new shoots even when the rotation is four years. But a 3-year rotation, some of the old culms being left standing, would probably give better results than a 2-year rotation.

'Clear-felling all culms, including shoots of the current year, nearly, but not quite, kills the clump. After four rains the clumps are beginning to look up again, and shoots ¾ in. thick to arise. Repeating the complete cutting of all culms without exception for two consecutive years would here probably kill most clumps.

'General Remarks.

'To work these bamboos economically, it would appear that in every clump some old culms must be left standing. A 2-year rotation leaving half the old culms may be better than a 3-year rotation felling all the old culms. But a 3-year rotation leaving some old culms would very likely be better still.

'A system of working bamboos may be based on the size of the clump, on the number of new shoots produced, or on a minimum number of old culms to be left standing. But the system must be one which admits of easy check. If a proportion of the old culms is laid down as the standard, it is in practice difficult to check whether too many culms have been felled or not. If the Punjab this method has been adopted, and I understand that it cannot be strictly enforced though it is said to work well in practice. Similarly, any rule prescribing a minimum number of old culms to be left based on the number of new shoots is practically unworkable.

'It would be simpler to fix a minimum number of old, sound culms at least one inch thick, which must be left in each clump. But clumps vary in size. So the average size of clump in the locality must be ascertained. In the average clump contains 20 old culms, and the rotation is three years, a minimum of seven old culms per clump might be fixed.

'Another problem is the distribution within the clump of the culms left standing. Clear-felling part of a clump is liable to kill that part of the clump; so the culms left standing should be distributed evenly over the clump.

'While a fully-stocked clump produces more shoots than a severely worked clump, there seems ground for the belief that if kept in an open condition more shoots will arise than if allowed to become congested. Loosening the earth and heaping it up round the base of a clump is likely to stimulate the sprouting of new buds.

'Where bamboos have been worked continuously for years, it might be highly beneficial to give the clumps a period of rest for three or four years before introducing a new method of treatment.'

ERADICATION OR CONTROL OF BAMBOO GROWTH. In some localities bamboo growth is so rampant as to interfere with the reproduction or development of valuable tree species, and measures have to be adopted to keep the bamboo

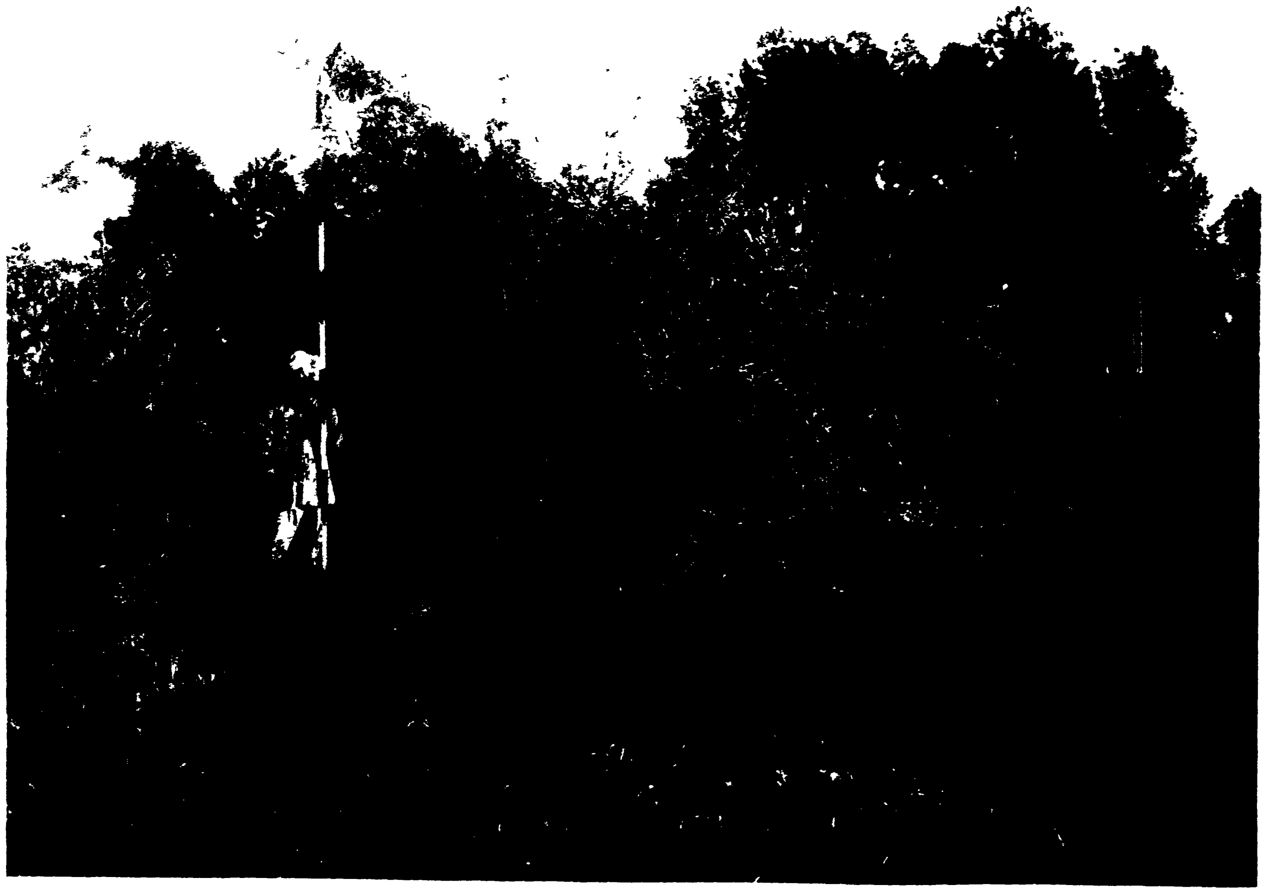


FIG. 383 *Dendrocalamus strictus*, unirrigated weeded line sowing, end of third season, Dehra Dun.

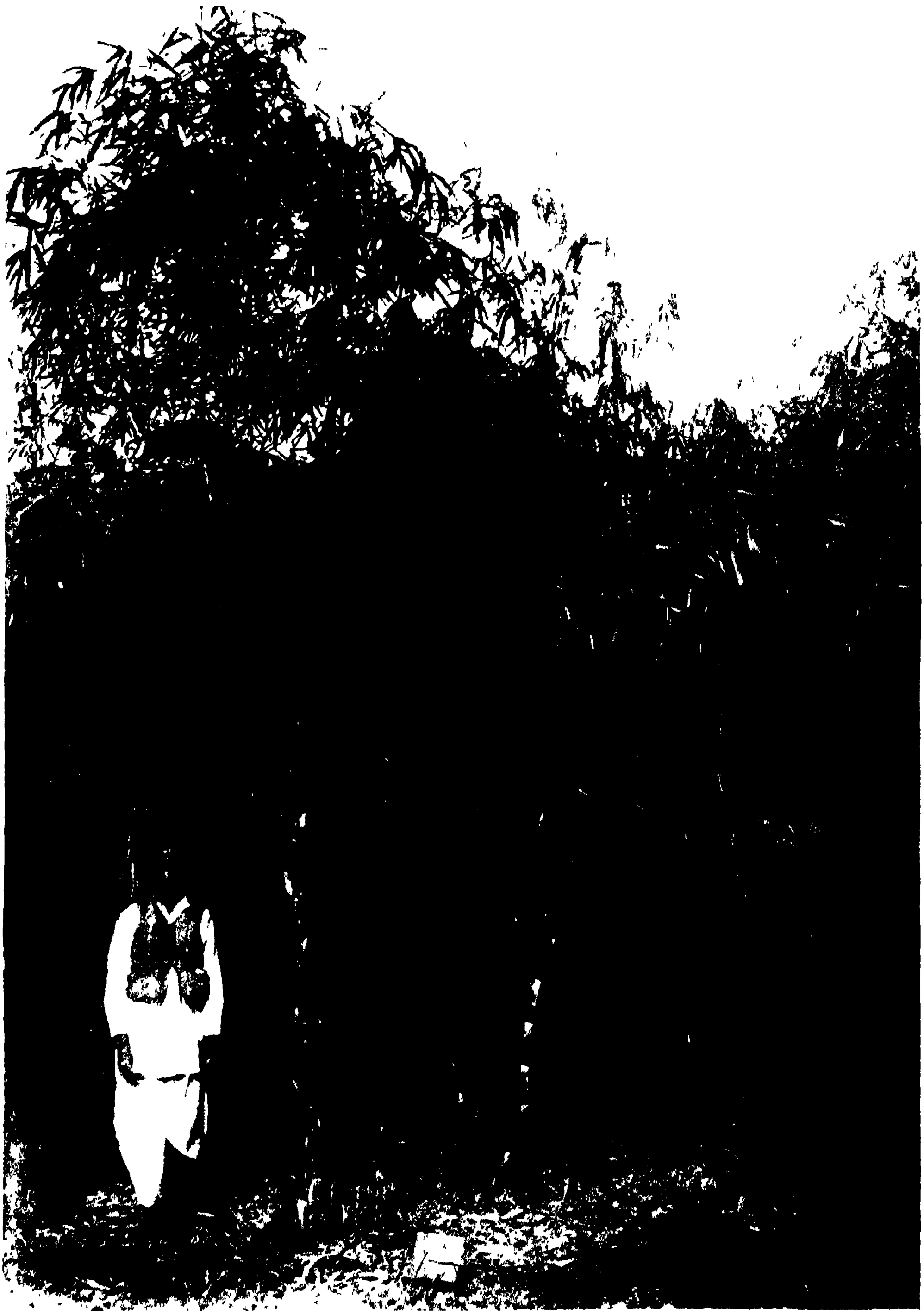


FIG. 384 *Dendrocalamus strictus*, irrigated weeded line sowing 4 years old, Dehra Dun . clumps recently thinned by removal of all thin culms.

in check. This can be done most effectively at the time of flowering or seeding; failing this, established clumps have to be dealt with.

The species whose eradication over limited areas can be most easily carried out is *Melocanna bambusoides*, whose large fruits can be collected off the ground when they fall; this is done by *taungya*-cutters in the Arakan hills, in order to obtain areas free from bamboo in which to practise shifting cultivation. Otherwise experiment has shown in the case of this species that by cutting the bamboo in April, when the fruits are almost ripe, the bamboos are killed and the great majority of the fruits are destroyed; if the bamboo is cut in the cold season when about to flower it flowers from dwarf shoots next year. As regards other species, experiments carried out in recent years in Burma have shown that when gregarious flowering takes place, burning early in the season has little effect. The most effective plan is to fire-protect the area until the seed has fallen and burn late in the hot season in order to cause as intense a fire as possible; even so only a portion of the seed is destroyed, and seedling growth appears in the rainy season. Subsequent burning tends to reduce the density of the young growth, but does not destroy it. The admission of grazing for a few years after seeding further tends to keep the young bamboo growth in check, for as long as there are bamboo seedlings on the ground it is found that cattle prefer them and will not eat tree seedlings. Where gregarious seeding has taken place and the young bamboo crop is allowed to establish itself unchecked for two or three years, fire alone has little effect on it, while the alternative of cutting and burning, which has to be repeated as a rule, is costly. Fire-protection has the effect of aggravating greatly the density of the young bamboo growth, and it is usually impossible to produce any effect on it except by cutting followed by burning.

The eradication of mature bamboo clumps is usually a tedious operation. The complete cutting of all the culms of a clump results, in the ensuing rainy season, in the production of thin whippy shoots, and if no further cutting is carried out the culms produced in successive years become larger until the clump again reaches its normal state. A single complete cutting, therefore, though it may afford a temporary opening for the establishment of tree species, is not sufficient to eradicate the bamboo. If, however, the cutting of the new culms is repeated at intervals of one or two years it has been found that the clump is so weakened as to die after a short period. Where shifting cultivation is practised in Burma, the usual custom is to cut down the bamboos, pile them on the stumps, and burn them; this kills a certain number of the clumps, but not all, though if the operation is repeated for another year or at most two years, this usually suffices to eradicate the bamboo. On fire-lines, where bamboos are cut and burnt annually, they are as a rule killed out within three years. Experiments in Katha, Upper Burma, have shown that *Dendrocalamus Hamiltonii* can be killed by one cutting and burning if the cut culms are heaped on the bamboo stumps and burnt, and the young shoots in the following rains are broken off as they appear.

An experiment was commenced in the forests of the Tharrawaddy district of Burma in 1893 with the object of ascertaining if the annual cutting out of the new year's culms would kill the clump within a reasonable time. The species experimented with were *Bambusa polymorpha* and *Cephalostachyum* *pergracile*. Two areas were set aside, one in the Kônbilin and the other in the Bawbin forest, and the cutting out of the new year's culms was carried out annually for ten years, the older culms being left; during this period an average of two new culms per clump were cut out annually, and at the end of the ten years' period the clumps were found not to have been perceptibly weakened, though the cover was somewhat lightened.

A few years ago an experiment was carried out in Kollegal, Madras, to ascertain, by clear-felling an acre of bamboo forest each month of the year, if there was any particular period of the year in which clearing assists in keeping down the bamboos. The experiment gave no definite results, it being found that the regrowth was more or less the same in each case.

Genera 1. ARUNDINARIA, Michaux; 2. BAMBUSA, Schreber; 3. THYRSOSTACHYS, Gamble; 4. GIGANTOCHLOA, Kurz; 5. OXYTENANTHERA, Munro; 6. DENDROCALAMUS, Nees; 7. CEPHALOSTACHYUM, Munro; 8. MELOCANNA, Trin.

1. ARUNDINARIA, Michaux.

Erect, sometimes climbing, shrubby bamboos, in India almost exclusively hill species, often gregarious and forming an undergrowth in the forest.

Species 1. *A. Wightiana*, Nees; 2. *A. racemosa*, Munro; 3. *A. falcata*, Nees; 4. *A. spathiflora*, Trin.

1. **Arundinaria Wightiana,** Nees.

Hills of southern India, especially the Nilgiris, where it forms a gregarious undergrowth in the evergreen *sholas*. Culms 6–10 ft. high. Flowers annually.

2. **Arundinaria racemosa,** Munro. Vern. *Maling*, Nep.

Common in the eastern Himalaya at 6,000–10,000 ft., growing gregariously, and much used for pony fodder. Gamble notes that there may be two species: (1) the larger low-level form, which has never been known to flower, and (2) the small high-level form of which flowers were collected in 1857 and 1887 to 1890 This bamboo forms a very dense undergrowth, impeding the natural reproduction of tree species (Fig. 387). When fires occur in such areas a fierce conflagration results, causing destruction to the tree growth (Fig. 388).

3. **Arundinaria falcata,** Nees. Vern. *Ringal*, Jaunsar.

The low-level ringal of the western Himalaya, used for basket-work, fishing-rods, &c. Forms clumps containing a large number of culms, often more than 100 in a clump; culms 6–10 ft. high. This bamboo grows gregariously, forming an undergrowth in forests of oak, deodar, and other trees, usually in moist shady situations, at 4,000–7,000 ft. It flowers both sporadically and gregariously. General flowering has been recorded as follows:

1858. Simla.
1886. Jaunsar and Tehri Garhwal.
1916. Simla, Mussoorie, Jaunsar.

In Simla, 1916, the flower-buds became visible in April, the flowers opened early in July, and the seed ripened and fell in November. Under natural conditions the seed lies on the ground until the commencement of the following rainy season, in June–July, when it germinates, and seedlings may be found in quantity around the parent clumps and in places where the seed has been washed by rain. Fig. 373 shows the seedling and the manner in which the clump forms (see p. 986).

FIG. 385 *Dendrocalamus strictus*, weeded line sowing with field crops, end of first rainy season, Dehra Dun.

FIG. 386 *Bambusa arundinacea*, effect of heavy thinning of clump four years previously, Tinnevelly, Madras

4. **Arundinaria spathiflora,** Trin. Vern. *Ringal,* Jaunsar.

The high level ringal of the western Himalaya. Grows gregariously at 7,000–9,000 ft. from the Sutlej to Nepal, forming an undergrowth in forests of oak, deodar, spruce, silver fir, and other trees, usually in moist shady situations. Culms 12–20 ft. high, in definite clumps. Flowers sporadically and gregariously. There was a general flowering in Jaunsar and Tehri-Garhwal in 1882, and in 1898–9 the culms were reported to be about 10 ft. high, and not yet full sized, indicating that the growth is slow.[1]

2. BAMBUSA, Schreber.

Species 1. *B. Tulda,* Roxb.; 2. *B. nutans,* Wall.; 3. *B. burmanica,* Gamble; 4. *B. polymorpha,* Munro; 5. *B. arundinacea,* Willd.

1. **Bambusa Tulda,** Roxb. Vern. *Peka,* Hind.; *Tulda, mitenga, jowa, kiranti,* Beng.; *Wamuna, bijuli,* Ass.; *Thaikwa,* Burm. (Fig. 389.)

A thick-walled caespitose evergreen or deciduous bamboo, attaining 70 ft. in height under favourable conditions, branching freely from nearly all the nodes, the branches from the lower nodes being thin and more or less horizontal. A useful species for building, owing to its strong culms; also used for basket-work, mats, &c. A native of Bengal, Assam, Northern Circars, Chittagong, and Burma. Frequently cultivated, especially in Bengal. In its wild state it is characteristically gregarious. In Burma it is frequent on flat alluvial land along streams in the mixed deciduous forests and along the banks of dry water-courses.

It often flowers sporadically or in small groups, while occasional gregarious flowering takes place, of which the following cases have been recorded:

Burma.	About 1865.	Tharrawaddy.
	1903–5.	Tharrawaddy: fairly extensive flowering in single clumps or groups of varying extent.
	1908.	Prome.
	1911.	Gangaw.
	1913.	Toungoo, Zigôn, Rangoon.
	1914.	Southern Toungoo, Pegu, Prome, Zigôn, Tharrawaddy, Rangoon, Henzada, Yaw.
	1915.	Northern Toungoo, Shwegyin, Prome, Zigôn.
	1916.	Southern Shan States.
Assam.	1889.	Locality not stated.
	1910.	Sylhet.
Bengal.	1867–8, 1872, 1884.	Locality not stated.
	1876, 1886.	Chittagong.

Brandis[2] records various flowering years, but it is not certain if these refer to gregarious flowering or to years in which flowers were collected.

2. **Bambusa nutans,** Wall.

A fairly thick-walled species much resembling the last, but the culms are not so densely clustered. Attains 40 ft. Frequently cultivated in the sub-Himalayan tract; Gamble says that it is doubtful if it is really wild west of

[1] F. Gleadow, Forest School Tour in Jaunsar 1898–9, p. 32.
[2] Ind. Forester, xxv (1899), p. 12.

the Sarda river, and that it is found in the Sikkim hills up to 5,000 ft. Its culms are strong and useful.

3. **Bambusa burmanica,** Gamble. Vern. *Thaikwa, thaikwagyi*, Burm.

A large thick-walled bamboo attaining 50–60 ft. in height and 4 in. in diameter, somewhat resembling *B. Tulda*, but growing in more open clumps. Indigenous to Upper Burma, on dry hill-slopes. Plants have been raised in considerable quantity at Dehra Dun from seed received from Burma, and have succeeded well. There is a plantation of this species at Lachiwala, near Dehra Dun; here the culms were all killed down in the abnormal frost of 1905, but the rhizomes were not injured, and in a few years the clumps had completely recovered by the production of new culms. This bamboo is a useful one, with strong culms.

4. **Bambusa polymorpha**, Munro. Vern. *Kyathaungwa*, Burm. (Fig. 390.)

A large, handsome tufted bamboo with tall, clean culms, attaining a height of 80–90 ft. and a diameter of 6 in., evergreen, or in dry localities and seasons partially deciduous. This bamboo, which has moderately thick walls and large cavities, is probably more extensively used for building purposes than any other species in Burma. It is a promising source of supply of paper-pulp. In Burma it is abundant throughout the moister types of upper mixed deciduous forest in the Pegu Yoma, particularly on the lower slopes and in well-drained valleys, where it flourishes best and reaches its largest dimensions on deep moist fertile loam. It is not found in the driest parts of the range. It occurs also in Martaban in the Salween valley and locally in other parts of Burma, for instance in the Thaungyin drainage in Tenasserim and in a few places in the Yaw drainage in Upper Burma; it extends into eastern Bengal and Sylhet.

Silviculturally this is probably the most important bamboo in the Pegu Yoma forests, where it is commonly associated with teak and is an indicator of deep, rich, well-drained soil on which the teak reaches its best development. On such soil it is gregarious to a marked degree, but a frequent companion and a species of almost equal importance is *Cephalostachyum pergracile,* which, however, also extends into forests of a somewhat drier type than those in which *Bambusa polymorpha* is characteristically found. The large size and vigorous growth of the latter make it a serious competitor of the teak.

This species flowers at long intervals, and the flowering is remarkably gregarious. Until recent years sporadic flowering has been rarely recorded, but occasional flowering clumps have been observed. In 1899 three clumps are reported to have flowered in the Pegu forests. I found two flowering clumps in the Tharrawaddy forests in February 1903. It flowered sporadically in 1913 in Minbu, Thayetmyo, and Prome, while in Prome in 1914 it is reported to have flowered over an area of about 3 square miles; this is the first record of anything approaching gregarious flowering for about fifty-five years. Since 1918 there have been signs of an approaching general flowering on the western side of the Pegu Yoma; if this materializes the life-cycle of the bamboo may be placed at about 60 years or a little more. From records available it appears to have flowered gregariously in the Upper Zamayi forests, Pegu, in 1852, but probably 1859 and 1860 were the years of most extensive general flowering in the Pegu Yoma forests, at all events in the Tharrawaddy

FIG 387. Dense growth of *Arundinaria racemosa*, Darjeeling hills

FIG 388 Forest with undergrowth of *Arundinaria racemosa* after a fire, showing destruction of tree-growth. Darjeeling hills.

and Prome districts. Brandis[1] notes general flowering all along the west side of the Pegu Yoma in 1859, and adds: 'The jungle fires of March, April, and May subsequently swept away the tangled masses of dry stems, and after the rains of 1861 the ground everywhere was covered with millions of seedling bamboos, which soon grew up into slender plants 2 to 3 ft. high, forming dense waving green masses on the ground under the trees.'

About 750 seeds weigh 1 oz. (sample collected in 1914).

The only available record of the rate of growth is contained in the following note by Brandis:[2] '*Bambusa polymorpha*, which had flowered in the Pegu Yomah hills in 1859, had, when I visited those hills in 1868, grown up into a forest similar to that which I had known before flowering; the tufts, however, were small, that is, they had not yet as many stems as formerly.'

5. **Bambusa arundinacea,** Willd. Thorny bamboo. Vern. *Kattang*, C.P.; *Dougi*, *padhai*, *kalak*, Bombay; *Mungil*, Tam.; *Vedru*, Tel.: *Kyakatwa*, Burm. (Fig. 391.)

A large bamboo with bright green, fairly thick-walled culms, attaining a height of 80–100 ft. or more and a diameter of 6 or 7 in., forming dense clumps of large size. The culms produce quantities of thorny branchlets interlacing into a dense mass and rendering the culms difficult to extract from the clump. M. Velu Pillai[3] records the measurement of a culm felled in November 1904 at Pattazhi in Travancore, 121½ ft. long and 20 in. in girth at its centre; the whole clump had 112 culms, of which six measured 118 ft. in length. The culms are used for building, basket-work, &c.

This bamboo is found throughout the greater part of India, except in the driest regions, particularly along river valleys and in other moist situations. It occurs in ravines near water in the sub-Himalayan tract of Kumaun, but has probably been introduced; it is not considered to be indigenous to the Indo-Gangetic plain or north of it, but is largely cultivated in northern India and elsewhere. It is abundant in the forests of the west coast from North Kanara southwards, particularly on flat ground near rivers and streams. In Burma it is common in parts of Pegu and Martaban, in the Moulmein neighbourhood and in the Salween and Thaungyin drainages, often along the banks of rivers. It is somewhat scarce in lower Assam, eastern Bengal, and Chittagong. Gamble says it is probably found in its largest size and finest condition in the hills of the Circars, especially about the Godavari, on the hill ranges of the eastern and southern scarps of the Mysore plateau, and in the Nilgiris.

This species, although it occasionally flowers sporadically, as in the Thaungyin forests of Tenasserim in 1916, is one of those characterized by marked gregariousness in flowering. The following years of gregarious flowering have been recorded:

Dehra Dun (planted).	1900.
Bihar and Orissa.	1913. Angul and other localities.
Central Provinces.	1869. Satpuras.
Bombay.	About 1874–84, mainly 1878. Kanara, Belgaum, Dharwar.
	About 1910. Throughout the Dangs.

[1] Indian Forester, xxv (1899), p. 4. [2] *Ibid.*, p. 9. [3] *Ibid.*, xxxi (1905), p. 153.

Bombay.	About 1905–18, mainly 1912. Kanara, Belgaum Dharwar.
Coorg.	1913–15.
Madras.	1896. Parts of Walayar forest, Coimbatore.
	1912–15. Commenced on plateau tracts of Wynaad and spread southwards to Kollegal and Coimbatore.

Brandis says that as far as is known it flowers at intervals of thirty-two years ; the dates just quoted indicate thirty-four years as the flowering period in the southern part of Bombay, which more or less confirms Brandis's statement.

As regards rate of growth, Brandis[1] in 1876 observed thickets of young plants 15 ft. high and seven years old, the result of a general flowering in 1869 in the Pandratola reserve of the Satpuras, Central Provinces. Bourdillon[2] stated in 1895 that bamboos which flowered gregariously between 1879 and 1882 had not reached full size by 1895, their age being then about thirteen to sixteen years, though they were actually cut to float timber eight years after flowering. He subsequently noted,[3] after actual measurements of clumps of known age in Travancore, that it requires more than twenty years for the clumps to reach full bearing, but that culms large enough to float timber are produced in twelve years.

The danger of thinning out this bamboo too heavily, resulting in the bending or breaking of the remaining culms, has already been alluded to (see p. 996 and Fig. 386).

3. THYRSOSTACHYS, Gamble.

Species 1. *T. Oliveri*, Gamble ; 2. *T. siamensis*, Gamble.

1. **Thyrsostachys Oliveri**, Gamble. Vern. *Thanawa*, Burm. (Fig. 392.)

A large, handsome, caespitose, rather thin-walled bamboo, 40–80 ft. high, with straight culms, the lower parts of which are comparatively free from side branchlets. The persistent sheaths envelop the greater part of the internodes. The culms are much used for building.

This bamboo covers extensive areas on well-drained ground in the mixed deciduous forests of Upper Burma, often in association with teak, padauk, and other important trees, as in the Ruby Mines district, the Madaya forests of the Mandalay district, the Shan hills, and elsewhere. It has also been reported from Henzada. It does not occur in very moist types of forest, but is characteristic of intermediate types between these and the drier types in which *Dendrocalamus strictus* is the prevailing bamboo. It has been successfully raised from seed at Dehra Dun, where there are a number of clumps in gardens.

Gregarious flowering has been reported in 1891, in 1911–12 in the Thabeitkyin subdivision of the Ruby Mines district, in 1914 in the Ruby Mines, Mandalay, and Meiktila districts, in 1916 in the Southern Shan States, and in 1917 in the Mandalay district. Sporadic flowering has been reported in 1902–5 in the Ruby Mines district, and in 1916 in the Henzada-Maubin forest division.

[1] Ind. Forester, xxv (1899), p. 8. [2] *Ibid.*, xxi (1895), p. 229.
[3] *Ibid.*, xxv (1899), p. 152.

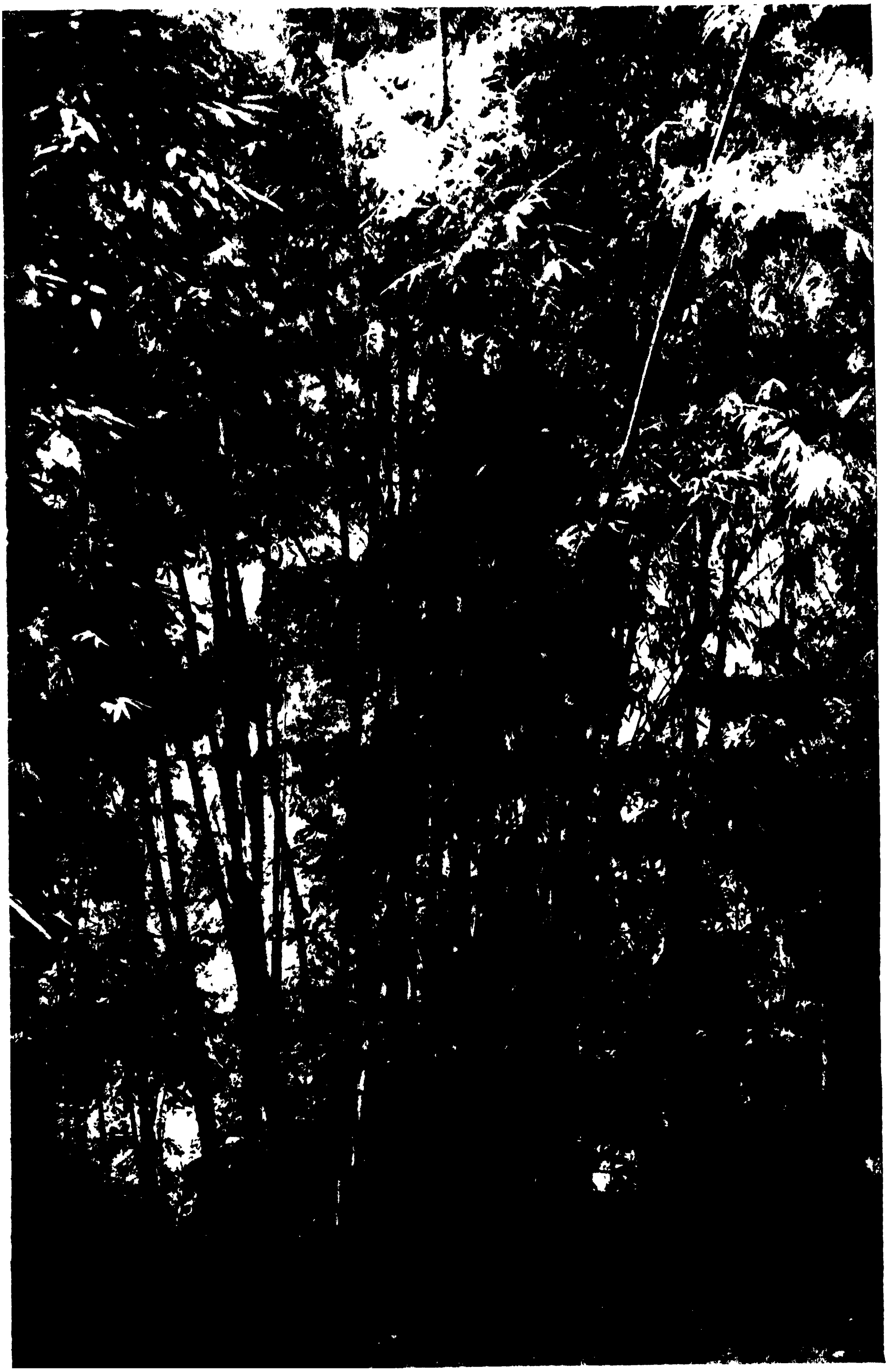


FIG 389. *Bambusa Tulda*, Chittagong hill tracts.

Fig. 390. *Bambusa polymorpha*, Burma.

2. **Thyrsostachys siamensis,** Gamble. Vern. *Tiyowa,* Burm.

A handsome caespitose deciduous bamboo with straight culms of regular growth, 25–40 ft. high, the lower parts free from branchlets, somewhat resembling but smaller and thinner than *T. Oliveri.* The culms are used in Burma for the manufacture of umbrella handles. This bamboo is cultivated in monastery compounds throughout the greater part of Burma. Brandis says it is indigenous in small side valleys of the Salween river between the Solo and Kemapyu *chaungs,* and in Siam. He also says it flowered in the Royal Botanic Gardens, Calcutta, in 1892.

4. GIGANTOCHLOA, Kurz.

Gigantochloa macrostachya, Kurz. Vern. *Tekserah,* Garo ; *Wapyugyi, wanet,* Burm.

An evergreen bamboo, with dark green culms often with white longitudinal stripes, attaining a height of 25–50 ft. and a diameter of 3–4 in., forming somewhat lax clumps. A native of Assam, Chittagong, and Burma. In Burma it is one of the most characteristic bamboos in the forests east of the Sittang river, where it covers extensive areas on low hills ; it is abundant round Shwegyin.

5. OXYTENANTHERA, Munro.

Species 1. *O. nigrociliata,* Munro ; 2. *O. albociliata,* Munro ; 3. *O. monostigma,* Bedd.

1. **Oxytenanthera nigrociliata,** Munro. Syn. *Bambusa auriculata,* Kurz. Vern. *Kalia,* Beng. ; *Wanwè,* Burm.

A densely tufted evergreen bamboo with culms 30–50 ft. high and up to 4 in. in diameter, dark green, sometimes with longitudinal yellow stripes. Widely distributed from the Garo hills, through Sylhet, Chittagong, and Burma, chiefly in Tenasserim, and southwards to Singapore ; also in the Andamans, in semi-deciduous forest and along streams. Often flowers sporadically.

2. **Oxytenanthera albociliata,** Munro. Vern. *Wapyu, wapyugale, wanwè, wagôk,* Burm.

A densely tufted bamboo with thin culms which bend over, forming a nearly horizontal crown with a dense low cover. A common species throughout the greater part of Burma, chiefly in mixed deciduous forests, often on very sandy soil and sometimes on decomposing laterite. It is often markedly gregarious, and its dense low cover is inimical to the reproduction of teak and other tree species, while severe fires occur where it forms a dense growth.

This bamboo often flowers sporadically. The following gregarious flowerings have been recorded :

1911. Pyinmana, in part of the Yanaungmyin reserve.
1912. Thayetmyo, in the East Yoma reserve.
1913. Toungoo.
1914. South Toungoo, Shwegyin, Rangoon, and Yaw forest divisions.
1916. North Toungoo and Thaungyin forest divisions.
1917. Zigôn, Tharrawaddy, and West Salween forest divisions.

3. **Oxytenanthera monostigma**, Bedd.

An erect thick-walled bamboo with isolated culms up to 20 ft. or more in height and 1 in. in diameter, covered when young with a yellowish white velvety tomentum. It occurs gregariously in the Western Ghats and hills of south-west India, usually as an undergrowth in mixed deciduous forests. It is used for basket-work, but is not considered of very good quality.

6. DENDROCALAMUS, Nees.

Species 1. *D. strictus*, Nees; 2. *D. membranaceus*, Munro; 3. *D. sikkimensis*, Gamble; 4. *D. Hamiltonii*, Nees and Arn.; 5. *D. giganteus*, Munro; 6. *D. longispathus*, Kurz; 7. *D. Brandisii*, Kurz.

1. **Dendrocalamus strictus**, Nees. Syn. *Bambusa stricta*, Roxb. Male bamboo. Vern. *Báns*, Hind.; *Kiribidru*, Kan.; *Kal mungil*, Tam.; *Myinwa*, Burm.

A densely tufted deciduous bamboo with strong thick-walled or solid culms varying much in size according to locality, usually from 20 to 50 ft. high and 1–3 in. in diameter. Culms glaucous green when young, losing their glaucous appearance in the second year, and often turning yellowish when old. Branchlets from the nodes are ordinarily produced almost throughout the entire length of the culm; the lowest few nodes often produce rootlets. In dry localities on poor soil the culms, though small in size, are solid or nearly so, whereas in more fertile localities, although they reach larger dimensions they are as a rule hollow. This bamboo is extensively used for building, furniture, lance-shafts, walking-sticks, mats, basket-work, axe-handles, and numerous other purposes.

This is the best known, commonest, and most widely distributed of all Indian bamboos, occurring in deciduous forests throughout the greater part of India, except in northern and eastern Bengal and Assam; it is common in the drier types of mixed forest throughout Burma. It is found typically on hilly country, ascending to 3,500 ft. and occurring gregariously sometimes almost to the exclusion of tree growth, but usually forming an under-story to or a mixture with deciduous trees. It is not uncommon in certain types of sal forest on hilly country. It is abundant in many parts of the Siwalik tract and outer Himalaya from the Punjab eastward to Nepal, occurring most plentifully between the Ganges and Ramganga rivers. It is also common in most of the hilly parts of the Indian Peninsula, except in very moist regions. In Burma it is the typical bamboo of the drier types of upper mixed deciduous forest with or without teak; it also extends into *indaing* (dry dipterocarp) forest.

This is the hardiest of all Indian bamboos, thriving in regions which suffer periodically from excessive drought. Within its habitat it is frost-hardy. In the abnormal frost of 1905 in northern India it withstood the effects of the frost better than almost any of the tree species; only isolated clumps suffered, and in these only the younger and more tender culms were affected. In the abnormal drought of 1899–1900 in the Indian Peninsula it escaped damage, although other species of bamboo and many tree species suffered severely.

This species commonly flowers sporadically, in isolated clumps or in small groups, almost every year; it also flowers gregariously over large tracts

FIG. 391. *Bambusa arundinacea*, North Kanara, Bombay.

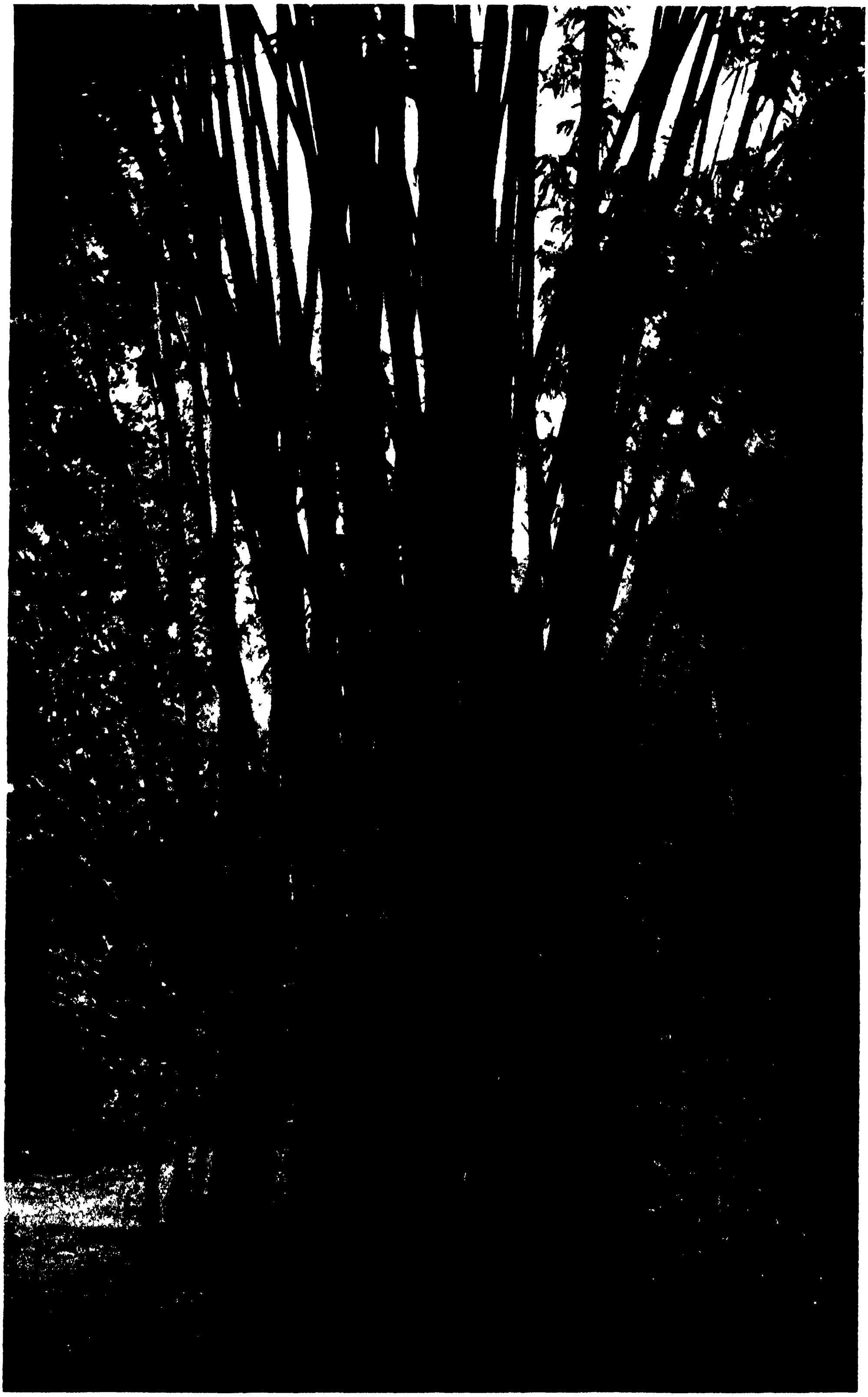


FIG. 392. *Thyrsostachys Oliveri*, Ruby Mines district, Upper Burma

at long intervals, the gregarious flowering usually taking some years to complete, and often progressing in a definite direction in successive years. Actually it is often difficult to distinguish between sporadic flowering on a plentiful scale and gregarious flowering, there being all stages between the two. In the Garhwal outer Himalayan tract the interval between the last two recorded general flowerings was between thirty-six and forty years (i. e. 1872–6 and 1908–13). Mr. A. Smythies[1] estimates the interval in the Chanda district, Central Provinces, at about thirty years. The correct periodicity, however, is difficult to determine in view of the irregular manner of flowering of this species. The flowers, in dense globular heads, appear from November to February, and the ripe seeds fall from April to June, according to locality. About 800–900 seeds weigh 1 oz. In years of abnormal drought, flowering and fruiting may occur earlier ; Mr. A. E. Lowrie[2] notes that in the abnormal drought of 1899–1900 in the Chanda district, flowering took place early in October, and the ripe seed was shed in December. The old leaves fall as a rule from December to March and the new foliage appears from April to June. The following years of gregarious flowering and seeding have been recorded :

United Provinces.	1872–6. Garhwal outer Himalayan tract.
	1880. Oudh.
	1883–6. Saharanpur Siwaliks.
	1908–13. Garhwal outer Himalayan tract.
	1911. Bundelkhand.
Central Provinces.	1899. Seoni (Kurai and Ganginala ranges)
	1900. Balaghat (Motinala range).
	1900 and 1901. South Chanda.
	1908. Nimar (partial).
Bombay.	1901. Thana (Mokhada hills).
Madras.	1887. Kurnool.
	1890. Vizagapatam (Golgonda hills).
	1891. North Arcot.
	1894. Coimbatore (Pollachi range).
	1897. Coimbatore (part of Walayar forests).
Burma.	About 1865. Tharrawaddy.
	1888. Tharrawaddy.
	1895. Tharrawaddy (Zigôn and Minhla).
	1906. Thayetmyo.
	1908 and 1909. Henzada.
	1911–12. Ruby Mines (Thabeitkyin range).
	1911–13. Mu forest division (Inga in Wuntho range).
	1912 and 1913. Tharrawaddy (Zigôn).
	1914. Thayetmyo, Rangoon, Henzada, Upper Chindwin, Mu, Mandalay, and Yaw forest divisions.

The new culms are produced in the rainy season. In northern India they do not as a rule attain full length until September, but farther south they

[1] Ind. Forester, xxvii (1901), p. 126.
[2] *Ibid.*, xxvi (1900), p. 505.

develop earlier. In years of favourable rainfall as many as twenty may be produced from fair-sized clumps.

This species, owing to its importance and wide distribution, has subject of much more study and experiment than any other. Informa on natural and artificial reproduction, the development of young plants and of clumps, the formation of congested clumps, methods of working and other details will be found in the introductory note to this tribe (pp. 985 to 998). As regards rate of development it may be repeated here that under natural conditions probably at least twelve years are required from the time of seeding until the clumps are ready for working; thus in the Dhaba range of South Chanda natural bamboos which sprang from seed in 1900 were reported in 1912 to be still too small to be readily saleable. Under specially favourable conditions working could probably be commenced from about the seventh to the tenth year; line sowings in Kaunli garden, Dehra Dun, kept regularly weeded but not irrigated, had by the sixth year formed well-developed clumps capable of yielding an average of one to two fair-sized culms per clump.

2. **Dendrocalamus membranaceus**, Munro. Vern. *Wapyu*, Burm.

A graceful bamboo, forming rather open clumps, with light green, fairly thin-walled culms, attaining a height up to 60–70 ft. and a diameter up to 4 in. The culms are useful and are employed for building. This bamboo is indigenous to Upper Burma and Martaban. It has been planted at Dehra Dun, where it grows well. Gregarious flowering has been reported in the Shweli forests, Ruby Mines district, about 1912, and in Shwegyin in 1915.

3. **Dendrocalamus sikkimensis**, Gamble. Vern. *Pugriang*, Lepcha.

A large handsome tufted thick-walled bamboo, with few culms in each clump, attaining a height of 50–70 ft. and a diameter of 5–7 in. Indigenous to Sikkim and Bhutan at 4,000–6,000 ft., and on Tura peak in the Garo hills; cultivated in India and in Europe. Sections of the culms are used in Sikkim as buckets for carrying water and milk. Gregarious flowering is reported to have occurred near Kalimpong in 1916, the seed ripening in October.

4. **Dendrocalamus Hamiltonii**, Nees and Arn. Vern. *Kaghsi bans*, Hind.; *Pecha*, Beng.; *Tama*, Nep.; *Kokwa*, Ass.; *Wabo-myetsangyè*, Burm.

A large tufted bamboo, with culms sometimes erect but often overhanging and almost horizontal, with large branches. The culms sometimes attain a length of 80 ft. and a diameter of 6 or 7 in.; they are thin-walled, rather soft, and grey in colour.

Indigenous to the central and eastern sub-Himalayan region, ascending to 3,000 ft., Assam, Burma; frequently cultivated in the western sub-Himalayan region, for example at Dehra Dun and in other valleys. In Burma it is common, especially in the Bhamo, Katha, and Ruby Mines districts, where it occurs in moist places along streams and in valleys, often bending over and forming dense thickets (see Fig. 393).

This bamboo often flowers sporadically, and is easily recognized from its reddish purple flowers. The following gregarious flowerings have been recorded:

1894. Sikkim and Dehra Dun (cultivated).
1912. Northern parts of the Khasi hills.
1910, 1911, 1914. Ruby Mines district, Upper Burma.

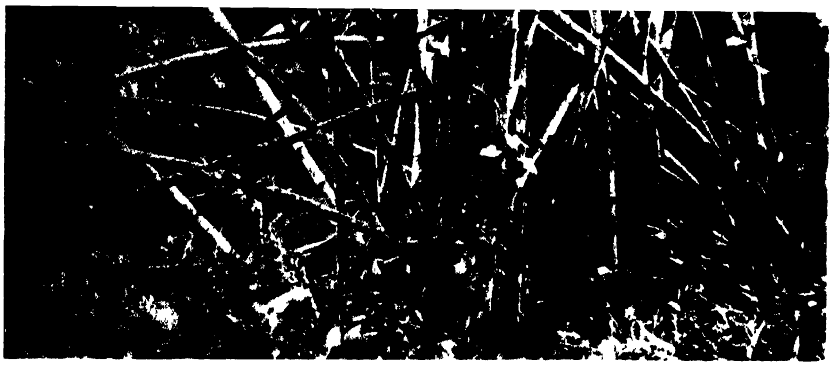


FIG. 393. *Dendrocalamus Hamiltonii*, Ruby Mines district, Upper Burma.

FIG. 394. Forest of *Cephalostachyum pergracile* (on right half of picture) and *Bambusa polymorpha* (clump on left) protected from fire for many years, showing dense growth, Tharrawaddy, Burma.

Fig. 395 *Dendrocalamus longispathus*, Chittagong hill tracts.

1916. Myittha forest division, Upper Burma.
1917. Myitkyina, Upper Burma.

5. **Dendrocalamus giganteus,** Munro. Vern. *Wabo*, Burm.

A very large bamboo with culms attaining 80–100 ft. in height and 8–10 in. in diameter, forming dense clumps. This is, with *D. Brandisii*, perhaps the largest of the bamboos. Probably indigenous to Martaban (Brandis); cultivated in many parts of Burma and in Assam, Bengal, southern India, and elsewhere. This bamboo is used for building and for masts of boats, while sections of the culms are utilized as buckets. According to Gamble it flowered in the Calcutta Botanic Gardens in 1860–1 and again in 1888. It is occasionally found in flower in Burma. An account of a plantation of this bamboo near Myanaung in the Irrawaddy delta is contained in the *Indian Forester*, vol. ii (1876–7), p. 311. This plantation, over 20 acres in extent, situated on rich sandy alluvium within half a mile of the river bank, was formed by planting, at the beginning of the rainy season, offsets consisting of the young shoots of the year with small portions of rhizome attached. The villagers estimated the age of flowering at forty years, and maintained that by planting offsets in the gaps formed from time to time by the flowering and dying of clumps the plantation could be maintained indefinitely, since young offsets so planted would complete the whole span of life before flowering, after the manner of seedling plants, the mother clump flowering and dying long before the newer clumps produced from its offsets. This, it may be noted, is contrary to what has generally been observed in the case of bamboos, namely that offsets, whatever their age, flower at the same time as the parent clumps. In the first year the offsets produced small whip-like shoots, the subsequent culms increasing in size each successive year until after seven years they attained a girth of about 10 in. and a height of about 40 ft., when they were cut for the market. The culms did not, however, attain full size until the clump had reached an age of fifteen or sixteen years. When the clump had attained maturity, all culms three years old were cut annually, each clump yielding three to four culms. The number of clumps per acre was fifteen to twenty, and the prices paid to the cultivator were Rs. 1–4–0 each for straight, mature bamboos, and 4 annas for the smallest sizes.

6. **Dendrocalamus longispathus,** Kurz. Vern. *Khang*, Beng.; *Ora*, Chittagong; *Waya, wanet, talagu-wa*, Burm. (Fig. 395.)

A large tufted bamboo, the culms attaining a height of 40–60 ft. and a diameter of 3 to 4 in., the internodes covered by long papery sheaths with irritant black hairs. A native of Sylhet, Chittagong, Arakan, and Burma. This is a well-known bamboo in the moister parts of the upper mixed forests of Burma, along the sides of ravines on moist fertile loam. It is often found flowering sporadically. Gregarious flowering has been reported in the Chittagong hill tracts in 1879, in the Tharrawaddy district of Burma in 1887 (Thonzè and Kônbilin forests) and 1912 (parts of the Minhla, Môkka, and Kadinbilin forests and elsewhere), and in the Toungoo district in 1913.

7. **Dendrocalamus Brandisii,** Kurz. Vern. *Wabo, kyellowa*, Burm.; *Thaikwabo*, Upper Burma.

A very large evergreen tufted bamboo, with culms attaining 80–120 ft. in height and 5–8 in. in diameter, along with *D. giganteus* perhaps the largest of the bamboos. Found throughout the greater part of Burma from Bhamo southwards through the Sittang, Salween, Thaungyin, and Ataran drainages. It is frequently, but by no means exclusively, found on limestone. It flowers sporadically as well as gregariously. The only gregarious flowerings hitherto recorded have been in the Thaungyin forests in 1914 and in the Lower Chindwin in 1916. In recent experiments at Dehra Dun it was the only species tried which gave successful results in propagation by means of cuttings laid horizontally just below ground ; the growth of the resulting shoots, however, was slow, a maximum height of 7 ft. having been attained in three years.

7. CEPHALOSTACHYUM, Munro.

Cephalostachyum pergracile, Munro. Vern. *Tinwa*, Burm.

A graceful deciduous tufted bamboo with thin-walled glaucous green culms, attaining under favourable conditions a height of 40 to 50 ft. or more, and a diameter of 3 in. ; culm-sheaths of a characteristic orange or almost brick-red colour, covered when young with stiff black hairs. In Burma it is much used for building and mat-making. A promising source of supply of paper-pulp.

This is one of the commonest and most widely spread bamboos in the upper mixed deciduous forests of Burma, and in association with teak and other valuable timber trees is of great silvicultural importance. It occurs both in the moister types of deciduous forest with *Bambusa polymorpha* and in stunted form in the semi-dry types, verging on the driest types where *Dendrocalamus strictus* is the prevailing bamboo. It is characteristic of low, hilly country, thriving best on well-drained fresh loam, and is remarkably gregarious. It occurs, though of small size and rare, in valleys in the forest of Singhbhum, Chota Nagpur ; it is also said to be wild on the lower Naga hills.

Fig. 394 shows a dense growth of this bamboo, such as is characteristic of forests which have been protected from fire for some time (see also Fig. 276).

This species often flowers sporadically, and occasionally flowers gregariously over extensive areas. The following gregarious flowerings have been recorded in Burma :

About 1865. Tharrawaddy (round Kodugwe).

1875–6. Prome and Tharrawaddy ; extensive flowering, embracing at least from the Bwet reserve in Prome through the Zigôn forests to the Kônbilin reserve in Tharrawaddy.

About 1887–8. Tharrawaddy (Kônbilin reserve).

1894–5. Tharrawaddy (Minhla) and Zigôn.

1899–1900. Pyinmana, Yônbin reserve.

1900–7. Upper Chindwin, Myittha, and Katha ; commenced in Upper Chindwin and spread in a wave southwards and eastwards. Auktaw and Pile reserves, Katha, in 1905–6.

1902–3. Shwegyin (Nyaunglebin).

1904–6. Myitkyina (Indaw valley).

1906–8. Pyinmana.

1906–9. Toungoo (Gwethe and Kabaung reserves in 1906–7).

1907–9. Henzada.
1908–9. Bassein.
1911–12. Pegu (North and South Zamayi reserves), Shwegyin (Nyaunglebin working circle).
1912–13. Toungoo, Rangoon, Thayetmyo, and Minbu forest divisions.
1913–14. Parts of Zigôn, Tharrawaddy, Rangoon, Upper Chindwin, Myittha, Mu, Yaw, and Katha forest divisions.
1914–15. Parts of Zigôn, Shwegyin (Nyaunglebin), and Mansi forest divisions.
1915–16. Nyaunglebin, Pegu, West Salween, and Southern Shan States forest divisions.
1916–17. Nyaunglebin, Pegu, West Salween, and Mansi forest divisions.

Little is known about the rate of growth of this bamboo. Mr. F. A. Leete [1] says that under the most favourable conditions it takes from twelve to fifteen years to produce full-sized stems, while under unfavourable conditions the time required may be anything up to thirty years.

8. MELOCANNA, Trin.

Melocanna bambusoides, Trin. Vern. *Muli*, Beng. ; *Tarai, wati*, Ass. ; *Kayaungwa*, Arakan ; *Tabinwa, tabindaingwa, kayinwa*, Burm.

An evergreen bamboo with single culms arising at a distance of about 2 ft. apart, more or less, from a ramifying underground rhizome. The culms are straight, and attain a height of 30 to 50 ft. and a diameter of 1½ to 2½ in. Although thin-walled, they are strong and are extensively used for building, as well as for basket-work, matting, and other purposes.

This bamboo is found in the Garo, Khasi, and Lushai hills, the Chittagong and Arakan hills, crossing the crest of the Arakan Yoma into the Prome, Henzada, and Bassein districts of Lower Burma ; it is also found in the Upper Chindwin district of Upper Burma. Brandis (*Indian Trees*) regards the Tenasserim single-stemmed bamboo as a different species.

Melocanna bambusoides is a typically gregarious bamboo, and occupies extensive tracts of country in the Chittagong and Arakan hills, where the destruction of tree-growth by shifting cultivation has over considerable areas produced a veritable sea of bamboo resulting from culms which have sprung from rhizomes remaining alive in the ground after the tree-growth has been destroyed. Enumerations carried out in two separate plots of 1 acre each in Arakan gave respectively (1) 10,575 culms weighing 27,404 lb., and (2) 6,855 culms weighing 33,248 lb.

The fruit is large, fleshy, and pear-shaped, 3–5 in. long and 2–3 in. broad, the stalk being inserted at the thick end and the apex terminating in a curved beak. The thick fleshy pericarp is filled with starch, and the fruits are readily devoured by cattle, elephants, bison, rhinoceros, deer, pig, and other animals. This bamboo flowers gregariously over large stretches of country. No new culms are produced the season before flowering takes place. The flower-buds are first visible about September or October, and flowering takes place in

[1] Ind. Forester, xxxviii (1912), p. 355.

December or January. Soon after the flowering the leaves wither and fall, the culms turn yellow, and the fruit forms rapidly, ripening and falling about April to June ; large numbers of fruits fail to mature. Often as many as eight or ten fruits may be found hanging in clusters round each node down the whole length of the culm. The fruits perish rapidly, and if they are sent to a distance they require to be packed carefully in dry sand or charcoal.

Germination commences with the first heavy showers of the rainy season, roots and shoots being produced from the thick end of the fruit ; roots often begin to appear before the fruit falls. The seedlings, unlike those of most bamboos, make vigorous growth from the commencement. By the end of the first season each fruit will usually have produced about four or five shoots, of which the latest may be as much as 10 ft. high ; these shoots are crowded together in a clump. During the second season more shoots are produced, the clump expands somewhat, and the largest culms reach a height of about 20 ft. By the fifth season the culms attain almost their maximum height, but are still thin and crowded together, and it is not until later that they become spaced out with the gradual extension of the rhizomes. Young crops of bamboo are extremely dense, the rhizomes being closely interlaced. Fig. 396 shows a natural crop seven years old from seed.

This bamboo spreads to a remarkable extent by its long vigorous rhizomes. At the last general fruiting in Arakan it was also observed to spread, owing to the rolling of the heavy fruits down the hill-sides, to places where it did not exist before, and was found springing up on savannahs and in beds of streams. It does not thrive well under shade, but springs up readily in gaps.

As an instance of the great vigour and vitality of the rhizomes, it may be mentioned that Mr. W. D. Turner of Hurbanswala, Dehra Dun, obtained seeds from Assam in 1912, of which six germinated successfully and produced strong plants, which grew and spread rapidly on moist fertile ground. In 1917 he was able to dig up no fewer than 400 offsets for transplanting elsewhere, after which a fairly large grove of bamboos still remained in the parent crop ; the appearance of this grove early in 1919, after seven rainy seasons' growth from seed, is shown in Fig. 397. Small portions of the rhizomes left lying on the ground when the offsets were dug up immediately took root and sent up strong shoots from dormant buds. The propagation of this bamboo from sections of rhizome, therefore, is an easy matter. The vitality of the rhizomes is well demonstrated in the natural home of this bamboo by the difficulty experienced in eradicating it on ground cleared for cultivation, for areas cleared one year become thickly covered with bamboos the next year. On this account the *taungya*-cutters in the Arakan hills are said to prefer flowered areas for making their clearings ; the large fruits are easy to collect off the ground, the reproduction of the bamboo being thus prevented, and the subsequent weeding of the cultivated patches being rendered much easier.

Experiments were carried out in Arakan at the last general flowering in order to ascertain the best means of eradicating this bamboo in the interests of tree-growth. It was found that if the bamboos were cut in the cold weather when about to flower, they flowered from dwarf shoots next year. By cutting the culms down in April when the fruits were almost ripe, however, the rhizomes were killed and the great majority of the fruits were destroyed.

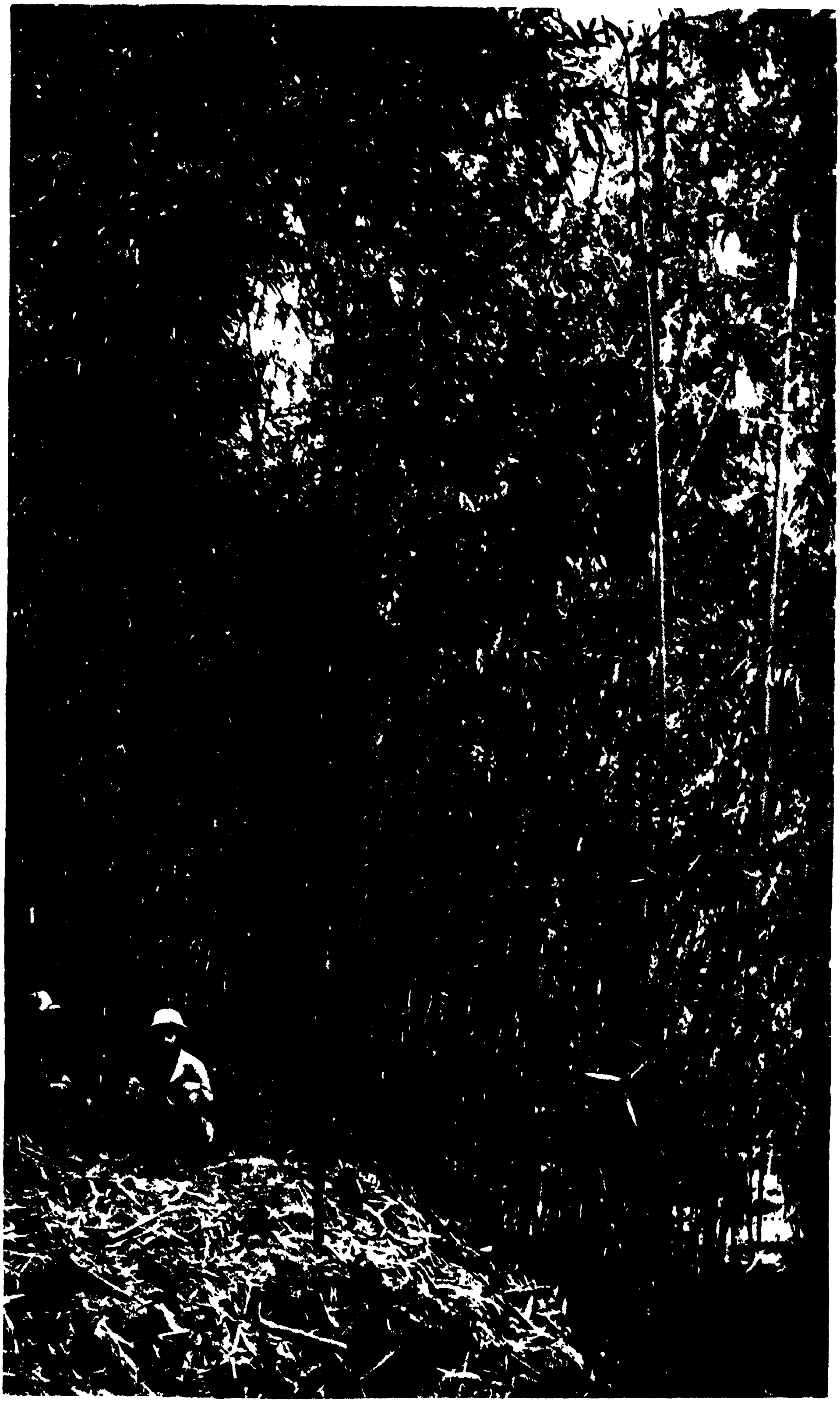


FIG. 396. *Melocanna bambusoides*, natural crop 7 years old, Chittagong hill tracts

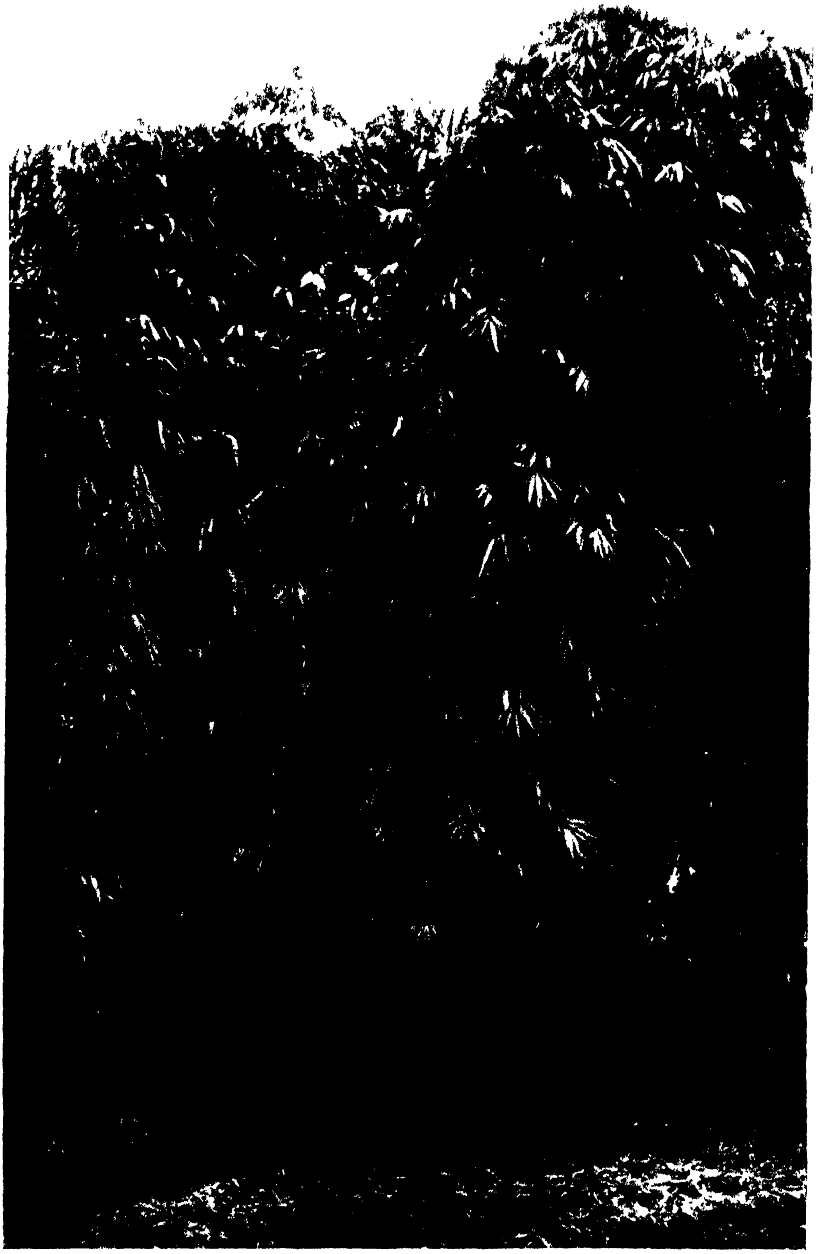


FIG. 397. *Melocanna bambusoides*, 7 years old, artificially raised from seed, Dehra Dun.

The following instances of general flowering have been recorded :

1863–6. Chittagong and Arakan, extensive flowering, also in Botanic Gardens, Calcutta.

1889. Garo and Khasi hills.

1892. Assam.

1900, 1902. Garo and Khasi hills.

1901–2 and 1904–5. Chittagong and Arakan, apparently over restricted areas.

1908–12. Chittagong : extensive flowering.

1910–13. Arakan : extensive flowering, spreading in 1912–13 to the east side of the Yoma into the Prome, Henzada, and Bassein districts.

1910–11. Assam (Sylhet).

1911–12. Assam (Garo hills, Cachar, Sylhet, Lushai hills).

1915–16. Arakan.

ORDER LXIII. CONIFERAE

A very important order, represented mainly in the Himalaya, and to some extent in the hills of Assam and Burma ; only one species (*Podocarpus latifolia*, Wall.) is indigenous to the Indian Peninsula. Several of the Himalayan conifers are of great importance from a silvicultural and economic point of view, and many of them grow gregariously, unlike most of the broad-leaved trees of India. Apart from the introduced species mentioned below, several exotic conifers are cultivated for ornament in India, among which may be mentioned *Thuya orientalis*, Linn., *Cunninghamia sinensis*, R. Br., *Araucaria excelsa*, R. Br., *A. Cunninghamii*, Ait., and *Ginkgo biloba*, Linn. ; none of these, however, is of special forest importance. Two rather rare species of *Cephalotaxus* are indigenous : *C. Mannii*, Hook. f., in the Khasi, Jaintia, and Naga hills, and *C. Griffithii*, Hook. f., in the Mishmi hills, Manipur, and the hills of the Ruby Mines district, Upper Burma.

Genera 1. PINUS, Linn. ; 2. CEDRUS, Link ; 3. ABIES, Juss. ; 4. PICEA, Link ; 5. TSUGA, Carr. ; 6. LARIX, Miller ; 7. CUPRESSUS, Linn. ; 8. JUNIPERUS, Linn. ; 9. CRYPTOMERIA, Don ; 10. CALLITRIS, Vent. ; 11. PODOCARPUS, L'Hérit. ; 12. TAXUS, Tourn.

1. PINUS, Linn.

Evergreen trees, generally with whorled branches. Five species in the Indian region, of which three are Himalayan, *P. excelsa*, Wall., *P. longifolia*, Roxb., and *P. Gerardiana*, Wall. ; one, *P. Khasya*, Royle, occurs in Assam and Burma, and one, *P. Merkusii*, Jungh., is found in Burma. The bark of most pines is rough, thick, and fissured ; *P. Gerardiana* is a representative of a small group with thin, smooth bark exfoliating in large thin scales.

In most pines a single whorl of branches is produced each year, the internode representing one year's growth. Young and vigorous trees, however, may often produce two whorls in one year by the development of a summer shoot in continuation of the spring shoot ; the summer internode is usually much shorter than the spring one. This often occurs in *P. excelsa* and

P. Khasya. Scattered side branches, not in regular whorls, are commonly produced by *P. Gerardiana*.

The leaves are of three kinds: (1) primordial leaves, found on seedlings or on shoots produced by saplings after injury; these are solitary, linear lanceolate, spreading; (2) scale leaves, containing in their axils the fascicles of adult leaves, usually quickly deciduous, with persistent bases; (3) adult leaves, needle-like, in fascicles of 2, 3, or 5 in Indian species, situated on short arrested branchlets which fall with the needles; the base of each fascicle of needles is enclosed in a sheath formed by the scales of the buds of the arrested branchlets, and the sheath is either quickly deciduous (*P. excelsa*, *P. Gerardiana*) or persistent (*P. longifolia*, *P. Khasya*, *P. Merkusii*).

Of the Indian pines *P. Merkusii* is 2-needled, *P. longifolia*, *P. Gerardiana*, and *P. Khasya* are 3-needled, and *P. excelsa* is 5-needled. The adult needles persist from one year and a few months to several years.

The flowers are monoecious. The male flowers, catkin-like, in the axils of membranous bracts, are spirally arranged in dense clusters at the base of the current year's young shoot; the flowers fall soon after maturing. The female flowers, or young cones, solitary or two or more in pairs or whorls, are situated at the apex of the current year's young shoot; they consist of a central axis round which are spirally arranged two sets of scales, namely a series of larger ovuliferous scales each bearing two pendulous ovules and a series of smaller scales which disappear before the cone ripens. Pollination takes place in the first year, shortly after the first appearance of the flower; the scales open to receive the pollen and close immediately afterwards. Fertilization is not completed, that is, the pollen-tube does not reach the embryo-sac, until the early part of the second year; thus the cone remains comparatively small during the first season, and commences to increase conspicuously in size only during the second season.

The fruit is a woody cone composed of spirally arranged scales, with two winged seeds on each scale. The end of each scale, which is exposed in the unopened cone, is called the apophysis, in the centre of which is a knob or scar known as the umbo, which represents the apex of the scale in the first year's growth of the young cone. In most pines, and in all Indian species, the cones open on the tree without assistance, the seeds escaping and falling to the ground, or, in large-winged species, being carried some distance by wind; in *P. Gerardiana* the wing is short and deciduous. The open cones remain for a time on the tree, in some cases for several years. In some non-Indian species the cones open only by the aid of fire or of squirrels and other animals.

Germination is epigeous, and the testa is carried up like a cap over the extremities of the cotyledons, which in Indian species vary in number from six to thirteen.

The Indian pines are all light-demanders, *P. longifolia* probably being the most marked in this respect, though on hot, dry aspects even this species benefits in youth by slight shade, particularly of broad-leaved species. Requirements for natural reproduction are more or less similar in all the Indian pines, which reproduce freely with abundance of light on recently exposed ground, such as abandoned cultivation and areas recently overrun by fire, particularly where the soil is free and loose. Young pine crops suffer severely from fire, and wherever there is any inflammable soil-covering, that is, in the majority of cases, protection from fire is essential for the satisfactory establishment of reproduction. On the other hand, fire is useful in preparing a germinating bed by removing the thick layer of needles or too dense a soil-covering of grass or bushes.

Certain exotic pines are occasionally planted in India on a small scale. In the Nilgiris small plantations have been formed of *P. Pinaster*, Solander (2-needled), the maritime or cluster pine of Europe, and *P. radiata*, Don (*P. insignis*, Douglas, 3-needled), the Monterey pine of California. Neither species thrives well; the latter grows well in the earlier stages, but subsequently falls off. *P. Pinaster* is occasionally planted in the Himalaya, and does moderately well in some localities at about 7,000 ft. *P. sylvestris*, Linn. (2-needled), the Scotch pine of Europe, has been planted in one or two places in Jaunsar, at about 8,000–9,000 ft., but does not thrive.

Species 1. *P. excelsa*, Wall.; 2. *P. longifolia*, Roxb.; 3. *P. Khasya*, Royle; 4. *P. Gerardiana*, Wall.; 5. *P. Merkusii*, Jungh.

1. **Pinus excelsa**, Wall. Blue pine. Vern. *Kail*, Hind.; *Beyar*, *biar*, Kashm., Haz.

A large evergreen tree with bluish feathery foliage. Branches whorled, spreading, usually ascending in young trees and horizontal or drooping in old trees, with upturned ends; branchlets glabrous, glaucous. Two whorls are often produced in one season, the second or summer whorl being only a few inches above the first or spring whorl, below which is the long spring internode of the current year. Adult needles in fascicles of 5, 5–8 in. long, shorter in stunted or sickly trees, bluish green, slender; basal sheath 0·5–0·9 in. long, quickly deciduous, Fascicles of needles arranged in spirals of 5 × 3. Abnormal fascicles containing 4, 6, or even 7 needles may be found occasionally. Bark on young stems and branches greenish grey, smooth and thin, soon becoming scaly, grey, or greyish brown, divided into small oblong plates by shallow fissures. Measurements of bark thickness are given on p. 1033. Wood moderately hard, with a pink heartwood, of good quality, less durable than deodar but easily worked, and much used for building, especially interior work, furniture, and general carpentry. The resin yielded by this pine is superior to that of *P. longifolia*, but systematic tapping operations on a large scale have not yet been organized.

When growing vigorously, and before reaching old age, this is one of the most beautiful pines in the world, its long bluish drooping needles and regular growth giving it a particularly graceful appearance; as it becomes old, however, it loses its graceful form and tends to become ragged. Under favourable conditions the tree reaches large dimensions. The following measurements have been recorded by Rai Bahadur Keshavanand in the Kishanganga valley, Kashmir:[1] (1) height 165 ft., girth 9 ft.; (2) height 147 ft., girth 6 ft. 11 in.; (3) height 146 ft., girth 6 ft. 11 in.; (4) height 110 ft., girth 16 ft. In the case of 55 mature trees (i. e. 6 ft. and over in girth) he found the average height to be 118 ft., and the average girth 8 ft. 7 in. These measurements are exceptional. Under favourable conditions a height of 120 ft., with a girth of 8–10 ft., is not uncommon, while larger dimensions are attained. A tree 125 ft. high and

[1] Working Plan for the Karnah-Drawa Forests, Kishanganga Valley, Kashmir.

10 ft. 10 in. in girth measured by me in 1914 in Kulu probably falls short of the maximum attainable in that locality. In 1918 I measured a tree 12 ft. 4 in. in girth and 110 ft. high in the Kagan valley, Hazara. Fig. 398 shows a tree 9 ft. in girth and 110 ft. in height. In many places, however, a height of only 80–100 ft. is reached, while on poor shallow soil and exposed situations the trees are often stunted, attaining a maximum height of only about 30–50 ft.

DISTRIBUTION AND HABITAT. *Distribution and types of forest.* The blue pine is found throughout the temperate regions of the Himalaya, chiefly at 6,000–10,000 ft., but sometimes ascending to 12,000 and descending to 4,000 ft., extending westward to Afghanistan and Kafiristan and eastward to Bhutan, though absent from Sikkim and a considerable portion of Kumaun. Its altitudinal range is greater than that of any other Himalayan conifer. At the lower elevations it descends into the region of *Pinus longifolia*, with which it is frequently associated at the upper limits of the latter. At the higher elevations it ascends into the region of birch and juniper, but here it is stunted and often so broken and bent down by snow as to assume a shrubby prostrate form. In the western Himalaya the blue pine is most abundant between 6,000 and 8,500 ft.; here the tree is typically gregarious, often forming extensive pure crops owing to its capacity for springing up in dense even-aged masses on open hill-sides and on abandoned cultivation. In such cases the effect of aspect is very marked, for the pine as a rule affects the warmer slopes and spurs, while the cold aspects and depressions are occupied by the silver fir, spruce, and broad-leaved species. At the lower elevations, however, where *Pinus longifolia* is the associate species, the latter occupies the hotter slopes and spurs, while the blue pine clings to the colder aspects and the moister depressions. In spite of its tendency to form pure crops the blue pine very frequently occurs mixed with other species, of which the commonest are, among conifers, deodar, spruce, and silver fir, and among broad-leaved species, oaks (*Quercus incana*, *Q. dilatata*, and at the higher elevations, *Q. semecarpifolia*), *Rhododendron arboreum*, *Pieris ovalifolia*, *Populus ciliata*, *Cornus macrophylla*, *Prunus Padus*, *Cedrela serrata*, *Aesculus indica*, *Acer caesium*, *A. pictum*, *Ulmus Wallichiana*, and others.

Among conifers the most important companion of the blue pine is the deodar. The conditions of locality which favour the two are in many respects similar, and mixed crops of the two trees are frequently met with. The mixture of blue pine and oak (*Q. dilatata* or *Q. incana*) is also common, the pine usually flourishing well with the oak. Where, as is often the case, the oak is subjected to systematic lopping, instances may be seen of oak forest being converted gradually into forest of pure blue pine through the admission of light which favours the spread of the latter. The mixture of blue pine and spruce (*Picea Morinda*), which is common, is one in which the pine usually reaches large dimensions.

Undergrowth in the blue pine forests is sometimes absent owing to the density of the crop. In fairly dense crops, however, maidenhair fern and wild strawberry often cover the ground, and are indicators of good soil conditions. Where light is sufficient there may be a plentiful growth of grass, while shrubs and herbaceous plants also make their appearance. In open places where the

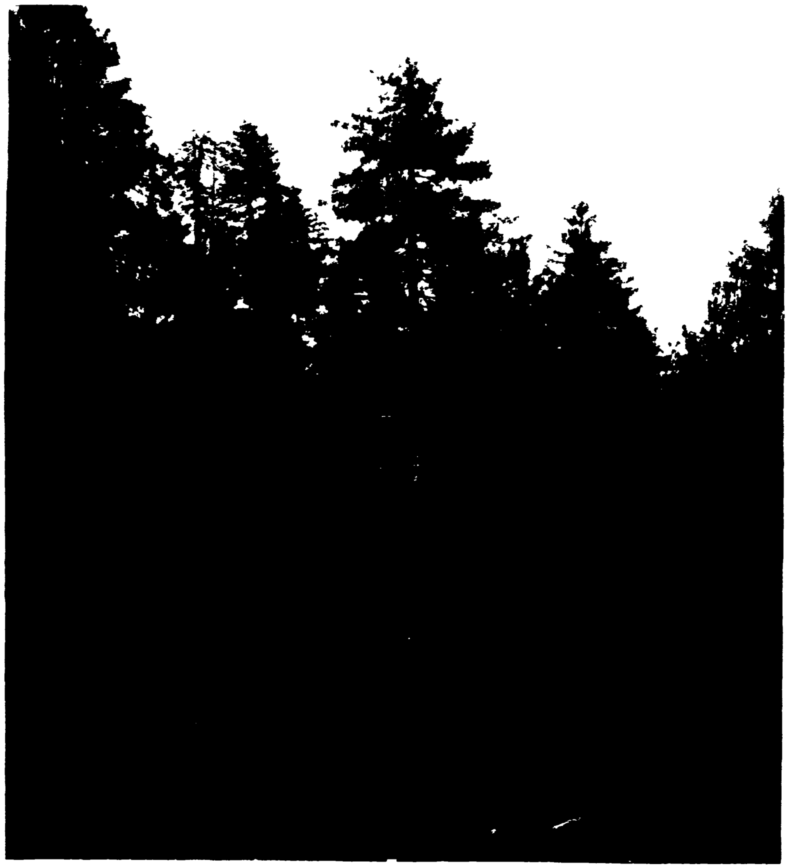


FIG. 398. *Pinus excelsa* tree, girth 9 ft., height 110 ft., Bashahr.

Fig. 399. Mixed forest of *Pinus excelsa*, *Cedrus Deodara*, *Picea Morinda*, and *Abies Pindrow*, upper Siran valley, Hazara.

FIG. 400 Crop of *Pinus excelsa* approaching maturity, Hazara, North-West Frontier Province.

pine springs up so freely, among the best indications of suitable soil conditions are *Indigofera* and *Desmodium*. But perhaps the best indicator of all is the bracken fern, *Pteris aquilina*, the presence of which is a sure sign that conditions are favourable for the pine, so much so that the bracken is one of the most characteristic plants in localities where the blue pine grows in greatest profusion.

As regards local occurrence, in the western Himalaya the blue pine extends in an almost unbroken succession of pure or mixed crops at suitable elevations from Garhwal through Jaunsar, the Simla Hill States, Bashahr, Kulu, Chamba, Kashmir, the Murree hills, Hazara, and into the tribal territory beyond. In Jaunsar, Tehri Garhwal, the Simla hills, and Bashahr pure forests occur chiefly between 6,000 and 8,500 ft., but between these elevations mixed forests of blue pine and deodar, often with oak, are also frequent. In Kulu pure crops of blue pine are to be found occasionally as low as 4,500 ft. on northerly aspects. Mixed crops of deodar and pine, often with spruce, are frequent between 5,500 and 7,500 ft., sometimes higher.

In the Murree hills of the Rawalpindi district the pine appears first at about 4,000 ft. in moist ravines on cool northerly aspects, while on southerly aspects it commences at about 5,500 ft. From these elevations up to about 6,000–6,500 ft., according to aspect, it is mixed with *Pinus longifolia* and oak (*Quercus incana*), and above this it occurs either pure or mixed with oak, poplar, horse-chestnut, and other broad-leaved species. In Hazara the blue pine is well represented between 6,000 and 10,000 ft. It occurs either in the form of pure crops, usually on spurs and warm aspects, or mixed with other species. Pure crops of large extent and excellent quality occur, particularly in the Thandiani range. Fig. 400 shows a mature crop in this locality. In the Dungagali range the extent of the pine crops is smaller. In the upper Siran valley and the Kagan valley the extent of pure pine crops is considerable. The mixed crops vary in composition. In the Dungagali and Thandiani ranges the chief conifer associated with the blue pine is the silver fir (*Abies Pindrow*), which, however, seeks cool aspects, moist depressions, and upper slopes, while the pine seeks warm aspects, dry spurs, and lower slopes, though the two are often intermixed. Broad-leaved species, such as oak (chiefly *Q. dilatata*), poplar, maple, horse-chestnut, and bird-cherry, are also frequently found in mixture with these two conifers, while there is often a plentiful underwood of yew. In the upper Siran and Kagan valleys there are considerable areas of mixed forest in which the pine is associated with spruce, silver fir, and deodar, as well as broad-leaved species, including much walnut; here again the pine is more typical of the warmer aspects, and the silver fir of the colder aspects, moist depressions, and upper slopes. Fig. 399 shows a mixed coniferous forest in the upper Siran valley.

In the tribal territory adjoining Hazara the blue pine is plentiful in Agror. In Chitral it occurs in cool situations in the upper parts of the valleys, along with deodar. Here the rainfall is scanty, but there is a heavy snowfall in winter. According to Mr. Stebbing,[1] the blue pine occurs sparingly, associated with *Pinus Gerardiana*, on the Takht-i-Suliman range and in the Sherghali forest to the south of the Takht on the western slopes of the Suliman range.

[1] Note on the Chilgoza Forests of Zhob and the Takht-i-Suliman, For. Bull. No. 3, 1906.

It is commonest in ravines and on easterly aspects. This tract is a particularly dry one, and the occurrence of the pine is accounted for by the presence of moisture held up in depressions or pockets in the limestone formation. In places it grows on the sides of sheer limestone cliffs. In the Torgai nala on the Takht-i-Suliman the trees attain large dimensions.

In Bhutan, Mr. Jacob[1] notes that the blue pine grows chiefly between 8,500 and 10,500 ft., descending to 7,000, and ascending to nearly 11,000 ft. At the higher elevations it is usually mixed with spruce. It attains a large size and reproduces well.

Kashmir contains large areas of blue pine in the drainage of the Jhelum river and its tributaries, chiefly between 6,000 and 10,000 ft., but sometimes descending below 6,000 ft. It occurs either pure or mixed with deodar, spruce, silver fir, or broad-leaved species.

Geology and soil. The blue pine is found on a variety of geological formations. It thrives on moderately dry soils, but provided the drainage is good it grows best on moist, fresh, deep soil; it avoids very wet and badly drained ground. It sometimes springs up in great abundance on boulder and gravel deposits in the beds of streams, showing its partiality for a porous soil with a fair amount of subsoil moisture. Some of the best blue pine forests are found on mica schist, which decomposes into a moist fresh soil, often of considerable depth. On shale the growth varies much according to the hardness of the rock and the depth of the soil; where the soil is shallow the trees tend to be stunted. Limestone is favourable where there is a sufficient depth of soil, otherwise the soil becomes too dry for the pine to thrive. The effect of geological formation in determining the local distribution of the blue pine and chir pine towards the lower limit of the former is well illustrated below Bandal in the Tirthan valley, Kulu. Normally the blue pine occurs above the chir, but in this locality there is a belt of pure blue pine on moist mica schist, while above it is a belt of pure chir on quartzite, on which owing to the dryness of the soil the blue pine is unable to compete with the chir; higher up the blue pine again makes its appearance on mica schist.

Climate. Most of the important blue pine forests are situated in regions where the rainfall varies from 40 to 75 in. In Bhutan, however, the rainfall is probably well over 100 in., while in the Suliman range the pine occurs where possibly little more than 10 in. of rain fall in the year, but here, as already mentioned, its existence is believed to be due to the occurrence of pockets of moisture in depressions in the limestone formation. The blue pine does not extend so far as the deodar into the inner dry valleys of the western Himalaya. Temperature statistics are insufficient to give any accurate idea of the temperature conditions within the region of the blue pine. The absolute maximum and minimum shade temperatures respectively are 94° and 19° F. at Simla, 91° and 19° F. at Chakrata, and 102° and 17° F. at Murree. In the region of the blue pine, therefore, the absolute maximum may be placed at slightly over 100°, while the absolute minimum towards its upper limits must be near, if not below, zero Fahr. Throughout its habitat snow falls during the winter.

[1] Report on the Forests of Bhutan bordering on the Boundary of Eastern Bengal and Assam, 1912.

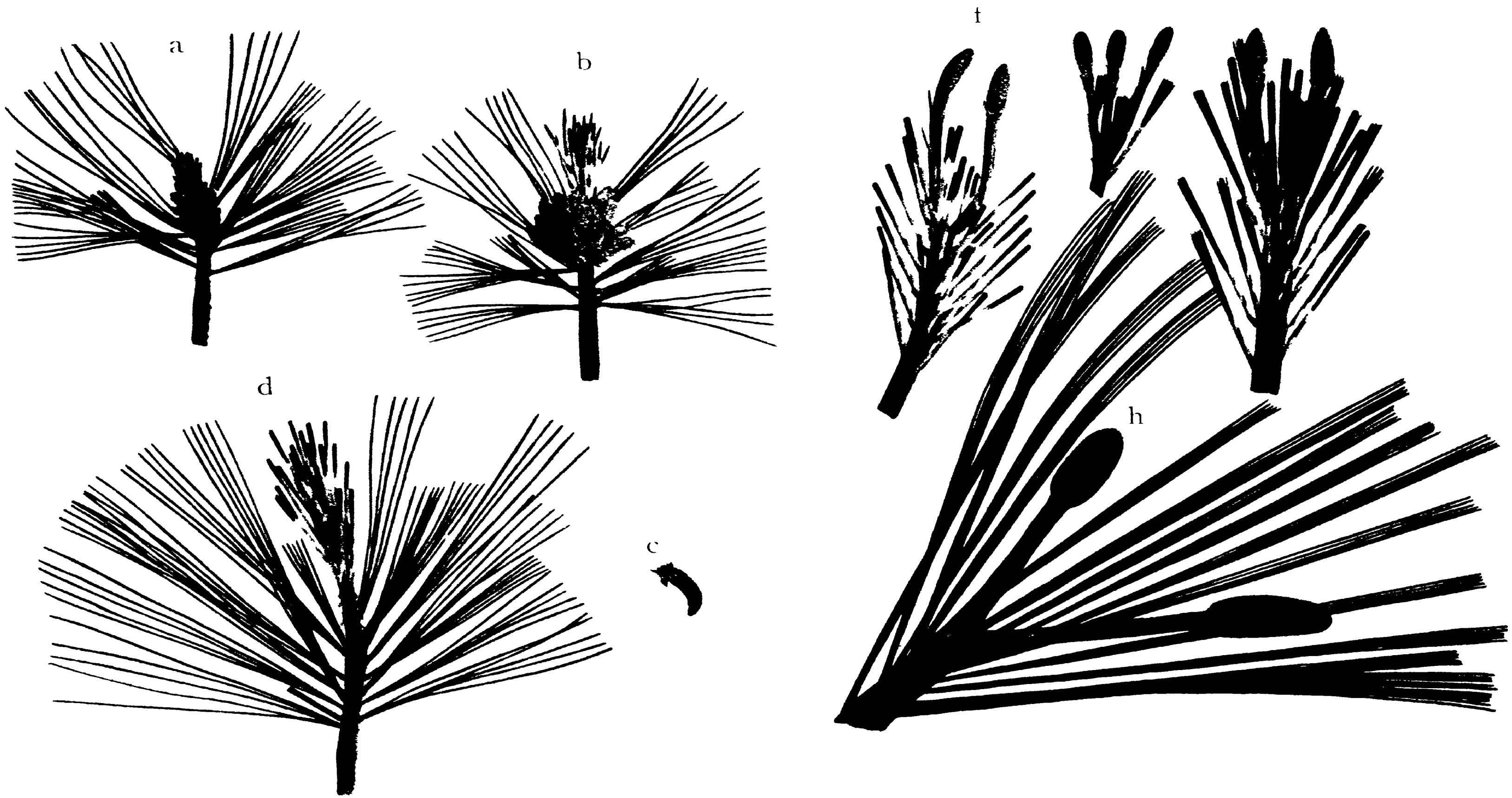


FIG. 401. *Pinus excelsa*—MALE AND FEMALE FLOWERS AND DEVELOPMENT OF YOUNG CONE × ½

a—Immature male flowers, April
b—Male flowers at time of shedding pollen, May
c—Single male catkin after falling, with involucre of scales
d—Branchlet from which male flowers have all fallen, after shedding pollen

e—Female flowers at time of pollination May
f—Female flowers after pollination scales closed
g—Female flowers a few weeks later
h—Young cones towards end of first season, October

(Note In each case last year s needles are shown partly cut off needles in h should be somewhat more lax than shown)

Leaf-shedding, flowering, and fruiting. The new shoots appear in March or early April, according to locality; by August to September the needles have attained full size (5–8 in. in length, or shorter under unfavourable conditions), and their basal sheaths have fallen. The needles persist either for one year and two or three months or, in part at least, for a second year. The normal season for the shedding of needles is the summer, chiefly during May, June, and July. In June–July the trees often have a somewhat bare appearance, many of the old needles having fallen, while the new ones have not yet expanded fully and are in tufts resembling tar-brushes. The needles are usually shed earlier in the case of less vigorous trees, at high elevations and on exposed ridges, than in the case of vigorous poles in favourable situations. Sometimes partial shedding of needles takes place at seasons other than the usual one, particularly from October to December.

Male flowers. The male flowers (catkins) ripen and shed their pollen from the end of April to the beginning of June, this taking place earliest at low elevations and in hot dry seasons. The male catkins are arranged in rather indistinct spirals in a cluster 0·5–2 in. long at the base of the current year's young shoot (Fig. 401, *a* and *b*). The catkins themselves immediately before ripening are 0·3–0·4 in. long, usually green but sometimes dark reddish purple; they lengthen to 0·4–0·8 in. after shedding their pollen, and when ripe are yellow to light brown, and often pink towards the apex. They fall soon after ripening. The base of the catkin is enveloped by an involucre of 8–12 imbricate scales, which adheres to the catkin when it falls (Fig. 401, *c*). The position of the catkins, after the fall, is marked on the shoot by a portion devoid of needles, and bearing only the small scales in the axils of which the catkins were situated (Fig. 401, *d*).

Female flowers and development of cones. The young female flowers become visible in April, and are pollinated from the end of April to the beginning of June, according to elevation, locality, and season. The flowers (young cones) are erect and terminal on scale-covered peduncles 1–1·5 in. long, solitary or usually two or three together, sometimes more, at the ends of the new shoots, forming a whorl round the terminal bud. At the time of pollination the flowers are 0·4–0·5 in. long by 0·15 in. in diameter, dark reddish purple, with scales open (Fig. 401, *e*); the scales are arranged in spirals of 5 × 3. After pollination the scales close (Fig. 401, *f*), the young cones increase somewhat in size, becoming 1–2 in. long by 0·4–0·5 in. in diameter by August, with a glaucous green or purplish colour, and the peduncles elongate to 1·3–2·5 in. (Fig. 401, *g* and *h*); they remain in this condition for the remainder of the first season.

Fertilization is not completed until the beginning of the year after pollination. An examination by Mr. G. H. Alington of young cones at the end of June, two months after pollination, showed that the pollen grains had entered the micropyle of the ovules and lodged on the nucellus, but so far had not produced pollen tubes, while the embryo sacs were not yet fully developed.

The young cones which first appeared in the spring of the previous year begin to grow towards the end of March or during April of the second year, and growth, once started, is rapid. The growth of the new season's terminal shoot throws the young cones out of the terminal into a horizontal position. and as they increase in size and weight they become pendulous instead of erect. The immature cone of the second season is bluish green, each scale being tipped with a small brown umbo, the remains of the first season's scales (Fig. 402, *a* and *b*); full length is attained from the latter half of June to the early part of August, according to elevation and locality, and the cones gradually turn from green to light brown from the end of August to the early part of October. They ripen, the scales opening and the seed being shed, from the end of September to the early part of November. The ripe cones (Fig. 402, *c* and *d*), generally two or three together, pendulous on peduncles 1·3–2·5 in. long, are cylindrical, 6–13 in. long, light brown, with scales arranged in spirals of 5 × 3, 1·5–2·5 in. long by 0·8–1·3 in. broad, apophysis convex, more or less rhomboidal, with a small dark brown umbo.

Thus the time taken from the first appearance of the female flower to the ripening of the cone is approximately eighteen months.

The old open cones may remain some time on the tree; I have found them, by counting internodes, occasionally persisting for five years or even more, though this is exceptional.

Succession of cones and flowers. The immature cones, as already explained, are terminal during the first season, becoming lateral after the succeeding season's growth commences. These lateral cones, whether immature or mature, are thus found at the nodes of the branches and branchlets, and immediately below the whorls of branchlets; on young trees cones are occasionally found on the main stem. From April to about October there are two succeeding stages of immature cones, one terminal and small and the other lateral and larger, followed by one or more stages of mature open cones, while from about October to April there is one stage of immature small terminal cones followed by one or more stages of mature open lateral cones. These successive stages, where all are present, differ in age by one year, and by counting the whorls the age of any stage of cones can be determined exactly. Each successive stage, however, is not necessarily present on one tree or branch; indeed it would be exceptional to find a continuous succession for a series of years. Thus Figs. 404 and 405 each show three stages with a fourth wanting. Male flowers may sometimes be found succeeding females of the previous season.

Seed and seeding. The winged seeds lie in pairs at the base of each cone scale. Seed without wing 0·25–0·4 in. by 0·15–0·2 in., dark brown, ovoid, compressed, acute at both ends, with a hard shell; seed with wing 1–1·5 in. long, wing 0·3–0·4 in. wide, oblique, light brown streaked with darker brown lines (Fig. 402, *e*). On an average about 7,500 seeds weigh 1 lb., though the actual weight of different samples varies considerably.

The blue pine seeds at a comparatively early age, trees ten to twelve years old being occasionally found with well-formed cones on them, while as a general rule cones begin to be formed regularly at an age of fifteen to twenty years. I have carried out various fertility tests with seed collected in Jaunsar from trees of different ages, with the following results:

Fig. 402. *Pinus excelsa*.—Development of cone during second year $\times \frac{5}{8}$

Pinus excelsa : fertility tests of seed collected in Jaunsar.

No. of test.	Locality.	Age of tree.	Dimensions of tree. Girth at breast-height.	Height.	Length of cone.	Percentage of fertility.
		years.	ft. in.	ft.	in.	
1	Bodyar, 8,000 ft.	10				30
2	"	18				84
3	"	20				55
4	"	26	..			55
5	Kathiyan, 7,000 ft.	28	1 3	38	5	75
6	Bodyar, 8,000 ft.	29	..	..	..	83
7	Kathiyan, 7,000 ft.	34	2 0	54	5·5	90
8	Bodyar, 8,000 ft.	40	..	..	..	70
9	Kathiyan, 7,000 ft.	41	3 0	65	9·4	85
10	"	45	4 0	77	10·1	90
11	"	48	5 0	87	10·5	50
12	Deoban, 9,000 ft.	50	..	..	..	40
13	Kathiyan, 7,000 ft.	100	7 0	113	12·5	95

These figures show that a fair proportion of fertile seed is produced at a comparatively early age. Observations show, however, that as long as the trees remain vigorous the number of cones produced increases with the size of the crown, that is, with the size of the tree, and consequently seed-bearers should be selected where possible from among the larger vigorous trees with well-developed crowns. This, however, though important, is not so necessary as in the case of *Pinus longifolia*, which, unlike the blue pine, reaches a definite stage when the conical crown gives place to the rounded crown which marks the good seed-bearer.

I noticed in 1911 a remarkable example of early seeding round a small blue pine plantation below Chaubattia in the Kumaun hills. The plantation was then thirty-four years old, and round it were natural seedlings up to seventeen years old, the oldest of which were in their turn producing cones. The trees in the plantation must have begun to produce fertile seed at an age of not more than seventeen years, since the blue pine is not indigenous to the locality, and there were no other trees of that species in the neighbourhood.

Tests at Dehra Dun have shown that the seed retains its fertility, to some extent at least, for eighteen months ; no older seed was tested.

Good seed-years are more frequent in the case of the blue pine than in that of any other important Himalayan conifer. In the Murree hills, in eight years out of nine consecutive years, 1905 to 1913, good seeding was recorded five times and bad seeding three times. In Jaunsar, in sixteen years out of twenty-one consecutive years, 1894 to 1914, good seeding was recorded ten times and bad seeding six times. A certain amount of seed is produced almost every year, complete failure to seed being rare.

Probable good seed-years can be foretold about eighteen months in advance of the seeding, by examining, preferably with the aid of field-glasses, the production of female flowers at the apices of the new shoots in the end of April or during May. The crop of cones may, however, be largely or completely destroyed in the immature state by animals and birds. Of the former, monkeys and flying squirrels are the chief offenders, more especially the squirrels, which destroy large quantities of green cones of the second year, from about

May onwards. The damage may be detected from the fact that the ground is strewn with the green cone scales and the cone axes from which the scales have been bitten off sharp at the base. Both the common western Himalayan species are concerned, namely, *Pteromys inornatus*, Geoffroy, the large red flying squirrel, and *Sciuropterus fimbriatus*, Gray, the smaller flying squirrel. These animals are nocturnal. In May 1916 I watched the latter with the aid of an electric lamp, for four successive nights, devouring the cones on a small blue pine tree at Simla, and in that time the tree was stripped of all its cones, about 120 in number ; the cones were then about 4 in. long, green and tender, and the young seed was apparently the part sought for, since the scales and axes of the cones were discarded. Although on this occasion I saw only one animal, there may have been more, but at all events the destruction of even thirty cones per night by a colony of squirrels for say five months, from May to September, would mean a loss in one season of nearly 4,600 cones, or at a moderate estimate, 500,000 seeds.

Among birds, the worst offenders are jays and nutcrackers, which attack the immature green cones from about June onwards, and also extract the seed from the ripe cones as they open. When the cone scales are young and tender they bite them off much as the flying squirrels do, but as they become more mature and tougher, they shred them, leaving the fibrous parts ; this is apparently done in the effort to open the scales and reach the immature seeds beneath. After the seeds fall they are consumed in quantity by pheasants, which are very partial to them and feed on them throughout the winter.

Considering that the seed is destroyed to such an extent, it is surprising that the tree reproduces as freely as it does ; where reproduction is satisfactory, the only explanation seems to be that the seed is produced in such large quantities that there is enough to spare after satisfying the requirements of beast and bird.

Germination (Fig. 403, *b–f*). Epigeous. The radicle emerges from the end of the seed and descends, the hypocotyl elongates, sometimes arching slightly, and the cotyledons, 9–12 in number, are carried above ground. As the cotyledons elongate the shell of the seed remains enclosing their apices for a time, eventually falling to the ground, when the cotyledons spread out radially in a whorl, from the centre of which the young shoot develops.

The seedling (Fig. 403). The following is a description of the natural forest seedling during the first four years, grown under average conditions :

First year (Fig. 403, *f*).—*Roots.* Primary root short to moderately long, terete, tapering, thin, somewhat delicate, brown or greenish brown ; lateral roots usually absent, or if present, few and small. *Hypocotyl* distinct from the root, 1–2·5 in. long, cylindrical, thin, tender, pale green at first, becoming reddish or brownish green. *Cotyledons* 9–12, whorled, 1–1·5 in. long, acicular, triquetrous, compressed laterally, incurved when young, becoming straighter afterwards, pale green, inner edges minutely and somewhat widely serrulate. *Stem.* Natural seedlings form no stem above the cotyledons during the first season, producing at most a central tuft of primordial needles ; many produce nothing more than the whorl of cotyledons, while some have scarcely completed germination. In reckoning the age of a natural seedling, therefore, the first season's growth may be taken up to the remains of the cotyledonary whorl or immediately above it. *Leaves.* Primordial single needles, if present, up to 0·75 in. long in a dense, starlike cluster in the centre of the whorl of

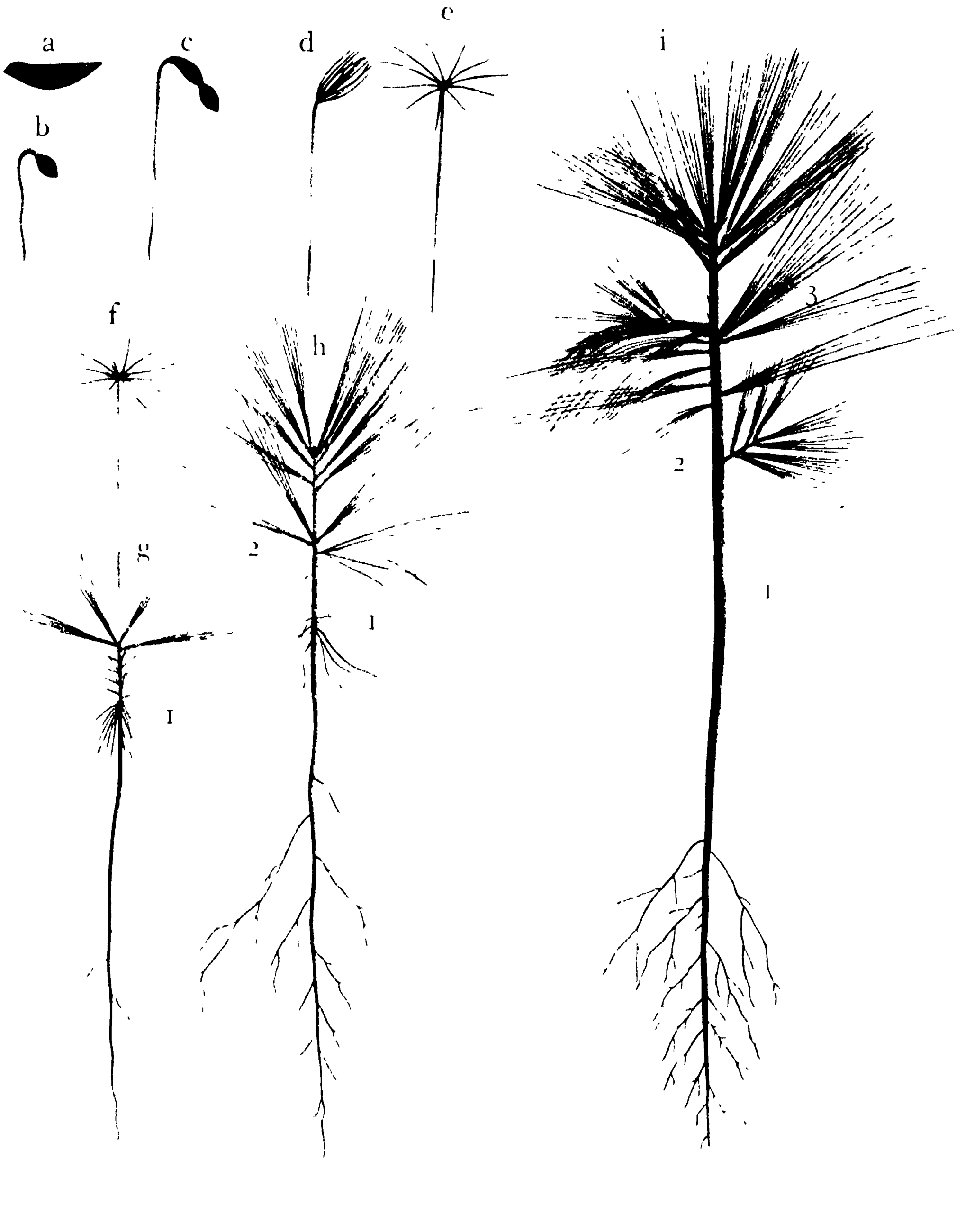


FIG. 403. *Pinus excelsa*—SEEDLING × $\frac{3}{8}$

a—Seed. b-f. Germination and development of natural seedling to end of first season.
g. Natural seedling at end of second season. h.—Natural seedling at end of third season.
i. Natural seedling at end of fourth season.
1, 2, 3. end of first, second and third season's growth respectively.

cotyledons, acicular, acuminate, pale green or silvery bluish green. Adult needles absent.

Second year (Fig. 403, *g*).—*Roots*. Primary root moderately long, wiry, flexuose; lateral roots few or moderate in number, short or moderately long. *Hypocotyl* greenish brown or light brown, smooth. *Cotyledons* usually green in spring, turning brown during the season, dead and drooping or some fallen by the end of the year. *Stem* (above cotyledons) green or greenish brown, glabrous, usually attaining 0·5–1·5 in. in length. *Leaves*. Primordial needles spirally arranged, acuminate, up to 1 in. long, green, lower ones turning brown by the end of the year. Adult needles, in fascicles of five, up to 2·5 in. long, with a basal sheath of light brown scales, appear for the first time towards the apex of the shoot; fascicles more or less whorled, often in two tiers, the lower with one or two fascicles, the upper with two, three, or more. Terminal bud distinct, greenish.

Third year (Fig. 403, *h*).—*Roots*. Primary root moderately long, tapering, wiry; lateral roots moderate in number and length. *Hypocotyl* greenish brown, smooth, wiry or woody. *Cotyledons* usually still visible in part, dead, brown, drooping; if absent, their position marked by a distinct ring. *Stem and leaves*. Stem still comparatively thin except in specially vigorous specimens. Second year's shoot (above cotyledons) greenish grey, usually with remains of primordial needles present, these being dead and often fragmentary, thickly grouped at base of shoot; insertions of fallen needles conspicuous, whorl of fascicles of adult needles in fives, up to 3 in. long, present on upper part of shoot, some often dead, reddish-brown; living needles green, with two pale silvery blue lines on inner surface. Third year's shoot pale green, 1–2·5 in. long, with small spirally arranged scales, whose insertions after they fall are prominent in the form of raised dots; fascicles of adult needles in fives, up to 3 in. long, in axils of scales on upper part of shoot, becoming densely clustered towards the apex. Terminal winter bud greenish, with thin papery scales.

Fourth year (Fig. 403, *i*).—*Roots*. Primary root moderately long, tapering, considerably thickened, woody; lateral roots moderate in length and number. *Hypocotyl* (first year's shoot) fairly smooth, with occasiona llenticels, greyish brown. *Cotyledons* absent, their position usually marked by slight annular markings with a cluster of dormant buds immediately above. *Stem and leaves*. Stem considerably thickened, woody. Lateral shoots often commence appearing at the nodes, representing the bases of the successive years' main shoots. Second year's shoot greenish grey to greyish brown, devoid of needles, scale insertions visible, often with dormant buds immediately above them; upper extremity of shoot marked by closer grouping of scale insertions and dormant buds, often with slight swelling. Third year's shoot silvery greyish green, marked with spiral scale insertions; upper part of shoot with spirally arranged fascicles of adult needles in fives, up to 4 in. long, closely grouped towards the apex of the shoot, basal sheath up to 0 35 in. long, with light reddish brown papery scales. Fourth year's shoot, 1–2·5 in. long, pale green to greenish grey, with spirally arranged triangular acuminate scales 0·1 in. long, or mere scale insertions; fascicles of adult needles in fives, up to 4 in. long, more silvery blue than those of previous year's shoot, densely clustered towards apex, basal sheath up to 0·5 in. long with light reddish brown papery scales. Terminal bud green, with a winter covering of pale reddish papery scales.

In the above description the dimensions given may be taken to represent those of the natural forest seedling grown under average conditions; such a seedling may be expected to attain a height of about 5 to 8 in. in four years, though under specially favourable conditions the height may be considerably more. It may be noted that there is little or no growth above the cotyledons in the first year, and that adult needles commence to form in the second year.

In counting rings on stumps at least five years should be added for the time taken for a seedling to reach stump height.

Nursery-raised seedlings, which are usually grown under much more favourable conditions, show more rapid growth and better development both of the stem and of the root-system, including usually a distinct elongation of the stem above the cotyledons during the first season, with buds of adult needles towards their apex. Nursery seedlings ordinarily reach a height of about 9 to 15 in. in three years, with stout stems and well-developed masses of adult needles (Fig. 406).

Seedlings flourish best on well-drained fresh soil with an abundance of light. They tend to damp off with an excess of moisture and to die of drought in shallow, dry soil. They are frost-hardy in their natural habitat. Under slight shade they persist for a time, but develop slowly, while under heavy shade they soon die off. Where rats are prevalent the roots of young plants are apt to be gnawed through immediately below the surface of the ground, particularly in nurseries.

Silvicultural characters. The blue pine is a strong light-demander from youth onwards. It persists under moderate shade for many years, but makes little progress, and eventually becomes completely suppressed ; vigorous growth is attained only with complete overhead light. In the Ramgarh Kundi forest, Kulu, on a southerly to south-westerly aspect, I measured a number of young trees, aged twelve to fifteen years, growing completely in the open ; these had an average height of 25 ft., and were particularly vigorous. In close proximity were numerous young trees under a moderately open overwood of blue pine ; these young trees averaged twenty years of age for a mean height of 6 ft., and were thin and feeble. Even in fair-sized gaps the growth was poor compared with that in the open. Nevertheless young blue pine plants have a remarkable aptitude for pushing their way through shrubby growth if this is not too heavy, and on hot aspects the protection afforded by shrubs is useful. Under the shade of broad-leaved species, and particularly oak, the blue pine persists for a long time, and if the shade is light it makes its way in time through the canopy ; the lopping of oak trees is specially favourable to the establishment of young blue pine.

The root-system of the blue pine is massive, though somewhat less so than that of *Pinus longifolia* ; it is to some extent superficial, footpaths through blue pine forest being often covered with a network of roots. The tree is wind-firm.

The blue pine is subject to various forms of injury. It suffers more from snow than any other Himalayan conifer, the damage being of two kinds, breakage of the crowns and stems and curvature at the base of the stem. The latter, which is prevalent in many localities, is caused in youth, when the plants are still flexible, by masses of snow sliding down the hill-sides and pressing down the young plants ; the leaders persist in taking a vertical course, and eventually the stem becomes strong enough to grow erect, but the base retains a pronounced curve, and the lower part of the bole, often to a length of many feet, is rendered useless as timber. Snow-break is particularly common in dense pole crops, and is aggravated if these crops are suddenly opened out after growing in a dense condition for some time. The

FIG. 404. Branch of *Pinus excelsa* in July, showing *a*, immature small terminal cones about 2 months after pollination, *b*, immature lateral cones, 1 year older than *a*, to ripen the following October; *c*, node with one stage wanting; *d*, old open cones, 3 years older than *a*. Squares show inches.

FIG. 405. Branch of *Pinus excelsa* in September, showing: *a*, immature cones about to ripen; *b*, old open cone 1 year older than *a*; *c*, old open cone 2 years older than *a*; one stage, the small terminal immature cone, wanting.

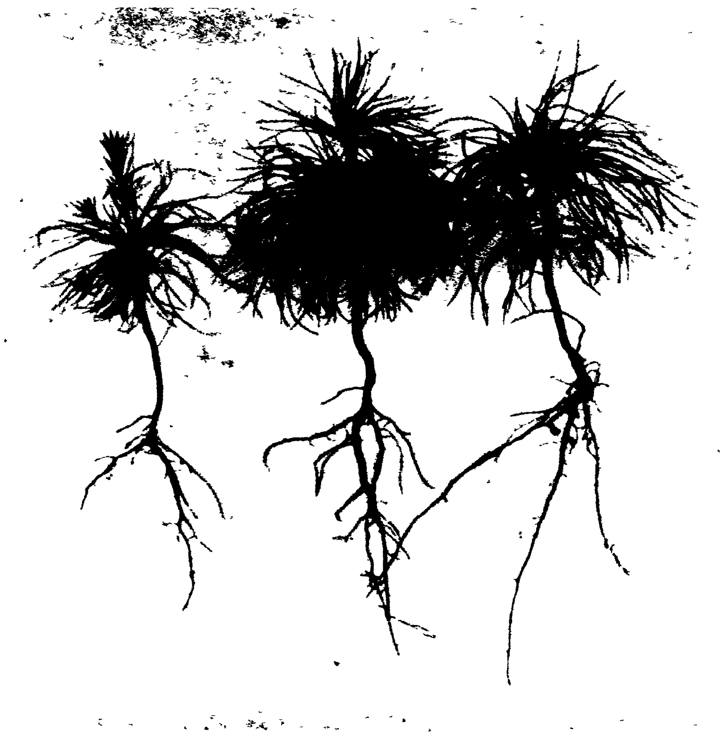


FIG. 406. *Pinus excelsa*, nursery seedlings 3 years old, Jaunsar; centre plant 2 ft. 1 in. long from top of shoot to end of root.

FIG. 407. Natural reproduction of *Pinus excelsa* springing up on abandoned cultivation; pure forest of *Pinus excelsa* behind, Bashahr, Punjab.

best preventive measure is to commence thinnings early and to carry them out lightly and at frequent intervals.

The blue pine is very sensitive to fire, although fires are not as a rule so common in the region of this pine as they are in the hotter and drier belt below it occupied by *Pinus longifolia* ; still when fires do occur the blue pine suffers more severely, since it has not the advantage of such a thick protective bark as *Pinus longifolia.* When a fire occurs, pole crops are frequently killed outright, while even large trees often succumb.

Browsing by goats causes serious injury to young blue pine, the plants acquiring a low bushy form in areas where goat browsing is permitted. Sheep and cattle are less harmful, as these animals avoid the pine if other food is plentiful, though in the case of cattle and buffaloes, particularly the latter, damage is caused by trampling. Bears and porcupines do much injury in some localities by barking the stems of poles and saplings, often ringing them completely and killing them. Porcupines remove the bark by gnawing, and bears tear it off with their teeth and claws, the damage being done chiefly in the spring. Among direct forms of injury caused by man are lopping of the branches for litter and manure and cutting out torch-wood from the base of the tree, thereby producing a large cavity to which fire is sometimes applied to stimulate the accumulation of resin. Lopping is particularly injurious in that it results in the admission of the fungus *Trametes Pini* (see below).

The only serious climber in blue pine forest is *Rosa moschata.* Among others which occur, but as a rule do comparatively little damage, are *Vitis semicordata, Hedera Helix, Clematis montana,* and *Jasminum grandiflorum.* In some localities the branches of the blue pine are attacked by the minute loranthaceous parasite, *Arceuthobium minutissimum,* Hook. f., which does considerable injury when it occurs in quantity. Dr. Duthie found it prevalent in Kumaun and Kashmir, and I have noticed it, not on a large scale, in Hazara and in the Simla hills. It appears in the form of bright green masses and produces small excrescences on the twigs.

Among fungus pests of the blue pine by far the most serious is *Trametes Pini,* Fries, an account of which has been published by Mr. R. S. Hole.[1] This fungus attacks many coniferous species in different parts of the world ; in Europe its principal host is *Pinus sylvestris.* The obvious signs of attack are (1) the rotting and disintegration of the heart-wood, rendering the timber more or less valueless and the trees liable to be broken by wind, and (2) the appearance of the sporophores on the stems or on exposed roots, at points where some injury has been inflicted and the wood has been exposed, particularly where branches have been lopped or broken off. The sporophores, which are produced chiefly during the monsoon, from July to September, and to some extent also in the early spring, are usually bracket-like, but vary much in shape ; they may persist for some time, finally dropping off. Several years may elapse between the date of first infection and the production of the sporophores, and hence trees may be affected by the fungus and yet show no outward sign of it. Trees of all sizes are attacked, and the damage done in some districts is enormous, a large proportion of the trees being rendered entirely useless for timber. Although they are not ordinarily visible to the

[1] Ind. For. Records, vol. v, pt. v, 1915.

naked eye, a microscopic examination by Mr. Hole revealed numerous hyphae in the sap-wood and in the sieve-tubes of the bark. In bad cases the entire heart-wood of the stem and roots is more or less disintegrated. Mr. Hole's investigations, carried out in parts of Bashahr and the Simla hills, led to the conclusion that primary infection as a rule takes place through the stem by means of wind-carried spores, and not through the roots, though the mycelium is capable of spreading from tree to tree through the roots, where, as is often the case, natural root-grafting takes place.

The most fruitful cause of the spread of the disease in the western Himalaya is undoubtedly the practice of lopping, which is extensively carried out in many tracts. Preventive and remedial measures suggested include (1) strict prevention of lopping, cutting out torch-wood and other forms of mutilation; (2) felling all infected trees at or below ground-level, burning the stumps or covering them with earth, burning all sporophores and unutilizable material and quickly removing what is utilizable; (3) removal in thinnings of trees injured by snow or other causes; (4) in badly affected areas complete removal of the crop, replacing it by deodar or broad-leaved species; (5) in gaps caused by the removal of diseased trees, likewise replacing the blue pine by deodar or broad-leaved species; (6) planting protective belts of species other than blue pine along the edges of blue pine forests adjoining village lands where the pine is lopped, and from which the fungus spores may spread.

Resin-tapping operations have not yet been introduced systematically in blue pine forests, and it is not yet known if they will, when introduced, result in causing a spread of *Trametes Pini*. Possibly tapping to death for a few years prior to felling may have no adverse results, but if light tapping for a long series of years is to be introduced its effects should be carefully watched before it is carried out on an extensive scale.

Peridermium brevius, Barcl., is a fungus of comparatively small importance which attacks needles, twigs, and branches of blue pine trees and stems of saplings. It appears in May and June in the form of small orange-coloured sacs of spores on the needles. In the bark form the bark becomes blistered, often with swelling of the part affected, and orange-coloured sacs of spores burst through to the surface in May and June. The fungus attacks the living cortex, rendering it at first soft and spongy and afterwards dry and brittle; in bad attacks it encircles the stem or branch and kills the part above the point affected. I have noticed the bark form locally in Kulu and Hazara, but so far it does not appear to be widespread.

Natural reproduction. Wherever conditions are favourable there are few if any Himalayan trees which regenerate in such profusion as the blue pine. The factors which influence natural reproduction may be considered separately under (1) seeding conditions, (2) germination, (3) climatic conditions, (4) soil and soil covering, (5) light, (6) fire, (7) grazing.

(1) *Seeding conditions*. The seeding conditions of the blue pine are particularly favourable; these conditions have already been dealt with, but they may be recapitulated briefly. Fertile seed commences to be produced at an early age, and sufficient seed for complete regeneration is produced at an earlier stage than in the case of *Pinus longifolia*. Good seed-years are more frequent than is the case with any other important Himalayan conifer, and

a year seldom occurs in which at least a fair proportion of the trees in a blue pine forest do not bear seed, while in good years seed is produced in large quantities. Much seed may be destroyed on the tree by jays, nutcrackers, monkeys, and flying squirrels, and on the ground by pheasants, but in spite of this the quantity produced is usually amply sufficient for purposes of regeneration. The winged seeds are shed from the end of September to the early part of November, the open cones remaining on the tree, and are carried to a considerable distance. Natural seedlings of blue pine are often found on open ground a surprisingly long distance from any seed-bearer, and it is no uncommon thing to find natural reproduction springing up in dense masses at least 200 yards from any mother tree. Blue pine saplings are constantly found appearing under broad-leaved species or in gaps in forest of deodar, spruce, or even silver fir, in places where no pine seed-bearer can be found anywhere near. In Hazara, for instance, there are numerous examples of silver fir forest, when opened out, giving place to young blue pine crops originating from seed spread from seed-bearers a considerable distance away. In deodar forests this encroachment is common in many localities. Numerous examples may be found of bare slopes becoming clothed with young blue pine crops from seed-bearers growing on the ridges far above, or widely scattered over the area.

(2) *Germination.* The seed lies on the ground through the winter and ensuing hot season, and does not germinate until the rainy season ; this is undoubtedly a disadvantage in that it is exposed for several months to the attacks of birds. Under natural conditions germination commences in warm situations in June, after the first heavy showers, and continues during the rainy season ; in cool, shady places seed may be found germinating as late as October. Seed may occasionally be found germinating inside cones which have fallen, and dense clusters of seedlings may be found in one place, having arisen from seed which has germinated in cones lying on the ground or has escaped from such cones and germinated *in situ.*

(3) *Climatic conditions.* The winter snowfall acts beneficially in protecting the seed on the ground from being devoured by birds. Owing to the late germination of the seed the seedling, unlike that of the deodar, is not exposed to the drought of the hot season during and immediately after germination. In hot, dry places, however, seedlings may die off in quantity during periods of drought following the rainy season, particularly from September to November of the first year and during the next hot season from April to June. Years of ample snowfall and rainfall are beneficial in preventing this mortality.

(4) *Soil and soil-covering.* The blue pine regenerates most freely on newly exposed loose porous soil. This is well illustrated by the remarkable manner in which it springs up on abandoned cultivation (Figs. 407 and 408), on new soil produced by landslips, and wherever the soil has been freshly exposed or deposited. In certain localities, again, dense crops of blue pine spring up on new deposits of shingle and boulders in river-beds. Micaceous loamy soil resulting from the decomposition of mica schist is particularly favourable, since it is porous, while at the same time it retains moisture. Dry, shallow, or stiff soil is unsuitable for blue pine reproduction, which fails on hot aspects where there is a mass of hard rock near the surface ; this is particularly

noticeable on limestone formations, on which the seedlings die of drought where the soil is shallow. Water-logged or very wet soil is equally unfavourable.

As regards soil-covering, the blue pine has a remarkable capacity for making its way through a growth of shrubs and even through fairly heavy weed-growth, and on hot aspects shrubby growth is most beneficial in protecting the soil from desiccation. Some plants are particularly favourable in this respect, and it cannot fail to be noticed that even on the hottest slopes, where there is a growth of bracken and *Indigofera*, the reproduction of blue pine on areas protected from fire and grazing is a foregone conclusion wherever there are seed-bearers present. *Desmodium* and *Spiraea sorbifolia* are also very favourable shrubs, as is the dwarf willow, *Salix elegans*. Among unfavourable shrubs perhaps the most typical are *Viburnum foetens* and *Parrotia Jacquemontiana*, which often cover the ground over large areas with a growth so dense as entirely to prevent natural reproduction of the pine ; these weeds are particularly abundant in Hazara. Fig. 409 shows a dense growth of *Parrotia* covering a hill-side, on which pine reproduction is unable to establish itself although seed-bearers are plentiful. A dense matted growth of grass is unfavourable in preventing the roots of the pine seedlings from penetrating to the mineral soil before the young plants perish from drought ; a moderate soil-covering of grass, however, is not unfavourable.

(5) *Light.* As already mentioned, the blue pine from the earliest stage is a strong light-demander, for although it is capable of persisting under moderate shade, particularly of broad-leaved species, its growth is always more vigorous with complete light. On hot aspects it is only the need for protection against desiccation that may render a protective cover of shrubs or trees advisable and even essential, but such cover should not be retained longer than is necessary. The profusion with which blue pine reproduction sometimes springs up in severely lopped oak forest is evidence of the beneficial effect of the admission of light following on the protection of the seedling in its early stages. Even in unlopped oak forest the blue pine often regenerates in quantity and succeeds in making its way through a moderately light canopy, but nevertheless its growth suffers until it has penetrated the canopy, and many plants may become entirely suppressed.

The most vigorous blue pine reproduction is always found completely in the open, granted that during the first few years protective cover may be necessary on hot aspects, particularly if the soil is dry or shallow. On bare, grassy hill-sides natural reproduction is as a rule better on northerly than on southerly aspects, but where there is a protective growth of bracken, *Indigofera*, *Desmodium*, and other favourable shrubs the pine has no difficulty in regenerating with the greatest freedom on the latter.

(6) *Fire.* Fire is probably the most adverse of all factors relating to natural reproduction, for blue pine seedlings are extremely sensitive to it, and in areas annually or periodically burnt reproduction has no chance of establishing itself. Bare hill-sides suitable for blue pine, if carefully protected from fire, fill up with young pine crops in a surprising manner where there are any seed-bearers in the neighbourhood ; some of the best even-aged pole crops existing at the present day are the result of the introduction of fire-protection on bare or sparsely tree-covered hill-sides forty to fifty years ago.

FIG. 408. Pure forest of *Pinus excelsa* sprung up on old cultivated land as a result of the introduction of fire protection 40 years previously, Jaunsar.

FIG. 409. *Pinus excelsa* with a dense undergrowth of *Parrotia Jacquemontiana*, which prevents natural reproduction of the pine, Kagan valley, Hazara.

FIG. 410. Young crop of *Pinus excelsa*, up to 25 ft. in height, sprung up in a blank caused by the destruction of the overwood by a severe fire more than 20 years previously, Bashahr.

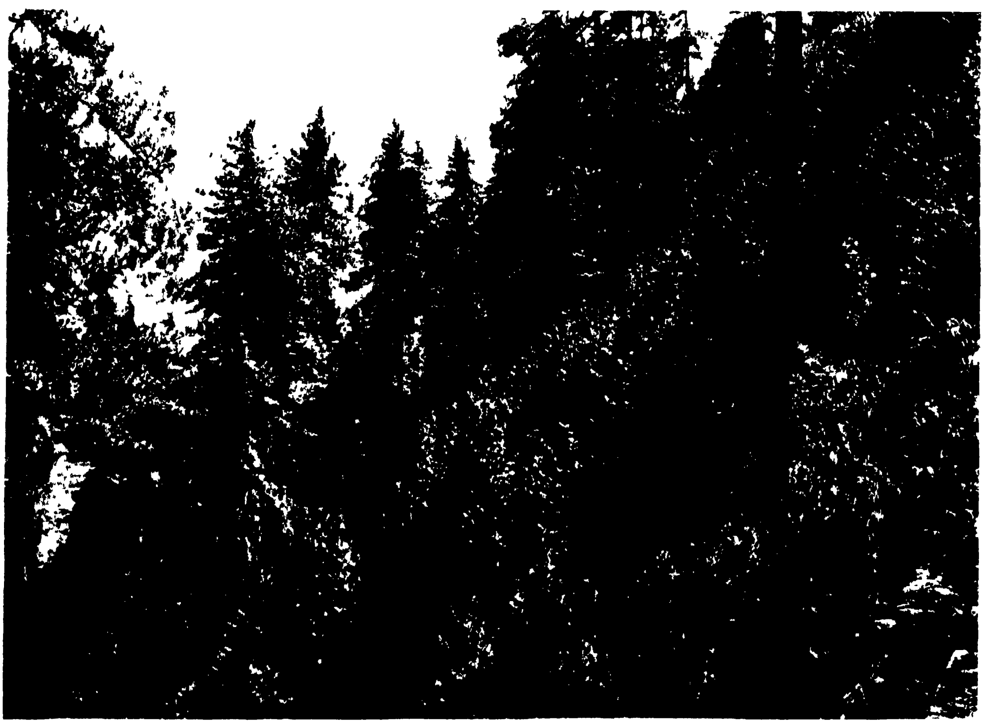


FIG. 411. Natural reproduction of *Pinus excelsa*, with some deodar, produced by an even spacing of seed-bearers to 5 or 6 trees per acre ; aspect south-west, elevation 7,500 ft., Bashahr.

One result of fire-protection is to cause the blue pine to spread downhill into the region of *Pinus longifolia* where the zones of the two pines meet, and it is not an uncommon sight in such localities to find an open overwood of *Pinus longifolia* with a young crop beneath it consisting largely of blue pine and deodar (see Fig. 450).

Although fire destroys blue pine seedlings and prevents natural reproduction, nevertheless the thorough burning of an area is often followed by profuse reproduction, owing to the action of fire in clearing the ground and producing a favourable germinating bed. Fig. 410 shows a dense natural young crop which sprang up after an intense fire ; this fire occurred more than twenty years previously, destroying much of the overwood, and the charred remains of some of the overwood trees are still visible, standing over the young crop. The burning of undergrowth and felling refuse, as will be seen later, is an important regenerative measure.

(7) *Grazing*. There are few, if any, Himalayan conifers which suffer more from grazing than the blue pine. Light cattle grazing, as opposed to goat browsing, may be comparatively harmless if there is a plentiful supply of other fodder present, but as a general rule it is a safe procedure to enforce strict closure to grazing of any kind if complete reproduction is desired in the shortest time possible. Natural reproduction is often found in grazed areas, but here young seedlings are usually absent except under the shelter of shrubs, and as soon as they grow large enough to come within the reach of animals they are browsed down. The young plants stand repeated browsing for many years, but acquire a low bushy form ; eventually a leader may survive and a normal plant arises from the centre of the bushy growth, the result being a tree much branched at the base.

Pine crops thus arise on grazed areas, and at first sight they may appear satisfactory, but a closer examination usually shows that the stems, instead of forming a close crop, are widely spaced and are much branched towards the base ; if these stems are felled at ground-level it will be found from an examination of the annual rings in the centre that the plants have had a long struggle in youth, and for years have put on little or no growth.

Where young spruce and blue pine spring up together in grazed areas the spruce often survives at the expense of the pine, the latter being browsed down, while the spruce establishes itself and eventually suppresses and kills out the pine.

Artificial reproduction. Direct sowing is usually considered preferable to transplanting from the nursery, as the latter requires great care in order to avoid damage to the tender rootlets, and where planting operations on a large scale are to be carried out the amount of close supervision necessary to ensure success is not always available. Successful transplanting, however, can be carried out if sufficient care is taken to plant only in wet weather and to avoid damaging the roots in any way. Nursery soil should be light and not binding, and should not be manured. The seed-beds are sown in November and protected from pheasants, and germination takes place at the commencement of the following rainy season. The usual custom is to transplant seedlings either two or three years old during the rainy season. They are pricked out about 9 in. by 6 in. during the rains a year after germination, and if plants three years old are required they are again pricked out about 15 in. by 12 in. when two years old. They are finally planted out with balls of earth. The spacing most commonly adopted has been 5 ft. by 5 ft., or 4 ft. apart in contour lines 8 ft. to 10 ft. apart.

Direct sowing is much more usual than transplanting, and is, as already remarked, usually more successful. For sowing up abandoned fields and open places of the kind broadcast sowing is suitable. Sowing in prepared contour lines, broken or continuous, or in prepared patches, can be carried out with great success. The general lines on which this work is done are similar to those described for the deodar (see p. 1117). The quantity of seed, by weight, required to sow up a given area with blue pine is about half that required in the case of the deodar. In Kulu gaps on which undergrowth and felling refuse have been collected and burnt have been successfully sown up in the manner described for deodar. The early thinning out of excess plants in sowings is a very necessary operation ; it is usual to dig up such plants when one to two years old and use them for planting up gaps.

Blue pine seed may be sown at any time from November to early June. Where pheasants are at all plentiful it is preferable to sow in May or early June, in order to avoid exposing the seed to their attacks during the winter ; in this case soaking the seed in water for twenty-four hours is said to stimulate germination.

On favourable soil and on cool aspects blue pine sowings succeed well entirely in the open, but on hot aspects and shallow soil it is preferable, and may be necessary, to sow in the shade of bushes. Failing such natural protection artificial shades consisting of bundles of grass supported on rough tripods of sticks or pieces of ringal bamboo have been found effective.

The readiness with which blue pine springs up in the open has at times been made the plea for sowing it on bare hill-sides with shallow soil overlying hard rock such as limestone ; such efforts are foredoomed to failure, for the pine will not survive in such localities. Sowings have been made from time to time with the view of filling up blank grassy areas of this kind on hill-sides where seed-bearers are plentiful in the neighbourhood and where natural reproduction has sprung up wherever possible ; such sowings, as might be expected, have always resulted in failure, for if there are seed-bearers present, natural reproduction hardly ever fails to establish itself wherever conditions for its establishment are favourable, and blank areas in such places indicate unfavourable conditions which will similarly prevent success resulting from sowings.

Silvicultural treatment. The treatment of the blue pine may be considered under two heads : (1) regeneration, (2) tending.

(1) *Regeneration.* The main factors affecting the natural reproduction of the blue pine have already been dealt with. In practice, given abundance of light and protection from fire and grazing, wherever conditions for natural reproduction are favourable, the blue pine is one of the easiest of all species to regenerate. The careful selection of seed-bearers, although important, is of less consequence than in the case of *Pinus longifolia*, in which they should be chosen as far as possible from among trees with umbrella-shaped or large round crowns. The blue pine does not produce an umbrella-shaped crown,

and seeds freely from a comparatively early age. Except on hot dry slopes with shallow soil a wide spacing of seed-bearers will effect completer regeneration than in the case of the deodar, and a spacing which may be open enough for deodar may not be open enough for blue pine. As regards the method of spacing seed-bearers, experience so far has shown that the best results have been attained by an even spacing of single trees, and not by creating large gaps leaving intervening belts of forest untouched, as in the group system, for the latter method, besides being more complicated, often results in a strong growth of weeds and coarse grass in the gaps. The aim should be to produce even-aged crops, for which the blue pine is admirably adapted.

The actual spacing of seed-bearers must vary with aspect and other local conditions. As explained in the case of the deodar (p. 1121), excellent young crops of that species mixed with blue pine have been produced with a spacing of from five or six to twenty seed-bearers per acre. The former spacing, however, is ordinarily too dense for the blue pine alone. In Kulu good results have been obtained with a spacing of 60 or 70 ft., representing nine to twelve trees per acre, and generally speaking about ten seed-bearers per acre is perhaps the most suitable number to retain under ordinary conditions, though on hot slopes the number might be increased to twenty. Better results could not be wished than those shown in Fig. 411, representing blue pine forest in Bashahr with an even spacing of seed-bearers to about five trees per acre. The good reproduction shown in Fig. 412 was secured with an average spacing of about 40 ft., giving twenty-seven trees to the acre, but the overwood should have been removed some years previously, as the young crop was showing signs of suppression. The overwood should never be retained over the young crop longer than is absolutely necessary, since the latter does not require protection from the sun after the first two or three years, and grows best completely in the open. The effect on reproducion of even a moderate opening of the canopy in a comparatively young crop is illustrated by a case at Koti Kanasar in Jaunsar. A sample plot consisting of a dense even-aged crop of blue pine thirty-eight years old, averaging 2 ft. 1 in. in girth, was laid out in 1911 and thinned to 456 stems per acre. During the following winter severe snow damage opened the canopy farther. When the plot was laid out seedlings were entirely absent, but when it was again visited in 1916 the ground was covered with natural seedlings averaging 8 in. in height, particularly in gaps caused by snow-break. Probably this reproduction would not survive long without a farther opening of the canopy, but this instance demonstrates the fact that natural reproduction is capable of appearing with only a moderate opening, and in comparatively young crops.

Where deodar and blue pine are to be regenerated in mixture, a convenient method is to open the canopy moderately at first, thus securing a certain amount of deodar reproduction, and then opening out drastically with the object of filling the gaps in the young deodar crop with blue pine.

Blue pine reproduction can often be secured without difficulty by merely opening out the canopy in the manner just indicated. Where there is a heavy growth of undesirable weeds or a mass of felling refuse littering the ground, it is necessary to cut and burn the weeds and to collect and burn the felling refuse. The details of this operation are as described for the deodar (p. 1122).

In making seeding fellings the retention of badly suppressed advance growth is useless, as such growth will not respond to the opening; vigorous groups of advance growth, however, may be retained.

Where pure blue pine crops are concerned a fairly short regeneration period should ordinarily suffice. For the Hazara blue pine forests a period of twenty years is to be adopted, though experience alone will show whether or not this will be suitable. Where blue pine and deodar are mixed a longer period is usually necessary. In the Kulu and Hazara forests where these two species are mixed, a period of thirty years is provided for; under favourable conditions, however, a period of twenty-five years would probably be found sufficient.

(2) *Tending*. Weeding in young blue pine crops is not always necessary. Where there is a growth of favourable shrubs such as *Indigofera* and *Desmodium*, or of bracken, the young pine crop makes its way through them without difficulty; where there is a dense growth of troublesome weeds such as *Viburnum foetens*, *Parrotia*, and others, however, regular weeding is necessary until the young crop is free from suppression. Thinnings present some difficulty. Even in very dense crops there is a great tendency for numerous side branches to persist. Yet if these crops are kept unthinned for any length of time and are then suddenly thinned when they have reached the pole stage, severe damage from snow-break is almost certain to occur. Thinnings should be commenced early, carried out lightly, and repeated at fairly frequent intervals, that is, not more than ten years, in order to minimize the damage from snow; in many cases thinnings from pole crops will often consist largely of the removal of snow-broken stems. Where there is any risk of fire the removal of dead and suppressed stems in sapling and pole crops, in order to prevent fire from ascending to the crowns of the trees, is of importance. Some years before the crop reaches maturity it is advisable to thin it fairly heavily in order to produce increment and to induce crown development for the production of seed. Fig. 400 shows a blue pine crop of good quality which has been finally thinned in this way.

The tending of mixed blue pine and deodar crops is a question of importance. The timber of the deodar being of more value than that of the pine, the latter has in the past been too often regarded as nothing more than the nurse of the deodar, to be cut out at all costs in order to favour it. Recently a more rational view has been taken of the respective merits of the two trees: blue pine timber has risen considerably in value, the growth of the pine is usually more rapid than that of the deodar, and its value will be further enhanced in the event of resin-tapping operations being carried out systematically. The cutting out of blue pine in deodar areas, therefore, is now carried out more cautiously than it was at one time, and the removal of large well-grown pine trees in order to favour small and possibly branchy deodar is no longer considered to be sound policy. It has often been the custom during cleaning operations in favour of the deodar to lop or girdle the pine instead of felling it. This exposes the pine to the risk of infection by *Trametes Pini*, and cannot be recommended.

STATISTICAL. (1) *Bark thickness.* The following figures, based on numerous measurements, may be taken approximately to represent the average bark thickness for trees of different girths :

Girth.	Bark thickness.
Under 2 ft.	0·5 in.
2 ft.–2 ft. 11 in.	0·6 in.
3 ft.–3 ft. 11 in.	0·7 in.
4 ft.–4 ft. 11 in.	0·8 in.
5 ft.–5 ft. 11 in.	0·9 in.
6 ft.–6 ft. 11 in.	1·0 in.
7 ft. and over	1·1 in.

(2) *Growth in youth.* Measurements made at different times in fifteen young plantations in Jaunsar showed the following mean growth in girth and height :

Pinus excelsa : growth in young plantations, Jaunsar.

Age. years. (from seed)	Mean girth. in.	Mean height. ft.
4	..	1·8
6	3·2	2·7
8	5·5	5·2
10	8·2	8·5
12	11·4	12·5

Under specially favourable conditions the growth in youth is much more rapid than this. Three plants in an old nursery at Koti Kanasar in Jaunsar were measured in 1887, when eleven years old from seed, and showed heights of 18 ft., 19 ft., and 28 ft.[1] As mentioned above, natural seedlings may be expected to reach a height of only about 5 to 8 in. in four years.

(3) *Girth and height increment.* After the young plant has established itself and normal increment begins, the rate of growth under favourable conditions is rapid until the tree approaches maturity, when the growth in girth usually becomes slower, while height-growth may almost cease. The blue pine is not a long-lived tree, reaching its physical maturity as a rule at 120 to 180 years, after which it often becomes unsound in the centre ; at the higher elevations and in dry climates, however, it may maintain its soundness longer, although the growth is slow. In the first half of its life the blue pine easily outstrips the deodar both in girth and in height, and vigorous young poles may exhibit an annual height-growth, judged by the length of the internodes, of as much as 3 ft., and an annual girth increment of nearly 2 in.

The table below summarizes the information available regarding the rate of growth of the blue pine in girth and height. In working plans the information is recorded in various ways, but for purposes of comparison all figures in the statement have been reduced to girth measurements over bark, while no allowance has been made for the time required for a seedling to establish itself ; hence in applying these figures in practice about five to ten years should be added to the age in order to allow for the establishment of the seedling.

[1] Notes on Forest Operations, Jaunsar, A. F. Broun, 1887.

Pinus excelsa : rate of growth in girth and height.

Age.	Mean girth.																	Mean height.		
	Hazara.	Rawalpindi.	Chamba.					Kulu.[6]				Bashahr.[7]	Simla hills.		Jaunsar.		Kashmir.	Chamba.	Jaunsar.	
	Dungagali and Thandiani.[1]	Murree hills.[2]	Pangi.[3]	Pangi block.[4]	Margaon block (towards upper limit).[4]	Upper Ravi.[5]	Four Research Institute sample plots in dense even-aged crops at 8,500–10,300 ft.	Inner Saraj.	Outer Saraj.	Kulu.	Rupi.		Jubal state.[8]	Kotkhai and Kotguru.[9]	Working plan figures.[10]	Six Research Institute sample plots in dense even-aged crops.	Batot range.[11]	Four Research Institute sample plots in dense even-aged crops at 8,500 to 10,300 ft.	Working plan figures.[10]	Six Research Institute sample plots in dense even-aged crops.
yrs.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft.	ft.	ft.
20	1 11	..	1 6	1 2	0 7	1 10	..	1 3	2 2	2 1	2 6	..	2 6	2 1	1 8	1 2	1 6	..	14	30
30	2 10	..	2 2	1 9	0 11	3 2	..	2 6	3 2	3 2	3 8	..	3 7	3 1	2 6	1 10	2 4	..	30	45
40	3 9	..	2 11	2 4	1 4	4 3	..	3 6	4 3	4 3	4 10	3 10	4 6	4 1	3 4	2 5	3 2	45	43	73
50	4 7		3 8	3 0	1 9	5 2	1 4	4 6	5 5	5 4	5 11	4 9	5 3	5 0	4 2	3 0	4 0	54	56	..
60	5 5	3 6	4 4	3 8	2 2	5 11	1 10	5 6	6 7	6 5	6 11	5 7	5 11	5 11	4 11	..	4 9	62	68	..
70	6 3	4 7	5 0	4 3	2 8	6 7	2 4	6 5	7 9	7 7	7 10	6 4	6 7	6 10	5 7	..	5 6	69	80	..
80	7 1	5 6	5 7	4 9	3 2	7 3	2 11	7 3	8 11	8 9	8 8	7 0	7 3	7 9	6 2	..	6 1	76	91	..
90	7 11	6 5	6 2	5 3	3 8	7 10	3 6	7 11	..	..	..	7 8	7 10	..	6 9	..	6 8	..	101	..
100	8 9	7 2	6 9	5 9	4 1	8 5	..	8 2	..	..	..	8 3	8 5	..	7 4	..	7 3	..	111	..
110	9 6	7 9	7 4	6 3	4 6	..	..	..	..	..	..	..	9 0	..	7 11	..	7 10	..	121	..
120	10 2	8 4	7 11	6 8	4 10	..	..	..	..	..	..	..	9 7	..	8 5	..	8 4	..	129	..
130	..	..	8 6	7 1	5 2	..	..	..	..	..	..	..	10 2	..	..	..	8 10	..	..	..
140	..	..	9 1	7 5	5 6	..	..	..	..	..	..	..	10 7	..	..	..	9 4	..	..	..
150	..	..	9 8	7 9	5 10	..	..	..	..	..	..	..	11 0	..	..	..	9 9	..	..	..
160	..	..	..	8 1	6 2	..	..	..	..	..	..	..	..	..	..	..	10 2	..	..	..
170	..	..	..	8 5	..	..	..	..	..	..	..	..	..	..	..	..	10 6	..	..	..
180	..	..	..	8 8	..	..	..	..	..	..	..	..	..	..	..	..	10 10	..	..	..
190	..	..	..	8 11	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
200	..	..	..	9 2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

[1] Working Plan for the Dungagali and Thandiani Ranges, Hazara, A. V. Monro, 1908 (92 trees).
[2] Revised Working Plan for the Forests of the Murree and Kahuta Ranges, Rawalpindi Division, M. R. K. Jerram 1915 (17 trees).
[3] Revised Working Plan for the Leased Forests in Pangi, Chamba State, J. H. Lace, 1901 (14 trees).
[4] Revised Felling Statement under the Revised Working Plan for the Pangi Forests, J. Copeland, 1917.
[5] Working Plan for the Forests of the Upper Ravi, Chamba State, C. G. Trevor, 1910 (43 trees).
[6] Working Plan for the Kulu Forests, C. P. Fisher, 1898 (160 trees).
[7] Revised Working Plan for the Bashahr Leased Sutlej Valley Forests, G. S. Hart and A. J. Gibson, 1905 (50 trees).
[8] Working Plan for the Reserved Forests of the Jubal State, E. M. Coventry, 1904.
[9] Revised Working Plan for the Kotkhai and Kotguru Ilaquas, E. M. Coventry, 1903 (24 trees).
[10] Working Plan for the Jaunsar Bawar Forests, P. H. Clutterbuck, 1902.
[11] Working Plan for the Batot Range Forests, Riasi Division, Kashmir, Hans Raj, 1917.

Ring-countings on 49 stumps in the forests of the Kishanganga valley, Kashmir, gave an average of 9·1 rings per inch of radius, representing a mean annual girth increment of about 0·7 in.[1] In the Tehri Garhwal leased forests it is estimated that a girth of 6 ft. is attained in ninety-one years, which gives a mean annual girth increment of 0·79 in.[2]

(4) *Out-turn.* Figures of out-turn are at present somewhat fragmentary. Systematic measurements of sample plots in blue pine crops have been carried out for some years by the Forest Research Institute, but the results are not yet complete enough to form the basis of classification into quality classes or to enable representative yield tables to be compiled. Some out-turn figures recorded in working plans and elsewhere may be quoted here.

In the Kulu working plan of 1898 the average out-turn per tree of serviceable timber in the round, including bark, based on the results of measurements of nearly 400 trees, is given as follows :

Girth at 4½ ft. from ground, 6–6½ ft. ; volume, 65 cubic ft.
Girth at 4½ ft. from ground, 6½–7½ ft. ; volume, 89 cubic ft.
Girth at 4½ ft. from ground, 7½–8½ ft. ; volume 112 cubic ft.

Mr. C. G. Trevor has prepared the following yield table from more recent measurements in Kulu :

Pinus excelsa : yield table, Kulu.

			Volume.							
			Local quality I.		Local quality II.		Local quality III.		Average.	
Diameter at 4½ ft.	Age.	Mean annual increment of sawn scantling.	Logs.	Scantlings.	Logs.	Scantlings.	Logs.	Scantlings.	Logs.	Scantlings.
in.	years.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.
12	42	0·24	26	13	20	10	15	7	20	10
13	45	0·27	31	15	24	12	18	8	24	12
14	49	0·29	37	18	28	14	21	9	28	14
15	52	0·30	43	21	32	16	24	11	32	16
16	55	0·33	50	24	38	18	28	13	38	18
17	60	0·35	58	28	44	21	33	15	44	21
18	63	0·38	66	33	51	24	38	17	51	24
19	65	0·41	76	38	59	27	44	19	59	27
20	72	0·43	86	43	68	31	50	22	68	31
21	77	0·45	100	48	74	35	56	25	74	35
22	81	0·49	114	54	82	40	63	28	82	40
23	87	0·51	126	61	93	45	70	31	93	45
24	91	0·54	140	68	103	50	78	35	103	50
25	97	0·57	158	75	114	55	83	39	114	55
26	103	0·58	170	82	123	60	90	43	123	60
27	109	0·59	183	89	133	65	97	47	133	65
28	115	0·61	191	96	142	71	104	51	142	71
29	121	0·63	200	102	150	77	111	55	150	77
30	129	0·64	207	109	160	83	119	60	160	83
31	137	0·65	215	115	168	89	127	65	168	89
32	145	0·65	223	120	178	94	134	70	178	94
33	155	0·64	229	126	185	99	142	75	185	99
34	..	..	234	131	193	104	150	80	193	104
35			238	136	202	109	159	85	202	109
36			243	141	208	114	168	90	208	114
37			248	145	214	118	177	93	214	118
38			253	149	220	122	186	96	220	122
39 and over			258	153	226	126	192	100	226	126

[1] Working Plan for the Karnah-Drawa Forests, Kishanganga Valley, Kashmir, Rai Keshavanand Bahadur.

[2] Working Plan for the Leased Deodar Forests, Tehri Garhwal, J. C. Tulloch, 1907.

The following out-turn figures are recorded in the working plan of 1901 for the Pangi forests, Chamba :

Pinus excelsa : out-turn statistics, Pangi forests, Chamba, 1901.

Number of trees.	Forest.	Mean diameter at 4½ ft.	Average length of useful bole.	Average out-turn per tree. Gross contents.	Logs.
		in.	ft.	cub. ft.	cub. ft.
100	Luj	32·2	39	177	135
100	Urnu	31·9	54	227	175
100	Pontu	32·9	52	379	236
120	Moji	31	41	164	148
380	Saichu	28	37·6	160	134

The following table of out-turn has been prepared from measurements recorded in the revised felling statement of 1917 for the same forests :

Pinus excelsa : out-turn statistics, Pangi forests, Chamba, 1917.

Diameter.	Corresponding girth.	Average out-turn. Logs.	Scantlings.	Diameter.	Corresponding girth.	Average out-turn. Logs.	Scantlings.
in.	ft. in.	cub. ft.	cub. ft.	in.	ft. in.	cub. ft.	cub. ft.
18	4 9	48	..	32	8 5	200	110
20	5 3	58	..	34	8 11	225	123
22	5 9	75	..	36	9 5	250	136
24	6 3	98	50	38	9 11	270	149
26	6 9	123	65	40	10 6	290	160
28	7 4	150	80	42	11 0	305	170
30	7 10	175	95	..	..	..	..

In the Bashahr working plan of 1905, as a result of measurements of 1,351 trees of various exploitable sizes, the average gross volume per tree was found to be 114·1 cubic ft., giving an average volume in scantlings of 55·9 cubic ft., which represents a loss in conversion of 51 per cent.

The Kotkhai and Kotguru working plan of 1903 contains the following outturn figures :

Girth (feet)	¾–1½,	1½–2¼,	2¼–3,	3–3¾,	3¾–4½,	4½–5¼
Solid contents, including branchwood (cub. ft.)	2	8	16	27	41	60

2. **Pinus longifolia,** Roxb. Long-leaved pine, chir pine. Vern. *Chir*, Hind. ; *Chil*, Pb. ; *Shti*, Sutlej ; *Sarol, sirli*, Jaunsar ; *Dhúp*, Nep.

A more detailed account of this tree will be found in my note on *Pinus longifolia*, *Indian Forest Memoirs*, Silv. series, vol. i, pt. 1, 1916.

A large evergreen tree, sometimes nearly deciduous in dry localities and seasons. Branches up to middle age whorled, with verticils scarcely so well defined as those of *P. excelsa.* Crown up to middle age elongated and more or less pyramidal, afterwards becoming spreading, rounded, or umbrella-shaped, with a massive branch-system. Primordial needles solitary, 0·6 in. (in young seedlings) to 2·5 in. long, acicular, obscurely triquetrous, pale, glaucous green, sharply serrulate, minutely punctate in longitudinal lines of stomata. Adult needles in fascicles of 3, 8–13 in. long, triquetrous, with one rounded and two flat sides, light green, not glaucous, minutely but closely serrulate, densely punctate in several longitudinal lines of stomata ; basal

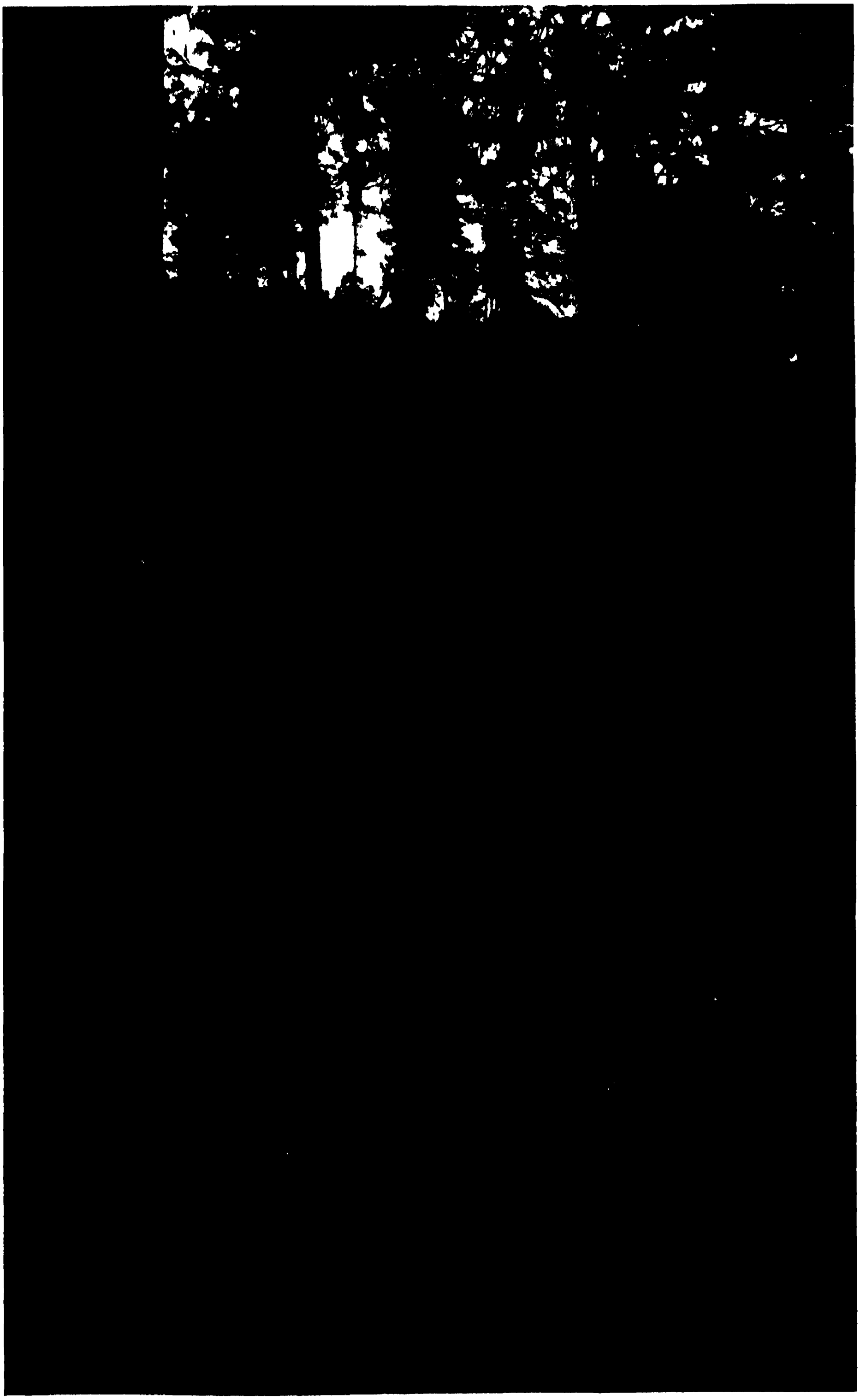


Fig. 412. Uniform regeneration felling in forest of *Pinus excelsa*, with seed-bearers spaced to an average of 40 ft., and young crop 10–20 ft. high; overwood should have been removed some years previously, Bashahr.

FIG. 413. *Pinus longifolia* forest on gneiss, Siran range, Hazara, showing effect of light in stimulating natural reproduction; heavily opened out on left, resulting in plentiful reproduction; insufficiently opened out at top of slope on right, resulting in absence of reproduction.

FIG. 414. Open forest of *Pinus longifolia* on gneiss with very shallow soil; maximum height of trees 20 ft., Kangra valley, Punjab.

sheath persistent, 0·6–1 in. long, of 10–15 imbricate chartaceous acuminate fimbriate scales, at first white or light brown, later turning grey. Needles long on vigorous trees, short in poor localities, at high elevations and on over-mature or sickly trees.

Bark of poles and immature trees dark grey, deeply fissured, exfoliating in rough longitudinally elongated plates, that of older trees with large plates up to 2 ft. or more in length by 9 in. in breadth, red turning light grey on the surface with exposure. Bark thickness varies from 0·4 in. in young saplings to an average of about 2 in. in mature trees, though not infrequently reaching 3 in. on the lower part of the stem. Detailed measurements of bark thickness are given on p. 1079. Sap-wood white. Heart-wood light reddish-brown, moderately hard, somewhat coarser than that of *P. excelsa*, with conspicuous resin-ducts, much used for building, common furniture, boxes, and general carpentry. This is the principal resin-producing pine of India. The resin is slightly inferior in quality to that of *P. excelsa*, *P. Khasya*, and *P. Merkusii*, but owing to the accessibility of the chir forests this pine is at present the only species systematically tapped. The pine-resin industry in the Punjab and the United Provinces is now in a flourishing condition, and its importance must increase considerably in future as tapping operations are extended.

Under favourable conditions the chir pine attains large dimensions and forms a straight cylindrical bole. Perhaps the largest trees to be found anywhere are those in the Tons valley of Jaunsar and Tehri Garhwal, where the following measurements have been recorded :

(1) Height 180 ft., girth at breast-height 10 ft. (W. R. Fisher, 1887).
(2) „ 178 „ „ 11 ft. 3 in. (W. R. Fisher, 1885).
(3) „ 175 „ „ 7 ft. 4 in. (F. Gleadow, 1899).
(4) „ 174 „ „ 8 ft. 2 in. (A. F. Broun, 1886).
(5) „ 170 „ „ 10 ft. 6 in. (W. R. Fisher, 1885).

In this locality trees up to 150 ft. in height are by no means uncommon, while trees are to be found with girths up to 12 ft., and exceptionally up to 14 ft. Large-sized trees are met with in the forests of the Siran valley of Hazara, where Mr. A. V. Monro in the working plan for these forests records the following two measurements :

(1) Height 151 ft., girth at breast-height 7 ft. ; volume 236 cub. ft. ; age 118 years.
(2) „ 149 „ „ 7 ft. 6 in. ; volume 254 cub. ft. ; age 105 years.

In the Rawalpindi forests Mr. Jerram mentions having measured a tree 145 ft. in height and 8½ ft. in girth, which is quite exceptional for that locality. Mr. C. M. McCrie in 1910 measured trees up to 115 ft. in height and 12 ft. in girth in the Binsar forest, Kumaun.

On shallow soil, exposed ridges and other unfavourable situations, the trees are stunted, with tapering and often twisted or gnarled boles, and may attain a maximum height of not more than 20 to 30 ft.

Distribution and habitat. *General distribution and types of forest.* The chir pine is found in the outer ranges and principal valleys of the Himalaya and on the ridges of the Siwalik hills flanking the Himalaya, from 1,500 to 7,500 ft. and occasionally higher, from Bhutan in the east to Afghanistan in the west. Excluding Sikkim, Bhutan, Nepal, Mandi, the frontier states and Afghanistan, this pine is roughly estimated to extend over about 3,370 square miles of country and to occur more or less gregariously over about 3,230 square miles ; the total area of chir forest, including the territories mentioned, must be considerably greater. Owing to their accessibility, however, large areas of chir forest have been destroyed in the past by cutting, lopping, and burning, and many of the existing grass-covered slopes of the outer Himalaya must have been covered at one time with pine forests.

The chir pine is a typically gregarious tree, forming pure forests of considerable extent, though it often occurs mixed with other species, particularly at its upper and lower limits. Towards its upper limits its common companions are *Cedrus Deodara, Pinus excelsa, Quercus incana, Rhododendron arboreum, Pieris ovalifolia, Myrica Nagi*, and various other trees ; at the higher elevations *Pinus longifolia* seeks the hotter slopes and drier spurs, on which it ascends higher than it does on cool northerly slopes, and the moister depressions and cooler slopes are occupied by its associate species, particularly oak, blue pine, or deodar. The oak mixture, shown in Fig. 340, is a useful one, as the oak, often in the form of an underwood, acts as an efficient soil-protector. Towards its lower limit the chir pine is associated with low-level species such as *Shorea robusta, Anogeissus latifolia, Ougeinia dalbergioides, Buchanania latifolia, Bauhinia retusa, B. variegata*, and others. The true chir belt, in which the pine occurs pure or nearly so over considerable areas, is found between the upper and lower mixed belts, its limit of elevation varying with locality and aspect. Apart from its gregariousness, the pine has a marked tendency to form even-aged crops of varying extent from small patches to extensive stretches ; this is due partly to the freedom with which it regenerates where conditions are favourable, particularly in open places, and partly to its light-demanding character, which prevents it normally from forming uneven-aged crops.

The undergrowth in *Pinus longifolia* forests varies locally. In many localities, notably in the forests of the Tons valley, there is a luxuriant growth of grass. In some of the Punjab forests at the lower elevations there is often a dense undergrowth of *Carissa spinarum* and *Dodonaea viscosa*, which gives place higher up to *Myrsine africana* and *Berberis Lycium*. In many chir forests, at elevations of 4,000 ft. and over, the undergrowth consists of a shrubby growth of *Rhododendron arboreum* and *Pieris ovalifolia*. Among other undergrowth species may be mentioned *Colebrookia oppositifolia, Desmodium concinnum, Euphorbia Royleana* (dry open places at low elevations), *Ficus palmata, F. Roxburghii, Flacourtia Ramontchi* (low elevations), *Indigofera pulchella, Inula Cappa, Lespedeza* spp., *Lonicera quinquelocularis, Mimosa rubicaulis, Phoenix humilis, Prinsepia utilis, Pyrus Pashia, Randia tetrasperma, Rhus Cotinus, R. parviflora, R. semialata, Rosa moschata, Rubus ellipticus*, and *Woodfordia floribunda* (low elevations).

Local occurrence. In Hazara the most important chir forests occur in the Siran valley from 3,000 ft., the approximate level of the Pakhli plain, to about 6,000 ft. ; these forests extend to a small extent over the watershed into the Kunhar drainage. Here the pine grows excellently on granite and gneiss with a porous sandy and gravelly soil, the trees attaining large dimensions and natural reproduction springing up in abundance wherever sufficient light is admitted. The undergrowth consists chiefly of grass and *Indigofera*. The pine is for the most part pure, though in moist ravines broad-leaved species, including *Rhododendron arboreum*, are found ; above 5,500 ft. the chir is mixed with blue pine. Owing to past treatment under the selection system these forests consist not so much of large even-aged crops as of comparatively small even-aged patches of different ages, groups of young growth springing up readily wherever there are gaps in the canopy (see Fig. 413). In the Dungagali and Thandiani ranges of Hazara the chir occurs on limestone or shale on hot aspects up to 7,000 ft. ; in government forests it is very limited in quantity and is mixed chiefly with *Pinus excelsa*, while outside these forests the pine tracts have been largely cleared for grazing and cultivation. In the Khanpur range, on the outer hills of Hazara, the chir pine occurs from 2,500 ft. upwards on hard limestone with shallow soil. Here the trees as a general rule are stunted, with tapering and much-branched boles and poor height-growth, though a fair girth is reached, trees over 7 ft. in girth being not uncommon ; on northerly slopes with deep fertile soil the quality of the forest is very fair. Where there is sufficient depth of soil natural reproduction is often good, though it is poor where the rock is near the surface. The chief companions of the pine are *Pistacia integerrima*, *Olea cuspidata*, *Punica Granatum*, *Bauhinia variegata*, *Ficus palmata*, and *F. Roxburghii*, while on the cooler aspects and in moist ravines are found *Quercus incana*, *Q. glauca*, *Cornus macrophylla*, and other broad-leaved trees. Among the commoner undergrowth species are *Rhus Cotinus*, *R. punjabensis*, *Dodonaea viscosa*, *Myrsine africana*, *Rosa moschata*, *Woodfordia floribunda*, and *Indigofera*.

The *Pinus longifolia* forests of the Rawalpindi district, situated on the outer Murree and Kahuta hills from below 2,000 ft. to about 6,800 ft., are of much importance owing to their accessibility. At the lowest elevations the trees are somewhat scattered on sandstone hills in scrub forest of *Acacia modesta*, *Olea cuspidata*, *Flacourtia Ramontchi*, *Bauhinia variegata*, and other species. Pure chir forests commence at about 2,500 ft. and ascend to about 5,000 ft. on northern and 5,500 ft. on southern aspects ; above this the chir is mixed with *Pinus excelsa*, *Quercus incana*, and other species. The undergrowth, which is sometimes dense, consists chiefly of *Dodonaea viscosa* and *Carissa spinarum* at the lower elevations and *Myrsine africana* and *Berberis Lycium* higher up ; often there is little or no undergrowth. The underlying rock is tertiary sandstone with bands of clay ; the sandstone is easily disintegrated and much of the sand is washed away, leaving the more adhesive clay. The resulting soil, often containing as it does an excess of clay, is not altogether favourable for the growth of chir, and the general quality of the forest is therefore inferior to that of the Siran forests of Hazara. Nevertheless in favourable situations the trees attain very fair dimensions. Fig. 436 shows a crop of good quality approaching full height-growth. A portion of the area is occupied by open stunted forest of excessively poor quality growing on bare sandstone rocks on gentle slopes, where the pine is able to exist only by gaining a footing in occasional joints in the rock. In the Rawalpindi forests natural reproduction is somewhat uncertain owing partly to the difficulty of protecting the forests from fire, partly to excessive grazing, and partly to the exposure of the seedlings in certain places to a hot sun on a rather bare stiff soil.

In the lower parts of Kashmir proper there are a few square miles of chir forest in which the trees are of good quality, though the forests themselves have suffered from neglect. The area of chir forest in Jammu and Poonch is estimated to be slightly over 1,000 square miles. These forests are situated in the outer hills, descending to 2,000 ft. or even lower and ascending to about 6,000 ft.; below 3,000 ft. the trees are for the most part stunted and crooked. The general condition of the forests is poor; the best trees are found in the northern part of Riasi, but the stock is open and the forests are intersected by cultivation. Most of the Jammu forests have only recently been demarcated and brought under control; near water-ways and large areas of cultivation they have been overworked and subjected to indiscriminate burning, and are therefore not well stocked. In Poonch the condition of the forests is very similar, but they have been under fire-protection since about 1900, and regeneration is in most places satisfactory.

In the Kangra forest division chir forests are scattered over the outer Siwalik hills, in the Kangra valley and on the lower slopes of the main range forming the boundary with Chamba, at elevations of 1,800 to over 6,000 ft. The majority of the forests are pure, and are in the pole stage, the area of mature crops being comparatively small; the best crops are found in the Hamirpur range at an elevation of 2,600 to 3,500 ft. In a few places in the outer hills the pine is mixed with *Shorea robusta*, the latter being chiefly in the form of an underwood. In the Kangra valley at low elevations it is associated with various low-level species, such as *Dalbergia Sissoo, Acacia Catechu, Albizzia stipulata, Mallotus philippinensis, Anogeissus latifolia, Ehretia acuminata, Bauhinia variegata, Zizyphus Jujuba, Z. Xylopyrus*, and others, sometimes with an undergrowth of *Woodfordia floribunda, Dodonaea viscosa*, or *Carissa spinarum*. At about 4,300 ft. an undergrowth of *Rhododendron arboreum* and *Pieris ovalifolia* begins to appear. The upper limit of pure chir is about 5,500 ft. on southerly aspects and somewhat lower on northerly aspects; at the higher elevations the pine is mixed with *Quercus incana*. On low, hot hills in the Kangra valley, on rocky ground with shallow soil, a very poor open type of forest is met with, the trees being stunted, with a height scarcely exceeding 20 ft. (Fig. 414).

In Chamba *Pinus longifolia* occurs, usually pure, on the outer hills at 3,000 to 4,500 ft. in the south-west corner of the state adjoining the Kangra district, in the Dalhousie range chiefly at 4,000–5,000 ft., and in the lower valleys of the upper Ravi forests, where it is mixed with *Quercus incana*. The growth is slow and the trees do not reach large dimensions, while the forests are heavily grazed.

In Kulu *Pinus longifolia* forests occur in the outer Saraj, in the Sainj and Tirthan valleys, on both banks of the Parbatti up to Manikarn, and to a limited extent in the Hurla and lower Beas valleys. The forests are found at elevations of 3,500 ft. to nearly 7,000 ft. near Manikarn; elsewhere they seldom occur above 6,000 ft. They are for the most part pure and are usually somewhat open. In some localities, notably in the Tirthan and Parbatti valleys, the chir trees reach very fair dimensions. Where excessive grazing is not practised reproduction is generally good, but in many places it is kept down by grazing. In parts of the Rupi working circle the pine is associated with deodar, while in the Tirthan valley it is occasionally mixed with blue pine. Most of the chir forests are situated on quartzite, while in some cases the underlying rock is mica schist.

In the leased forests of Bashahr *Pinus longifolia* occurs at elevations of 4,000 to 6,500 ft. in the Nogli, Taranda, Pandrabis, and Pabar ranges; in certain localities the trees are found scattered up to about 7,800 ft. on hot aspects. The forests are situated for the most part on quartzite or mica schist, and are sometimes of very good quality, the trees attaining large dimensions. The forests are pure up to about 5,500 ft. on northerly and 6,000 ft. on southerly aspects, above which the chir is associated with blue pine, oak, and other broad-leaved species. Where fire-protection has been successful and grazing is not excessive, natural reproduction as a rule springs up in abundance.

In the Simla hills *Pinus longifolia* occurs in various localities at suitable elevations. In the Simla municipal forests it is found in crops which are for the most part pure at the lower elevations but somewhat irregular. The growth is usually inferior, owing largely to past maltreatment; reproduction is generally fairly good. At the upper elevations (about 6,000 ft. and over) the chir pine is mixed with blue pine, deodar, and oak. In Kotguru the pine grows on warm slopes up to 6,500 ft.; it is rare in Kotkhai. In the Jubal state it forms very open forests, intersected by cultivation, on steep slopes up to an elevation of 5,600 ft. These forests have been annually burnt in the past, and contain little except trees of the larger classes. Fire-protection has been introduced in the case of certain areas within recent years.

In the Mandi state many of the hills have been denuded of forests, but a fair extent of chir forest is still left, though much of it is very open, and many of the areas consist of scattered trees rather than forests. The chir forests extend up to about 6,000 ft. As a rule natural reproduction is poor, owing largely to excessive grazing, but there are certain areas where the grazing is limited, and here reproduction springs up in quantity. At the higher elevations and on cool aspects the pine is mixed with *Quercus incana* and locally with *Q. glauca*. The geology varies: the rocks consist chiefly of schist, shale, and quartzite, with occasional sandstone and conglomerate.

The Chakrata forest division comprises the forests of Jaunsar-Bawar and the leased forests of Tehri Garhwal state. The *Pinus longifolia* forests of this tract occupy considerable areas in the valley of the Tons river and its feeders, the chief of which are the Rupin and the Pabar, at elevations of 3,000 ft. and upwards. The forests are situated for the most part on steep mountain slopes rising many thousands of feet from the river valleys. The upper limit of gregarious chir forest may be placed generally at 6,500 ft., though the tree is found scattered on warm aspects up to 7,500 ft. or even higher. At the lower elevations the forests are usually pure, but as the elevation increases the pine becomes mixed with *Quercus incana*, the latter species at first occupying the moister ravines and the pine the intervening spurs. From about 5,000 ft. upwards the forest is usually a mixed one of chir pine, oak, *Rhododendron arboreum*, and *Pieris ovalifolia*. Near its upper limit the chir is frequently mixed with blue pine and deodar.

The quality of the forest varies, the trees being stunted on rocky ground and shallow soils, while in favourable localities they reach a size probably unequalled anywhere else. A considerable proportion of these forests consists of a rather open crop of mature or nearly mature trees; where fire-protection is enforced, however, there is little difficulty in obtaining natural reproduction if the crop is opened out sufficiently, and such measures have resulted in promising crops of young growth (see Fig. 430). A luxuriant growth of grass covers the ground in most of the chir forests of the Tons valley. Grazing is nowhere very heavy; near villages there is a certain amount of light grazing, particularly in Jaunsar proper, but in the leased Tehri Garhwal forests there is comparatively little.

Apart from the leased forests of the Tehri Garhwal state, which form part of the Chakrata division, this state is estimated to contain 368,000 acres of *Pinus longifolia* forest, situated in the valleys of the Tons, Jumna, Bhagirathi, Bhilangna, and Kaliganga. In the Tons valley the important chir forests are all leased to the British Government; these contain some timber crops of exceptionally fine quality, whose future maintenance and improvement is assured by systematic management. In the Jumna valley the forest has been largely denuded, and the chir forests are, with the exception of some at the top of the Kameldagadh, of very poor quality with but scanty reproduction. In the Bhagirathi valley there is some good chir forest on the left bank, but elsewhere the forest has been maltreated to a large extent, although reproduction is promising where steps are taken to save it. The Bhilangna valley, from about 30 miles below the glacier down to the mouth of the Balkhela river, contains some of the best chir forest in the state. In the Kaliganga basin there is some fairly good forest in the lower portion of the Lastargadh valley. The general condition of the unleased forests is, with a few exceptions, what might be expected in the case where fellings for the supply of timber to free-grantees have often been excessive, while fires have greatly increased the damage done. These conditions account for the fact that the majority of the forests are insufficiently stocked and are not so even aged as chir forest usually is. On the other hand, the pine is, if anything, tending to spread into the oak forests. The latter have been subjected to excessive maltreatment in the way of lopping and browsing, and are tending to disappear in many places; in such cases chir regeneration frequently appears on the ground, taking the place of the oak.

In the Dehra Dun neighbourhood *Pinus longifolia* forests occupy some of the outer ranges of the Himalaya overlooking the eastern Dun; most of these forests are in Tehri Garhwal state, the area in British territory being represented by less than 100 acres of forest in the Malkot hills, at an elevation of about 4,500 to 6,500 ft. In and around the station of Dehra Dun, the chir pine has been largely planted and thrives well; the elevation here is about 2,000 to 2,300 ft.

In the Saharanpur Siwaliks, a low range of hills formed of tertiary sandstone and conglomerate, and separated from the main Himalayan range by the Dehra Dun valley, chir pine is found scattered over the main ridges and spurs from the highest point (3,140 ft.) downwards, descending occasionally to the level of the main watercourses, where the elevation is about 1,500 ft. Large trees are found chiefly on the higher ridges, the lower slopes and spurs being occupied by saplings and poles, which have sprung up as a result of fire-

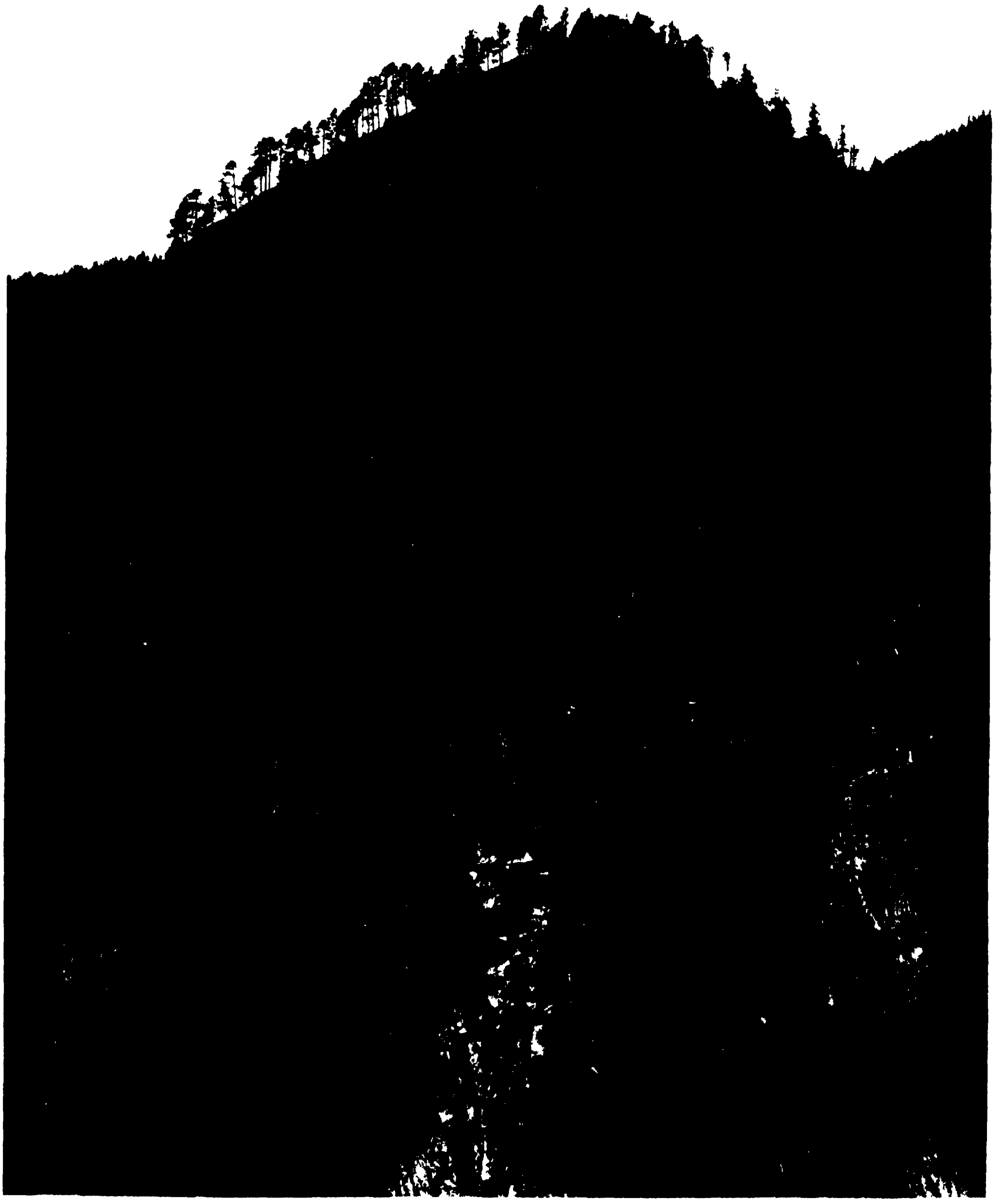


FIG. 415. *Pinus longifolia* forest on bare quartzite rocks, Tons valley, Chakrata division, United Provinces.

protection. In the Siwaliks the chir pine does not form extensive pure crops, but is found mixed with various broad-leaved species, of which the chief are *Anogeissus latifolia, Buchanania latifolia, Ougeinia dalbergioides, Shorea robusta, Stereospermum suaveolens, Terminalia tomentosa, Wendlandia exserta*, and the palm *Phoenix humilis*.

In the outer hills stretching from the Ganges to the Sarda, a distance of 150 miles, *Pinus longifolia* occurs in greater or less abundance on many of the ridges and spurs, descending into the valleys in some localities, notably in the Nandhaur and Sara valleys and the Chaukam Dun. Its lowest limit is about 1,500 ft. It is convenient to separate these forests of the outer hills from the main *Pinus longifolia* forests of the Garhwal and Kumaun hills, because the latter comprise the typically gregarious chir forests of the Himalaya, whereas in the outer hills, up to an elevation varying from 3,500 to 4,500 ft. and even higher, where pure chir forests commence, the pine is found either in pure patches of limited extent or mixed with various broad-leaved species, such as *Shorea robusta, Anogeissus latifolia, Terminalia tomentosa, Buchanania latifolia, Bauhinia retusa, Ougeinia dalbergioides, Engelhardtia Colebrookiana*, and others. Fire-protection has caused the pine to spread extensively.

In the great mass of the Garhwal and Kumaun Himalaya, in which the chir pine is pure or mixed with hill species—as distinct from the outer hills just referred to, in which it is more or less scattered in mixed forests of low-level species—the pine forests extend over a large extent of hilly country at elevations of 3,500 to 7,000 ft. On northern aspects pure chir forests occur mainly at elevations of 3,500 to 5,500 ft., above which the pine is mixed with *Quercus incana*, with or without *Rhododendron arboreum* ; on southern aspects the limits are broadly speaking 500 ft. higher, though in each case the figures should be taken as only roughly approximate, since variations occur according to local conditions. In the inner valleys below 4,000 ft. the pine is often associated with miscellaneous species such as *Ougeinia dalbergioides, Bauhinia retusa, Engelhardtia Colebrookiana, Machilus odoratissima*, and others. The geology of this tract presents considerable variation. The outer hills below Naini Tal are composed largely of tertiary sandstone. The Lansdowne hills are formed of mica schist, with occasional slate, limestone, and gneiss. The Himalayan rocks of Naini Tal, Ranikhet, and Almora consist of mica schist, shale, quartzite, and gneiss, while limestone occurs locally. With this variation in the geological formations, there is considerable variation in the types and qualities of forest met with. Although the average quality of the forest is perhaps hardly equal to that of the Chakrata division, on favourable situations the trees reach large dimensions, while in many localities the loose micaceous or sandy soil is very favourable to natural reproduction.

Among the poorer types of chir forest in this region may be mentioned those in which 'twisted fibre' is prevalent, the trees often being stunted as well as twisted. Some remarks on this phenomenon will be found on pp. 1056–1061.

No accurate information is available regarding the chir forests of Nepal. Pundit Sadanand Gairola, who reported on the *tarai* forests of that state, mentions that he occasionally came across chir trees at elevations where the sal ended ; from accounts which he heard, and judging from the drift-wood found along the rivers, he concluded that there are at least some extensive chir forests in the hills.

In Sikkim, according to Gamble, the forest is not always pure, but the pine is much mixed with sal and other trees, and has the appearance of being slowly driven out.

In Bhutan Mr. Jacob [1] states that *Pinus longifolia* does not appear to grow west of the high ridge between the Raidak and Sankos valleys. East of that ridge it is very common, growing as low as 2,000 ft. and ascending to 6,000 ft., though occurring chiefly between 3,000 and 5,000 ft. In the outer hills the forests have been much denuded; those of the inner hills are in a somewhat better condition, but here also they have suffered from maltreatment and clearing for cultivation.

Mr. Jacob states that in the inner hills the forests of *Pinus longifolia* usually alternate with broad-leaved forest, the former occupying the ridges and drier slopes, and the latter the ravines and damper situations; the pine forests are invariably open and grassy, and when pure have little or no undergrowth except for a species of small palm, 2 to 3 ft. high, which is common in some forests; the only tree associated to any extent with the pine is *Quercus Griffithii*, though other oaks and chestnuts are occasionally found. There are few trees over 6 ft. in girth, but this is probably due to the extraction of large trees for building purposes. The forests are habitually burnt, with the result that most of the larger trees are unsound at the base; in spite of this reproduction is good.

In Bengal the chir pine is found in the Darjeeling district over an area of about 50 acres mixed with sal on the upper ridge of the Badamtan block on the right bank of the Great Ranjit river adjoining Sikkim. The elevation is about 2,000 ft., and the rock is mica schist, furnishing a micaceous sandy soil.

Climate. Within the natural region of *Pinus longifolia* the absolute maximum shade temperature at the lowest elevations, for instance in some of the hot valleys of the Rawalpindi district, is probably about 115° F.; in the pure chir zone, however, the absolute maximum probably varies from 90° to slightly over 100° F. The absolute minimum shade temperature within most parts of the region of the pine habitually falls below freezing-point. The normal rainfall varies from about 35 in. to 117 in. (at Dharmsala). Of twenty-three stations in the neighbourhood of the chir zone no fewer than fifteen have a rainfall between 40 and 70 in., while in the Tons valley, where the pine reaches its finest development, the rainfall is probably about 40 in. or in places even less. Within the region of the pine the great bulk of the rain falls during the monsoon, that is, from the end of June or beginning of July to September, after which there is usually a period of dry weather till the winter rains, which occur from December to February or early March; from March to June there are occasional showers of rain, often accompanied by thunderstorms. In the winter months there are occasional falls of snow towards the upper limit of the pine, but heavy falls are not common. The tree is grown successfully on the plains in places with a hotter and drier climate than it experiences in its natural habitat, for instance at Lahore and Rawalpindi, with absolute maximum

[1] Report on the Forests of Bhutan bordering on the Boundary of Eastern Bengal and Assam, W. R. Le G. Jacob, 1912.

shade temperatures of 120° and 118° F., and normal rainfalls of 18 in. and 32 in. respectively.

Geology and soil. The chir pine is found naturally on a variety of geological formations. In the outer Himalaya and the Siwalik hills it occurs on tertiary sandstone with occasional bands of clay or beds of conglomerate. In the Himalayan valleys considerable stretches of chir forest are found on quartzite ; here the trees often attain large dimensions. Other common Himalayan formations on which the tree occurs frequently are mica schist, gneiss, and shales, often with bands of quartzite. In certain localities, for example in the Khanpur range of Hazara and locally in the Kumaun Himalaya, it is found on limestone ; many of the important limestone tracts of the Himalaya, however, lie above the chir zone. Depth and porosity of soil have a most important effect on the growth of *Pinus longifolia*, as of other species. In Dehra Dun a chir seedling planted on a mound of loose new earth grew to a height of 20 ft. in four years. To the same factors are due the exceptional growth seen on deep boulder formations in river valleys, notably in the Tons valley ; the consistency and depth of the soil and subsoil, in fact, appear to have more effect on the growth of the trees and on natural reproduction than the underlying rock.

The chir pine will grow on bare rock to an extent seldom seen in other species, but the trees in such localities are often stunted and gnarled. Reference has already been made to types of open stunted forest in the Rawalpindi district on bare sandstone rock with no soil whatever, and in the Kangra valley, where the pine occurs on gneiss, schist, and sandstone, with a very scanty surface soil consisting mainly of gneiss boulders in a stiff clayey matrix (Fig. 414). On the other hand, chir trees of very fair quality may be found growing on bare quartzite rocks, as in parts of the Tons valley (Fig. 415) ; here, however, the roots are able to penetrate to a considerable depth into the joints of the rock, and to find sufficient sustenance there.

On quartzite the chir forests are as a rule remarkably pure, other species occurring mainly in the moister depressions. This is apparently due to the fact that the soil and subsoil, while containing sufficient moisture for the establishment and maintenance of the pine, are too dry to support the majority of species. In the Tirthan valley, Kulu, a somewhat dry quartzite formation is found above mica schist with a moist soil ; the mica schist is monopolized by blue pine, with oak and other trees, while the chir pine covers the quartzite area at a higher elevation than the blue pine. The geological formation here has a direct effect on the local distribution of the two pines, since the blue pine occurs normally at higher elevations than the chir. On mica schist with a deep moist soil the chir pine is often found mixed with oak and other broad-leaved species, and attains large dimensions under these favourable conditions. The limestone hills of the Khanpur range, Hazara, are not favourable to chir pine, the trees being as a rule stunted ; this, however, appears to be due not to the presence of lime, but to the hardness of the rock and shallowness and dryness of the soil overlying it, since forest of very fair quality is to be found on northerly slopes where there is sufficient depth of soil. On the softer limestones of Garhwal and Kumaun the chir grows well where the soil is not too shallow. In the Naini Tal hills chir is only occasionally found on dolomite, but it does not grow well on this formation ; dolomite is here characterized, as a rule, by the absence of chir.

On the Supkhar plateau of the Balaghat district, Central Provinces, chir sowings have proved successful on a sandy loam derived from the decomposition of laterite with several feet of subsoil. On fertile arable land, as at Dehra Dun, the growth is rapid provided the soil is porous and well drained.

LEAF-SHEDDING, FLOWERING, AND FRUITING. *Growth and persistence of needles.* As a general rule the needles of the chir pine persist for about one year and five months, more or less, including the whole period from the sprouting of the buds in January to the shedding of the needles in May or June of the following year. In a large number of cases, however, and particularly, though not exclusively, where vigorous saplings and poles are concerned, they persist in whole or in part for a second year, while exceptional cases have been observed where they remain for a third year. In dry, hot localities and in exceptionally dry seasons the trees are nearly deciduous, and in very dry years trees which ordinarily retain their mature needles for a second year may shed all except the new ones of the current year, causing an abnormal fall of needles.

The resting period of the chir pine is short. The winter buds form in October or November, and growth ceases till December or early January, when the new shoots begin to appear. At low elevations suppressed trees and lower suppressed branches may begin to shed their old needles as early as the beginning of March, but normally the needles do not begin to fall in any quantity till April or May, and by the end of June most, if not all, have fallen, though in some cases a few may continue to fall during July. In hot, dry seasons the needles fall earlier than they do in cool, wet seasons. While the old needles are falling the new ones lengthen rapidly, and by the time the former have fallen the latter are 3 to 5 in. long, and still erect. At this time in the case of trees which are approaching maturity the new needles are grouped in stiff tufts resembling tar-brushes (Fig. 417, *a*), and in the month of June the trees have a characteristic bare appearance, though this is not so marked in vigorous saplings and poles. Fig. 426 shows the appearance in June of mature trees and vigorous saplings respectively.

From July onwards the new needles continue to lengthen rapidly, and by September they have reached their full length, and the majority, if not all, are drooping, though often some of the upper needles remain permanently more or less erect. In October or November the terminal light reddish brown winter bud forms, and growth ceases till December or early January.

Male flowers. The male flowers, 0·5–0·7 in. long when ripening, cylindrical ovoid, subtended by protruding light brown acuminate scales with fimbriate margins, are grouped on the axis of the new shoots in spirals of 8×5, the whole inflorescence being 1–4 in. long by 1·5–2 in. in diameter (Fig. 416, *a*, *b*). The flowers are yellowish green before ripening, turning light reddish brown after the pollen is shed. At low elevations the male inflorescence is distinctly visible by the beginning of January. The flowers ripen, and pollen showers take place, from February to April, according to altitude and season. Wet, cold weather retards the escape of pollen, while hot, dry weather accelerates it. The flowers on the south side of the tree usually ripen before those on the north side. After the pollen escapes the flowers elongate to nearly 1 in. The

FIG. 416. *Pinus longifolia*—MALE AND FEMALE FLOWERS AND YOUNG CONES OF FIRST YEAR × $\frac{3}{4}$

a—Male flowers immediately before shedding pollen (February-April) b—Male flowers after shedding pollen (March April) c—Male flowers after shedding pollen, catkins nearly all fallen off (March-April) d Single male flower, after falling (March-April) e Female flowers on first appearance (February-March) f—Female flowers, some days later (March) g—Young cones, two whorls of three each (March) h—Young cones, somewhat more developed (end of March-April)

NOTE—In Figs a, b, c, e and f the needles of last year are shown cut off

male inflorescences are generally more numerous on the central and lower branches than on the upper parts of the tree. Pollen is produced in large quantities, ensuring fertilization by the agency of wind. The flowers remain on the shoot for a short time after shedding the pollen, when they fall off one by one, leaving the pale green axis destitute of any covering except the persistent recurved triangular bases of the scales which subtend the flowers (Fig. 416, *c*); the upper parts of these scales fall with the flowers. The axis soon changes from pale green to light reddish brown. The corresponding axis of the previous year is still distinguishable, the remains of the triangular scale-bases being visible. From the middle of March (at the lower elevations) and for some weeks afterwards, the ground near the trees is strewn with the fallen male flowers (Fig. 416, *d*).

Female flowers, and development of cones. The female flowers, pale green, or slightly purplish at first, are found at or near the apices of the new shoots, either solitary or in pairs or in one or two whorls of three each. Fig. 416, *e*, shows the female flowers at first appearance, that is, in the early part of February at low elevations, and somewhat later at higher elevations. The development of the young cones during the first month is shown in Fig. 416, *f–h*. The young cones are erect and ovoid, with scales arranged in spirals of 8 × 5. Pollination takes place from February to April, according to altitude and weather; within a month of pollination the young cones increase to about 0·6–0·8 in. in length. They remain green during the greater part of the first season, increasing somewhat in thickness but not much in length (Fig. 417, *a*). About the end of October they are 0·7–1 in. long by 0·6–0·8 in. in diameter, and turn greyish brown outside, remaining green inside; they are fairly soft, and are easily cut with a knife. By this time a light reddish brown bud has formed at the end of the shoot; the cones are at the base of this bud, and are pushed out of their erect position into a more horizontal one (Fig. 417, *b*). In this stage the cones pass the winter. The new needles are now full-sized, and envelop the young cones, which are difficult to see on the trees.

Shortly after pollination the cone scales close. A preliminary microscopic examination, by Mr. G. H. Alington, of young cones collected in the end of June, about three months after pollination, revealed the fact that the pollen grains had entered the micropyle of the ovules and lodged on the nucellus, though no sign of the development of pollen-tubes could be detected. This would indicate that the chir conforms to the normal conditions of the genus *Pinus*, in which the pollen tube, though it commences its growth during the first season, does not complete it and fertilize the oosphere until the second year.

At the beginning of the second season the young cones again become active and turn green, the brown portion (the remains of the winter stage) being pushed to the tips of the scales. The growth from now onwards is very rapid. At the lower elevations by the beginning of March the one-year-old cones are green, 1–1·8 in. long by 1–1·5 in. in diameter, with soft not conspicuously recurved scales with brown tips. These cones are found at the base of the new season's shoot (Fig. 417, *c*); one or more may be found on the same shoot. By the middle of April they are 3–4 in. long, green, with scales already becoming recurved and the general shape of the cone beginning to resemble that of the mature cone (Fig. 417, *d*); the scales are soft and easily cut with a knife.

By June or July the cone has reached full size, but is still green (Fig. 417, *e*). Towards the beginning of winter the cones gradually turn brown and hard; they are now fully developed, and in this stage they pass the winter.

The dates given above refer to low elevations; at higher elevations the cones may be as much as six weeks later in developing.

In the spring of the third season, twenty-four months after the appearance of the female flower, the cones are light brown, 4·5–8 in. long by 2·5–3·5 in. in diameter near the base, elongate-ovoid, on short stout stalks; the scales are hard, thick, reflexed, and tightly closed (Fig. 418, *a*). These cones, solitary or in clusters of two to six, are found at the base of last year's needle-covered shoot; the portion of the shoot immediately below is usually leafless, or in cases where the needles persist for two seasons, is partially or wholly needle-covered.

The cones begin to open as a rule in April or May, but sometimes as early as March. They open only in dry weather, closing up again with rain; given sunny weather, however, complete opening takes place rapidly. The seed does not all fall at once, but may take two or three weeks, or even more, to escape completely; in cool localities and after rainy weather the seed may not be shed till June, while some of it may remain unshed till July. Even in fine weather there is some delay in the escape of the seeds owing to the fact that a good shaking by the breeze is required to dislodge them all; their escape is also retarded by the fact that the cones are attached to the branches at various angles, some being more or less pendulous, some horizontal, and some inclining upwards. The fact that the seed is not all dislodged without the help of a fairly stiff breeze ensures its spread to a distance from the tree. Fig. 418, *b*, shows a cone at the time of opening.

From the foregoing details it will be seen that the period elapsing from the first appearance of the young female cones till the mature cones open and shed their seed is about twenty-six or twenty-seven months.

The time for which the open cones remain on the tree after shedding their seed depends largely on the weather. Some are blown down during the storms preceding the monsoon, and others in the autumn storms. A certain number remain on the tree for a year; if they remain longer they usually disintegrate by degrees, only remnants persisting. The age of these remnants can be deduced by counting the number of years of growth on the branch, as exhibited by the rings left by former bud-scales. The open cones are sometimes of large size, as much as 8 in. by 6 in. After heavy rain they frequently close up, whether on the tree or on the ground, but open again after a few days of sunshine. Fig. 418, *e*, shows an old empty cone.

Succession of cones and flowers. Male inflorescences may follow each other in successive years on the same branch. Female cones may succeed female cones at intervals of one or more years; Fig. 420 shows cones of three successive years on one branch. Male flowers may succeed female flowers on the same shoot at intervals of one or more years; no case has yet been observed of males and females of the same year on the same shoot.

Seed and seeding. The winged seeds lie in pairs at the base of each cone-scale. Fig. 418, *c*, shows a detached scale with a pair of seeds in position. The seeds (Fig. 418, *d*), including the wing, are 1·1–1·8 in. long, the wing being 0·3–0·4 in. wide; without the wing they measure 0·3–0·5 in. by 0·2–0·25 in.

FIG. 417. *Pinus longifolia*—DEVELOPMENT OF CONES DURING FIRST YEAR (continued) AND SECOND YEAR $\times \frac{3}{4}$

a Young cones of first year, July (needles removed in front of cones, to show latter)
b Young cones, end of first season, November-December
c—Immature cone early in second year, March, about 12 months from first appearance
d—Immature cone during second year, April, May, about 13-14 months from first appearance
e—Immature cone during second year, July, about 16 months from first appearance

In samples of seed collected from 36 different trees the number of seeds per ounce varied from 192 to 704, and averaged 358. A fair average may be taken at 350 seeds per ounce. The specific gravity of well-formed seed appears to have no relation to its fertility; in tests carried out with the samples in question the lightest seed of all had a fertility of 100 per cent., while some of the heavier samples also had a high germinative power.

An examination of 284 cones gave an average of 51 seeds per cone, the actual number varying from 31 to 105; the number of malformed seeds was remarkably small, there being an average of less than one such seed to every four cones. Mr. Jerram states that the normal average number of fertile seeds per cone from mature trees in the Rawalpindi district is 38, but that in very large over-mature trees the average is often much below this.

The age of production of fertile seed depends largely on local environment factors. Under ordinary forest conditions it is probable that few chir trees produce cones at an earlier stage than thirty years, and then only sparingly, while it is by no means unusual to find trees forty years old or more with no sign of ever having borne them. Vigorous trees in the open yield seed earlier than trees grown in close canopy or suppressed trees. In the Mandi state, at 4,500 ft., a vigorous young tree only twenty years old was observed bearing a well-developed cone. At Dehra Dun a plantation on good arable land commenced to regenerate naturally on open hoed ground round its edge in 1913; the trees were then thirty years old, and averaged 79 ft. in height and 3 ft. 3 in. in girth. In 1911 a plantation thirty-five years old in Baldhoti block, Almora, was noticed to be regenerating an adjacent blank area; seedlings older than three years were not found, and this would indicate that regeneration commenced when the mother trees were slightly over thirty years old. In the cases quoted it is probable that regeneration was effected entirely from the trees round the edges of the plantations. On the other hand, numerous instances have been observed where trees in dense crops well above the minimum age of seed production, and in localities of good quality, have failed to bear any cones, even in good seed-years. It may be noted that male flowers are produced at an earlier age than female flowers.

Crown development has an important influence on seed production, trees with full rounded or umbrella-shaped crowns bearing a much larger number of cones than those with conical crowns; in good seed-years, nearly every tree of the former type is heavily laden with cones. The selection of seed-bearers from among trees with full crowns is therefore a matter of great importance.

As regards the fertility of seed from trees of different sizes, germination tests carried out at Dehra Dun with seed collected in the Naini Tal and Rawalpindi divisions from 38 trees varying from 1 ft. 11 in. to 10 ft. 8 in. in girth, gave the following results:

1. Seed from 33 trees 1 ft. 11 in. to 5 ft. 6 in. in girth had a fertility varying from 40 to 100 per cent. and averaging 83 per cent.; the Naini Tal seed averaged 93 and the Rawalpindi seed 81 per cent. Seed from only five trees had a germination percentage of less than 75; seed from one tree 1 ft. 11 in. in girth had a fertility of 100 per cent.

2. Seed from five over-mature trees 6 ft. to 10 ft. 8 in. in girth had a fertility varying from 35 to 60 per cent.

3. The density of the crop, the aspect, the quality of the locality, the slope, and the altitude, had no appreciable effect on the fertility; seed, however, was not collected from the upper and lower limits of the pine.

4. Seed from one tree of girth 1 ft. 3 in., not included in those mentioned above, was all malformed and unfertile.

Tests carried out in the United Provinces in 1910–11 showed that small trees are capable of producing good healthy seed, but in small quantities.

The conclusions to be drawn from these tests are that trees of fairly small dimensions, say about 2 ft. in girth, are capable of producing seed of good fertility, and that the fertility remains high until the trees become over-mature, when it diminishes. As regards the quantity of seed produced, extensive observations show that as a general rule only trees approaching maturity, with well-developed crowns, produce seed in sufficient quantity to effect complete regeneration.

The statement below gives a record of seed-years in different localities, commencing with the year 1894, from which it would appear that a fair to good seed-year occurs on an average once every two to three years, according to locality. Generally speaking, it may be said that a certain amount of seed is produced almost every year, and that the aggregate yielded for a period of say three or four years is sufficient for purposes of regeneration under conditions at all favourable.

Pinus longifolia: record of seed-years in different localities (in three degrees, good, fair, and bad).

	North-West Frontier Province,	Punjab.					United Provinces.		
Year.	Hazara division.	Rawalpindi division.	Kangra division.	Kulu division.	Bashahr division.	Simla division.	Chakrata division.	Naini Tal division.	Haldwani division (outer hills
1894	bad	bad	bad	..	..	..	bad	bad	..
1895	bad	bad	bad	..	..	..	bad	bad	..
1896	bad	bad	bad	..	..	..	good	bad	..
1897	..	good	fair	..	..	..	good	fair	..
1898	..	fair	good	..	.	..	bad	fair	..
1899	good	bad	bad	..	..	..	good	fair	..
1900	..	fair	good	..	..	..	bad	fair	good
1901	..	bad	bad	..	.	bad	bad	good	good
1902	..	bad	bad	..	..	bad	bad	bad	..
1903	..	bad	bad	.	.	..	..	fair	..
1904	..	bad	bad	..	..	..	bad	bad	..
1905	bad	fair	fair	..	..	good	good	good	..
1906	fair	good	bad	..	.	bad	bad	bad	..
1907	bad	bad	bad	..	..	good	fair	fair	good
1908	bad	fair	bad	bad	..	bad	good	fair	good
1909	bad	bad	fair	..	good	good	bad	bad	..
1910	bad	good	bad	bad	bad	fair	bad	fair	..
1911	bad	..	bad	bad	..	good	bad	bad	..
1912	fair	bad	bad	bad	bad	bad	bad	bad	bad
1913	fair	good	bad	bad	..	bad	fair	bad	fair
1914	fair	fair	good	good	good	..	good	good	fair
1915	bad	bad	bad	bad	bad	bad	bad	bad	bad
1916	..	fair	fair	fair	fair	fair	..	..	..
1917	fair	fair	fair	fair	fair	fair	good	fair	..
Average periodicity of good and fair seed-years. One year in:	2·7	2·1	3·0	3·0	Insufficient sequence of records.	2·0	2·44	1·92	Insufficient sequence of records.

Fig. 418. *Pinus longifolia* Cones of the third and fourth years ×

a - Cone during winter of second year and early part of third year (needles cut short) b —Cone during process of opening, May of third year c —Single cone scale showing pair of seeds d Seed
e—Old empty cone in fourth year

It is important at times to be able to forecast a good seed-year two years in advance. The majority of the young female cones are found in the upper parts of the tree. With a pair of field-glasses they can be seen distinctly at the apices of the new shoots in March and April. They are, however, clearly visible from below only for three or four weeks or even less, while the new needles are quite short; after this the needles soon become long enough to hide the young cones, so that the time during which it is possible to see them is strictly limited.

The seed of the chir pine falls some little time before the commencement of the rains and germinates not long after falling; while on the ground, therefore, it is not subjected to the attacks of pheasants and other birds to the same extent as the seed of the blue pine or the deodar, which lies throughout the winter. While still in the cone, however, the seed is subject to the attacks of certain birds and animals. Mr. A. E. Osmaston,[1] from observations in British Garhwal, enumerates wood-pigeons, nutcrackers, woodpeckers, and grosbeaks, as well as monkeys and flying squirrels. The large amount of seed consumed by flying squirrels in the case of *Pinus excelsa* has been noted on p. 1022; similar extensive damage is caused in the case of *P. longifolia*, and can be detected from the fact that the cone-scales are bitten off sharp at the base, the central axis of the cone being left. Monkeys tear the cones in shreds to extract the seeds. Mr. Osmaston notes that in Garhwal the seeds are eaten by man, the cones being collected before they open and opened by the action of fire: this is done also in parts of the Punjab.

GERMINATION (Fig. 419, *b–f*). Epigeous. The radicle emerges from the end of the seed and descends, the hypocotyl elongating and raising above ground the cotyledons, the extremities of which are enclosed for a time by the shell of the seed, which eventually falls to the ground, when the cotyledons, 9–13 in number, spread out in a whorl, from the centre of which the young shoot makes its appearance.

THE SEEDLING. The following is a description of the seedling and its development during the first five years:

First year (Fig. 419). *Roots*: primary root long, wiry, flexuose, brown, with a moderate number of fibrous lateral rootlets. Natural seedlings in dry localities frequently have taproots 15 in. in length or more in one year; in rocky ground the taproot is often much twisted in its efforts to penetrate cracks in the rocks. *Hypocotyl* distinct from the root, 0·75–1·8 in. long, cylindrical or fusiform, at first white and green, soon becoming reddish or light brown, glabrous. During the first year the epidermis commences to peel off in longitudinal papery exfoliations, and in luxuriant specimens the hypocotyl is often much thickened by the end of the first season. *Cotyledons* 9–13, whorled, 1·2–2·7 in. long, acicular, incurved, prominently triquetrous, compressed laterally, glaucous green or light green, inner edges minutely and somewhat widely serrulate. Towards the end of the first season the cotyledons sometimes turn yellow or brown, and may even disappear if much bespattered with earth in the rains. *Stem* (above cotyledons) erect, terete, pale green or greenish grey; length by the end of the first season varies greatly from under 0·5 in. in poor specimens to 3 in. or more in vigorous plants. One or more lateral buds sometimes appear at or near the base of the stem above the cotyledons. *Leaves* of the first season all primordial, 0·6–1·7 in. long, some-

[1] Ind. Forester, xliv (1918), p. 462.

times longer in vigorous seedlings, acicular, obscurely triquetrous, pale glaucous green, sharply serrulate, minutely punctate in longitudinal lines of stomata.

Second year (Fig. 421). *Roots*: primary root in vigorous specimens on rich soil often much thickened and not conspicuously elongated; on poorer soil the root may elongate to 2 ft. or more; lateral roots usually few and short in natural seedlings, longer in well-developed nursery plants. *Hypocotyl* still distinct, light brown with greyish brown papery exfoliations, often much thickened in vigorous specimens. *Cotyledons* at beginning of season either present or fallen off; if present, usually turning yellow or brown; by the end of the season the cotyledons have disappeared, but their position is still well marked. *Stem* elongates to as much as 14 in. in vigorous specimens, but as a rule reaches a height of only about 5–8 in. in natural seedlings; in vigorous plants there are frequently side shoots of some length springing from the base of the stem, otherwise buds are generally perceptible at that point. *Leaves*: primordial needles up to 2 3 in. long, the longest near the apex of the shoot; these needles cover the whole stem down to the top of the hypocotyl unless killed off by the wash of earth. Only in the most vigorous plants do adult needles in clusters of three commence to be formed during the second season; in most seedlings buds only are formed, these giving rise to adult needles in the third season.

Third year. The seedling during the third season (age about 1 year 7 months to 2 years 5 months) is characterized by the appearance of adult needles in clusters of three as well as primordial single needles. In strong uninjured plants only adult needles, up to 8 in. long, are produced towards the apex of the shoot, where also a group of buds, forming next year's terminal shoot and whorl of lateral shoots, forms towards the end of the season; these buds enclose adult needles. In injured or backward specimens primordial needles may occur up to the apex of the shoot, adult needles being usually also present. The size of the seedlings varies greatly, the maximum height ordinarily attained being about 2 ft. by the end of the season. In the lower part of the stem side shoots of some length are often numerous in strong plants, while rosette-like arrested branches are also common. The primordial needles of former seasons in the lower part of the stem wither and hang down or fall off in part.

Fourth year. In the fourth season (age about 2 years 7 months to 3 years 5 months) adult needles are regularly produced, though primordial needles are also formed on all but the most vigorous plants, and particularly if any injury is suffered. By the end of the season a maximum height of 3 ft. 4 in. may be reached, though for natural forest seedlings about 1 ft. 8 in. would be a fair average. The lower part of the stem becomes free of dead needles, and in vigorous plants the first semblance of rough bark commences. Fig. 422 shows natural forest seedlings early in the fourth season.

Fifth year. In the fifth season (age about 3 years 7 months to 4 years 5 months), only adult needles are formed, except when the plant has been injured or retarded by some extraneous influence, when primordial needles are also formed. Vigorous uninjured plants now commence to assume the characteristics of the tree rather than of the seedling. The lower part of the main stem has lost its needles, is forming rough bark, and at the end of the season has a diameter up to 2½ ft. at 8 in. from ground-level; the upper part of the stem is thick and covered with adult needles, and there are strong whorls of stout branches, also covered with similar needles. The maximum height attained by the end of the season is normally about 6 ft., though the average height of natural forest plants is probably under 3 ft.

Fig. 423 shows a vigorous nursery-raised plant 5½ ft. in height in the latter half of the fifth season.

The rate of growth of chir seedlings varies greatly according to the con-

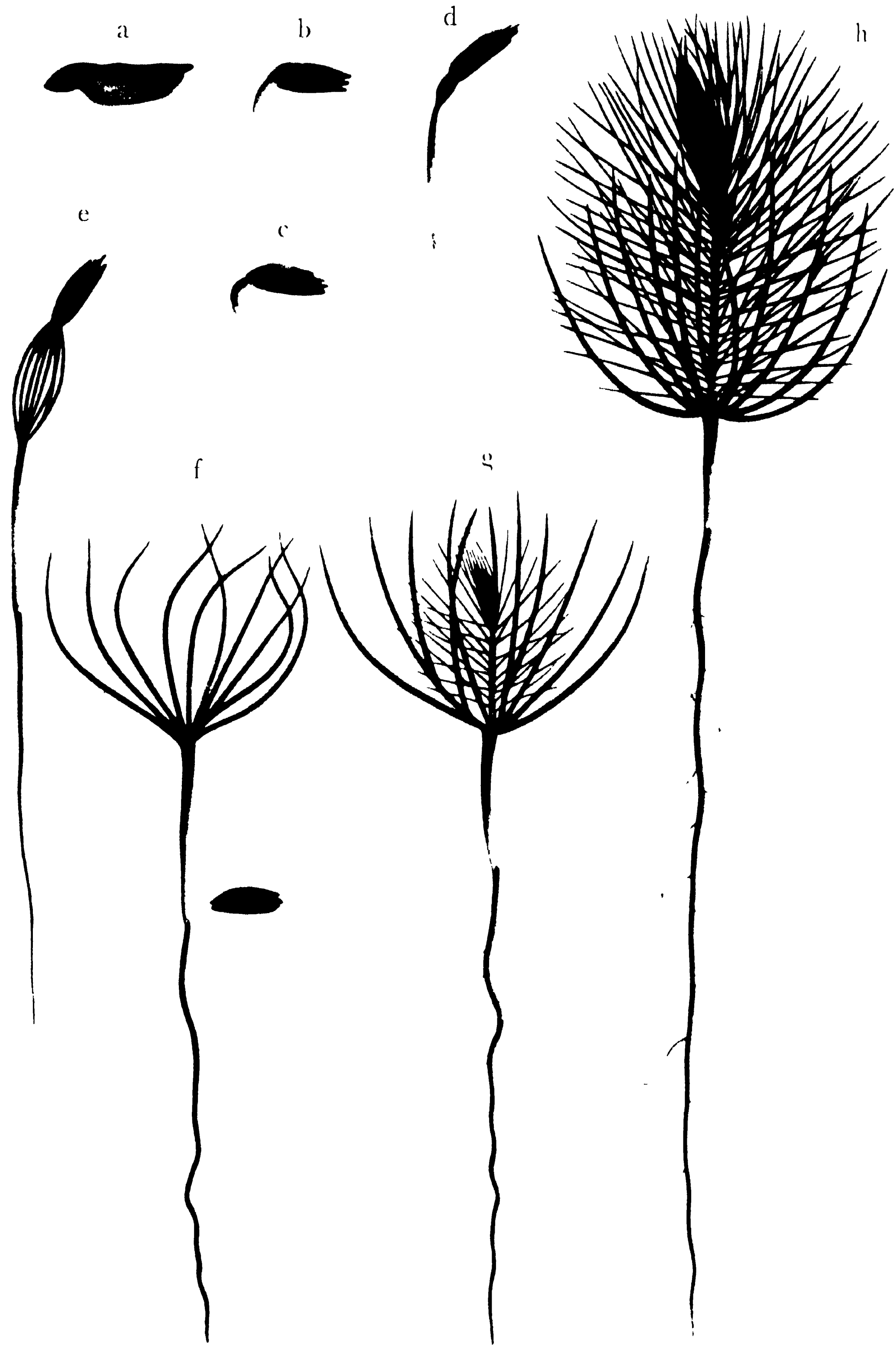


FIG. 419 *Pinus longifolia* SEEDLING $\times \frac{3}{4}$

a Seed b - f Germination stages g, h Development of seedling to end of first season

ditions under which they are grown. Various measurements have shown that given suitable light conditions and ordinary immunity from external dangers, the period required for the seedlings to develop until they begin to put on normal height-growth is under the most favourable conditions five years, while under less favourable conditions it may be as much as twelve to fifteen years ; a fair general average might be taken at eight to ten years, by which time a height of 7 to 9 ft. may be expected to be reached. From measurements of seedlings growing under average conditions it has been estimated that a chir seedling may be expected to attain by the end of the first five seasons a height respectively of (1) 2 in., (2) 6 in., (3) 1 ft., (4) 1 ft. 8 in., (5) 2 ft. 10 in. In a small plantation at Dehra Dun on good arable land, where the height-growth of a plantation thirty years old on similar land showed a mean annual height increment of 2 ft. 7 in., the height of the dominant seedlings at the end of each of the first five seasons was (1) 5 in., (2) 1 ft. 1 in., (3) 2 ft., (4) 3 ft. 4 in., (5) 6 ft. In this case normal height-growth began to be produced in the fifth year. The time at which seedlings began their new season's growth varies considerably ; at Dehra Dun new growth has been observed to commence at various dates from the end of December to the beginning of March, and at higher elevations it begins later. The season's growth ordinarily ceases about October to December.

Chir seedlings are very light-demanding. They persist for a time under slight shade, particularly in fertile soil under broad-leaved species, but even here they become readily suppressed. Measurements of a number of seedlings, suppressed but still growing under a canopy of oak in the Rawalpindi forests, showed that a height of only 3 to 4 ft. was reached in sixteen years, while in an adjoining crop without any overhead cover a mean height of 15 ft. was reached in the same period.

Within the natural habitat of the pine the seedlings are frost-hardy. They are drought-resistant, but on stiff soils in which the root is unable to develop satisfactorily, they may die off in quantity in places exposed to the heat of the sun for any length of time during the day. Young plants cannot endure bad drainage, and where there is excessive moisture in the soil or undergrowth they damp off. Although the seedlings are probably more fire-resistant than those of other Himalayan conifers they suffer greatly from the severe fires which occur within the region of the pine. They are not readily browsed if there are more palatable plants at hand, but in many localities heavy grazing is accountable for a great deal of injury to the young plants, which are browsed down to bush-like form. The effect of fire and grazing on natural reproduction will be considered below.

Among animals, porcupines and rats, where plentiful, do much damage to young chir plants ; the former eat the roots of seedlings and saplings, and the latter gnaw through the taproots of seedlings, especially in nurseries and plantations. Birds do much damage during and shortly after germination, biting off the cotyledons and usually killing the plants. Young seedlings are subjected to various forms of insect damage, perhaps the most serious being that caused by grasshoppers, which bite through the stems.

SILVICULTURAL CHARACTERS. *Pinus longifolia* is a strong light-demander, and where mixed with *P. excelsa* it exhibits more demand for light than the latter, which is itself a light-demander. On hot, southerly aspects, however, it may require protection from the sun during youth on stiff clayey soil. Hence, although in favourable localities, and especially on cool aspects, a complete removal of the canopy is greatly to the benefit of the young crop, on hot aspects a certain amount of side protection from the sun may be necessary.

The soil requirements of the pine have already been dealt with ; it is one of the least exacting of Himalayan trees, growing on bare rock where few species are capable of existing, but it is intolerant of badly drained ground.

The root-system of the chir is massive, and spreads both downwards and laterally. Although the tree is wind-firm under ordinary conditions, windfalls are not uncommon on loose soil and on denuded ground. The effect of wind in producing a gnarled and stunted growth is frequently observed, particularly along the edges of woods and on exposed ridges.

In its natural habitat the chir pine is not ordinarily called on to face severe frosts on the airy hill-sides on which it grows ; it has, however, proved itself to be a hardy tree when introduced into frosty localities in India. Thus in the great frost of February 1905, chir trees of all ages planted in the Dehra Dun valley, sometimes in frosty hollows, escaped completely the severe injury suffered by the majority of the broad-leaved species. In some of the frosty valleys of the outer Himalaya the pine, encouraged by fire-protection, can be seen establishing itself at the expense of more frost-tender species.

Growing as it does at comparatively low elevations, the chir is not as a rule exposed to great risk of injury by snow, but when heavy falls of snow do occur within its zone the damage done may be considerable, since the pine is somewhat brittle. Pole crops, particularly those which have not been regularly thinned, suffer most, the poles being snapped in two or bent down, and in some cases uprooted. Snow damage has been observed on various aspects and at different elevations ; it is as a rule more prevalent towards the end of the winter season, when heavy falls of snow in a somewhat wet state are apt to occur.

The chir pine has greater power of resistance to fire than any other important Himalayan conifer, owing to the exceptionally thick bark produced alike on young saplings and on older trees, to the thickened and sometimes almost fleshy taproot developed in the seedling and young sapling stage, and to the power of recovery from injury possessed by plants of various ages. Nevertheless, owing to the fact that the tree is found on hot, dry, inflammable slopes, the actual damage done by fire in chir forests is so great, that in the majority of cases fire is the greatest source of danger to which these forests are exposed. The damage is sometimes aggravated by the custom of chipping out torchwood from the base of the tree, exposing the resinous wood to the direct effect of fire, and in time producing a large charred hollow ; trees so damaged eventually fall, and may be entirely consumed by fire on the ground. Where resin-tapping is in operation the effects of fire are destructive unless the precaution is taken to clear all grass, fallen needles, and débris for some distance round the bases of the tapped trees, otherwise the resin-covered blazes catch fire and great damage may be done to the trees. The effects of fire are aggravated on steep slopes with a heavy growth of grass or bushes ; the fallen needles lodge in the latter, and a fierce conflagration may ensue when they

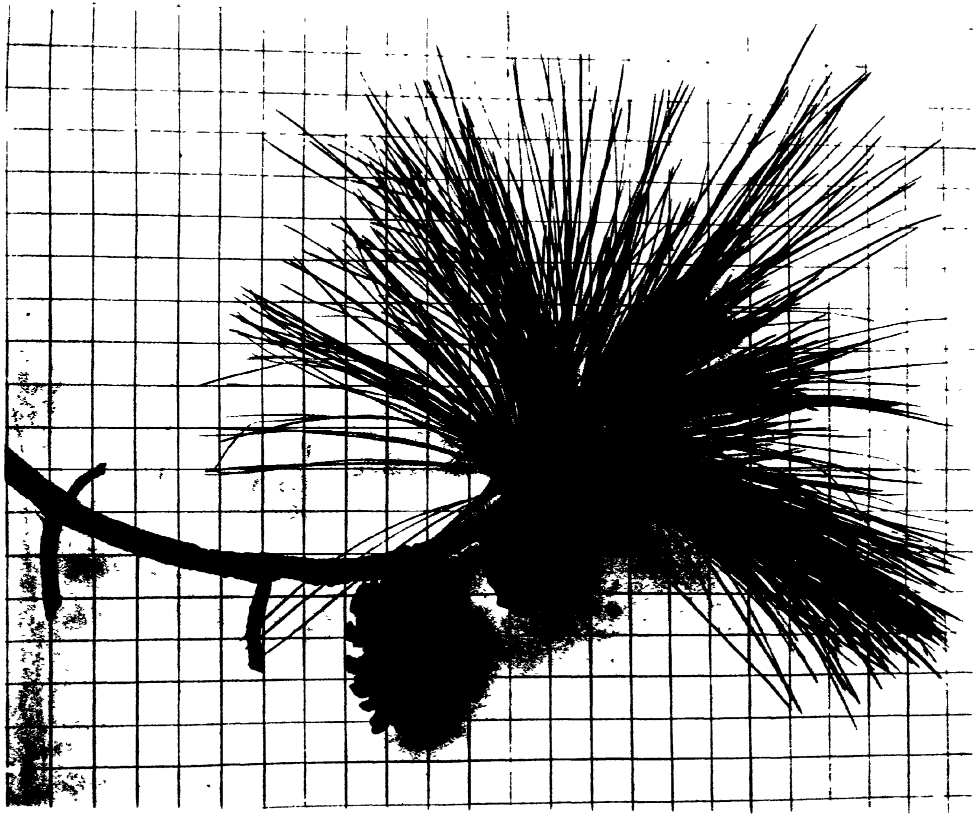


Fig. 420. *Pinus longifolia*, cones of three successive years on one branch, end of October: (1) young cone of current year, about 7 months old, (2) immature cone a year older, (3) old cone which opened in summer of current year. Squares show inches.

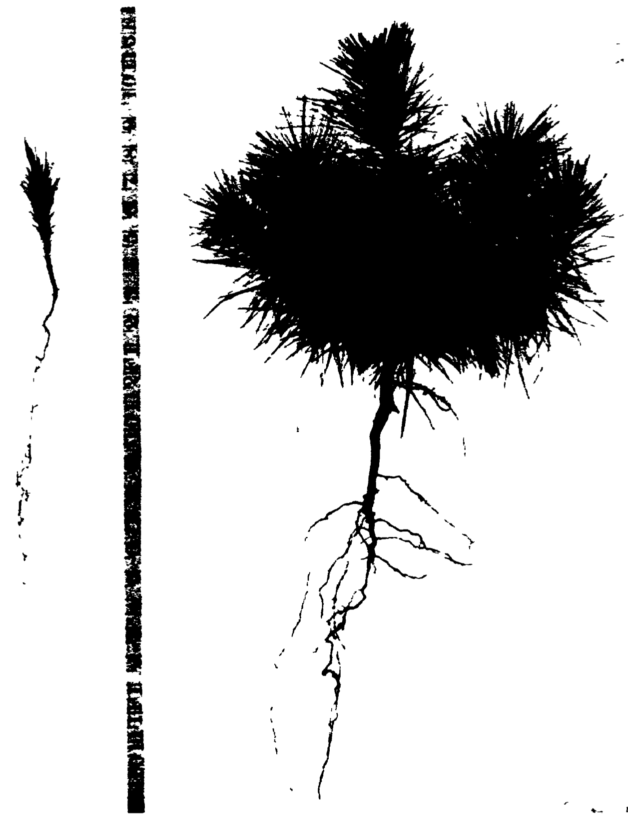


Fig. 421. *Pinus longifolia*, two nursery plants, August of second season, age about 13 months; plant on left poorly developed, with no adult needles yet appearing; plant on right vigorous, with adult needles beginning to appear and several side-shoots from the base.

FIG. 422. *Pinus longifolia*, natural seedlings. April of fourth season, age about 2 years 10 months. primordial and adult needles both present.

FIG. 423. *Pinus longifolia*, artificially raised plant, September of fifth season, age about 4 years 3 months, height 5½ ft., needles all of the adult form

catch fire. Uneven-aged crops generally suffer more than even-aged crops, since in the former the fire sometimes ascends into the crowns of the larger trees, producing crown fires which may destroy trees of all sizes ; in the case of even-aged crops large trees are not exposed to this risk to the same extent. The full effect of fire damage is not always apparent for a year or more after the occurrence of a fire, since badly scorched trees may linger for a time and then die ; in the meantime the injured trees become attacked by boring beetles.

In order to mitigate the injurious effects of intense fires in the hot season it is customary in some localities to carry out controlled burning early in the season in areas not under regeneration, thereby reducing the quantity of inflammable material. This burning, which always proceeds downhill, is carried out during the winter or early spring, as a rule shortly after rain. In regenerated areas controlled burning is commenced as soon as the young crop is free from risk of serious damage by fire ; before the initial burning is carried out dead and suppressed stems are removed by an early thinning. The question of fire in its relation to reproduction will be considered under 'natural reproduction'.

Although the damage done by fire to chir pine forests may be very considerable, still its fire-resisting power, as compared with that of other conifers, is strikingly exhibited in some localities in which other species of conifers are encouraged by fire-protection at the expense of the chir. This is seen where the chir zone meets that of the deodar and blue pine. Here the result frequently observed, where fire-protection has been in operation for some time, is that the latter species descend naturally into the chir zone, and a plentiful crop of deodar and blue pine regeneration springs up under the usually open overwood of chir. Fig. 450 shows an open mature crop of chir pine adjoining the deodar zone, under which, as a result of continued fire-protection, a dense young natural crop consisting mainly of deodar, with some blue pine and chir pine, has sprung up. Although this result is due in part to the more shade-bearing character of the deodar, still it is in tracts where fire-protection has been introduced that this form of crop is met with, and the absence of fire is the primary cause of the change of species.

Near the upper limits of the chir, where the pine is mixed with oak (*Quercus incana*), the result of fire-protection as a rule is to favour the latter. At the lower limits of the chir, however, where it is mixed with miscellaneous species of the outer hills, continued fire-protection has been greatly in favour of the pine, which in the Siwalik hills and outer low ranges of the Himalaya has spread, during the last thirty years or so of fire-protection, over a much greater area than it occupied previously.

Within the true chir zone the only destructive climber of serious importance is *Rosa moschata* ; of comparatively small account are *Vitis rugosa*, *V. parvifolia*, and *Clematis Gouriana*. In the Siwalik hills and outer Himalaya the pine, in common with the other trees of the low-level mixed forests, is subjected to damage by such climbers as *Bauhinia Vahlii*, *Spatholobus Roxburghii*, *Cryptolepis Buchanani*, and others.

The commonest fungus found on *Pinus longifolia* is *Peridermium* (*Aecidium*) *complanatum*, Barcl. (*P. orientale*, Cooke), which appears on the needles in the form of orange-coloured sacs of spores about April–June ; in this form it seems to do little if any damage, but when the fungus attacks the branches or the stems of saplings the damage is more serious. In the latter form, known as var. *corticola*, the spores probably enter through wounds, and the fructifications appear about April to June in the form of rather large orange-coloured sacs protruding from the affected portion. The fungus *Hysterium Pinastri*, a most destructive pest in nurseries and young plantations in Europe, was first observed by the late Professor Mayr in 1886 on *Pinus longifolia* in Lurli plantation, Chakrata. This fungus, which is saprophytic as well as parasitic, appears in the form of yellow spots on the needles; these spread until the whole needle turns reddish, and badly affected seedlings die off. The fungus *Trametes Pini*, so destructive to *Pinus excelsa* in some parts of the Himalaya, has been recorded to a limited extent on *P. longifolia*. The spores gain admission through wounds, and the sporophores appear in the form of irregular brackets, usually at the points where branches have been lopped off. Where this fungus is found it is most advisable to prohibit any lopping of the pine.

The branches of the chir pine are sometimes attacked by *Loranthus longiflorus*, particularly at low elevations. This parasite, however, is not so prevalent on the pine as to be a source of any great injury.

Twisted fibre. In certain localities 'twisted fibre' is one of the most striking characteristics of *Pinus longifolia* trees over extensive areas. As the name implies, it denotes that the fibres, instead of running parallel to the axis of the tree, follow a corkscrew-like course at an angle to it. Two distinct forms of twist have been recorded: (1) left-handed twist, in which the fibres run upwards from right to left, and (2) right-handed twist, in which they run from left to right. These two forms possess in some respects entirely different characteristics. Some interesting observations regarding them have been recorded by Messrs. F. Canning and E. A. Smythies;[1] nevertheless the phenomenon of twisted fibre still remains to some extent an obscure one, as its origin has not yet been fully determined. The chief characteristics of left-handed and right-handed twist respectively are as follows:

1. Left-handed twist. The degree of twist varies greatly in intensity from a hardly perceptible inclination to the vertical to one of nearly 90°. Badly twisted trees are often swollen or bulbous at the base, the fibres in the swelling running almost horizontally, and gradually assuming an angle of about 45° when the main stem is reached. In seedlings also a bulbous base is a common preliminary to a twisted-fibred stem. Where the twist is severe it extends into the branches, and the whole tree appears as if it had been subjected to some force which had twisted it into fantastic contortions, the stem and branches being gnarled in every part. Very frequently the twist of the fibres can be observed on the exterior of the tree, the bark-plates following the twist. Sometimes, however, the bark-plates may run vertically up the stem, while the fibres of the wood may be twisted, so that it is not until the tree is felled and barked that the defect becomes apparent. Mr. Smythies notes cases where the tendency to twist diminishes as the tree gets older, so that there is a central core of badly twisted wood surrounded by outer layers of slightly twisted or straight-grained wood. Similarly, poles may be found with

[1] Ind. Forester, xli (1915), pp. 69 and 112.

the lower part of the bole twisted for a few feet above ground-level, and with little or no twist higher up. Mr. Canning mentions that a curve in the stem up to a height of 4 or 5 ft. is often the only outward sign of left-handed twist in young saplings, in which the twisted fibres of the wood are not discernible in the bark; as the tree increases in size this curvature, which appears to be due to injury or to an unfavourable locality, becomes less conspicuous, though it does not necessarily follow that the twist diminishes. Generally speaking, twist is more difficult to detect in young trees than in older ones, where the bark plates are larger and the direction of the fibres is often indicated by faint markings on the plates. These markings do not always run parallel to the direction of the wood fibres, though it is probable that they did so at the time the tissues were formed; this would indicate that the degree of twist in such trees undergoes a gradual change. Left-handed twist is frequently associated with a stunted growth owing to the fact that it is often characteristic of poor shallow soils.

2. Right-handed twist. This form of twist is, according to Mr. Canning, most noticeable in mature trees, particularly in those of good height-growth and with well-formed boles; so far it has not been observed to any great extent on younger trees. As a rule the twist is slight near the base, and gradually becomes more intense higher up the stem; thus almost the only way in which to detect it at some distance is by the contorted form of the branches. The swollen base characteristic of trees with left-handed twist is not found in those with right-handed twist. Again, the latter is not necessarily associated with the stunted form of growth often observed in the case of left-handed twist; it may occur in forests of large well-grown trees. From this it will be seen that the two forms of twist differ in essential particulars, and notably in the fact that left-handed twist is usually more intense at the base of the stem, and often becomes less marked higher up, that is, in the later stages of the life of the tree, whereas in trees with right-handed twist the reverse is the case. Mr. Canning suggests as a reason for right-handed twist being more intense in the upper part of the tree, that during its earlier life, when the height-growth is vigorous, the twist, though present, does not receive full play owing to the rapid upward growth of the stem; when this upward growth diminishes as the tree becomes mature, however, the twist becomes more marked.

Twisted fibre is far more prevalent in the Kumaun hills than in any other locality hitherto examined. Of the two forms of twist the left-handed is, so far as present observations go, far the more widely spread. Right-handed twist is the commoner form in eastern Almora, where in certain localities it is the only form; in all other tracts where twisted fibre has been reported to be prevalent the left-handed form is the invariable rule, and although occasional trees may be found with right-handed twist, these are so rare as to constitute remarkable exceptions. In western Almora left-handed twist is almost universal. It may be mentioned that the trees in eastern Almora are taller and of finer growth than those in western Almora, though this is no doubt due in part to the fact that the population in the former is more scanty and the felling of trees for local requirements has been less extensive.

The effect of twisted fibre on the market value of the trees may be realized from the fact that trees with anything but the slightest twist are unsuitable for sawing into planks or sleepers, while badly twisted wood cannot even be split into fuel billets ; twisted poles are used to some extent by right-holders. Since considerable areas of forest exist where practically every tree is badly twisted, it can be realized that such forests are useless for the production of either timber or fuel. The case of trees to outward appearance straight-grained, while internally twisted, is perhaps the most serious of all, since additional loss is occasioned in felling and partial conversion before the twist is detected. In the forest administration report of the Kumaun circle for 1913–14 it is mentioned that in selecting sleepers for antiseptic treatment, 17 per cent. were rejected owing to twisted grain. The following instance noted by Mr. Smythies will further serve to show the extent of loss which may be occasioned through twisted fibre :

'Three years ago, when there was a big demand for sleepers, a contractor applied for some trees from a block in the valley of the Kosi river, which had never been exploited. Many of the trees in this block were obviously twisted, but many appeared magnificent specimens, with tall straight cylindrical boles of large girth. The writer personally marked the trees, and to give the experiment a fair trial picked out the finest trees available ; every tree taken the contractor himself approved as straight grown. In due course the sleepers obtained were inspected. Undoubtedly 75 per cent. would have been rejected for antiseptic treatment, while not less than 10 per cent. had actually broken across in seasoning ; many of the trees had proved to be twisted inside, with an outer ring of practically straight-grained fibre.'

The above remarks refer mainly to left-handed twists. As regards right-handed twist, Mr. Canning records the following observations :

'It is a generally accepted fact in the district that a right-hand twisted tree is not so bad as a left-hand twisted tree. So long as the commercial exploitation of tracts containing these trees had not commenced the right-holder was the only person affected. His usual custom was to fell a tree and use only a small portion from the base of the same, leaving the remainder to rot in the forest. As the twist is least towards the base, it did not affect him much. With commercial exploitation this twist is really more objectionable than the left-hand one, as sawyers fell a tree which on casual examination at the base appears fairly straight, and then having had the trouble of felling it are loth to leave the portion in which the twist is bad. Forest officers in marking such trees are apt to make bad mistakes in classifying them as fit for sawing unless great care is taken, and even with great care must often be in doubt. Until the tree is actually felled and barked, the exact degree of twist in the upper portions cannot be definitely known, and consequently until then the possibility of its being fit for sawing is doubtful. Whether right-hand twisted sawn timber warps in the same manner as that of the left-hand twisted trees is not yet determined. It appears likely that it is not so bad, but the doubt at present precludes its use for railway sleepers. In checking sleepers sawn from such trees when freshly sawn, I have often only been able to see the twist in one or two sleepers out of a batch of sixteen sawn from the same tree. If any sleeper has a wane the twist of the fibre is clear on it, but with four sawn surfaces it is very difficult to detect. The twist is not so great that the timber could not be split up into billets for fuel, but in the tracts where it is found there is no demand for fuel of this nature.'

We may now proceed to discuss the evidence available which will throw any light on the origin of twisted fibre. Right-handed twist has not yet received sufficient study, and the following remarks should be taken to apply mainly to left-handed twist.

Heredity has been suggested as being responsible for the defect. Mr. Smythies has on two separate occasions raised nursery seedlings from seed collected from trees with intense twist, and without exception the seedlings came up without any sign of twist. Again, in the Almora plantations, although the seed sown must almost certainly have been obtained from trees with twisted fibre, there being no straight-grained trees in the neighbourhood, the trees in the young crop are remarkably free from twist; they have been systematically protected from fire, grazing, and other injury, and the soil has improved owing to this protection. Mr. Canning mentions an area in eastern Almora where mother trees with right-handed twist have produced offspring with left-handed twist; here the conditions were unfavourable to the seedlings. In 1912 seedlings were raised in Dehra Dun from seed collected from badly twisted trees in Kumaun and planted on fertile arable land. By 1919 they had developed into saplings 8 to 12 ft. high. There were four survivors, and of these three showed pronounced twist from right to left, while the fourth was very nearly straight-grained. So far as evidence goes, therefore, the question of heredity has not been satisfactorily solved, and before a solution is reached the results of experiments of a more exhaustive nature will have to be awaited; such experiments have already been started in Kumaun.

Geological formation is almost certainly a contributory factor in the production of twisted fibre. Generally speaking, stratified rocks, such as tertiary sandstones, are remarkably free from twist, while laminated metamorphic rocks, and particularly mica schist, are markedly productive of twisted fibre, though there are notable exceptions. On the tertiary Siwalik sandstones flanking the Himalayan formations in the Naini Tal district, twisted fibre is almost unknown, and this is also true of the Siwalik hills farther west, where the pine grows chiefly on sandstone and conglomerate. Even in the poorest portions of the Rawalpindi district, on bare sandstone rock, the trees, though excessively stunted and gnarled, do not show any marked tendency to twist. On quartzite formations, which do not exhibit a laminated structure, the pine appears to be generally free from twist, even though growing on almost bare rock. On the dolomites of the Naini Tal hills twist is rare. In the Khanpur range of Hazara chir trees growing on hard limestone are usually stunted, but they do not exhibit any marked tendency to twist. The granites and granitic gneiss of eastern Almora are fairly free from twist; on the other hand, Mr. Smythies mentions that in the Siahidevi block near Almora, on granite, the chir trees show intense twist. The mica schists round Almora are the true home of twisted fibre. In the Kangra valley twisted fibre is fairly common on gneiss and mica schist, the trees being at the same time stunted and misshapen where the soil is shallow; the areas in question are often in exposed situations, and are subject to grazing. Trees with twisted fibre have been observed on mica schist in the Beas valley in Mandi state at an elevation of 3,200 ft., while trees growing on quartzite in the neighbouring Tirthan valley are not twisted. Some good examples of the effect of mica schist may be seen in the Siran forests of Hazara. The prevailing rock is gneiss, which decomposes into a soft free sandy soil, and on this the chir attains large dimensions and is free from twist. Occasional twisted-fibred trees occur singly or in small groups, and these are invariably found in places where the gneiss becomes schistose or gives place to mica schist. The occurrence of mica schist, however, does not necessarily result in twisted fibre, as in many parts of the Siran forests there is no sign of twist on this formation. This seems to imply that the properties in the rock which provide the stimulus necessary to induce twisted fibre in the pine are not always present; what these properties are is not known, though possibly they may include the degree of lamination and the extent or direction of folding. The general prevalence of twisted fibre on mica schist would seem to indicate that under certain conditions the laminated structure and folding of schistose rocks, in causing a gnarling or twisting of the roots, induces a twist in the stem. This might explain the fact that both twisted and straight trees are sometimes found mixed on the same area; in such cases it is possible that those trees whose roots have to struggle through folded laminations may acquire a twist, while those growing in clefts and pockets in the rock, where the roots have freer play, may tend to grow straight. There are, however, puzzling exceptions which indicate that twisted fibre is not necessarily caused by geological formation alone, and may possibly be the result of a combination of external stimuli. In the Kumaun hills Mr. Smythies has observed that twisted fibre is generally more prevalent on southern and western aspects than on northern and eastern aspects, though there are exceptions, while the intensity of twist almost invariably increases in proximity to villages; altitude has apparently little to do with its prevalence except in so far that villages are commoner at the lower altitudes than elsewhere.

Climate and wind probably have little or no direct effect, otherwise it would be impossible to explain the fact that straight and twisted trees grow side by side on the same area.

Regarding other probable factors, the following conclusions recorded by Mr. Smythies go far towards solving the question of the origin of twisted fibre:

'*Soil and aspect*, although possibly not primary causes, are undoubtedly predisposing factors causing twisted fibre. That is to say, forests which under certain treatment might grow up straight grained on favourable soil and aspects, with the same treatment might grow up twisted on unfavourable soils and aspects.

'*Fire*. A note of Mr. Canning's in the Kumaon Circle Annual Report, 1913–14, is very much to the point: "If burnt-over, one year old seedlings are generally killed outright, and older ones die back to near the ground-level, and send out a new shoot, developing a swollen carroty base. The fibres of the wood in the centre of these swollen (bulbous) bases is always twisted. This twist appears to be generally continued in the upper parts of such young plants, although it is less marked. The dying back of seedlings, whether occasioned by fire or otherwise, appears likely to be one of the causes of twisted fibre in this Circle, but it does not explain the local distribution of this defect." The writer corroborates every word of this note. There is further evidence to bear on this point. In some private estates (at Kausani) there were originally some very fine chir forests in which possibly 30 per cent. of the trees showed twisted fibre. These forests have been burnt annually for years past, despite which a thick crop of young chir plants has come up. But in this young crop the proportion of twist is 100 per cent. This establishes the fact that fire is a primary cause. Fire, however, is not the only primary cause. If it was, the regeneration in all our fire-protected forests should be coming up straight-grained, whereas in the neighbourhood of villages and where grazing is heavy, a certain portion is still coming up twisted. Cattle in these hills are frequently only taken a short way from the villages, and as we get out of the range of the cattle the regeneration loses its tendency to twist. Here then is another primary cause established.

'To put the matter in a nutshell, the primary causes may be included in the expression, "Damage during youth". In the writer's opinion, a primary cause combined with predisposing factors, in other words, *Damage during youth in unfavourable localities*, is the fundamental reason of twisted fibre in the chir forests of Kumaon. It is undoubtedly a fact that twisted fibre is acquired at a very young stage of development, since damage to an old tree or pole does not produce twist, nor is it inherent in the seed. This combination theory at least helps to explain the local distribution of this defect to a considerable extent. It should also be noted that excessive or repeated damage during the seedling stage alone, even on good localities, is sufficient to cause twist, and also plants growing on pure rock or exceptionally impoverished soil, even if they had not been damaged, are liable to twist.'

The conclusions arrived at so far indicate the lines which should be followed with a view to ameliorating the condition of things in tracts where twisted fibre is prevalent. These are the protection of all regeneration areas from fire, grazing, lopping, removal of litter, and any influence which would tend to damage the young crop or impoverish the soil. In addition, the removal of twisted stems in subsequent thinnings, as far as is feasible, should tend to improve the quality of the crop; in the case of saplings and young poles this will not always be easy owing to the difficulty often experienced in detecting the defect from the outside.

Although the complete eradication of the defect in tracts where it is prevalent may not be possible, the steps indicated should at all events go far towards diminishing its extent and improving the value of the forests; the case of the Almora plantations, already cited, furnishes sufficient proof of the value of protective measures in this respect.

NATURAL REPRODUCTION. The chir pine sheds its seed for the most part from April or May to July. Under natural conditions the seed does not lie ungerminated for any length of time if rain falls in sufficient quantity, but may begin to germinate within ten days of falling; otherwise if the weather is dry the seed lies until there has been a sufficient fall of rain. As a general rule germination commences at the beginning of the monsoon or after the early showers preceding it, if these bring sufficient rain. The readiness with which the seed germinates even under a moderately dense canopy indicates that temperature conditions are suitable for germination in the shade of the pine forests; under conditions of insufficient light, however, the resulting seedlings rapidly die off.

There are several factors which have a favourable or adverse influence on natural reproduction, and it will be convenient to consider them separately under the heads of (1) nature of seed-bearers, (2) light, (3) drought, (4) aspect, (5) topography and soil, (6) soil-covering and undergrowth, (7) fire, (8) grazing and grass-cutting.

1. *Seed-bearers.* It has already been noted that trees still in the vigour of their height-growth and possessing conical crowns with definite leaders

produce good fertile seed and are capable of affording natural reproduction to a greater or less extent ; as a general rule, however, seed in quantity sufficient to effect complete regeneration, after allowing for casualties, is not produced until the trees have acquired the rounded or umbrella-shaped crown characteristic of approaching maturity. Trees of the latter type, therefore, should be selected as seed-bearers in regeneration fellings. Neglect of this principle has in some cases led to almost complete failure in the regeneration of compartments ; examples of this are to be seen in some parts of the Ranikhet forests, where a former working plan prescribed the cutting out of mature trees in seeding fellings and the retention of medium-sized trees as seed-bearers, with the result that considerable areas have failed to restock themselves, although the conditions for regeneration are otherwise favourable. Requirements as regards seed-bearers are now better understood, and such mistakes are no longer made in the forests in question.

2. *Light.* The chir pine is a strong light-demander in all stages of its life, and under favourable conditions the more light admitted the more successful and complete will be the regeneration. The effect of light is clearly shown in Figs. 413 and 431. In the former natural reproduction has appeared in quantity in an open gap on the left, whereas it has failed to appear under a moderate overwood at the top of the slope on the right ; in the latter the mature crop on the upper part of the slope, although fairly open, is not open enough to secure regeneration, whereas the dense young natural crop below it is the result of the free admission of light by the drastic opening of the canopy, amounting in part to an entire clearance of the overwood.

It may be said that under ordinary favourable conditions five to eight good seed-bearers per acre are ample for effecting complete regeneration, and that a greater number are not only unnecessary, but may even be detrimental to the establishment of a healthy young crop. This statement, however, should not be taken to apply universally, for on hot slopes where the soil is stiff and the seedlings are liable to suffer from insolation, protective shade is essential, and the demand for such protection may outweigh the demand for light. There are instances in the Rawalpindi forests, where the slopes are hot and the soil contains a large proportion of clay, of good regeneration establishing itself under an almost complete canopy. Where protection against drought is necessary, therefore, the number of seed-bearers per acre may have to be increased very considerably ; again, on southerly aspects a larger number of seed-bearers are required as a rule than on northerly aspects. Observations further tend to show that in crops of poor quality the spacing of seed-bearers can be a good deal closer than in crops of good quality, the main reason being that the trees are larger and the crowns are broader and denser in the latter than in the former. Fig. 424 shows natural reproduction establishing itself on a hot south-westerly slope in the Rawalpindi forests under cover of an overwood which in a cooler and shadier situation would be dense enough to prevent its establishment ; under these conditions the crop does not regenerate in large even-aged masses, but tends to form groups differing in age. Exceptional cases, however, occur in which reproduction will spring up even on cool aspects under a fairly complete canopy. It is noteworthy that chir pine regeneration, in common with that of other conifers, persists under the shade

FIG. 424. Natural reproduction of *Pinus longifolia* establishing itself under moderate shade on a hot south-westerly aspect, Rawalpindi Punjab.

FIG. 425. *Pinus longifolia* forest not fire-protected, and characterized by an absence of natural reproduction, Jaunsar, United Provinces.

FIG. 426 Natural reproduction of *Pinus longifolia* established on an area always open to fire and grazing, owing to favourable conditions afforded by a loose porous soil on a gentle slope. Kumaun hills.

of oak for a longer time than it does under equally dense shade of its own kind ; the reason of this is possibly that the soil under an oak crop is ordinarily richer and moister than that under a pine crop, and the young pine rètains its vitality for a longer time. Examples of the direct influence of light may be seen in the case of mixed forests of chir and oak where the latter is lopped or browsed ; here pine regeneration usually tends to spread in the gaps created by the mutilation of the oak.

3. *Drought.* In certain localities the mortality among *Pinus longifolia* seedlings owing to insolation is so excessive that regeneration may be entirely prevented ; in some cases even germination fails. This is particularly the case on stiff bare clayey soil, or on shallow soil overlying limestone, on hot southerly aspects. The failure of regeneration on hot slopes where the soil is stiff and clayey is well exemplified in many parts of the Rawalpindi forests, where the scarcity of grass and undergrowth on some of the hotter slopes aggravates the ill effects of insolation ; in such places it has been found that if the canopy is heavily opened out complete failure of reproduction is the result. In the Khanpur forests of Hazara natural reproduction may similarly fail on hot aspects where there is only a shallow soil overlying limestone. The best measures for aiding reproduction in such places are the retention of grass and undergrowth if present, the hoeing of the soil where it is stiff, to enable the roots to penetrate to some depth, the retention of side shade by working in groups or strips, and encouragement of a mixture of broad-leaved species if any can be got to grow.

4. *Aspect.* As a general but by no means universal rule, regeneration is better on northerly than on southerly aspects, except near the upper limits of the pine, this being attributable for the most part to the greater protection against drought afforded to seedlings on the former aspects as compared with the latter ; it is possible also that the beating of the monsoon rain may account in part for the absence of regeneration on some of the bare south-western slopes.

The question of aspect is intimately bound up with questions of soil, insolation, denudation, undergrowth, associate species, light, and other possible factors such as local topography. In the Rawalpindi forests, where conditions for regeneration are on the whole by no means favourable, aspect with its attendant factors appears to play an important part on natural reproduction, and Mr. Jerram [1] has recorded some interesting observations on the subject. He notes that on cleared boundary lines running north and south regeneration is usually absent, while on lines not exposed to the south or south-east it is often excellent. He has also observed that while on southerly aspects regeneration is capable of establishing itself under a fairly dense overwood, it does not necessarily follow that it fails on northerly aspects under similar conditions ; thus he cites an instance in Bagla protected forest, on a north-north-westerly aspect, where good regeneration appeared under a nearly mature overwood in which the crowns of the trees were almost touching, and where the regeneration was excellent in places where they were only 15 yds. apart. This case shows that in dealing with aspect and its attendant factors we are met with exceptions to the ordinary rule, and that generalizations are apt to be misleading.

[1] Revised Working Plan for the Murree Kahuta Forests, 1915.

5. *Topography and soil.* *Pinus longifolia* reproduces well as a rule on well-drained porous soils, such as those containing a fair proportion of sand or fine mica. This is particularly the case on moderate or gentle slopes and rounded spurs; there are many examples of profuse reproduction in such localities in the Naini Tal division (see Fig. 432); cases even occur where reproduction establishes itself well on loose soils in spite of grazing and fire (Fig. 426). On flat places with bad drainage, on stiff clayey soils, and on shallow soil overlying limestone, the pine regenerates badly. This is also the case on bare shaly slopes without any soil-covering, where the seedlings are washed away and regeneration is usually absent; in such places the presence of tussocks of grass is of great assistance in the establishment of seedling growth. On loose friable shale decomposing into a soft soil resembling coarse sand, natural reproduction is often plentiful, as in parts of the Simla hills. Natural reproduction sometimes springs up in great abundance on abandoned cultivation, where the loosening of the soil is favourable to the germination and growth of the seedlings; in such places, however, it fails to appear where the drainage is bad. A marked feature in the case of pine crops on old terraced fields is the tendency of the trees to come up in lines along the tops of the walls separating the fields, whither the seed is washed by rain. The pine readily takes possession of new ground on landslips in the loose tertiary sandstone and conglomerate formations of the Siwalik hills and the flanks of the outer Himalaya.

6. *Soil-covering and undergrowth.* The presence of a thick layer of undecomposed needles, characteristic of chir forests which have been protected from fire and grazing for some years, is inimical to reproduction, and in some cases is responsible for its entire failure. Experiments to demonstrate this have been in progress in Dehra Dun within recent years, and it has been proved that not only does the seed frequently fail to germinate on the top of a thick layer of needles, but has been destroyed, before germination was possible, by ants, which were found to be more plentiful on the needles than on bare ground, while on grass-covered ground there were still fewer ants. If a fire occurs in a chir forest in a good seed-year, before the fall of the seed, the ground at the end of the following rains is usually found to be carpeted with vigorous seedlings, the burnt layer of needles acting as a good germinating bed, and the soil, enriched by the ashes, being in a condition to stimulate the growth of the young plants. On a deep layer of needles, even if germination takes place successfully, the subsequent mortality among the seedlings is often considerable owing to the difficulty experienced by their roots in reaching the mineral soil. In some respects, therefore, the use of fire and the admission of limited grazing may be useful in promoting regeneration. The accumulation of débris from fellings, where plentiful, acts as a serious hindrance to reproduction, and the measures described for the collection and burning of such débris in deodar forests are in certain cases applicable to chir forests.

The presence of a fairly heavy growth of grass on moderate to steep slopes is by no means inimical to chir reproduction, a fact which is proved by the abundance with which the pine regenerates on the grassy hill-sides of the Chakrata division. Fig. 430 shows an example of excellent reproduction which has established itself in such an area. The grass, indeed, is more of a protection than otherwise, as may be realized by comparing the success of reproduction on even the hottest grass-covered slopes of the Chakrata division with that on those slopes on hot aspects in the Rawalpindi forests which are destitute of soil-covering. On bare slopes with scattered tussocks of grass it is specially noticeable that seedlings are to be found mainly in the shelter of the tussocks, against which the seed is washed before or during germination. A heavy growth of grass on flat ground often denotes bad drainage; in such places reproduction fails. In a good seed-year burnt grassy areas, like burnt needle-covered areas, become covered with seedlings where there are sufficient seed-bearers.

The effect of shrubby undergrowth on reproduction depends greatly on the locality. If not too dense it is as a rule beneficial, especially on hot or unstable slopes, as it affords protection against the sun and prevents the wash of the surface soil. In grazed areas, also, the presence of undergrowth species which are browsed may be the saving of the less palatable pine seedlings. On hot aspects in the Rawalpindi forests the undergrowth, chiefly *Dodonaea* and *Berberis*, is of the greatest benefit; Fig. 424 gives an instance of how pine reproduction may establish itself by the aid of the undergrowth in such localities. Among the densest undergrowth species is *Myrsine africana*, which is characteristic of moderate elevations in the same division. Where it is not too dense it appears to be more of an assistance than otherwise, but over considerable areas, particularly in cool situations, it effectually prevents reproduction where it forms thick masses. In some localities, for instance in the Kangra valley, where there is a flourishing undergrowth of *Carissa spinarum*, *Dodonaea viscosa*, and other shrubs, if the opening of the canopy is not quickly followed by pine reproduction, it usually happens that the undergrowth is encouraged by the admission of light to such an extent that reproduction is effectually prevented until special measures are taken for the removal of the undergrowth. The masses of herbaceous and shrubby growth often found in moist situations on cool aspects, where the chir is usually mixed with oak and other broad-leaved species, are always adverse to the natural reproduction of the pine.

7. *Fire*. Under ordinary conditions fire may be regarded as the most destructive agency with which the natural reproduction of the chir pine has to contend. Forests subjected to frequent fires are doomed to eventual extermination, owing to their failure to regenerate themselves, and the introduction of successful fire-protection is followed as a matter of course by good natural reproduction, provided that the canopy is sufficiently open and that such abuses as excessive grazing and grass-cutting are kept in check. The effect on natural reproduction of some years of fire-protection on an area where the ground was previously covered with nothing but grass is strikingly exhibited in Fig. 430, which may be compared with Fig. 425, showing a forest burnt annually, in which not a seedling is to be found; this is typical of many localities. Further examples of the results of fire-protection may be seen in the spread of the pine in the fire-protected sal and miscellaneous forests of the outer Himalaya.

From this it might be concluded that under no circumstances is it possible to effect natural reproduction except in fire-protected areas. This, however, is not necessarily the case, for there are, particularly in the Kumaun hills, various instances where reproduction has established itself successfully in areas subjected to annual burning. In such cases, however, the ground is kept so free from grass and undergrowth by grazing, that there is little or nothing to burn, and these areas may almost be considered to be automatically fire-protected ; the matter, therefore, resolves itself rather into a question of the conditions under which natural reproduction is possible in conjunction with grazing, and it is therefore in areas with a loose free soil on gentle slopes that we find instances of successful reproduction in spite of grazing and annual burning. It is noteworthy that reproduction will not establish itself under these conditions except in gaps of considerable extent, since it is only in such gaps that the ground is free from an inflammable covering of dead needles. Fig. 426 shows a young crop established in a grazed area which has never been fire-protected ; it will be noticed that there is no inflammable undergrowth.

In an article entitled ' Some Aspects of Fire-Protection in Chir Forests ',[1] Mr. E. A. Smythies, while commenting on the extraordinarily successful results of fire-protection on chir reproduction in the Naini Tal forest division, quotes examples of the apparent anomaly just mentioned, and makes the further observation that in his experience areas which are brought under fire-protection after years of burning tend to regenerate in great profusion, whereas in those areas which have been successfully fire-protected for many years natural reproduction is becoming more and more difficult to obtain, doubtless owing mainly to the thick accumulation of needles with its adverse physical and chemical effects. The conclusions arrived at by Mr. Smythies are (1) that after years of burning, fire-protection gives an extraordinary and universal stimulus to regeneration ; (2) that successful regeneration is possible under the most favourable conditions without fire-protection ; (3) that long-continued fire-protection has an adverse effect on regeneration.

In considering the general effect of fire-protection on the natural reproduction of the chir it would be well, however, to avoid the risk of allowing exceptions under specially favourable conditions to obscure the main question. and we may accordingly accept the truth of the general statement that in systematic forest operations the introduction of fire-protection is essential for the successful regeneration of chir pine forests.

8. *Grazing and grass-cutting.* The question of damage done by grazing in *Pinus longifolia* forests is one on which opinions vary considerably owing to the widely different conditions under which local observations have been made. Many examples can be cited where excellent natural reproduction has established itself in spite of cattle-grazing as distinct from goat-browsing, provided the grazing is not excessive and other conditions are favourable. Fig. 426 shows to what extent regeneration is possible on a grazed area where the soil is free and not stiff, the slope is moderate, and there was a crop of palatable grass on the ground when the seedlings were young. Contrast with this the condition of things prevailing in Kāngra, where a large proportion of the state forests are subjected to excessive grazing, largely by goats and buffaloes, resulting in an almost entire absence of reproduction. Figs. 427 and

[1] Ind. Forester, xxxvii (1911). p. 54.

FIG. 427. *Pinus longifolia* forest open to excessive grazing, showing a complete absence of natural reproduction, Kangra valley.

FIG. 428 Area closely adjoining that shown in Fig. 427, but closed to grazing, and showing good reproduction of *Pinus longifolia*.

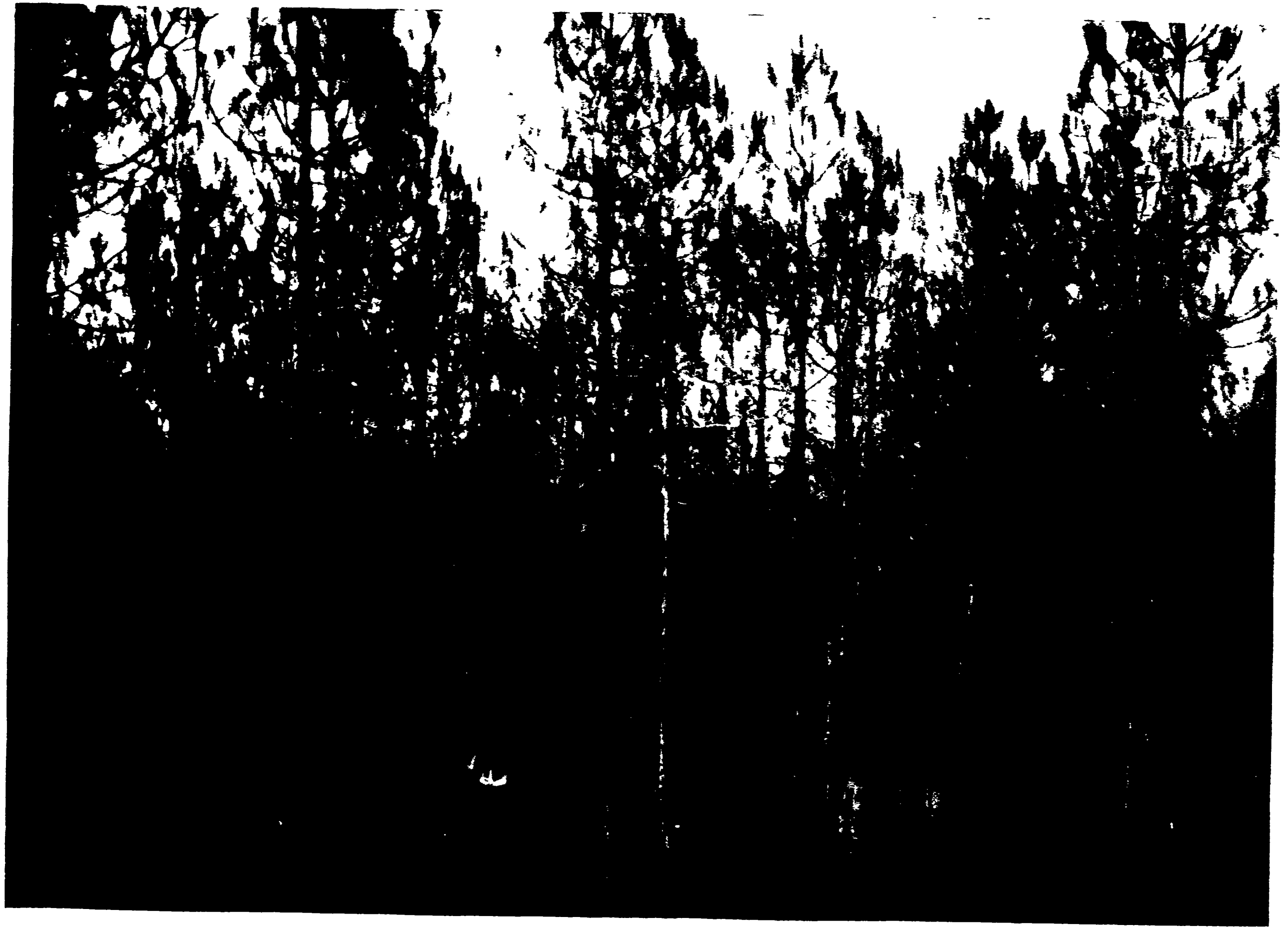


FIG 429 *Pinus longifolia* plantation 19 years old. Baldhoti Almora . mean girth 15 3 in . mean height 27 ft number of stems per acre 980. solid volume per acre 1 436 cub ft

428 show two closely adjoining areas in the Kangra valley; the former is open to grazing, and characterized by an entire absence of reproduction, while the latter is closed to grazing, and a promising young crop has established itself. It may be mentioned that grass-cutting in areas under regeneration is always harmful until the seedlings have grown well above the grass.

The chief advantages claimed for grazing in chir forests are (1) that it keeps down dense undergrowth which prevents reproduction; (2) that owing to the disturbance of the soil and the breaking up of the thick accumulation of needles, germinating seedlings are enabled to send their roots without difficulty down to the mineral soil; (3) that inflammable grass and undergrowth are kept down and damage by fire is thus lessened. It may be mentioned that these benefits can be secured to some extent by the system of controlled burning. The main disadvantages of grazing are (1) that the trampling of heavy animals, particularly buffaloes, destroys young seedlings, hardens the soil, especially if clayey, preventing free germination, and on steep hill-sides causes erosion and the washing away of seedlings; (2) that the young pines are browsed down.

On steep hill-sides, especially where the soil is friable, and on stiff soils, the damage done by trampling is aggravated. On difficult slopes, inaccessible to cattle, regeneration is often found to establish itself readily, while it is retarded in the more accessible places. On gentle slopes where the soil is free and sandy, regeneration is sometimes found to establish itself well in spite of grazing.

Where there is an abundance of grass or edible undergrowth the damage done to the chir is considerably lessened. Among favourite plants may be mentioned *Indigofera* spp., *Lespedeza* spp., *Desmodium* spp., *Carissa spinarum*, wild roses and brambles, and to some extent *Berberis* spp. Even goats will avoid *Dodonaea viscosa*, and also as a rule *Myrsine africana*. Where the chir is mixed with oak the former escapes browsing to a much greater extent than the latter, often filling up blanks where the oak and other broad-leaved species are browsed down and remain in the form of bushes; as regards the species of animal, buffaloes are decidedly harmful, for in addition to the fact that they browse the young pine, their weight aggravates the damage done by trampling, especially on steep hill-sides. Other bovine animals are less harmful, and where grass is plentiful the damage done by them is not great, provided the grazing is moderate: excessive cattle-grazing, however, entirely prevents regeneration. Sheep differ considerably from goats in their tastes, and prefer grass and herbs, provided these are not dried up, to any other form of diet: pine seedlings are not liable to much damage by these animals if any other form of fodder is available in plenty. Goats, although they do not actually prefer chir seedlings to other forms of diet, will eat them readily rather than go any distance in search of other food, and as they attack the buds and young shoots, avoiding the old stiff needles, the damage they do may be considerable. Goat-browsing is the cause of an almost total absence of natural reproduction in many of the protected forests of the Kangra district.

The incidence of grazing must necessarily vary much with local conditions, and particularly with the amount of grass and edible shrub growth present, and general figures, even if available, could have little practical application. Trials in Kangra have shown that very serious damage may be occasioned by as small an incidence as one goat to 4 acres within a comparatively short period of time.

The grazing question may be summarized by saying that grazing in chir forests not under regeneration is not harmful, but is if anything beneficial, except on unstable hill-sides and, for some years prior to the commencement of regenerative operations, on stiff soils. In areas under regeneration, although special instances can be cited where cattle-grazing in moderation has done little harm, in general grazing and grass-cutting should be strictly prohibited; this applies with special emphasis to grazing by goats and buffaloes. After reproduction has been established and the young crop is out of reach of danger, grazing and grass-cutting would probably be of advantage in most cases, in keeping down inflammable undergrowth and grass, and preparing the way for the first controlled burning. In practice, however serious the damage by grazing may be, questions of rights and privileges must be taken into account, and it may be difficult or impossible to close for regeneration more than a small proportion of the total area under management. This is a strong argument in favour of concentrating regenerative operations, working for even-aged crops, and shortening the regeneration period to the minimum compatible with safety.

ARTIFICIAL REPRODUCTION. *General.* The chir pine can be raised in the nursery and transplanted with success, provided due care is taken during and after transplanting, and plantations, as opposed to direct sowings, can be made successfully on a small scale in favourable localities; the tree is accordingly often planted in gardens, on roadsides, and in small plantations. For forest operations, however, direct sowing is much to be preferred, not only on the ground of economy, but also as being more successful, since transplanting is attended with great risk of failure in localities such as those in which the pine has ordinarily to be grown on an extensive scale.

The chir has been sown or planted in many localities outside its own habitat, for example in the Nilgiris, in Baluchistan, and even in the Central Provinces, where sowings have so far succeeded well on the Supkhar plateau of the Balaghat district. In the Nilgiris, although the growth of the trees is not good, the plantations, as such, may be considered on the whole to be fairly successful. The pine has been planted in gardens in many parts of the plains of northern India.

Collection of seed. The cones should be collected about the month of March and placed in the sun until they are thoroughly open. They should then be well shaken and beaten until the seed is all extracted. This can be done by placing them in an open box, the bottom of which is composed of wire-netting; the box is then oscillated sharply backwards and forwards by two persons who grasp handles fitted like a pair of shafts at each end of the box, and the seed is thus extracted and falls through the wire bottom of the box on to a sheet placed below. In a good seed-year seed can be collected at a cost of about Rs. 10 per maund of $82\frac{2}{7}$ lb. At Dehra Dun the seed has been found to be very subject to the attacks of ants, and it has been found advantageous to coat it before sowing with red oxide of lead; this protects it effectively in the seed-beds.

Planting. The seed-beds should consist of light unmanured soil, stiff clayey ground being avoided. The soil should be dug up to a depth of 1 ft.

or more and levelled, the beds being well raised. The seed should be sown in March or April in shallow drills 6 in. apart, and lightly covered with fine earth, and the drills should be watered every two or three days in the evening, care being taken not to give too much water. The seedlings will usually be ready for pricking out in July ; this should be done in lines about 9 in. apart, the plants being spaced 6 in. apart in the lines. They may be removed from the nursery and planted out at the beginning of the following rains, or kept another year in the nursery ; in the latter case they should again be pricked out in lines about 1 ft. 3 in. apart, the plants being spaced 1 ft. apart in the lines.

If basket planting is decided on the seedlings may be pricked out into baskets during the first or second rains, according as the intention is to plant out seedlings one year or two years old.

Both in the seed-beds and in the nursery lines careful weeding is necessary, and the ground should be kept loose to prevent caking.

Experiments at Dehra Dun have shown so far that the best time for transplanting is early in November, but in some localities success has been attained by planting early in the rains, about July. Care is necessary to avoid injury to the long taproot, for which reason planting should be done with balls of earth. Basket planting is also successful, but is expensive. A spacing of 5 ft. by 5 ft. will ordinarily be found sufficient.

Direct sowing. Direct sowing may be considered to be the only practicable method of carrying out the artificial regeneration of the pine on a scale extensive enough for forest purposes. Such sowings have been carried out in many localities, chiefly in patches varying in size and spacing or in lines, which on hilly ground should follow the contours. As a rule sowing in small patches or in contour lines has given good results, but on steep, bare slopes where the wash of water and débris is considerable, these have sometimes been found unsatisfactory owing to the scouring of water and the accumulation of débris ; in such places hoed patches at least 5 ft. square are generally more suitable. In all circumstances good drainage is essential, and it is advisable in patch sowings to make the surface of the patches slope slightly downwards to their outer edge or to cut a small drainage channel leading away from them. In selecting patches, advantage should be taken of the shelter afforded by bushes, tussocks of grass, banks, and large stones. The soil in the patches should be worked up to a depth of about 6 in., and the seed should be sown in June, shortly before the commencement of the rains. About three or four seeds per square foot of patch is a rough estimate of requirements. In dry, hot localities care should be taken not to remove grass from around the patches during the first few years, though where very heavy it may be bent back or slightly cleared from over the seedlings where necessary.

Afforestation works. The Baldhoti and Kalimath plantations at Almora, lying at an elevation of 5,000 to 6,250 ft., furnish a good example of successful afforestation with chir pine by means of patch sowings, under conditions by no means favourable. The plantations form two blocks the area of which aggregates about 1,000 acres. Sowings were commenced in 1875 on what was then a barren treeless hill-top with poor, dry shallow micaceous or sandy soil resting on mica schist, and situated for the most part on hot aspects varying from south-west to south-east.

The system of sowing followed was that of small patches spaced at an average distance of about 5 ft. apart, and the precautions noted above were taken as regards their selection and treatment. These barren slopes have in this way been successfully afforested, as may be judged from Fig. 429, which gives a typical view of one of the plantations. Thinnings have been in regular progress for many years, and the material finds a good sale as fuel for the supply of Almora. This, together with the sale of grass, brings in a fair revenue. The following average figures for the nine years 1905–6 to 1913–14 show that even in their present immature condition these plantations yield a very fair surplus :

	Rs.	*a.*	*p.*	
Gross revenue	1	6	0	per acre
Expenditure	0	12	0	„
Surplus	0	10	0	„

The results of measurements which I made in 1911 in fourteen sample plots laid out in crops of different ages in these plantations are given below. The figures show considerable variation in the quality of the crops, the majority of which fall into quality class II (as defined on pp. 1079–80); this is by no means unsatisfactory considering the nature of the locality, and serves to show that the chir pine can be grown successfully on ground where most species would have little chance of surviving.

Pinus longifolia : measurements made in 1911 in sample plots laid out in Baldhoti and Kalimath plantations, Almora.

Serial No.	Age.	Mean girth.	Mean height.	Number of stems per acre.	Solid volume per acre.	Quality.	Aspect.	Locality.
	years.	ft. in.	ft.		cub. ft.			
1	12	0 6·2	9	3,526	490	II–III	S.	Baldhoti C 6
2	12	0 7·6	13	1,947	549	II	E.	„
3	15	0 8·7	15	1,750	614	II	S.	Kalimath C 1
4	15	0 10·5	16	1,220	529	II	SE.	„
5	15	0 10·8	18	1,650	822	II	SE.	„
6	19	0 11·0	17	1,140	646	II	S.	Baldhoti C 4
7	19	0 11·6	20	920	585	II	S.	„
8	19	1 0·6	20	1,160	1,012	II	S.	„
9	19	1 3·3	27	980	1,436	I	S.	„
10	23	1 7·0	31	513	1,184	II	S.	„ C 3
11	23	1 7·9	29	560	1,528	II	S.	„
12	36	0 11·2	23	1,220	1,063	III	S.	„ C 1
13	36	1 5·3	31	820	1,786	III	S.	„
14	36	2 0·8	47	436	2,386	II	SW.	„

The Almora plantations, as well as contour sowings in lines about 5 to 6 ft. apart, carried out with success in other parts of the Kumaun hills, show that excellent results can be attained in the artificial regeneration of the chir pine at a remarkably low cost. A maund (82⅔ lb.) of clean seed ordinarily suffices for about 5 to 6½ acres, and costs about Rs. 10 to collect, that is, the cost of collection may be placed at Rs. 1–8–0 to Rs. 2 per acre. Labour for the preparation of the ground and sowing costs about Rs. 2–8–0 to Rs. 3 per acre, so that the total cost works out at about Rs. 4 to Rs. 5 per acre. In the Rawalpindi division recent experiments in hoeing completely—that is, not merely in patches or lines—to a depth of 8 in. cost Rs. 2 per acre, though on a larger scale with less supervision the cost would probably be somewhat higher. Experimental sowings carried out in 1913 in the same division proved even cheaper. An area of 40 acres, in which fellings had been completed, was burnt, and seed was sown in hoed lines 2 to 3 ft. apart in the beginning of July. An early monsoon prevented the soil-covering from being thoroughly burnt, and partly vitiated the results, though the seed germinated well where the surface and grass had been properly burnt. The cost of burning, collection of seed, hoeing lines, and sowing amounted to only Rs. 1–8–0 per acre.

SILVICULTURAL TREATMENT. The silvicultural treatment of the chir pine can best be considered under two separate heads: (1) silvicultural systems, (2) tending operations.

1. *Silvicultural systems.* The chir pine has hitherto been worked either as uneven-aged forest under some form of the selection system by single trees or groups, or as even-aged forest under regeneration fellings by periods. Owing to the light-demanding character of the pine and its tendency to regenerate where possible in even-aged masses, systems of the selection type have proved unsuitable, and are being discarded in revised working plans in favour of systems of regeneration fellings by periods with the view of producing even-aged crops. It is true that where selection fellings by groups are carried out the silvicultural requirements of the tree are to some extent provided for, but the diffusion of work renders subsequent tending difficult, and the suppression of much of the young stock is almost inevitable; damage by fire is intensified in the uneven-aged crops produced by such a system, while the concentration of fire-protection on areas under regeneration, with controlled burning for protective reasons in other areas, is impossible. Again, resin-tapping operations can be conducted more efficiently and economically when concentrated on definite areas than when scattered widely, as they would be under any form of the selection system. These considerations alone, apart from the question of economy of working under a concentrated system of regeneration and tending, have led in all properly organized chir forests to the abandonment of the selection system in favour of the system of regeneration fellings by periods. The latter system has entirely justified itself in practice, and has been in operation for many years in the forests of Ranikhet and Jaunsar and in the leased forests of Tehri Garhwal.

Under the general scheme of working the whole workable area is divided into two main parts: (1) periodic block I, that is, the portion to be regenerated first within a definite period of years, and (2) the remainder. The former requires complete protection from fire, grazing, and other forms of injury; the latter may, if necessary, be opened to controlled burning and grazing. In the former regeneration fellings are carried out; in the latter subsidiary fellings are made for the utilization of mature trees, the improvement of the existing stock, and where possible the more speedy attainment of the normal forest. In the existing state of the natural chir forests, which are almost without exception in a highly abnormal condition, the allotment of crops to periods, even tentatively, is a somewhat difficult matter. In the Chakrata division, comprising the forests of Jaunsar and the leased forests of Tehri Garhwal, there is an excess of open mature crops; in many of the forests of

Kumaun there is an excess of pole and sapling crops, while in Rawalpindi there is a total absence of woods up to thirty-five years old, such growth being scattered amongst older stock, and a large excess of woods thirty-five to fifty-five years old. Similar abnormality occurs throughout the region of the chir pine, and mature dense woods of considerable extent, such as those found on the continent of Europe, are unknown. Considering the irregular condition of the existing chir pine forests, the introduction of a regular system of management requires the utmost elasticity of working, a question which is gone into at some length in chapter viii of my note on *Pinus longifolia* referred to above.

Considering the value of resin as a minor product, the general scheme of working should, where possible, include provision for resin-tapping operations. As this involves certain complications, the management of resin-tapping is dealt with separately below. Resin-tapping may, for instance, have a decided influence on the formation of felling series, since there is a definite minimum number of trees which can be tapped profitably in one particular locality, for which reason the indefinite multiplication of felling series is impracticable. Resin-tapping, again, tends to increase the rotation if financial considerations are taken into account, since the out-turn of resin increases with the size of the tree until its vitality is impaired through age or otherwise.

In existing working plans the rotations adopted vary from 90 to 160 years, and the regeneration periods from 20 to 35 years, though a period as short as 20 years has been found in the Ranikhet forests to be too short.

The fixing of the regeneration period is a matter of considerable importance. There are obvious advantages in shortening it as far as is practicable. By so doing the area under regeneration at one time, that is, the area where special efforts are necessary to exclude fire and to enforce closure to grazing, is reduced to a minimum, while the hardy light-demanding gregarious pine receives early freedom from overhead cover and is encouraged to form the even-aged masses in which it thrives so well; again, the longer the period the greater the departure from the ideal normal forest. In fixing the period in actual practice, however, there is one consideration which outweighs all others, and that is, that the period must depend on the time required for complete regeneration to be effected and for the young crop to establish itself and become large enough to escape destruction by fire. This period varies with local conditions, but if we start with an unregenerated area it is improbable that it could be fixed at less than about twenty-five years, while in many localities the young crop could not be considered safe under thirty or even thirty-five years, and that only with carefully controlled burning at the end of the period. Where existing advance growth covers the ground the period could doubtless be shortened, and in many localities it would be possible and advisable to remove the overwood over groups of advance growth early in the period; taking the periodic block as a whole, however, it is the youngest regeneration that has to be considered.

In this connexion the use of artificial reproduction by sowings as a means of supplementing natural reproduction has perhaps not received the attention it deserves; such sowings, which can be carried out at a comparatively cheap rate, should assist materially in shortening the regeneration period and facilitating the attainment of the normal forest. Where seed-bearers are absent these

FIG. 430 Uniform seeding felling in fire-protected *Pinus longifolia* forest, resulting in an even-aged young crop Jaunsar

Fig. 431 Uniform regeneration fellings in *Pinus longifolia* forest. Kumaun hills young

sowings could be carried out at the beginning of the period, and elsewhere in places where natural reproduction is not likely to appear in sufficient quantity they might be made fairly early in the period.

The conduct of the regeneration fellings is a matter of great importance, and in the present irregular state of the chir forests, where conditions vary from place to place within narrow limits, anything in the way of rigid prescriptions should be avoided. The number of regeneration fellings should not ordinarily be fixed. In the open condition of most of the existing mature crops preparatory fellings are unnecessary. The seeding fellings are of great importance, and should be carried out as early in the period as is practicable, one or more secondary fellings, the last of which is termed the final felling, being carried out when and where the state of the reproduction requires them, with a view to the ultimate complete removal of the overwood, if possible, by the end of the period.

Under average favourable conditions, the experience of many years now shows fairly clearly that the correct method of carrying out seeding (or first) fellings is somewhat as follows :

1. The larger trees, with sound, well-developed crowns, should be selected as seed-bearers, and in the case of uniform fellings should be spaced at about five to eight trees per acre (say 25 to 30 yds. or more apart) ; only if no trees of this type are available should smaller trees be retained, in which case more trees per acre should be left. On hot aspects it may be advisable to leave considerably more trees per acre, or the fellings may be made in strips or in comparatively small groups.

2. Smaller trees and poles, if isolated or thinly scattered, should be felled to create blanks for regeneration. Well-stocked groups of promising poles should not be felled, but should be left to form part of the future crop.

3. Well-established advance growth of saplings and poles should be completely freed from overhead cover.

4. Opportunity should be taken to remove unsound or badly shaped trees and poles of any size, as well as trees of inferior species whose removal is desirable.

These rules are not intended to apply rigidly, but may be taken as a basis for the framing of rules to suit local conditions.

Generally speaking, it is possible to classify regeneration fellings into three main types—uniform, group, and strip fellings. Uniform fellings involve the more or less even spacing of seed-bearers ; their execution is simple, and wherever conditions are at all favourable they should be adopted in preference to other types of fellings. They have given remarkably good results in the fire-protected forests of the Chakrata division and in the Kumaun hills, especially on areas previously burnt. Fig. 430 shows an admirable example of the result of a uniform seeding felling in the Chakrata division. Fig 431 shows two adjacent areas in the Kumaun hills, one containing mature forest not yet regenerated, and the other a young regenerated crop obtained by uniform fellings. Fig. 432 shows a regenerated young even-aged crop, resulting from uniform fellings, awaiting the final felling within five years.

Group fellings, as applied to the chir pine, may ordinarily be taken to mean the removal of trees over and around groups of promising advance growth. The group system as exemplified in Europe would not be applicable in all its details under Indian conditions, as it demands an intimate study of the ground, the felling of a few trees at a time repeated at frequent intervals round each gap, and continuity of action to a degree not attainable in India under present conditions. Where fire-protection is a difficult matter, fellings in groups with a long regeneration period, tending towards uneven-aged reproduction, are sometimes considered to be a safeguard, as the groups of larger saplings and poles might escape destruction where an even-aged young crop would be destroyed. It should be remembered, however, that fires in uneven-aged crops are liable to develop into crown fires, and to do immense damage. On hot aspects natural reproduction springing up in comparatively small gaps has the advantage of side protection from the sun, which is not the case under uniform fellings.

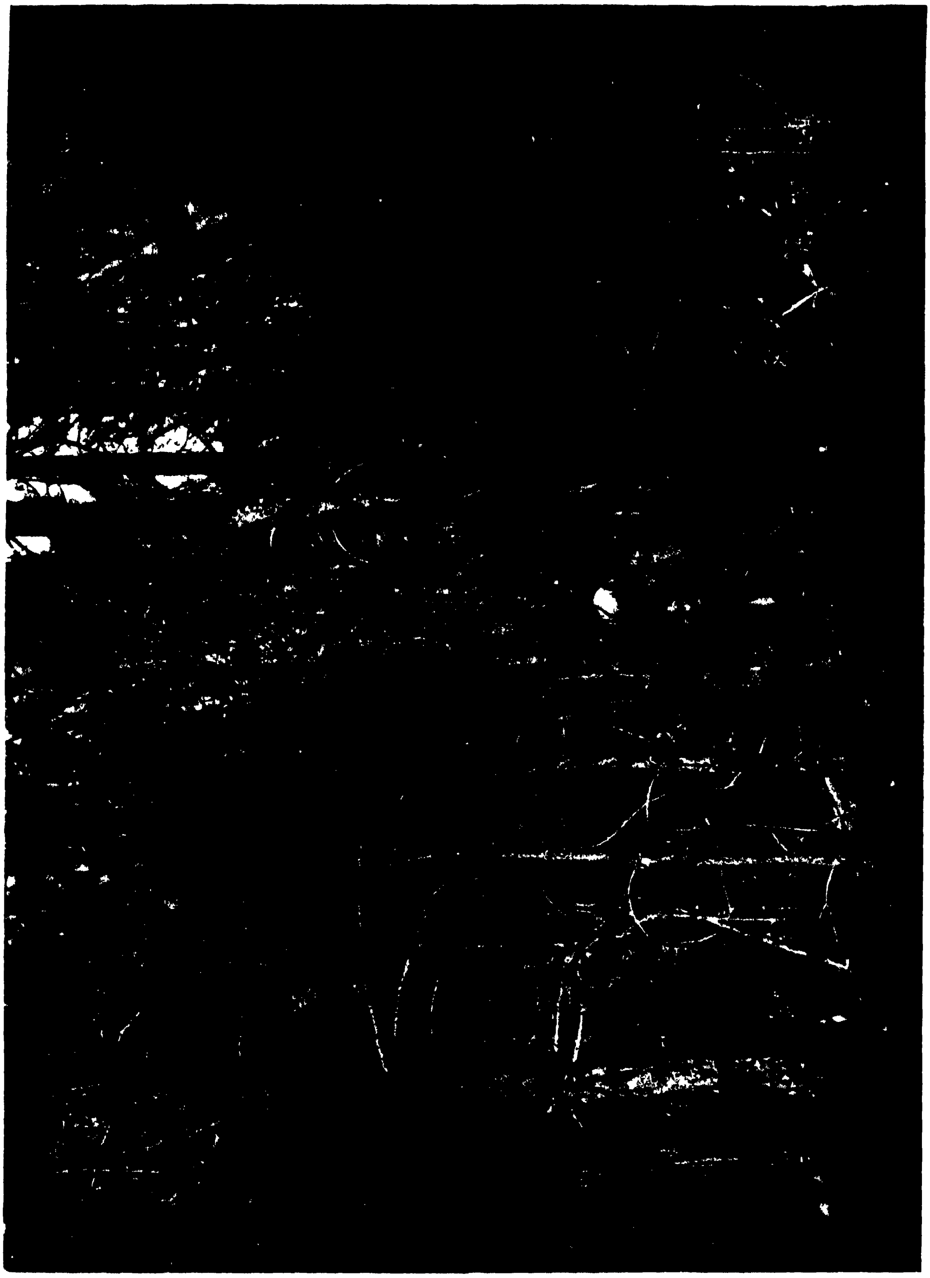
Strip fellings have not yet been tried in chir forests, but they may prove a possible means of regenerating hot slopes where the young crop requires side protection from the sun in its earlier stages ; such fellings would proceed against the direction from which the sun does most harm, and would follow a general downhill course, the strips following the contours or being inclined to them with the object of securing side protection from the sun.

Apart from the regeneration fellings, it may be necessary to carry out supplementary operations in order to secure complete reproduction ; these will consist usually of burning felling débris and accumulations of needles in the manner described for the deodar (p. 1122), followed by sowing.

2. *Tending operations.* The chir pine normally tends to regenerate in even-aged masses, and where conditions for regeneration are favourable the density is very great and the struggle for existence severe. Fig. 432 gives an idea of the density of young fire-protected sapling crops on loose, sandy soil. Thinnings in such crops require to be commenced in most cases by the time the crop is fifteen years old ; the operation comprises mainly the removal of forked or otherwise undesirable stems, and, where there is risk of fire, of dead and suppressed material. The latter work may be costly, but if controlled firing is to be carried out subsequently it is advisable to remove as much inflammable material as possible before commencing the first burning. True cleanings, that is, the removal of inferior species hampering the young crop, are not ordinarily necessary to any great extent in chir forests, except possibly in certain weed-covered areas on cool aspects, or where the pine is making its way through cover of oak and other species.

Existing working plans are somewhat reticent on the subject of thinnings, owing to the fact that dense pole and tree crops are at present the exception rather than the rule. In future years, however, the necessity for thinnings will become more apparent, when the dense sapling crops which have sprung into existence owing to fire-protection and systematic management have reached the pole and tree stage. It is true that a strong light-demander like the chir tends to thin itself out in the struggle for existence, and it is also true that where material from thinnings is unsaleable and the dead wood is left lying on the ground, danger from fire is greatly increased. At the same time, if regular thinnings in congested pole crops are not carried out, there may be considerable loss of increment during the struggle for existence, leading to

FIG. 432 *Pinus longifolia* forest regenerated by uniform fellings in the final stage. Naini Tal division seed-bearers being heavily tapped prior to felling.



a lengthening of the rotation with its attendant financial loss, while the value of the crops may deteriorate through the survival of undesirable stems ; finally, the risk of fire owing to the accumulation of dead material in the standing crop may be just as great as if this material lay on the ground. The importance of crown development for the production of seed in quantity has already been alluded to, and thinnings are necessary to assist this development.

Where resin-tapping operations are carried out, thinnings in congested crops are required in order to place the trees in a free enough position to be capable of yielding resin in quantity. This principle is well understood in the maritime pine forests in the neighbourhood of Bordeaux, where heavy thinnings are carried out in the interests of resin-tapping.

As already mentioned, it is reckoned that early thinnings, combined where necessary with cleanings, will in most cases be required by the time the young crop has reached an age of fifteen years, if not sooner. Little practical experience has as yet been gained regarding the frequency and intensity with which subsequent thinnings should be carried out, but judging by the results of thinnings made in sample plots within recent years, it appears certain that they should be repeated at least once in ten years. Fig. 433 gives some idea of the density attained by an unthinned pole crop. Fig. 434 shows a portion of the same crop after a thinning. Fig. 435 shows an unthinned crop thirty-two years old, and Fig. 436 a thinned crop seventy-eight years old.

The actual conduct of thinnings in chir crops does not present any special difficulty, involving as it does the general silvicultural principle of removing malformed and otherwise undesirable stems interfering with more promising stems, and giving the necessary growing room to the trees required for the future crop ; efforts should be made during thinnings to cut out stems with twisted fibre wherever possible. The necessity for stimulating crown development for the production of seed indicates the advisability of continuing thinnings after the full height-growth has been reached.

Management of resin-tapping. Under suitable conditions the tapping of resin in chir pine forests, for the manufacture of turpentine and rosin, has shown itself to be a highly profitable industry ; recent years have seen a great development in resin-tapping operations, both in the United Provinces and in the Punjab, and under favourable conditions the revenue derived from resin is larger than that derived from timber and fuel. There is still room for very considerable expansion in the resin industry, and hence in many localities schemes of resin-tapping must influence the management of chir pine forests in no small degree.

The method of tapping followed in India is based on that in vogue in France. An initial blaze about 6 in. long, 4 in. broad, and not more than 1 in. deep is cut near the base of the tree, and the blaze is freshened every six or seven days throughout the summer, until it is about 18 in. long by the end of the year ; if the freshening is carefully done the use of a ladder is thus as a rule unnecessary till the fifth year. The resin collects in a cup fixed at the base of the current year's blaze, and the contents are emptied periodically A curved channel, in place of the former rectangular channel, is now commonly adopted, as it works easily, does not injure the trees so much, gives a cleaner cut, and so far shows promise of giving a higher out-turn.

There are two classes of tapping, (1) light tapping and (2) heavy tapping, sometimes termed tapping to death. The former consists in making a moderate number of blazes, and is carried out in the case of trees not due to be felled within the next few years. The latter consists in making as many blazes as the tree will hold, and is carried out in the case of trees due to be felled within five years (see Fig. 432), the object being to obtain as much resin as possible before the trees are felled.

In the Naini Tal division light tapping under the present system begins when the trees reach a girth of $3\frac{1}{2}$ ft., and the following number of blazes are cut:

1. Trees over 6 ft. in girth, three blazes.
2. Trees $4\frac{1}{2}$–6 ft. in girth, two blazes.
3. Trees $3\frac{1}{2}$–$4\frac{1}{2}$ ft. in girth, one blaze.

The season's tapping commences in March and continues till November, after which the flow of resin practically ceases. In order to promote the free outflow of resin the blazes require to be freshened with an adze at intervals. Experiments carried out by Mr. E. A. Smythies in the Naini Tal division showed that the out-turn increased steadily up to at least ten freshenings per month; this is borne out by similar experiments made in the Punjab. In Naini Tal, however, it was found that the yield did not increase in proportion to the extra labour required beyond five freshenings per month, and this number, that is, once in about six days, is now universally adopted in that division. As regards labour, in the Naini Tal division the most economical working is found to be attained by an allotment of about 600 trees per man, that is, 100 trees a day per man.

In the case of light tapping, it was until recently always the custom in India to tap for a certain number of years and then to allow a period of rest before recommencing tapping. In Kumaun the rule was to tap for five years and then to give a rest for ten years before recommencing tapping; this complete period of fifteen years may be termed the tapping cycle. In the Chakrata division a similar procedure was in force till 1914, when a nine years' tapping cycle was introduced, with tapping for three years followed by a rest for six years. The cycle was shortened in order to avoid the use of a ladder, which was found necessary in the fifth year. The highest yield of resin, however, is obtained in the third and fourth years of tapping, and thus by reducing the tapping period to three years considerable loss is involved, which is avoidable considering that a ladder is not required in the fourth season if reasonable care is taken in freshening the blazes.

If a tapping cycle is to be decided on at all, twelve years—that is, four years' tapping and eight years' rest—would be preferable to either nine or fifteen years. The objection to the former has been mentioned, while in the case of the latter it cannot be made to fit in with a suitable scheme of thinnings; this point is explained below.

In the maritime pine forests of Bordeaux light tapping, once begun, continues without interruption, no rest being given unless a tapped tree shows signs of becoming sickly, when a rest of five years is given; such cases are rare. In the case of the chir pine, experiments have shown that the tree possesses remarkable vitality even under the strain of heavy tapping, and

Fig 434 *Pinus longifolia*, portion of crop shown in Fig 433, after thinning

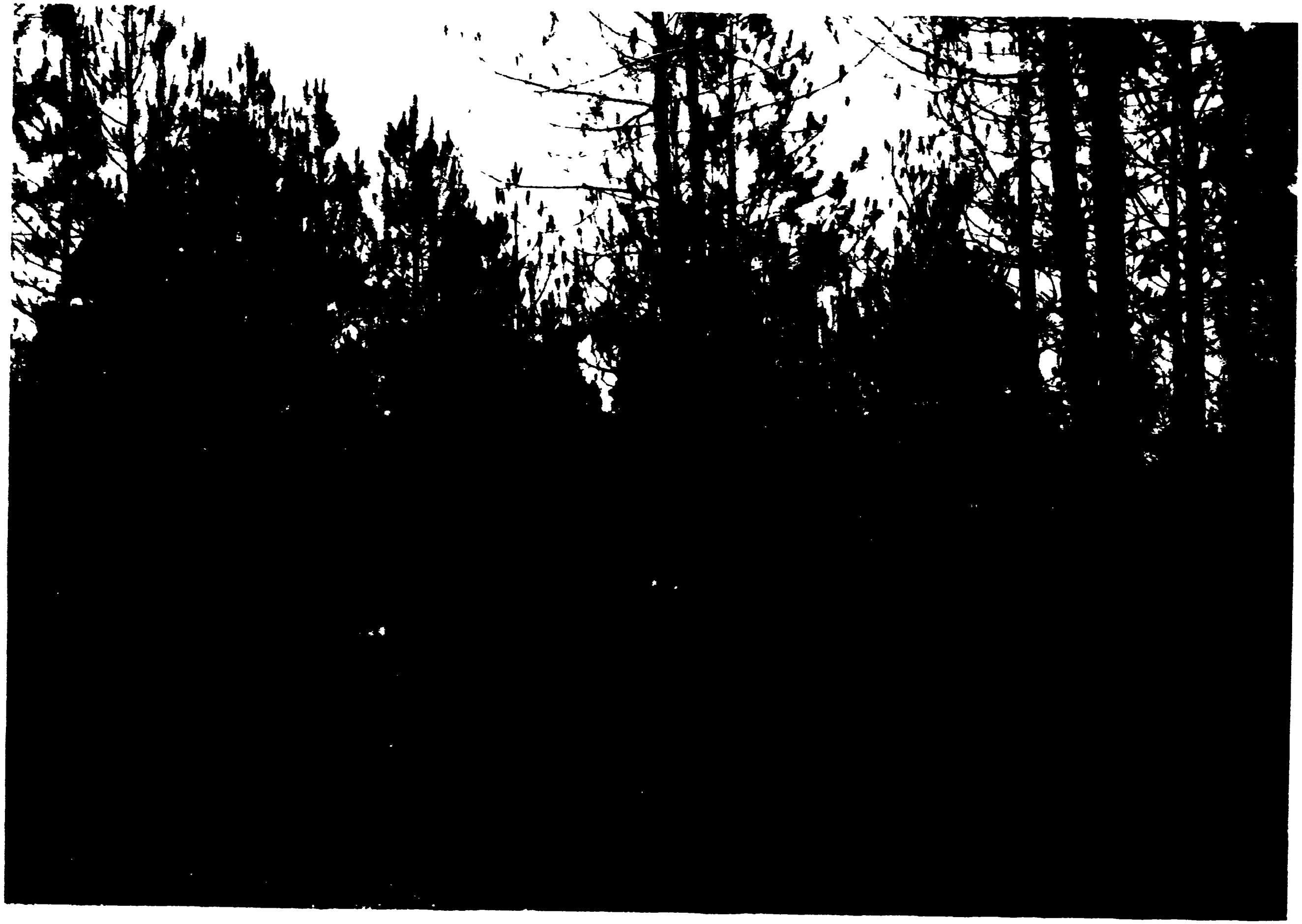


FIG 435 *Pinus longifolia*, natural even-aged unthinned pole crop 32 years old, Kumaun hills

hence rest periods are now being abandoned in favour of the continuous light tapping system of France. Under a scheme of continuous light tapping not only is the out-turn of resin largely increased, but the complication in the general scheme of management, which is inevitable if a tapping cycle is adopted, is avoided.

The main objects of a tapping scheme are to allot for tapping all areas within an economic radius of the distillery, to provide for the continuous working of the distillery up to its maximum capacity by ensuring a sustained equal annual output of crude resin, to allot the tapping areas in such a way as to fit in with the general scheme of working for timber and fuel, and to provide for concentration of tapping operations in the interests of economy.

The chief point to bear in mind is that the tapping of scattered or isolated trees is impracticable ; the minimum number of trees which can be profitably tapped on a given restricted area is estimated to be 2,000 to 2,500, and under certain conditions more. It follows, therefore, that heavy tapping is often impracticable by itself, and can be carried out only in conjunction with light tapping. Here the great advantage of continuous light tapping over the employment of a cycle involving a rest period becomes at once apparent, for in the latter case it is necessary to make the intervals between thinnings, regeneration fellings, and subsidiary fellings coincide with the tapping cycle if the maximum amount of heavy tapping is to be secured. In the case of regeneration fellings this is not usually possible without detriment to silvicultural requirements. As regards thinnings, a fifteen years' tapping cycle would be somewhat too long, and since a nine-years' cycle loses one of the years of high out-turn and is therefore unsuitable, we may conclude that a twelve-years' cycle is preferable to either if a tapping cycle is to be adopted at all. As regards subsidiary fellings, these could without detriment follow the tapping cycle.

In view of all these considerations it will be seen that the preparation of an ideal tapping scheme, securing the maximum out-turn with the greatest economy, is practically impossible if a tapping cycle of any kind is employed.

Further experience is necessary before deciding on the most suitable form of continuous light tapping to employ in the case of the chir pine, but a scheme proposed by Mr. Smythies in connexion with his revised working plan for the Naini Tal subdivision is a considerable improvement on previous tapping schemes. The proposed regeneration period is twenty-four years, and fellings are reckoned as commencing half-way through its course owing to the large quantity of advance growth requiring freeing; thus twelve years of the first period remain. The following is the proposed scheme of tapping :

1. Heavy tapping

A. In periodic block I. (1) On trees to be felled in the first five years, as many blazes as possible.

(2) On trees to be felled in the remaining seven years, to commence with

Trees 3–4 ft. in girth to receive one blaze.
Trees 4–5 ft. in girth to receive two blazes.
Trees 5–6 ft. in girth to receive three blazes.
Trees over 6 ft. in girth to receive four blazes.

Additional blazes up to full capacity to be added five years before felling.

B. In other periodic blocks. If marking in these blocks five years in advance of fellings is found practicable, trees to be tapped to full capacity.

2. Light tapping in periodic blocks other than No. 1.

Trees 3 ft. 9 in. to 6 ft. in girth to receive one blaze.
Trees over 6 ft. in girth to receive two blazes.

Continuous tapping to be carried out. Thus, since the first blaze continues for five years, and where the ground is not too steep and a ladder can be used, for six years, the trees will receive during the twelve years' half-period two and four blazes respectively according to size.

Mr. Smythies estimates that in a healthy tree a blaze will heal over completely in twenty-four years or less, and hence under his scheme if the first blaze is commenced on a tree 3 ft. 9 in. in girth, and new blazes are started at intervals of six years, there will never be more than four unhealed blazes on the tree, by which time it will be at least 4½ ft. in girth ; this means that there will be one channel to at least 1 ft. in girth, which will never kill a healthy tree.

The yield of crude resin is influenced in a marked degree by certain factors, the chief of which, according to Mr. Smythies, are as follows : [1]

1. *Temperature.* The yield per blaze is greater in hot, dry years than in cool, wet years ; it is also greater on southern than on northern slopes. The southern side of the tree produces more resin than the northern side. There is a free outflow of resin in the hot season of the year, whereas practically none is yielded in the winter. Tapping thus commences about the middle of March ; the output rises rapidly in April and May, reaching its maximum in July, after which there is a gradual drop, and tapping ceases in November as the yield becomes too small to justify the expense of collection.

2. *Year of tapping.* The yield is smallest in the first year, but the tapping produces wound response, for in the second year it is greater, while in the third year it reaches its maximum. The fourth year produces almost if not quite as much as the third year, while there is a visible decline in the fifth year.

3. *Period of freshening the blazes.* Unless the blazes are freshened the outflow of resin decreases considerably after about the seventh day, and hence labour should be adjusted so that the blazes may be freshened every six or seven days. Actually the yield increases up to about ten freshenings per month (i. e. one every three days), but in practice it has been found that the increase in yield after five freshenings a month is incommensurate with the extra expense of collection.

4. *Vigour of tree.* Vigorous trees produce a higher yield than unhealthy trees or those growing in unfavourable localities. Thus the highest yield is produced within the chir zone proper, that obtained from trees at the upper and lower limits being as a rule smaller, in spite of the fact that in the latter case the trees grow on hot situations.

It will thus be seen that the yield of crude resin may vary greatly according to season, locality, and other conditions. For general estimates an average of 5 maunds (of $82\frac{2}{7}$ lb.) per 100 blazes is usually taken. A maund of crude

[1] Ind. Forester, xxxvi (1910), p. 278.

resin yields on an average two-thirds of a maund of rosin and 1·75 gallons of turpentine, of which up to 1·5 gallons are of first quality.

STATISTICAL. 1. *Bark allowance.* The chir pine has an unusually thick bark, the thickness being as much as 3 in. in some cases. For trees 6 ft. in girth and over the average thickness may be taken to be about 2 in. at breast-height, corresponding to over 1 ft. in girth measurement; bark thickness, therefore, has a very appreciable effect where the volume of timber has to be ascertained. The thickness of bark varies greatly with individual trees even of the same girth, so that tables of bark allowance are suitable only for general averages.

The proportion of bark by volume varies considerably. In saplings and small poles it is much greater than in large trees. As a rule the more vigorous the tree the greater the percentage of bark; this percentage falls rapidly after the tree reaches maturity. Measurements carried out in the Rawalpindi forests showed the following percentages of bark in the volume of the whole stem (including bark) down to 6 in. in girth at the small end:

Size of tree.	Percentage of bark.
Poles 1–1½ ft. in girth.	40–56 per cent.
Trees about 3 ft. in girth.	Up to 30 per cent.
Trees 4 ft. to 6 ft. in girth.	10 to 29 per cent. (average about 17 per cent.).

In the Naini Tal division, Mr. E. A. Smythies found that in the case of trees 5 to 7 ft. in girth the proportion by weight of green bark to green fuel averages roughly 10 per cent.

The following may be taken as a rough approximation of the average bark allowance by girth and volume in the case of trees of different girths:

Pinus longifolia: general table of bark allowance.

Girth of tree at breast-height, including bark.	Bark thickness at breast-height.	Equivalent girth allowance for bark.	Average percentage of bark by volume.
	Inches.	Inches.	Per cent.
Immediately under 6 in.	0·4	2·5	. .
6 in.–11 in.	0·6	3·8	50
1 ft. 0 in.–1 ft. 5 in.	0·8	5·3	46
1 ft. 6 in.–1 ft. 11 in.	1·0	6·3	39
2 ft. 0 in.–2 ft. 5 in.	1·2	7·5	33
2 ft. 6 in.–2 ft. 11 in.	1·4	8·8	28
3 ft. 0 in.–3 ft. 11 in.	1·6	10·6	22
4 ft. 0 in.–4 ft. 11 in.	1·8	11·3	18
5 ft. 0 in.–5 ft. 11 in.	1·9	11·9	16
6 ft. 0 in. and over	2·0	12·6	15

2. *Height-growth and quality classes.* The table on next page, which has been compiled from measurements in 84 Research Institute sample plots in different localities, gives a provisional allotment to quality classes based on height-growth. For the present this allotment must be looked upon as purely tentative and subject to revision after more extensive measurements have been carried out. For ordinary practice it would be sufficient to form three quality classes. There is, however, an inferior type of stunted chir, usually forming rather open crops, where the trees in some cases do not reach a height of more than 25 to 30 ft., and where a maximum height of 50 to 60 ft. is never attained; such crops are hardly of sufficient economic importance to place even in class III, and they have therefore been relegated to a separate class, namely IV.

Pinus longifolia : table of general quality classes.

Age.	I quality.	II quality.	III quality.	IV quality.
	Limits of height.			
years.	ft.	ft.	ft.	ft.
10	12 and over	7–11	4–6	Under 4
20	28 ,,	17–27	10–16	,, 10
30	45	27–44	16–26	16
40	62	37–61	22–36	22
50	78	47–77	28–46	28
60	94	57–93	34–56	34
70	104	67–103	40–66	40
80	110	76–109	46–75	46
90	113	82–112	51–81	51
100	115	85–114	55–84	55
110	116	87–115	58–86	58
120	117	88–116	59–87	59
130	118	89–117	60–88	60
140	119	90–118	60–89	60
150	120	90–119	60–89	60

The table on next page has been compiled from graphs constructed, after discarding abnormalities, by plotting figures obtained from local measurements recorded in working plans and elsewhere. There are evident discrepancies in these figures, due no doubt to their compilation from measurements of single trees which on the whole were probably above the average in quality. For example, the mean height for Rawalpindi is represented as being greater than that for Jaunsar up to an age of 100 years, which is not actually the case, the average quality of the Jaunsar forests being superior to that of Rawalpindi.

3. *Girth measurements.* The following statement has been complied from girth measurements in 84 Research Institute sample plots in even-aged fully stocked crops :

Pinus longifolia : girth increment in even-aged fully stocked crops.

Age.	I quality.		II quality.		III quality.	
	Mean girth of crop at 4½ ft. (including bark).					
years.	ft.	in.	ft.	in.	ft.	in.
20	1	4	1	1	0	9
30	2	1	1	8	1	3
40	2	11	2	4	1	9
50	3	8	2	11	2	4
60	4	4	3	6	2	10
70	4	11	4	1	3	4
80	5	6	4	7	3	10
90	6	0	5	0	4	3
100	6	6	5	5	4	7
110	6	11	5	9	4	10
120	7	3	6	0	5	0
130	7	7	6	3	5	2

These girths are probably much below the correct normal average for crops which have been properly tended from youth and regularly thinned ; such are not yet available, and the measurements were actually made in crops the majority of which have been allowed to grow up with a density too high for the best development in girth and volume.

The statement opposite, showing girth statistics, has been compiled from the results of ring-countings recorded in working plans and elsewhere; for comparative purposes the figures recorded have all been reduced to girth over bark, and the rate of growth in girth has been deduced by constructing increment curves.

Chakrata division. Working plan for the Jaunsar-Bawar forests, 1901. P. H. Clutterbuck (366 stumps).	Working plan for the Naini Tal sub-divisional forests, 1896. N. Hearle (212 stumps).	Kumaun, measurements made in the Binsar forest by C. M. McCrie in 1910 (17 stumps).	Kumaun, measurements made in the Patharia forests by C. M. McCrie in 1911.	Naini Tal division, measurements made by E. A. Smythies in various localities in 1910–11 (500 stumps). Good quality.	Medium quality.	Poor quality.	Age.
ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	years.
0 0[2]	..	..	..	..	..	..	10
1 1	..	..	..	1 6	1 2	0 11	20
1 10	1 5	1 9	2 0	2 0½	1 8	1 4½	30
2 7	2 0	2 6	2 8	2 7	2 2	1 10	40
3 4	2 6	3 2	3 2	3 0½	2 8	2 3	50
3 11	2 11	3 7	3 7	3 6	3 1	2 7½	60
4 6	3 4	4 0	3 11	3 11	3 6	3 0	70
5 0	3 8	4 3½	4 3	4 3½	3 10	3 4½	80
5 6	4 0	4 7	4 6½	4 8	4 2	3 8½	90
5 11	4 4	4 10	4 10	5 0½	4 6	4 0	100
6 4	4 8	5 1	5 1½	5 4½	4 9½	4 3½	110
6 8	5 0	5 4	5 4½	5 8	5 1	4 6½	120
7 0	5 3	5 6½	5 7	5 11	5 4	4 9½	130
7 4	5 6	5 9	5 9	6 1½	5 7	5 0½	140
7 8	5 9	5 11½	5 11	6 4	5 9½	5 3½	150
..	6 0	6 1½	..	6 6½	6 0	5 6½	160
..	6 3	6 3½	..	6 9	6 2½	5 9	170
..	6 6	6 5½	..	6 11½	6 5	5 11	180
..	6 9	6 7	..	7 2	6 7	6 1	190
..	7 0	6 9	..	7 3½	6 8½	6 2½	200
..	7 3	..	..	7 5	6 10	6 4	210
..	7 5	..	..	7 6½	6 11½	6 5½	220
..	7 7	..	..	7 7½	7 0½	6 6½	230
..	7 9	..	..	7 8½	7 1½	6 7½	240
..	..	..	..	7 9½	7 2	6 8	250

een added to the girth excluding bark: this has been corrected by using the
le allowance of 10 years made for growth of seedling up to breast-height.

[To face p. 1090.

Pinus longifolia : height-growth of trees, from statistics recorded in working plans and elsewhere.

Age.	Siran range forests, Hazara division, 1905. A. V. Monro. Measurements of 148 single trees.			(1) Revised working plan for the Muree-Kahuta forests, Rawalpindi division, 1901. W. Mayes. 300 single trees. (2) 32 single trees more recently measured by divisional staff.			Working plan for the Kangra division, 1905. G. S. Hart. Measurement of 459 single trees.			Dharmsala municipal forests, 1912. Measurements of 23 trees by C. M. McCrie.	Jaunsar-Bawar working plan, 1901. P. H. Clutterbuck. Estimated average.	Binsar reserve, Kumaun. 17 selected sample trees measured by C. M. McCrie in 1910.	Patharia forests, Kumaun. Measurements by C. M. McCrie in 1911.	Approximate maximum height curve.	Approximate minimum height curve.
	Maximum curve.	Minimum curve.	Mean curve.	Maximum curve.	Minimum curve.	Mean curve.	Maximum curve.	Minimum curve.	Mean curve.	Mean curve.	Mean curve.	Mean curve.	Mean curve.		
years.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.
10	..	..	..	..	..	..	..	..	..	9	6	..	..	18	4
20	..	..	..	..	..	..	48	..	..	23	18	..	..	48	15
30	..	.	..	..	..	..	64	32	47	38	32	..	34	68	27
40	..	..	..	..	..	..	75	42	58	50	47	..	48	84	39
50	..	..	..	98	56	84	81	50	67	58	60	50	60	99	48
60	..	..	..	108	62	91	85	57	73	64	72	58	69	111	56
70	..	..	..	115	67	96	88	64	77	67	83	65	76	121	62
80	126	72	99	120	71	100	89	69	81	69	92	71	82	129	67
90	134	77	105	124	75	103	90	73	83	71.	98	76	87	136	70
100	140	81	110	128	78	105	90	75	84	..	104	81	91	141	72
110	145	85	114	130	81	107	90	77	85	..	109	84	94	145	74
120	148	88	116	132	84	109	90	79	85	..	..	86	96	148	75
130	150	90	118	134	86	111	..	..	..	..	..	88	98	150	76
140	..	..	..	135	88	113	..	..	..	..	..	90	100	151	76
150	..	..	..	136	90	114	..	..	..	..	..	92	102	152	76
160	..	..	..	137	91	115	..	..	..	..	..	94	..	..	..
170	..	..	..	..	..	..	..	..	..	..	..	96	..	..	..
180	..	..	..	..	..	..	..	..	..	..	..	98	..	..	..
190	..	..	..	..	..	..	..	..	..	..	..	99	..	..	..
200	..	..	..	..	..	..	..	..	..	..	..	100	..	..	..

4. *Volume of single trees.* The following table, based on the measurements of all sample trees felled in 84 Research Institute sample plots in even-aged fully stocked crops, gives the average volume of typical trees grown in such crops :

Pinus longifolia : mean volumes of typical trees in even-aged fully stocked crops.

Solid volume in the round (excluding bark in timber and including it in small-wood).

Age.	I quality.			II quality.			III quality.		
	Timber down to 24 in.[1] in girth.	Small-wood 6 to 24 in. in girth.	Total.	Timber.	Small-wood.	Total.	Timber.	Small-wood.	Total.
years.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.
10									
20	..	1·5	1·5	..	0·6	0·6		0·2	0·2
30	..	4·0	4·0	..	2·0	2·0		0·8	0·8
40	3	5·5	8·5	0·5	4·5	5·0		2·5	2·5
50	9	5·5	14·5	5·5	4	9·5		4·5	4·5
60	19	5·5	24·5	12	4	16	3	4	7·0
70	35	5	40	22	4	26	9	3	12
80	60	4	64	36	3	39	19	3	22
90	82	3	85	46	3	49	30	2	32
100	90	3	93	53	3	56	37	2	39
110	96	2	98	59	2	61	40	2	42
120	99	2	101	61	2	63	42	2	44
130	101	2	103	62	2	64	43	2	45

[1] Minimum girth measured over bark.

The crops in which these measurements were made had grown up without any special tending, and the volumes are considerably less than what might be expected in regularly thinned crops.

In existing working plans there are, on the whole, not many records of volume measurements, and as measurements of single trees growing under a variety of different conditions are apt to give considerable diversity in results, it is not easy to obtain averages of any great utility, particularly as the measurements are not always carried out on the same lines. In the table showing mean volumes of single trees an attempt has been made to arrange the volumes given in working plans and elsewhere as far as possible according to age, after constructing graphs and obtaining average curves. In the case of the Siran range, Hazara, there was such wide diversity in the measurements that an average curve was not easy to determine ; this would indicate that the trees grew under widely different conditions of espacement, quality, &c. In the case of the Kangra and Simla working plans there was little divergence, and the figures given may be considered as representing a fair average of the measurements made.

Subject to these limitations, the table gives as nearly as possible the averages obtained from a compilation of volume figures of single trees from working plans and other sources.

In this table the Rawalpindi and Kulu figures for loss in conversion are based on a large number of measurements, and are on the whole remarkably constant when it is considered that the trees had grown up under a variety of conditions and do not represent the results of careful tending in normal crops. Roughly speaking, these figures show the following results :

d elsewhere.

MEASUREMENTS ARRANGED ACCORDING TO DIAMETER.

Kulu division; figures prepared by C. G. Trevor in 1918.

Age.	Mean annual increment.	Volume.					
		Local quality I.		Local quality II.		Local quality III.	
		Logs.	Scant-lings.	Logs.	Scant-lings.	Logs.	Scant-lings.
years.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.
51	0·09	16	6	12	4	8	2
55	0·10	19	8	14	5	9	2
60	0·13	23	10	16	6	10	3
65	0·17	28	14	19	8	12	4
71	0·19	35	18	22	10	15	6
77	0·23	43	22	26	13	18	8
83	0·26	52	27	32	16	21	10
90	0·28	62	32	38	19	24	12
95	0·32	72	38	45	23	28	14
103	0·35	84	44	52	28	32	17
111	0·38	96	50	60	33	36	20
117	0·41	110	57	69	38	40	23
123	0·44	124	64	80	43	45	26
133	0·46	136	72	90	48	52	30
141	0·48	150	79	100	54	60	35
150	0·50	164	86	110	60	68	40
160	0·51	173	93	120	66	76	44
170	0·53	188	100	130	71	84	48
180	0·54	198	106	140	77	92	52
190	0·55	207	111	149	83	100	56
200	0·56	215	116	158	88	108	60
..	..	222	121	166	93	116	64
.	.	229	126	173	98	122	68
.	.	235	131	179	103	128	72
.	.	240	135	185	108	134	76
..	.	245	139	190	113	139	80
.	.	250	143	195	116	142	84
..	..	255	146	200	120	145	87

[*To face p.* 1082.

III QUALITY.

Standing crop.			Intermediate yields.				Total yield to date.		Mean annual increment calculated on total yield to date.	
			Current.		Total to date.					
Number of stems per acre.	Timber.	Total timber and small-wood.	Timber.	Total timber and small-wood.	Timber.	Total timber and small-wood.	Timber.	Total timber and small-wood.	Timber.	Total timber and small-wood.
	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.
..	..	..	..	..	..	..	..	..	..	..
2,000	..	400	..	..	..	..	..	400	..	20
1,500	.	1,200	..	..	..	..	..	1,200	..	40
880	..	2,200	..	..	..	..	..	2,200	..	55
670	..	3,000	..	130	..	130	..	3,130	..	63
500	1,500	3,500	40	180	40	310	1,540	3,810	26	63
309	2,780	3,700	80	155	120	465	2,900	4,165	41	59
175	3,320	3,850	100	150	220	615	3,540	4,465	44	56
125	3,750	4,000	120	130	340	745	4,090	4,745	45	53
105	3,880	4,100	115	125	455	870	4,335	4,970	43	50
100	4,000	4,200	115	125	570	995	4,570	5,195	42	47
97	4,070	4,250	110	120	680	1,115	4,750	5,365	40	45
95	4,080	4,280	110	120	790	1,235	4,870	5,515	37	42

The volume, obtained from quarter-girth-squared measurement, is solid volume in the round.

Size or age of trees.	Loss per cent. in conversion of round timber including bark.
(1) Poles about 40 years old (Rawalpindi)	70–80 per cent.
(2) Trees 50–100 years old (Rawalpindi)	about 57 per cent.
(3) Trees 100–160 years old, good or fair quality (Rawalpindi)	about 54 „
(4) Trees 100–150 years old, poor quality (Rawalpindi) .	about 60 „
(5) Large trees 30 in. and over in diam. (Kulu) . . .	about 55 to 60 per cent.

5. *Volume of whole crops.* The yield table facing this page has been compiled from measurements in 84 Research Institute sample plots in even-aged fully stocked crops. These sample plots have not been in existence long enough to provide accurate figures of yields from thinnings, and the figures given have therefore been based on Schwappach's intermediate yield figures for the Scotch pine, the ratio which these bear periodically to the standing crop being applied to the standing crop figures for chir pine. This procedure is likely to give a nearer approximation to what may be expected under normal conditions than an estimate based on the irregular yields furnished by thinnings carried out in sample plots hitherto. The figures showing the number of stems per acre apply to even-aged crops of full density, but as the crops measured were for the most part untended natural crops, in which the density for a given age was greater than what might be expected in regularly tended crops, these figures will almost certainly prove too high in crops where periodic thinnings have had full play for some time.

This yield table, therefore, should be regarded as purely tentative and subject to complete revision when more accurate figures of intermediate yield are available as a result of regular thinnings carried out over a sufficiently long period ; such figures will not be available for many years yet.

6. *Form factors.* The table below has been compiled from numerous measurements of typical trees in even-aged fully stocked crops :

Pinus longifolia : form factors of typical trees.

	Form factors.					
	I quality.		II quality.		III quality.	
leight.	Timber.	Total timber and small-wood.	Timber.	Total timber and small-wood.	Timber.	Total timber and small-wood.
ft.						
10–20	..	0·58	..	0·60	..	0·60
21–30	..	0·53	..	0·56	..	0·56
31–40	..	0·49	..	0·53	..	0·50
41–50	*	0·46	*	0·50	*	0·45
51–60	*	0·43	*	0·46	*	0·41
61–70	0·24	0·41	0·24	0·42	0·29	0·39
71–80	0·26	0·39	0·33	0·40	0·36	0·38
81–90	0·29	0·38	0·34	0·38	0·37	0·38
91–100	0·30	0·37	0·35	0·38	..	..
01–110	0·33	0·37	0·36	0·38	..	..
11–120	0·34	0·37	0·36	0·38	..	..
20 and over	0·36	0·37	..	..	..	..

Remarks.

* Timber ordinarily begins to be produced when the trees are between 41 and 60 ft. in height, and the proportion of timber depends on the girth of the tree. The following are as nearly as possible the timber form factors for different girths :

Girth at breast-height.	Timber form factors. Height 41–50 feet.	Height 51–60 feet.
in.		
25	0·06	0·06
26	0·10	0·12
27	0·12	0·15
28	0·15	0·19
29	0·18	0·21
30	0·20	0·22

NOTE.—(1) These form factors are calculated on solid volumes, obtained by quarter-girth-squared measurement, using the formula $f=\frac{v}{s\,h}$, where f = form factor; v = solid volume; s = sectional area at $4\frac{1}{2}$ ft. from ground-evel; h = total height of tree.

(2) Timber is measured without bark, and includes everything in the bole down to a girth (over bark) of 24 nches. Small-wood includes bark, and comprises the top and branches down to a girth of 6 inches.

3. **Pinus Khasya,** Royle. Khasi pine. Vern. *Dingsa,* Khasi hills ; *Tinyu,* Burm.

A large evergreen tree with more or less whorled branches and a crown, oval in young trees, rounded in mature trees. Bark reddish grey, deeply fissured, in moderate-sized to large trees about 1–1·8 in. thick, averaging about 1·5 in. thick. Adult needles 6–10 in. long, shorter on stunted trees, slender, in fascicles of three, the base of the fascicle enclosed in a persistent papery sheath 0·6–1 in. long. There are often two whorls of branches produced in one year, the spring internode being much longer than the summer internode. Wood moderately hard, pale brown to red, very resinous, used in the Khasi hills for building. In Burma it is seldom used except for interior work, as it is not considered durable enough if exposed to the weather. In Burma and in the Khasi hills the resinous wood is much used for torch-wood, the production of which causes considerable injury to the trees. A hole is cut into the bole in order to induce the flow of resin, forming in time a large wound from which pieces of resinous wood are constantly removed until the tree is nearly cut through, when it falls or is blown over.

Pinus Khasya and *P. Merkusii* have a high potential value as producers of resin. Professor Armstrong,[1] who examined samples in 1896, reported that both oils were of the highest quality, that they would probably serve every purpose for which oil of turpentine (French or American) is used, and that they even compared favourably with the French oil. This opinion was confirmed in 1913, after further tests, by Puran Singh,[2] who found that oil from Assam samples was somewhat inferior to Burma oil, as it contained a greater proportion of high boiling turpenes. Although the forests of *P. Khasya* have been examined to some extent, resin-tapping operations on a commercial scale have not yet been organized, nor has it been ascertained to what extent such operations will prove remunerative ; there is no doubt that many of the tracts of Burma are as yet too inaccessible for profitable tapping.

Under favourable conditions *Pinus Khasya* reaches a height of 100 ft. or more and a girth of 10 ft. and over. Mr. M. H. Ferrars [3] measured a tree 10 ft. 4 in. in girth, and another 8 ft. 7 in. in girth and 100 ft. in height, in the hills between the Sittang and Salween rivers in Burma. Round Shillong isolated trees have been measured up to 7½ ft. in girth and 70 ft. in height.

Distribution and habitat. Khasi and Naga hills, Manipur, hills of Upper Burma, the Shan States and the hills between the Sittang and Salween rivers.

In the Khasi hills it occurs at elevations of 2,500 to 6,400 ft., thriving best at 4,000–4,500 ft. Except for a comparatively small area under the control of Government the pine forests are much cut up by shifting cultivation, with the result that they consist mainly of young crops. The forests in the neighbourhood of Shillong have been under protection for many years, and now contain crops up to middle age, with girths up to 4 and sometimes 5 ft. The pine forms pure or nearly pure forests (Fig. 437), but it is sometimes associated with various broad-leaved species, particularly along the banks of streams and in damp places, where, if present, it is often represented only by scattered trees ;

[1] Imp. Inst. Tech. Reports, 1903, pp. 167–169. [2] For. Bull. No. 24, 1913.
[3] Ind. Forester, i (1875), p. 107.

FIG. 436. *Pinus longifolia*, thinned crop 78 years old, mean girth 4 ft 4 in., mean height 102 ft, with 86 stems per acre, Rawalpindi

FIG 437 *Pinus Khasya*, pure pole crop, Assam

among the more typical broad-leaved trees are *Rhus semialata*, *Quercus serrata*, *Myrica Nagi*, *Pieris ovalifolia*, *Eurya acuminata*, and *Rhododendron arboreum* (not common).

In Burma there are inconsiderable areas of pine forest on the ridges of the Chindwin drainage and in Myitkyina, aggregating not more than a few square miles. In the Chin hills and Pakokku hill tracts the pine forests are reported to exist at 4,000–8,000 ft. elevation, but their area has not been estimated. The pine is here associated with *Quercus serrata* and other oaks, *Rhododendron arboreum*, *Alnus nepalensis*, and other trees of the drier types of hill forest. In the hills between the Sittang and Salween rivers pine forests occur on most of the ridges from 2,500 or 3,000 ft. upwards, the pine growing either pure or mixed with oaks, chestnuts, and other broad-leaved trees. In the Northern Shan States about 75 square miles of pine forest are reported to exist in the state of Mongtung; elsewhere they are found in more or less scattered patches along ridges in those states and in the hills adjoining them. In the Maing Lon State to the south of Mogôk there are considerable tracts of pine. The largest areas of pine forest, however, are found in the Southern Shan States. A few years ago Mr. Watson estimated the total area occupied by *Pinus Khasya* and *Pinus Merkusii* in these states at 3,000 square miles, distributed as follows:

	Square miles.	
1. Myelat States	300	*P. Khasya.*
2. Lawksawk State .	300	
3. Loilong and Mongpai State	300	
4. Mongpawn and Laihka	150	
5. Mong Kung State	300	
6. Hsatung State .	50	*P. Merkusii.*
7. Mongnai State .	100	Both species: probably 70 per cent. *P. Merkusii* and 30 per cent. *P. Khasya.*
8. Mawkmai State .	100	
9. Mongpan State .	600	
10. Kentung (Mongpu and Monghsat)	800	
Total . .	3,000	

Many of the pine forests of the Shan States and other tracts in Burma have suffered severely from *taungya* cutting (shifting cultivation), working for torch-wood, fire, and wasteful felling generally, and it is probable that their original area has been restricted considerably in consequence. The undergrowth frequently consists of inflammable grass, and when this catches fire large areas of young pine may be destroyed.

Mr. M. H. Ferrars [1] in 1875 gave an interesting account of the pine forests in the hills east of Toungoo, between the Sittang and Salween rivers. He found the pine to occur most gregariously at about 4,500 ft., the forests being always purest on ridges and southerly aspects, and largely mixed with broad-leaved species in ravines and on northerly aspects. In some of the deeper gorges, pine trees of large dimensions were found among other trees. In dense pine forest there was no undergrowth, the soil being covered with a thick layer of humus; bracken fern occurred in clusters, and occasionally cycads were noticeable. The forests were much cut up by *taungya* cultivation, though the less accessible pine forests of the Karenni country were as yet intact. In the areas subject to *taungya* cutting the pine showed a marked tendency to

[1] *loc. cit.*

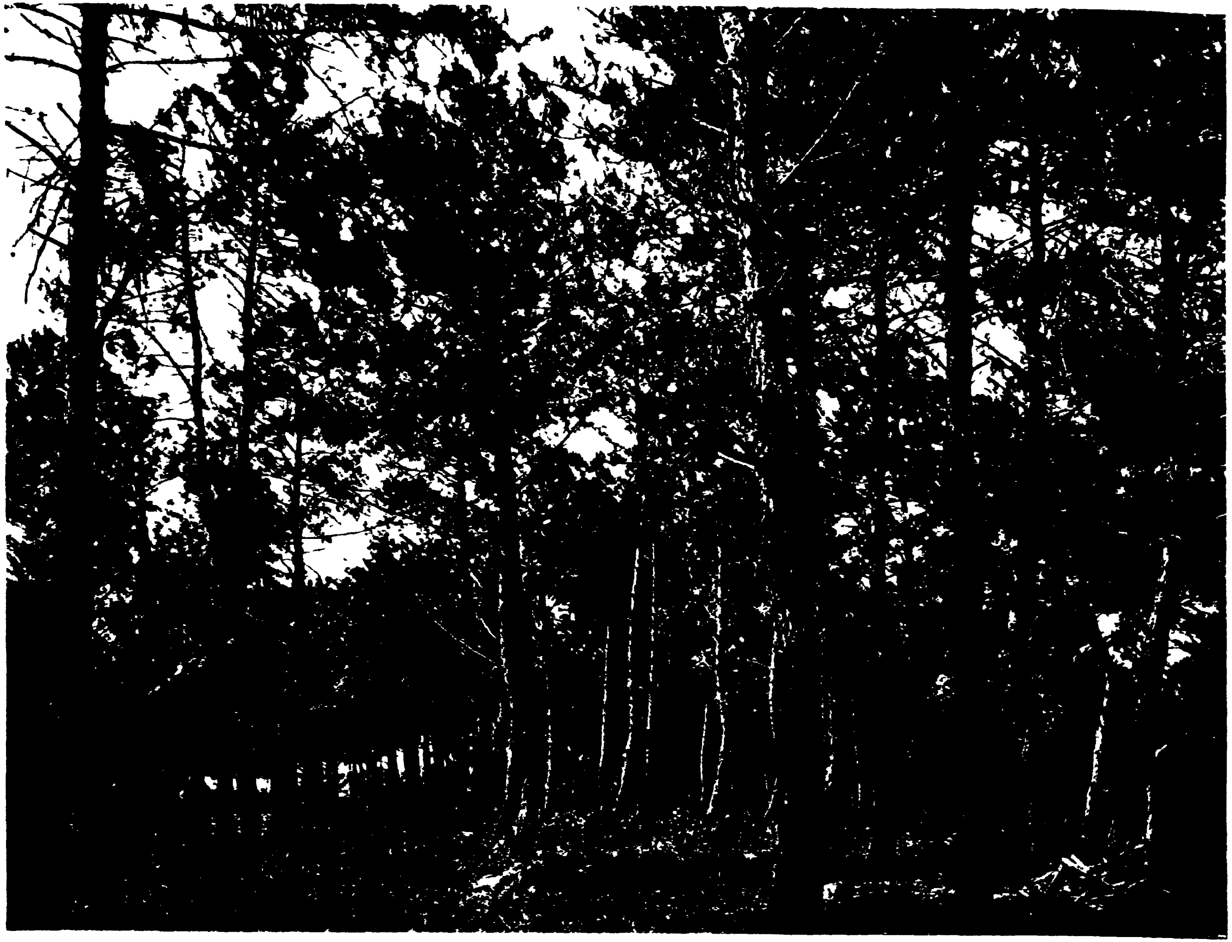


FIG. 437. *Pinus Khasya*, pure pole crop. Assam

among the more typical broad-leaved trees are *Rhus semialata*, *Quercus serrata*, *Myrica Nagi*, *Pieris ovalifolia*, *Eurya acuminata*, and *Rhododendron arboreum* (not common).

In Burma there are inconsiderable areas of pine forest on the ridges of the Chindwin drainage and in Myitkyina, aggregating not more than a few square miles. In the Chin hills and Pakokku hill tracts the pine forests are reported to exist at 4,000–8,000 ft. elevation, but their area has not been estimated. The pine is here associated with *Quercus serrata* and other oaks, *Rhododendron arboreum*, *Alnus nepalensis*, and other trees of the drier types of hill forest. In the hills between the Sittang and Salween rivers pine forests occur on most of the ridges from 2,500 or 3,000 ft. upwards, the pine growing either pure or mixed with oaks, chestnuts, and other broad-leaved trees. In the Northern Shan States about 75 square miles of pine forest are reported to exist in the state of Mongtung; elsewhere they are found in more or less scattered patches along ridges in those states and in the hills adjoining them. In the Maing Lon State to the south of Mogôk there are considerable tracts of pine. The largest areas of pine forest, however, are found in the Southern Shan States. A few years ago Mr. Watson estimated the total area occupied by *Pinus Khasya* and *Pinus Merkusii* in these states at 3,000 square miles, distributed as follows:

	Square miles.	
1. Myelat States	300	*P. Khasya.*
2. Lawksawk State	300	
3. Loilong and Mongpai State	300	
4. Mongpawn and Laihka	150	
5. Mong Kung State	300	
6. Hsatung State	50	*P. Merkusii.*
7. Mongnai State	100	Both species: probably 70 per cent. *P. Merkusii* and 30 per cent. *P. Khasya.*
8. Mawkmai State	100	
9. Mongpan State	600	
10. Kentung (Mongpu and Monghsat)	800	
Total	3,000	

Many of the pine forests of the Shan States and other tracts in Burma have suffered severely from *taungya* cutting (shifting cultivation), working for torch-wood, fire, and wasteful felling generally, and it is probable that their original area has been restricted considerably in consequence. The undergrowth frequently consists of inflammable grass, and when this catches fire large areas of young pine may be destroyed.

Mr. M. H. Ferrars [1] in 1875 gave an interesting account of the pine forests in the hills east of Toungoo, between the Sittang and Salween rivers. He found the pine to occur most gregariously at about 4,500 ft., the forests being always purest on ridges and southerly aspects, and largely mixed with broad-leaved species in ravines and on northerly aspects. In some of the deeper gorges, pine trees of large dimensions were found among other trees. In dense pine forest there was no undergrowth, the soil being covered with a thick layer of humus; bracken fern occurred in clusters, and occasionally cycads were noticeable. The forests were much cut up by *taungya* cultivation, though the less accessible pine forests of the Karenni country were as yet intact. In the areas subject to *taungya* cutting the pine showed a marked tendency to

[1] *loc. cit.*

form successive gradations of even-aged crops owing to the profusion with which reproduction springs up on abandoned *taungya* areas.

The geology of the various pine tracts has not yet been studied exhaustively. Round Shillong the pine occurs chiefly on sandstone covered by reddish clay, on which the tree grows well, while small areas of quartzite and shale are met with. In the hills between the Sittang and Salween in Burma the pine forests occur chiefly on granitic rocks and on sandstone. Good drainage appears to be essential; the pine will not grow on swampy ground. At high elevations, on exposed ridges and on shallow soil the trees become stunted.

Detailed climatic statistics are not available for the various regions of this pine. Generally speaking it occurs in sub-temperate, fairly moist regions free from extremes of heat and cold. Frosts may occur during winter, but snow is either unknown or where it does fall the fall is light. The rainfall probably exceeds 70 in. in most of the tracts where the pine is found; in the Khasi hills it exceeds 80 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The new shoots appear in February–March. The old needles fall for the most part in April–May, by which time the new ones are full-sized or nearly so. The needles persist for one year and one to three months. The male and female flowers appear on the new shoots in February–March. The male flowers when fully open are 1·5–2 in. in diameter, light brown, with a basal cup of imbricate brown scales which adheres to them when they fall soon after ripening. The female flowers (young cones), 1–3 at the apices of the new shoots, are about 0·5 in. long by 0·35–0·4 in. in diameter, light green, ovoid, the umbo sharply mucronate in the centre. By May next year the cones are nearly full-sized but still green; they ripen from February to April, two years after the first appearance of the female flower. The cones are solitary or in pairs, sometimes in threes, ovoid, 2–3 in. long by 1·5–2 in. in diameter near the base, brown when ripe; scales in spirals of 8 × 5, woody, thickened towards the apex; apophysis depressed pyramidal, with a blunt or mucronate umbo. Seed with wing 0·7–0·9 in. by 0·2–0·3 in. (Fig. 438, *a*), without wing 0·2 in. long; 1,400 to 1,600 seeds, without wings, weigh 1 oz.

Good seed-years are frequent, and the seeds have a high percentage of fertility. Tests carried out at Dehra Dun showed a fertility of 95 per cent. for fresh seed and 65 per cent. for seed kept for one year. In order to obtain seeds for sowing the cones should be collected in February and placed in the sun until they open, when the seeds can be readily shaken out.

GERMINATION (Fig. 438, *b–g*). Epigeous. The radicle emerges from the end of the seed and descends; the hypocotyl elongates, arching somewhat, and the cotyledons are carried above ground. As the cotyledons elongate the shell of the seed remains enclosing their apices for a time, finally falling to the ground, when the cotyledons spread out in a whorl, from the centre of which the young shoot develops.

THE SEEDLING (Fig. 438).

Roots: primary root moderately long, wiry, flexuose; lateral roots few to moderate in number, fibrous. *Hypocotyl* distinct from root, 1–1·7 in. long, green or reddish turning greenish brown. *Cotyledons* 6–8, rarely 9, 1–1·5 in. long, acicular, triquetrous, margins minutely and sparsely serrulate, glaucous green turning dark green. *Stem* erect, terete, woody. *Leaves* in first season all single primordial, 0·5–1·5 in. long, acicular, margins finely serrulate.

The requirements of the seedling have not been studied in detail. Young plants raised at Dehra Dun reached a height of about 4 in. in the first season ;

FIG. 438. *Pinus Khasya* and *P. Merkusii*. Seedling × ½.

Pinus Khasya : *a*, seed ; *b–g*, germination stages ; *h*, seedling towards end of first season. *Pinus Merkusii :* *i*, seed ; *j–o*, germination stages ; *p*, seedling towards end of first season.

they were found to suffer greatly from the attacks of insects, which killed off numbers of them.

SILVICULTURAL CHARACTERS. The tree is a light-demander, though it will stand slight shade in youth, the amount depending on situation and aspect. Young plants are able to push their way up through a moderate growth of scrub, particularly on dry, sunny aspects, where they appear to benefit by the shade afforded. In a close crop suppressed trees soon die off, and the crop tends to thin itself out. The tree is wind-firm. Young crops suffer greatly from fire, and are often killed outright; larger trees are fairly well protected from injury by their thick bark. As already mentioned, the trees suffer much injury through being cut into for the production of resinous torch-wood, rendering them liable to be blown down and to become charred by fire.

NATURAL REPRODUCTION. On abandoned cultivation, where the soil has been loosened and exposed, natural reproduction is profuse, and where shifting cultivation is practised dense pure crops of pine spring up; the same frequently happens on burnt areas where the layer of dead needles or the thick matted growth of grass has been burnt. For the establishment of the young crop, however, protection from fire is of great advantage, and may be essential. Reproduction does not appear under a dense canopy, but if the canopy is opened out sufficiently. seedlings establish themselves in quantity wherever soil conditions are suitable.

ARTIFICIAL REPRODUCTION. In certain tracts where shifting cultivation is practised, abandoned fields, as noted below, are regularly sown up broadcast with pine seed, the young pine crops being thereafter protected from fire. Experimental sowings of a similar nature in the Southern Shan States resulted in partial failure owing, it is believed, to too early sowing; it is probable that the best time for broadcast sowing is shortly before the beginning of the monsoon, on ground which has been well broken up. Sowings sometimes fail owing to a dense growth of tall grass, and where this is feared it may be advantageous to sow in lines subsequently kept weeded.

Young plants can be easily raised in the nursery, and bear transplanting well. Seed should be sown in March in raised seed-beds of light porous soil and well watered. Germination commences in a few days to about two weeks. The seedlings should be pricked out in the nursery during the first season, when about 3 in. high, and planted out early in the following rainy season.

In 1916 seed of this pine was sown in ploughed strips near Supkhar in the Balaghat district, Central Provinces, but the results were disappointing in spite of a favourable season. The seed germinated well, but a large number of seedlings were destroyed by caterpillars during the monsoon, and others perished from drought in the dry season. This locality is probably too hot and dry for this pine unless the soil is kept worked up and the seedlings are shaded in the hot season.

SILVICULTURAL TREATMENT. This pine is well adapted for treatment in even-aged crops either by clear felling with artificial or even natural reproduction or by successive regeneration fellings with natural reproduction. In the latter case the general principles applicable to *Pinus longifolia* would no doubt apply to *P. Khasya*.

So far only one working plan for Khasi pine forests has been prepared, namely, the plan dealing with the Shillong pine forests.[1] This plan prescribes a rotation of sixty years, divided into four regeneration periods of fifteen years each. The first periodic block is divided into five annual coupes, so that the block is worked over in three regeneration fellings at intervals of five

[1] Working Plan for the Shillong Pine Forests, E. M. Coventry, 1909.

years. The possibility is entirely by area, and silvicultural considerations have full play. The remaining periodic blocks are worked over by selection and improvement fellings. Provision is made for the conduct of thinnings at intervals, a very necessary prescription in any pine working plan. Where natural reproduction fails, broadcast sowings are prescribed 'in the manner practised by the Khasis', that is, on abandoned *jhums* (shifting cultivation).

In the Khasi hills the *jhuming* system is practised with a fallow interval of seven or eight years. Field crops are grown for two years, and the fields are then sown broadcast with pine. Fires are thereafter excluded. In the more accessible localities when the tree crop is felled, only the pine branches and brushwood are burnt as manure, the young poles finding a ready sale in Shillong. In the less accessible places poles not required for local use are burnt with the branch-wood. Potatoes are the principal field crop near Shillong on the gentler slopes and at the higher elevations. Mr. Ferrars[1] describes as follows the natural regeneration of cleared areas in the hills between the Sittang and Salween rivers in Burma, by the aid of seed-bearers left on the ridges :

'The rotation is twofold. First, there is the set of blocks which are cleared every 15 to 20 years ; these are large and are used for raising the main crops. Secondly, there is a set of smaller blocks or strips which are allowed to lie fallow two or three times as long as the former ; very good forest forms on these; and the land, when cleared, is suitable for growing a series of vegetable crops, &c. The process of regeneration seems to be this. The bare *yah* (temporary clearing) on the slope is seeded for a couple of years by the trees left standing on the ridge ; there being no combustible matter on the ground, the seedlings get a good start and are fireproof afterwards ; fires, however, are carefully and in general successfully excluded by the natives. *Kaing* grass (elephant grass) springs up simultaneously with the young pine, but before it has attained its full development—which it requires a few years to do—the young trees have out-topped it, and subsequently they drive it out of the field in their vicinity, paving the way for a quantity of undershrubs and young pine and leaf trees which then further oppress the grass. Under the struggling leaf tree scrub the pine seedlings, which here seem to thrive in moderate shade, get ahead, and suppress the young leaf trees in their turn. In ten to twenty years the block is full. Under less favourable circumstances the reproduction takes place in belts downwards from the ridge, the successive young generations of pine supplanting and suppressing the grass and scrub.'

The management of this pine for resin-tapping purposes may yet become a matter of importance, and until detailed experience is gained the system followed in the case of *Pinus longifolia* might be taken, *mutatis mutandis*, as applicable (see pp. 1075–1078).

RATE OF GROWTH. Ring-countings by Mr. E. M. Coventry in the Shillong pine forests showed an average of four rings per inch of radius at elevations of 4,500 to 5,500 ft., and five rings at higher elevations, representing mean annual girth increments of 1·57 and 1·26 in. respectively ; allowing 1·5 in. for the thickness of the bark, a girth of 6 ft. over bark would at this rate be attained in about forty to fifty years. The trees measured were in somewhat open situations, and showed a diameter growth probably above the average, which accounts for the adoption in the Shillong pine forests working plan of a rotation of sixty years, corresponding to an estimated girth of 6 ft.

[1] *loc. cit.*, p. 111.

In the hills between the Sittang and Salween rivers, Mr. Ferrars found the growth to vary from four to sixteen rings per inch of radius, giving a mean annual girth increment, without bark, of 0·39 to 1·57 in. Measurements made by Mr. J. Copeland in the Northern Shan States showed that an average tree reached a girth of 6 ft. and a height of 100 ft. in seventy-two years.

4. **Pinus Gerardiana,** Wall. Himalayan edible pine, chilgoza pine. Vern. *Chilghoza*, trans-Indus ; *Chújin*, Chitral ; *Mirri*, Chamba ; *Ri*, Kunawar. The seed, *Neoza*.

A moderate-sized evergreen, somewhat branchy tree, attaining ordinarily a girth of 6–8 ft. and a height of 50 to 60 ft., and occasionally a girth up to 12 ft. or more and a height up to 80 ft. Branches usually ascending, not whorled, or only obscurely whorled. Leaves in bundles of three, 2–4 in. long, dark green, somewhat stiff, with a basal sheath about 0·5 in. long, which falls by the second year. Bark thin, grey, smooth, with a mottled appearance, exfoliating in irregular thin flakes, which leave shallow depressions. Wood hard, tough, and very resinous, not much used except in regions where other timber is not available. The chief value of the tree lies in its seeds, which are roasted and eaten ; they are collected in quantity for export to the plains.

In exposed situations and on poor shallow soil the tree is stunted and gnarled, but under favourable conditions it is fairly tall and straight. Mr. Stebbing [1] records a tree 15 ft. in girth and 70 ft. high in the Shinghar forest in Zhob.

Distribution and habitat. Common in Afghanistan and northern Baluchistan. Hariab district of the Kurram valley at 7,000–11,000 ft. Somewhat local in the inner arid valleys of the Himalaya from the Niti pass in Garhwal westward to Chitral and beyond, chiefly between 6,000 and 10,000 ft. This pine is found in the upper parts of the Sutlej, Ravi, and Chenab valleys, not on the Jhelum or in the Kagan valley. It grows gregariously, forming forests of a somewhat open type (Fig. 440), though moderately dense pole crops are also met with (Fig. 441). It is sometimes found associated with deodar, or with *Quercus Ilex* and *Fraxinus xanthoxyloides*, or in the trans-Indus with *Pinus excelsa*. It is found only in the dry regions outside the influence of the monsoon, where the rainfall is scanty but there is a heavy winter snowfall, the total precipitation probably amounting to between 15 and 30 in. It endures severe cold in winter ; the summer temperature within its habitat probably seldom, if ever, exceeds 100° F. The chilgoza pine makes little demand on the fertility of the soil, and is capable of growing on excessively dry, barren hill-sides with shallow soil, and even on bare rock.

In his account of the chilgoza forests of Zhob and the Takht-i-Suliman, Mr. Stebbing says that in that region the tree thrives between 7,500 and 8,500 ft., but ascends to slightly over 10,000 ft. It occupies a particularly waterless tract, chiefly on limestone, growing at times on what appears to be solid rock. The forest is chiefly uneven aged, and is often fairly dense. In places the chilgoza is associated with *Pinus excelsa*, but the existence of the latter is probably accounted for by the presence of pockets of moisture held up in the rock.

Flowering and fruiting. The flowers appear in May–June, when

[1] Note on the Chilgoza Forests of Zhob and the Takht-i-Suliman, For. Bull. No. 7, 1906.

pollination takes place. The young female cone increases in size slightly during the first year and rapidly during the second year, becoming full-sized about July ; it ripens about September–October of the year after pollination. The old cones remain on the tree some time after the seed is shed. The mature cone is 5–9 in. long by 3–5 in. in diameter, with very thick, woody scales about 1·5 in. long by 1 in. broad ; the apophysis is triangular, reflexed, ending with a stout umbo which is often tipped with a recurved spine. The seed (Fig. 439, *a*) is 0·8–1 in. long, cylindrical, with a short wing which soon becomes detached and remains on the cone-scale when the seed falls. On an average about 85 seeds weigh 1 oz. The seed is oily, and does not retain its vitality long.

The seed-crop is an important matter from an economic point of view, and hence trees with broad spreading crowns, even if gnarled and stunted, are of more value than well-shaped trees with narrow crowns. Countings by Bhai Sadhu Singh in Baluchistan gave an average of 33 seeds per cone for 40 cones, and the following number of cones per tree :

1. 13 trees under 3 ft. in girth had an average of 28 cones per tree.
2. 18 trees 3 ft. to 4 ft. 11 in. in girth had an average of 51 cones per tree.
3. 17 trees 5 ft. to 6 ft. 11 in. in girth had an average of 80 cones per tree.
4. 12 trees 7 ft. and over in girth had an average of 129 cones per tree.

The largest number of cones on one tree was 400 on a tree 8 ft. 4 in. in girth.

Seeds required for edible purposes are obtained from cones which are still green. The cones are gathered from the trees, heaped up, and burnt in order to cause them to open, after which the seeds are picked out. Much damage is apt to be done to the trees during the collection of the cones ; men ascend the trees and by means of a long pole with a hook at the end they wrench off the cones, breaking a piece of the branch, and a tree which has been subjected to this form of injury for any length of time acquires a ragged appearance.

GERMINATION (Fig. 439, *b*–*g*). Epigeous. The radicle emerges from the end of the seed and descends ; the hypocotyl elongates, arching but soon straightening and carrying the cotyledons above ground. As the cotyledons elongate the shell of the seed remains enclosing their extremities for a time and then falls to the ground, when the cotyledons, 9–12 in number, spread out in a whorl, from the centre of which the young shoot develops. Sometimes the shell of the seed, which is heavier than in most pines, is not raised above ground but remains on or in the ground, the cotyledons extricating themselves gradually as the hypocotyl elongates.

THE SEEDLING (Fig. 439).

Roots : primary root very long, terete, wiry, brown ; lateral roots numerous, short to moderate in length, fibrous. *Hypocotyl* distinct from root, terete, 1–1·5 in. long, cylindrical, glabrous, at first smooth, pink and pale green, becoming dark green, then brown and striate by the cracking of the epidermis. *Cotyledons* 9–12, whorled, 1·5–2·3 in. long, acicular, triquetrous, compressed laterally, curving upwards, sparsely and minutely serrulate, green. *Stem* erect, wiry. *Leaves* of first season primordial, arranged in a close spiral 0·8–2 in. long, earlier leaves shorter than later ones, acicular, flattened, margins minutely but sharply serrulate.

The growth of the seedling above ground is somewhat slow, but a vigorous taproot is produced early, and may attain a length of as much as 1 ft. by the

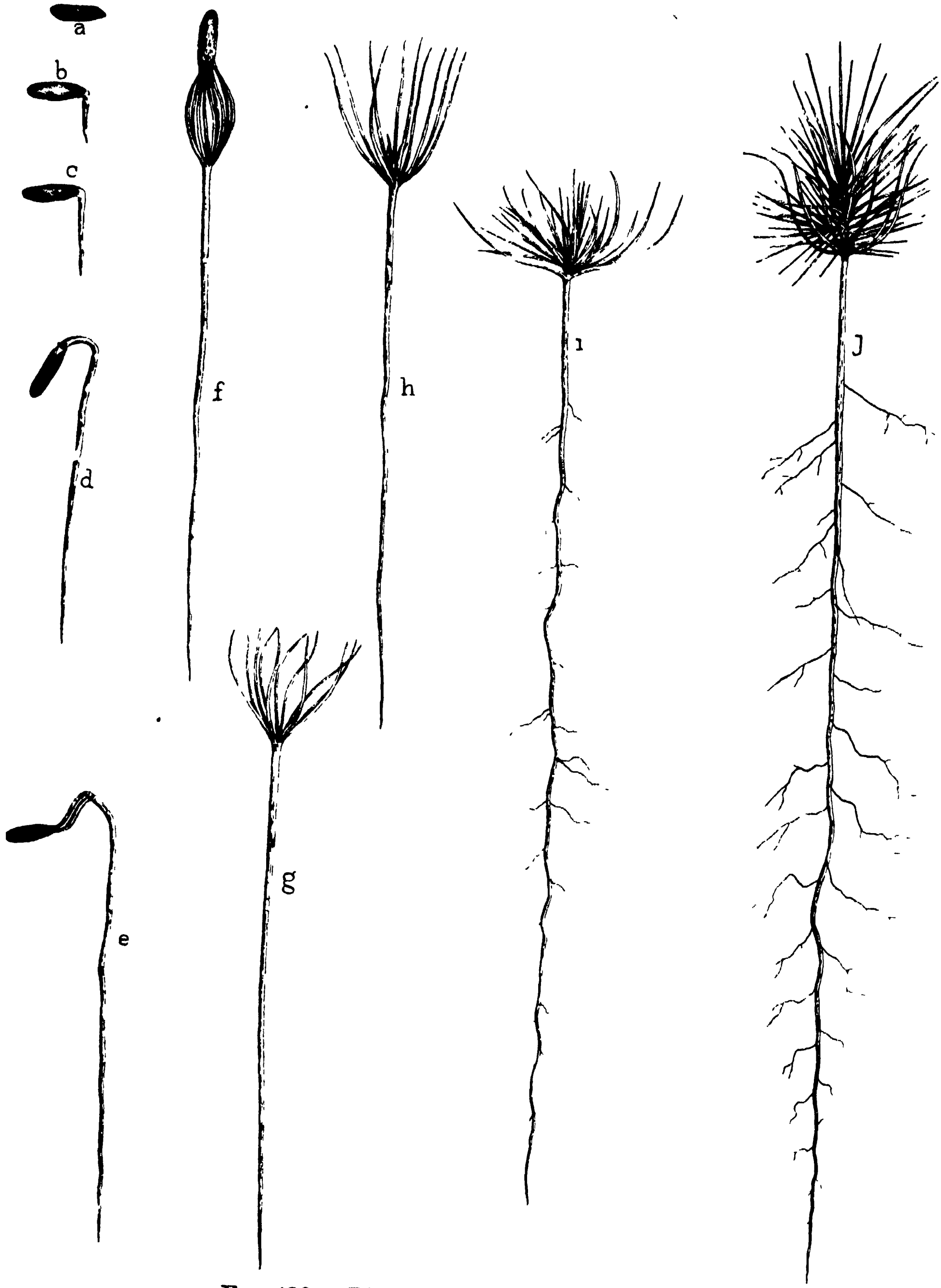


FIG. 439. *Pinus Gerardiana.* Seedling × $\frac{3}{8}$.
a, seed; *b–g*, germination stages; *h–j*, development of seedling to end of first season.

end of the first season. Seedlings raised at Dehra Dun produced a shoot about 1 in. long above the cotyledons during the first season. They were found to be very subject to the attacks of insects, birds, rats, and squirrels during and shortly after germination, the parts attacked being the tender hypocotyl and cotyledons. The seedling is very intolerant of stiff, badly drained, or wet ground, and requires a free porous soil without any excess of moisture.

SILVICULTURAL CHARACTERS. The chilgoza pine is a light-demander, though perhaps less so than *Pinus longifolia.* It is a hardy tree, standing a considerable degree of cold in winter and excessive drought. It is windfirm, but on very exposed situations becomes stunted and gnarled. Mr. Stebbing[1] notes that in Zhob bark beetles kill many trees, those attacked showing shot-holes, with resinous exudations, all over. Remedial measures proposed are to select affected trees for felling; to fell them when the insects are in the larval and pupal stages within the tree, about the beginning of June, the middle to the third week of July, the end of August, and the second to third week of October; to remove and burn all bark and to pile up and burn all branch-wood.

NATURAL REPRODUCTION. Where the seeds are extensively collected, natural reproduction suffers from this cause. Mr. Stebbing notes that in the forests of Zhob goat-browsing is very inimical to reproduction, which is scarce in heavily grazed areas, and appears mainly under the protection of thorny thickets, while in places protected from grazing it springs up readily.

SILVICULTURAL TREATMENT. The main object of working the chilgoza pine forests is the production of seed, for which purpose heavy thinnings are indicated where necessary to stimulate the expansion of the crown. In the case of the trans-Indus forests, Mr. Stebbing advocates uneven-aged forest with sowing up of unregenerated blanks and the felling of dead or beetle-infested trees only, a certain proportion of cones being left for natural regeneration. Possibly a system of rotational closures to seed-collection and grazing would also result in successful reproduction.

5. **Pinus Merkusii**, Jungh. Tenasserim pine. Vern. *Tinyu*, Burm.

A moderate-sized to large tree, attaining a height of 100 ft. in Sumatra, but seldom exceeding 60 ft. in Burma. Adult leaves in pairs, 7–10 in. long, enclosed at the base by a persistent sheath 0·6–0·8 in. long. Crown pyramidal in young trees, becoming spreading and umbrella-like in older trees. Bark brownish to ashy grey, thick, fissured. Wood very resinous, used for torches as in the case of *P. Khasya*. The tree produces resin of very good quality (see under *P. Khasya*, p. 1084), and may yet become an important source of supply; resin-tapping operations, however, have not hitherto been organized in the forests of *P. Merkusii*. Occasionally this pine reaches a fair size. Mr. M. H. Ferrars[2] measured one 9 ft. 7 in. in girth in the hills between the Sittang and Salween rivers.

DISTRIBUTION AND HABITAT. This essentially tropical pine extends from the southern portion of the Southern Shan States southward through the hills of the Salween and Thaungyin drainages. It occurs also in Siam, Cochin China, Sumatra, Java, Borneo, and the Philippines. In the Burmese region it is found at elevations varying from 500 to 2,500 ft., usually on low hills or spurs, associated with *Dipterocarpus tuberculatus* or with *Pentacme suavis*,

[1] Note on the Chilgoza Bark-boring Beetles of Zhob, Baluchistan, For. Bull. No. 3, 1905.

[2] Ind. Forester, i (1875), p. 114.

Shorea obtusa, and *Melanorrhoea usitata*, often on gravelly soil. It extends over a considerable area in the southern portion of the Southern Shan States (see under *P. Khasya*, p. 1085). In 1885 the area of forests of this pine in the Thaungyin valley was estimated at about 50 square miles, in the neighbourhood of Myawaddi.

Ryan and Kerr [1] say that on the Khoon Youan plateau, Siam, a narrow plateau at an altitude of about 1,500 ft. stretching for 7 or 8 miles, it is the predominant tree, *Dipterocarpus tuberculatus* coming next in order of frequency. The soil is a gravelly sand.

The tree requires very well drained ground and porous soil, and is frequently found on decidedly dry ground, but always in regions of comparatively heavy rainfall. Growing as it often does on the poor dry soil so frequently characteristic of Burmese *indaing* forest, it is not as a rule subjected so much to damage by shifting cultivation as *Pinus Khasya*, though possibly this may to some extent explain the fact that it does not ordinarily form such pure crops as that species in Burma.

In the Philippines, Foxworthy [2] says, it grows on dry ridges in the provinces of Zambales and Mindoro, and quotes the following field note from the former: 'Grows in pure stands on heights some 15 kilometers east of Santa Cruz, Zambales. Forest of irregular area covering, as estimated, 500 hectares. Soil is loose and impregnated with copper oxide, giving a dark colour. No undergrowth of trees other than pine exists, and fires greatly retard reproduction, so that seedlings are at present rarely found.' Of its occurrence in the Mindoro province Merritt [3] says: 'South-west of the high mountain chain stretching north and south from Mount Halcon is an area with a temperature considerably lower than that of sea-level and with a well-drained and extremely dry soil. Here conditions are right for the growth of pine (*P. Merkusii*). This tree grows in pure stands, and is found in open scattered groves along the higher ridges and slopes, sometimes extending well down toward sea-level. This pine was observed at elevations as low as 60 m. in the vicinity of Santa Cruz, the southern part of its range, while at its northern limits it was nowhere seen below 900 m. Ground fires annually burning over the grass which has crept in among these trees prevent the best of reproduction and keep the forest open.'

LEAF-SHEDDING, FLOWERING, AND FRUITING. The new shoots and the flowers appear in February–March, the old needles falling early in the second year (Brandis). Cones ripening April–May, solitary or in pairs, 2–3 in. long or longer, usually curved, ovate oblong with woody oblong scales; apophysis more or less rhomboidal, or 5-gonous on the basal scales, depressed pyramidal, furrowed. Seeds (Fig. 438, *i*) with an unequal-sided wing, the whole 0·8–1 in. long, wings 0·2–0·3 in. broad; seed without wings 0·15–0 25 in. long. About 650–700 seeds weigh 1 oz.

GERMINATION (Fig. 438, *j–o*). Epigeous. The radicle emerges from the end of the seed, the hypocotyl elongates, sometimes with slight arching, and the cotyledons are carried above ground. As the cotyledons, 8–12 in number,

[1] Journ. Siam Soc., viii (1), 1911.
[2] Philippine Gymnosperms, Philip. Journ. Science, vi, 3, Sec. C, July 1911.
[3] The Forests of Mindoro, Philip. For. Bur. Bull. No. 8 (1908), 22.

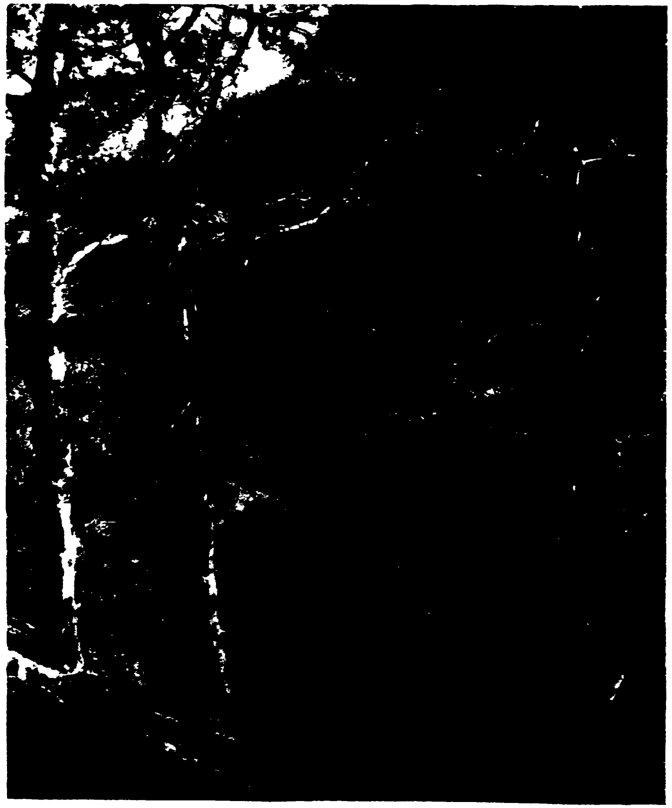


FIG. 440. *Pinus Gerardiana* trees, upper Sutlej valley.

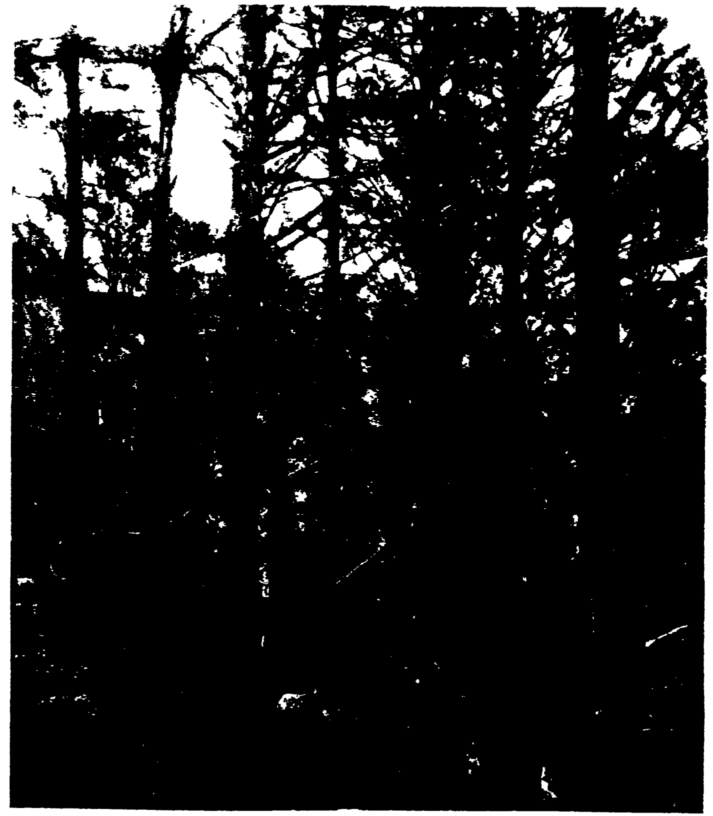


FIG. 441. Pure crop of *Pinus Gerardiana*, upper Sutlej valley.

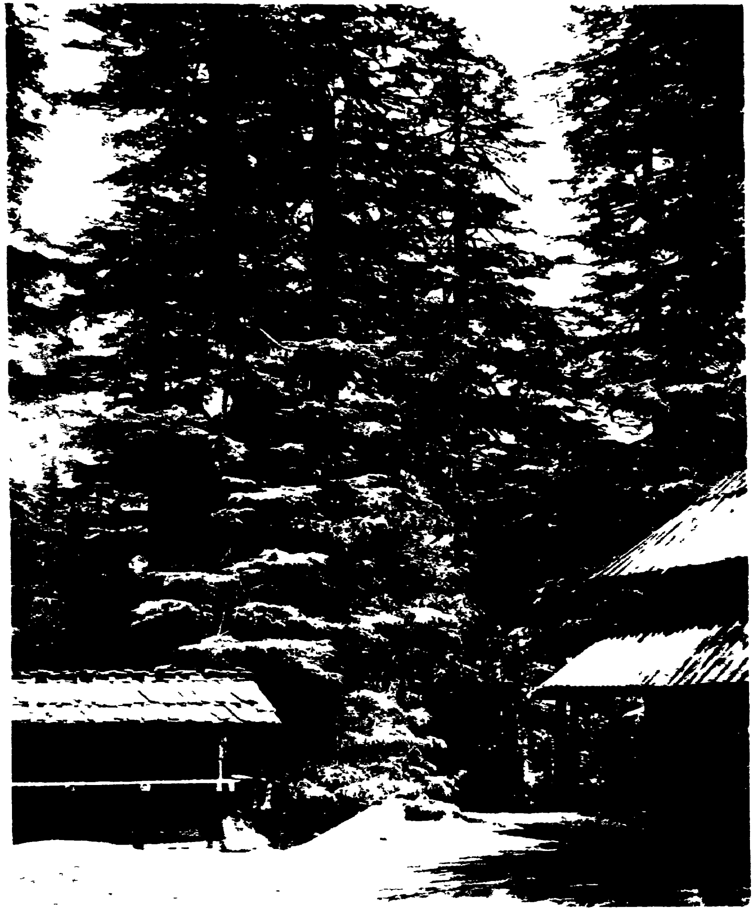


FIG. 442. *Cedrus Deodara*, large trees in temple grove at Dhungri, Kulu. largest tree 204 ft. high, 17 ft. 4 in. in girth.

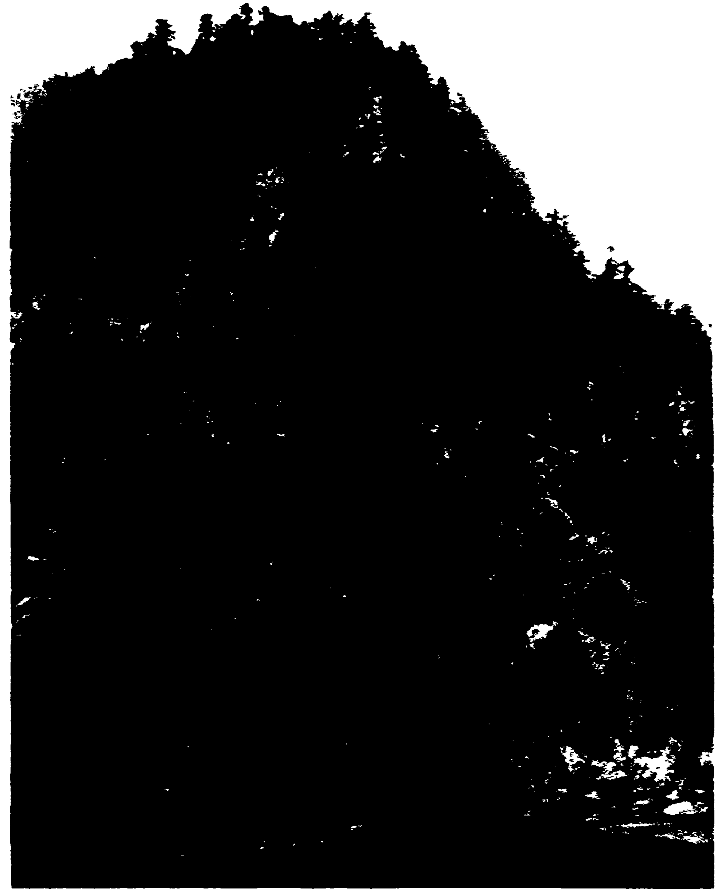


FIG. 443. Deodar forest on rocky precipitous ground, Kagan valley, Hazara.

elongate, the shell of the seed remains for a time enclosing their apices like a cap, finally dropping to the ground, when the cotyledons spread out radially and the young shoot develops from the centre of the whorl.

THE SEEDLING (Fig. 438).

Roots: primary root moderately long, wiry, flexuose; lateral roots moderate in number, fibrous. *Hypocotyl* distinct from root, 1·2–1·8 in. long, cylindrical or slightly fusiform, green or reddish turning light brown. *Cotyledons* 8–12, whorled, 1–1·8 in. long, acicular, triquetrous, compressed laterally, light green, inner margin sometimes remotely serrulate. *Stem* erect, terete, in first season pale green and almost hidden by the primordial needles. *Leaves*: first season, only primordial needles, 0·6–1·5 in. long, acicular, flattened above, rounded beneath, punctate in longitudinal lines of stomata, glaucous green, margins finely and sparsely serrulate; second season, adult needles begin to appear, in pairs, 2–7 in. long, inner surfaces flattened, outer rounded, margins finely and sharply serrulate, basal sheath 0·3–0·4 in. long, composed of grey chartaceous scales.

Nothing is known regarding the habits and requirements of the seedling in its natural habitat. Numerous seedlings raised at Dehra Dun showed slow growth during the first season, a height of about 2 in. being ordinarily attained. Few survived the winter frost, and many were destroyed by insects, a form of damage to which they are evidently very prone. The seedlings cannot tolerate stiff, badly drained soil, and require to be grown in free porous soil.

SILVICULTURAL CHARACTERS. The silvicultural characters of this tree require study. Like other pines, it suffers much from fire in its younger stages.

RATE OF GROWTH. Gamble gives the rate of growth as 11 rings per inch of radius, or a mean annual girth increment of 0·57 in.

2. CEDRUS, Link.

The cedars are evergreen trees with branches arising irregularly from the stem, not in whorls. Branchlets of two kinds, namely, long shoots bearing solitary leaves arranged spirally and short arrested shoots with leaves in pseudo-whorls (rosettes). The latter elongate slightly each year, adding a new whorl of leaves, and sometimes produce flowers; occasionally they develop into long shoots. Leaves acicular, rigid, triquetrous. Flowers monoecious or dioecious. Male flowers erect, catkin-like; female flowers small erect cones. Ripe cones solitary, erect, ovoid, ellipsoidal or cylindrical, breaking up on the tree and shedding the winged seeds with the cone scales, the central axis persisting for a long time.

There are three main forms of cedar usually classed as species, which come true from seed: (1) *Cedrus Libani*, Barrelier, the Lebanon cedar, with leading shoot and branchlets not pendulous, broad spreading flat crown, and large broad ellipsoidal cones, indigenous to the Lebanon range and Asia Minor; var. *brevifolia*, Hooker, the Cyprus cedar, a native of Cyprus, has much shorter leaves and cones; (2) *C. atlantica*, Manetti, the Atlas or Algerian cedar, with stiff leader and branchlets, short leaves, and cones shorter and more cylindrical than (1), indigenous to Algeria and Morocco; (3) *C. Deodara*, Loudon, the Himalayan cedar or deodar, with leader and branchlets pendulous on young trees, and with longer leaves and broader cones than the other species.

Cedrus Deodara, Loudon. Syn. *C. Libani*, Barr, var. *Deodara*, Hook. f.; *Pinus Deodara*, Roxb. Himalayan cedar, deodar. Vern. *Diár*, *deodár*, *dedwar*, *kelu*, *kilar*, W. Him.

A very large evergreen tree with dark green, or in some cases silvery, foliage; the form with silvery-blue foliage is conspicuous and handsome, and is fairly common in certain localities, for instance in Hazara. Branches horizontal or slightly ascending or descending, not whorled but arising irregularly from the stem. Extremities of leading shoot and branches drooping in normal young to middle-aged trees, stiffer on stunted slow-growing specimens. Up to middle age the tree has a conical crown with a definite leading shoot, but in later life the crown becomes rounded or broad and flat with spreading horizontal branches, the flat-topped formation being sometimes hastened by injury to the leading shoot or by the action of the wind in exposed situations. Leaves acicular, stiff, 1–1·5 in. long, on the normal long shoots spirally arranged, on the short arrested shoots in pseudo-whorls. On the branchlets the successive years of growth are marked by rings of recurved bud scales marking the points of junction between the successive years' shoots; on the arrested shoots also a fresh ring of small brown recurved scales marks each year's growth. Bark greyish brown, with vertical and diagonal cracks dividing it into irregular oblong scales.

Wood moderately hard; sap-wood white, heart-wood light yellowish brown, oily and strongly scented, very durable. The deodar is the most important timber tree of the western Himalaya. The wood is extensively used for building, railway sleepers, and other purposes for which durability is required, as well as for furniture, general carpentry, and many other purposes; it is largely exported to the plains of India.

The deodar reaches large dimensions. Dr. Schlich found one in the Sutlej valley 240 ft. high, Mr. W. R. Fisher one in the Pabar valley 216 ft. high. Mr. G. G. Minniken[1] records a tree near Purrang village, Bashahr, which was 150 ft. high and 31 ft. 6 in. in girth at 6 ft. from the ground, with a clean bole of 45 ft. to the first branch. Mr. Gamble measured a hollow stump 34 ft. in girth in the Moriru forest, Tehri Garhwal. Brandis mentions trees 30 to 36 ft. in girth in Kunawar. Messrs. Hart and Gibson[2] record trees in Bashahr measuring 35, 32, and 26 ft. in girth, and mention that 6,158 trees felled for export in the years immediately prior to 1905 averaged 9 ft. 5 in. in girth. Rai Bahadur Keshavanand[3] says that 108 selected large trees in well-stocked areas in the Karnah-Drawa forests, Kashmir, gave an average of 11 ft. 4 in. in girth and 125 ft. in height; the largest tree measured was 210 ft. high and 21 ft. in girth. In 1914 I measured a large branchy tree growing on a rock near Monali, Kulu, with a diameter at breast-height of 19 ft. 9 in.; the girth could not be measured owing to the inaccessible position of the tree, but even though the tree had a much greater diameter in one direction than the other, and the greater diameter was measured, the girth cannot have been short of 50 ft. In the Dhungri temple at Monali are some large trees, of which I measured several and found the largest to be 204 ft. high and 17 ft. 4 in. in girth (see Fig. 442). Some of the finest specimens of deodar trees now to be

[1] Ind. Forester, ix (1883), p. 44.

[2] Working Plan for the Leased Forests of the Bashahr State, Sutlej Valley, 1905.

[3] Working Plan for the Karnah-Drawa Forests, Kishanganga Valley, Kashmir.

found are those growing in sacred temple groves, where they are protected from injury and destruction and must in some cases be of great age.

DISTRIBUTION AND HABITAT. *General distribution.* The deodar is found throughout the western Himalaya from Afghanistan to Garhwal at elevations varying from 4,000 to over 10,000 ft., but most commonly at 6,000–8,500 ft. Its eastern natural limit is in the valley of the Dhauli river, a branch of the Alaknanda river in Garhwal, below the Niti pass, longitude 79° 48′. The altitudinal range of what may be termed the deodar belt varies in different localities, while it is usually higher on southerly than on northerly aspects; this belt is a well-marked one, since the tree is essentially gregarious, and often forms pure crops of considerable extent.

The chief deodar forests in British territory are confined to Jaunsar, Kulu, and Hazara, while the aggregate area in Indian states, including Kashmir, Chitral and Dir, Chamba, Bashahr, Tehri Garhwal, as well as various minor hill states, is considerably greater than that in British territory.

In Kashmir the chief zone of the deodar is between 6,500 and 8,000 ft., at which elevations it often forms pure forests; it descends on cool aspects to 5,000 ft., and occasionally to 4,500 ft., while on sunny slopes it may ascend to 10,000 ft. or even higher; at the higher elevations it is usually scattered and stunted. In Hazara, deodar is common in the Kagan valley, its extreme limits of elevation being about 4,000 ft. and 9,000 ft. In the upper parts of the valley, as the rainfall diminishes, it forms purer forests than it does lower down, and although it is frequently mixed with blue pine, spruce, and various broad-leaved species, and at the higher elevations with silver fir, it also forms pure crops of some extent; in the lower parts of the valley it is less plentiful and is usually mixed with other species. Although in places where the soil is deep it attains very fair dimensions, the deodar is not at its best in Hazara, the growth being usually slow and the trees showing a lack of vigour. It is very frequently found on rocky precipitous ground, where it usually forms pure crops (see Fig. 443), and in general it seeks the spurs, while the intervening depressions are occupied by other species. This is the condition in which it is commonly found in the Siran valley, where it is by no means abundant. In the Dungagali and Thandiani ranges it is very local, being found in comparatively small patches, usually at about 7,000–8,000 ft., associated with blue pine, yew, maple, horse-chestnut, and elm, and occasionally with silver fir. The largest tree I have measured in the Kagan valley was one of 21 ft. 6 in. girth in the Kamalban forest; its height, by estimation, was not more than 100 ft. In the Upper Ravi forests of Chamba the most important deodar forests lie between 7,000 and 8,500 ft. In Kulu they lie between 5,000 and 8,000 ft., but the deodar descends in places to 4,500 ft., and ascends to 9,000 ft. or over. In Kangra natural deodar is confined to Chota and Bara Bangahal, and the neighbourhood of Tathwani, where it occurs on a very limited scale. In the upper and drier parts of the Sutlej valley most of the deodar forests occur between 8,500 and 9,500 ft., but trees are found up to 10,000 ft., and occasionally up to 10,500 ft. In lower Bashahr and the Simla hills the principal zone of the deodar lies between 6,000 and 8,000 ft., the extreme limits being approximately 5,500 and 9,500 ft. In Jaunsar and Tehri Garhwal the most important deodar forests lie between 6,500 and 8,500 ft.; on northerly aspects the tree descends to 6,000 ft. or even lower, while on southerly aspects it ascends to 9,000 ft. or over, though it is stunted at the higher elevations.

Topography, geology, and soil. The deodar occurs naturally on mountainous country with slopes varying from moderate to precipitous, as well as on level ground in river valleys at suitable elevations. It is found on all aspects, though it grows best and reaches its largest dimensions on northerly aspects and in cool situations. It occurs, however, also on hot southerly slopes, though in such places the growth is usually poorer, and the establishment of young growth can as a rule be effected only with the aid of shelter. At the higher elevations it occurs only on sunny aspects.

The deodar is found naturally on all the important geological formations of the western Himalaya, including granite, gneiss, mica and other schists, shale, limestone, quartzite, and conglomerate, as well as on trap dykes and recent boulder beds. It avoids stiff badly drained soil, while on shallow rocky ground the growth is stunted; the best growth is attained on deep, fairly porous, fertile soil in cool situations, for instance along the sides of moist ravines.

Climate. The great majority of the best deodar forests are found where the rainfall varies from 40 to 70 in.; in these regions most of the rain falls during the south-west monsoon from June to September, while there are often considerable falls of snow during the winter, from December to March. The deodar occurs in the inner dry valleys of the upper Sutlej, the Kunhar and Swat rivers, and elsewhere; here the rainfall is probably less than 35 in., the great bulk falling in the form of winter snow, which in these dry regions is an important factor in relation to the deodar. In some of these dry tracts field cultivation is impossible without the aid of irrigation, and this indicates the dryness of the climate in which deodar is capable of growing, though this is probably rendered possible only by the favourable influence of the heavy snowfall. The shade temperature in the deodar zone probably varies for the most part from a minimum of 10° to 25° F. to a maximum of 80° to 100° F.; temperature statistics from stations within that zone, however, are somewhat scanty.

Types of forest. The deodar is a typically gregarious tree, and is frequently found in the form of pure forests. The pure type, which is shown in Figs. 443, 445, and 446, is widely represented throughout the deodar zone, and is especially typical of the inner dry valleys; in the latter regions, however, the trees are often stunted, and usually show very slow growth. Common as are pure crops, it is more usual to find the deodar in mixture with other species, both coniferous and broad-leaved, but in such cases it still tends to retain its gregarious habit, and often forms the bulk of the crop. Among conifers the most important companions of the deodar are the blue pine (*Pinus excelsa*) and the spruce (*Picea Morinda*), the former being as a rule characteristic of drier types of forest than the latter. The deodar-spruce mixture is one in which the deodar often attains excellent height-growth, with a tall, clean bole, since this mixture is frequently characteristic of moist, rich soil; it is well exemplified in the forests of Chamba, but is also frequently met with in Jaunsar, Bashahr, and elsewhere. The mixture of deodar with blue pine is perhaps the commonest met with, and is a most suitable one; it is sometimes found in the form of a deodar underwood making its way up beneath an upper story of blue pine where the latter is sufficiently open. At the higher elevations the deodar is sometimes found mixed with the silver fir (*Abies Pindrow*), though this mixture is less common than the spruce mixture, and sometimes takes the form of a deodar crop under which the silver fir is gradually making its appearance. Mixed forests of deodar, blue pine, spruce, and silver fir are common in parts of Hazara (see Fig. 399); here the deodar as a rule seeks the more rocky spurs. At the lower elevations deodar is found associated with *Pinus longifolia*, the pine usually occupying the drier ridges and spurs while he deodar occupies the moister and cooler depressions. Sometimes as a result of protection from fire, a young crop of deodar may be found making its appearance beneath an overwood of *Pinus longifolia* (see p. 1055). Where the cypress (*Cupressus torulosa*) is found it is not uncommonly associated with the deodar, while in the dry inner region of the Himalaya the latter is sometimes found with *Pinus Gerardiana*. In moist, shady situations the yew (*Taxus baccata*) sometimes occurs as an underwood species.

Among oaks, *Quercus incana* and *Q. dilatata* are very frequent companions of the deodar, the former at lower elevations than the latter. *Q. dilatata* often occurs in the spruce-deodar mixture in moist situations. At the higher elevations the deodar extends occasionally into the region of *Q. semecarpifolia*, but is hardly typical of that region. In Chitral and the dry parts of the Kishanganga valley in Kashmir and the Kagan valley in Hazara the deodar is associated with *Quercus Ilex*, which sometimes forms a shrubby undergrowth (see Fig. 358).

Besides oaks there are many other broad-leaved species associated with the deodar, for example *Pieris ovalifolia* and *Pyrus Pashia* at low elevations, *Rhododendron arboreum*, *Prunus Padus*, *P. Puddum*, *Aesculus indica*, *Cedrela serrata*, *Populus ciliata*, *Cornus macrophylla*, *C. capitata*, *Juglans regia*, *Ulmus Wallichiana*, *Betula alnoides*, *Corylus Colurna*, *Ilex dipyrena* (in moist situations), and various maples. Among shrubs and small trees of the undergrowth are various species of *Rosa*, *Rubus*, *Lonicera*, *Berberis*, *Viburnum*, *Salix*, *Indigofera*, and *Desmodium*, as well as *Cotoneaster bacillaris*, *Parrotia Jacquemontiana*, *Daphne cannabina*, and other trees and shrubs. Herbaceous plants are common, but the soil-covering in deodar forest not infrequently consists of grass, while in dense pole crops there may be no vegetation at all on the ground. Bamboos are represented by species of *Arundinaria*, of which *A. falcata* and *A. spathiflora* are the commonest. In some localities the bracken fern (*Pteris aquilina*) covers the ground, particularly where the deodar is associated with blue pine. This fern may be regarded as an indicator of soil well suited for both these trees; *Indigofera* and *Desmodium* are also indicators of suitable soil, and on hot aspects form a most useful protective cover for deodar seedlings. Among climbers found in deodar forests the commonest are *Rosa moschata*, *Vitis semicordata*, *Clematis montana*, and ivy (*Hedera Helix*).

LEAF-SHEDDING, FLOWERING, AND FRUITING. The new shoots appear in March or early April, small pale green opening buds marking their first appearance. The old leaves are shed for the most part in the hot season, chiefly in May, but leaf-shedding may also take place to some extent in the autumn, about the time the cones ripen. The persistence of the leaves varies. On vigorous saplings they do not persist so long as on older trees with slow-growing branchlets. In the former case they may all fall the year following their first appearance, while in the latter case they may persist, in part at least, as long as six years ; this applies both to the whorls of leaves on the arrested branchlets and to the solitary leaves which are spirally arranged on the normal shoots.

Male flowers. The male flowers, sometimes termed catkins (Fig. 444, *a–d*), first appear in June, by the end of which month they become clearly visible at moderate elevations. They ripen and shed their pollen from the middle of September to the middle of October, according to locality and season. The male flowers are solitary and erect at the ends of the arrested branchlets, and are found in quantity along the upper sides of the branches. When young they are pale green. Before ripening they are yellowish green with a purplish tinge, oblong ovoid, 1–1·8 in. long by 0·4–0·6 in. in diameter. On opening they elongate rapidly to 2–3 in. in length, and become yellow with pollen. Trees covered with ripe male flowers show a blaze of yellow on the upper sides of their spreading branches, and the pollen is blown far and wide by the wind, particularly on sunny days, when it may be observed in dense yellow clouds. The majority of the male flowers do not remain long on the tree after ripening, particularly if showers of rain occur to dislodge them, when they fall in quantity to the ground; some may remain for a few months.

Female flowers. The female flowers or young cones (Fig. 444, *e*) appear in August, and pollination takes place from the middle of September to the middle of October ; they are solitary and erect at the ends of the arrested branchlets on the upper sides of the branches, and usually farther towards their ends than the cones of the previous year. At the time of pollination they are inconspicuous, partly hidden by the rosettes of leaves, and somewhat difficult to find, oblong ovoid, 0·5–0·8 in. long by 0·25 in. in diameter, pale glaucous green. The scales, in spirals of 8 × 5, at the time of pollination stand perpendicular to the axis, exposing the ovules, but after pollination they close.

Development and ripening of cones (Fig. 444, *f–h*). There is no growth in the young cones until the following spring, when by the early part of May they have increased sufficiently in size to be clearly visible. By the end of June or during July they become full sized, and are pale bluish green. They turn chocolate-brown in colour during August, and ripen from the end of September to the middle or end of November, though at high elevations or in late seasons the seed may not all fall until the early part of December. Thus the time occupied from the first appearance of the female flower to the ripening of the cone is about 12½ to 13½ months. The ripe cones are erect, brown, ovoid or ellipsoidal, 3–4·5 in. long by 2–3·5 in. in diameter where broadest,

---

FIG. 444. *Cedrus Deodara.* Flowers and fruit × ⅔.

a, young male flower shortly after first appearance : end of June ; *b*, male flower immediately before ripening : September ; *c*, male flower ripening, and pollen emerging : latter part of September ; *d*, male flower completely opened, and pollen shed : end of September and during October ; *e*, female flower (young cone) at time of pollination : latter part of September ; *f*, young female cone beginning to grow : early part of May, seven months after pollination ; *g*, immature cone : June, eight to nine months after pollination ; *h*, ripe cone commencing to open : October, thirteen months after pollination ; *i*, single scale of cone with one seed present (on left) and one removed (on right) ; *j*, winged seed ; *k*, axis of old cone, a year after ripening.

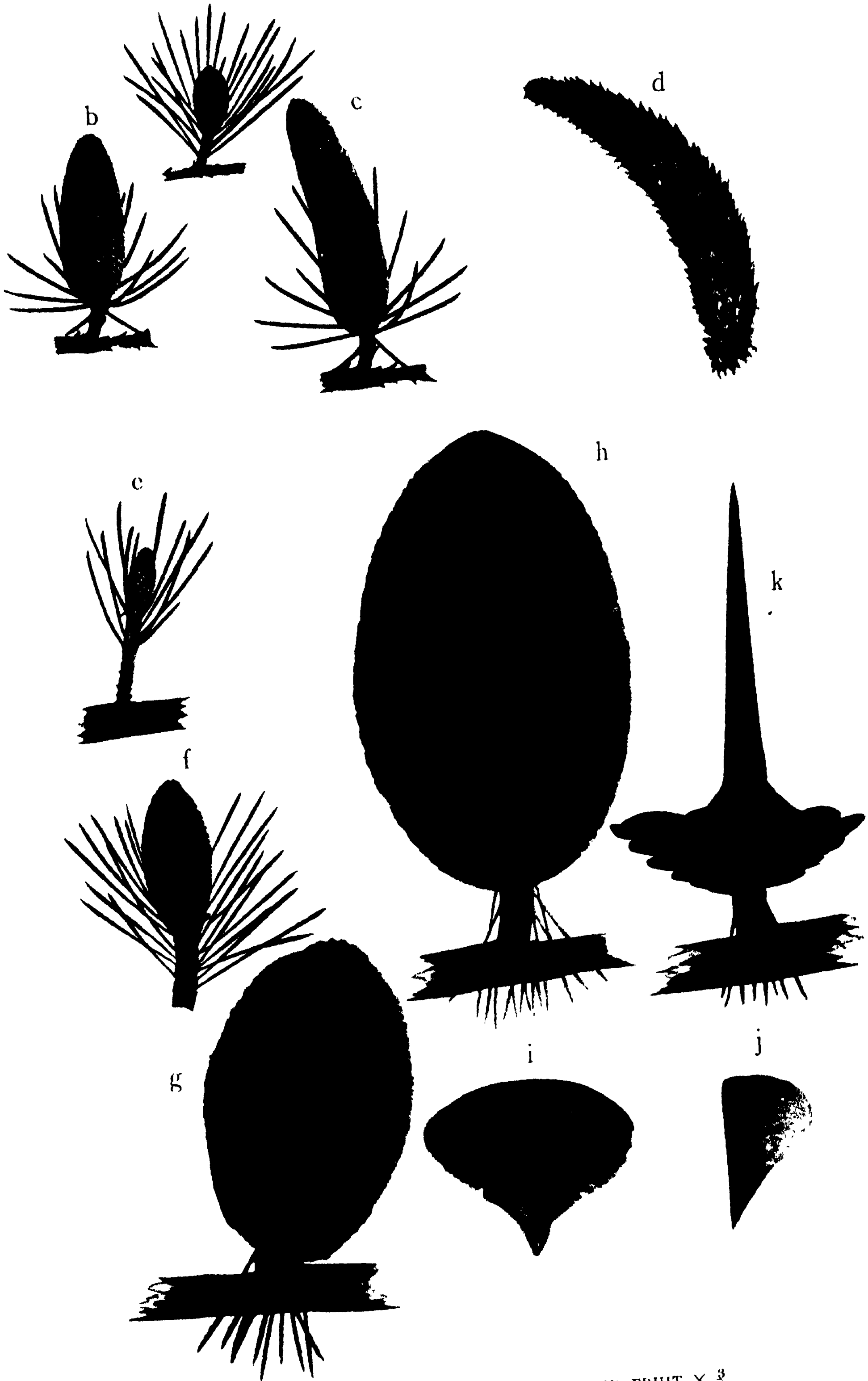


Fig. 444. *Cedrus Deodara*—Flowers and fruit × $\frac{3}{4}$

For details see footnote page 1100

with numerous fan-shaped scales arranged in spirals of 8×5 on a persistent woody central axis. On each scale rests a pair of winged seeds (Fig. 444, *i* and *j*). On ripening the cone breaks up on the tree, the scales and seeds falling to the ground and the persistent axis remaining (Fig. 444, *k*); these old cone-axes remain for years on the branches. The opening of the cones is favoured by dry, sunny weather. Fig. 447 shows two cones of successive years, namely, a mature cone about to ripen and immediately in front of it a young cone (flower) at the time of pollination; three old cones axes are also visible.

Sexual characters. As a general rule the deodar is dioecious. It is by no means uncommon, however, to find male flowers and female cones on the same tree, in which case, so far as has been observed, they are invariably on separate branches. Several years ago observations were recorded for a series of years in Jaunsar with the view of ascertaining to what extent deodar trees retain their sexual character year after year. The records were unfortunately lost before detailed results could be written up, but it was noticed while the observations lasted that the sex of the trees showed a tendency to remain constant; it is not known if there were any exceptions to the rule. Mr. B. B. Osmaston [1] observed a tree in October 1898 at Konain in Jaunsar, with male catkins on every branch but two, which bore numerous female cones. There were no cones on the male branches. He marked the cone-bearing branches, and these again bore cones in 1900, while there were no cones on the other branches. Although this single case does not afford conclusive evidence, it indicates that, subject to wider verification, there may be a tendency for branches to retain their sexual character. In October 1917 I noticed near Simla a whole group of moderately young trees all exhibiting the same character, namely, the lower branches covered with ripening female cones and the upper branches covered with opening male flowers; the constancy of this character in the several individuals of a whole group, which probably arose from the same seed-bearer, suggests heredity.

Seed and seeding. The seed with wing is 1–1·5 in. long, triangular (Figs. 444, *j*, and 449, *a*); wing with rounded corners, 0·7–1 in. broad; seed without wing 0·35–0·6 in. long, irregularly triangular. About 200 to 260 good seeds, or 230 on an average, weigh 1 oz.

The seeds are oily and soon lose their vitality, but good fresh seed usually shows a high percentage of fertility. The size of the tree appears to have little if any effect on the fertility of the seed, as is shown from the following results of tests, by Mr. R. N. Parker, of seed collected from trees of different sizes:

Girth of tree.	No. of samples tested.	Average germination per cent.
ft.		
1–2	9	72
2–3	12	86
3–4	12	87
4–5	17	75
5–6	7	82
6–7	8	77
7–8	1	85
8–9	2	82
9–10	1	98

[1] Ind. Forester, xxvi (1900), p. 389.

Cones with fertile seed may be produced in fair quantity at a comparatively early age. Seed from trees thirty-one and forty-five years old, tested at Dehra Dun, showed a fertility of 85 and 95 per cent. respectively. Numerous cones were observed on deodar trees in a plantation twenty-eight years old at Ramgarh Kundi, Kulu, in places where the trees were in fairly open positions, not where the crop was dense.

At one time it was believed that old trees did not produce fertile seed, but this idea has been proved from actual tests to be wrong. The effect of isolation on the seed-bearing capacity of deodar trees is always marked, trees in open positions with well-developed crowns bearing cones in quantity, whereas those in dense crops may bear few or no cones even in a good seed-year.

The collection of seed can best be effected by gathering the cones off the trees immediately before they open, towards the end of September or early in October, placing them in the sun until they open and break up, and shaking and stirring them up in an open-work basket or sieve with mesh large enough to let the seeds through but not the scales. Cones may also be gathered in quantity from felled trees where the felling is done in the autumn. If the cones fall in calm weather a certain amount of seed can be collected from the ground, as seeds and scales often fall together in small masses.

So far as the quantity of seed-bearing trees in a good seed-year is concerned, the effect of sex on natural reproduction has been found to be negligible; in other words, the necessity for retaining female trees is not strong enough to warrant their retention if silvicultural considerations demand otherwise. This fact has been brought out by the results of numerous observations made in 1912 in different parts of the Punjab, from which it was found that in a good seed-year, of 215 trees 6 ft. in girth and over, 167 bore cones and 48 did not, while of 1,039 trees 3 to 6 ft. in girth, 791 bore cones and 248 did not. This gives a ratio of cone-bearing to barren trees of 3·5 to 1 in the case of trees 6 ft. in girth and over and 3·2 to 1 in the case of trees 3 to 6 ft. in girth.

Considering the number of scales in a deodar cone, the number of good seeds is comparatively small. The scales at the base and apex of the cone contain abortive seeds, only the central scales containing well-developed fertile seeds. The cones commence opening in their lower parts, the process of opening proceeding upwards. The small scales at the base of the cone do not open, but usually persist for some time after the remaining scales have fallen (see Fig. 444, *k*). The small scales at the apex do not separate, but fall in a mass. An examination made by me of four cones collected at Konain, Jaunsar, in September 1911 gave the following result:

Cedrus Deodara: result of examination of four cones, Jaunsar, 1911.

No.	Dimensions of cone (length and diameter).	Number of scales with abortive seeds.			Number of central scales with well-formed seeds.		
	inches.	Basal.	Apical.	Total.	Scales.	Seeds.	Total scales.
1	4×2·5	45	28	73	86	172	159
2	3·5×2·5	53	20	73	117	234	190
3	3·25×2	62	24	86	92	184	178
4	4×2·75	65	24	89	132	264	221
	Average	56	24	80	107	213	187

FIG. 445. Dense natural pure pole crop of deodar, Jaunsar

FIG. 446. Pure even-aged natural deodar crop of good quality on an area formerly under cultivation, Jaunsar: age 60 years, mean girth 5 ft. 7 in., mean height 122 ft

FIG. 447. *Cedrus Deodara*, female cone about to ripen, female flower at time of pollination (in front of cone), and two old cone axes, one-third natural size.

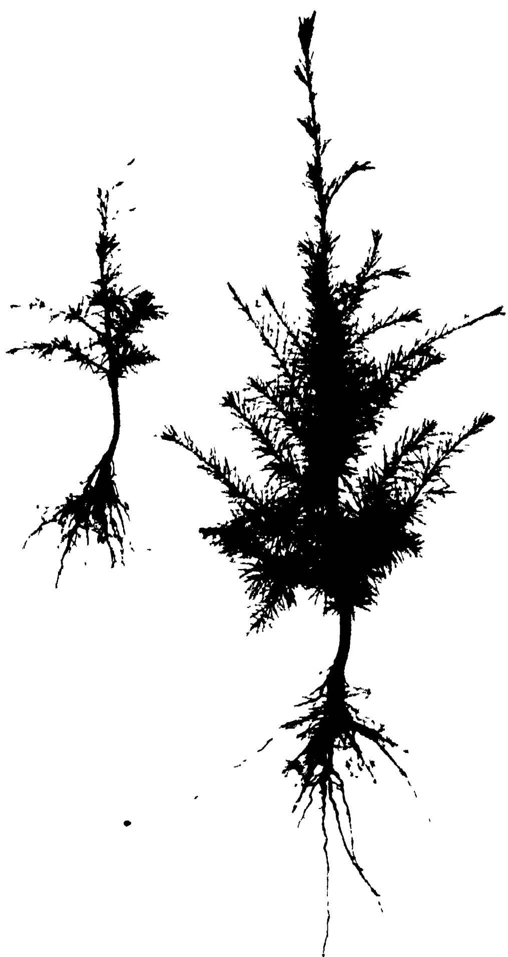


FIG. 448. *Cedrus Deodara*, two nursery plants 3 years old, the larger 3 ft. 3 in. from top of shoot to end of root.

An examination of a cone by Mr. B. B. Osmaston in 1900 showed 94 basal and 25 apical scales with abortive seeds, and 100 central scales with 90 good and 110 bad seeds; the whole cone had 219 scales with 438 seeds, of which 90 were good.

The following figures show the results of an examination made by Mr. R. N. Parker of cones from five ranges of Bashahr:

Cedrus Deodara: result of examination of cones from Bashahr.

	Pabar range.				Nogli range.				Taranda range.			Pandrabis range.				Kilba range.			
Girth of tree (inches)	18	21	29	35	18	21	29	36	20	30	36	16	21	25	32	17	22	27	34
Number of cones examined	5	7	6	6	4	7	8	7	6	6	5	3	6	7	6	7	6	7	7
Average number of fully developed seeds per cone	1·4	2·0	3·5	2·8	1·0	0·7	2·1	1·3	51 (18)	37 (?)	86 (23)	61 (2)	50 (9)	78 (16)	91 (16)	69 (3)	51 (7)	81 (20)	101 (6)
Average germination per cent.	73				83				76			85				80			

The figures in brackets are the numbers of fully developed seeds attacked by insects.

The small number of good seeds in the Pabar and Nogli ranges is noteworthy. In these two ranges the seed-year was a poor one, while in the other three ranges it was fair to good. The inference is that in a poor seed-year the proportion of good seeds per cone is small; if this is sometimes the case, however, it is apparently not always so, as the four cones noted above from Konain were collected in a poor seed-year, and they contained a comparatively large proportion of well-developed seeds.

The following table gives a summary of available records of seed-years in different parts of the western Himalaya:

Cedrus Deodara: records of seed-years, western Himalaya.

Locality.	Total period.	Number of years for which records are actually available.	State of seed-year. Good to abundant.	State of seed-year. Poor to partial.	Periodicity of good seed-years.
Jaunsar	1879 to 1916—38 years	36	12	24	1 in 3 years.
Bashahr	1873 to 1882, 1905 to 1913 } 19 years	18	7	11	1 in 2·6 years.
Kulu	1872 to 1882, 1905 to 1909 } 16 years	16	6	10	1 in 2·7 years.
Hazara	1905 to 1914—10 years	9	3	6	1 in 3 years.

It would appear from these records that the average periodicity of good seed-years may be taken at about one in three. The state of a seed-year may vary within comparatively narrow local ranges, an abundant crop being produced in one small locality, while in an adjacent locality not far distant the crop may be poor. In some years abundant seeding or failure to seed has been recorded consistently throughout almost the whole of the western Himalaya. Partial seeding, that is, where only a moderate number of cones are produced or where only a portion of the female trees produce cones, is frequent; indeed a complete lack of cones over any extent of area is comparatively rare.

The probable state of seeding in any year can be easily foretold early in

May of the year in question, that is, about five to six months before the cones ripen; by this time the young pale green cones have reached a length of 1–2 in., and are clearly visible on the trees. During the previous autumn and winter the young cones, though present, are so small that they cannot be distinguished from any distance.

Among pests which destroy the seed of the deodar the worst is the larva of a small brown moth, *Euzophera cedrella*, Hampson. The attack is noticeable on the half-grown green cones about July. The larva bores into the cones, making small round tunnels, the entrances to which are filled with excreta, much resin exuding. The scales and seeds in the neighbourhood of the tunnels become covered with resin, and even when the insect does not actually bore through the seeds those in the neighbourhood become saturated with resin, turning black and becoming infertile. Frequently the whole of the inside of the cone is eaten out, and in years of severe attack almost the entire seed-crop may be destroyed. The larva is full grown by the end of July, when it is about 1 in. long; pupation takes place in August, and the imago hatches out from September to November, in time to lay its eggs in the young cones when they first appear.

Among birds, the most destructive are jays and nutcrackers, which attack the unripe cones from early September onwards, tearing off the scales and devouring the seeds. They continue their attacks throughout the period of ripening, destroying considerable quantities of seed. During the winter months seed lying on the ground is devoured by pheasants.

GERMINATION (Fig. 449, *b–g*). Epigeous. The radicle emerges from the apex of the seed, opposite the wing, and descends. The hypocotyl, at first curving downwards or slightly arching, straightens in elongating, and raises above ground the cotyledons enclosed in the shell of the seed, to which the wing usually remains attached. As the cotyledons elongate, their apices remain enclosed in the oily endosperm within the shell of the seed, until finally the latter falls to the ground and the cotyledons, 9–11 in number, spread out in a whorl, from the centre of which the young shoot subsequently develops. In rare cases the shell of the seed remains underground, the hypocotyl arching and the cotyledons being gradually extricated.

The seedling. The following is a description of the seedling during the first three years:

First year (Fig. 449, *h*). *Roots*: primary root long, thin, tapering, wiry, dark brown; lateral roots, if present, few to moderate in number, short, fibrous. *Hypocotyl* distinct from root, 1·3–2·5 in. long, cylindrical, glabrous, at first reddish green and smooth, soon turning brown, wiry and striate by splitting of the epidermis; point of junction between hypocotyl and root marked in early stages by the loose prolongation of the ruptured root-epidermis. *Cotyledons* 9–11, whorled, 1·2–1·7 in. long, curving upwards, acicular, triquetrous, compressed laterally, glaucous green, often turning brown and commencing to fall by the end of the season. *Shoot* (above cotyledons) pale buff-coloured, with numerous spirally arranged leaves and often with one or more yellowish brown lateral buds, or in specially vigorous plants one or more arrested branchlets with pseudo-whorls of leaves may have formed. *Leaves* 0·6–1·3 in. long, usually not more than 1 in. long in natural seedlings, those of arrested branchlets, if present, much shorter, acicular, triquetrous, glaucous green.

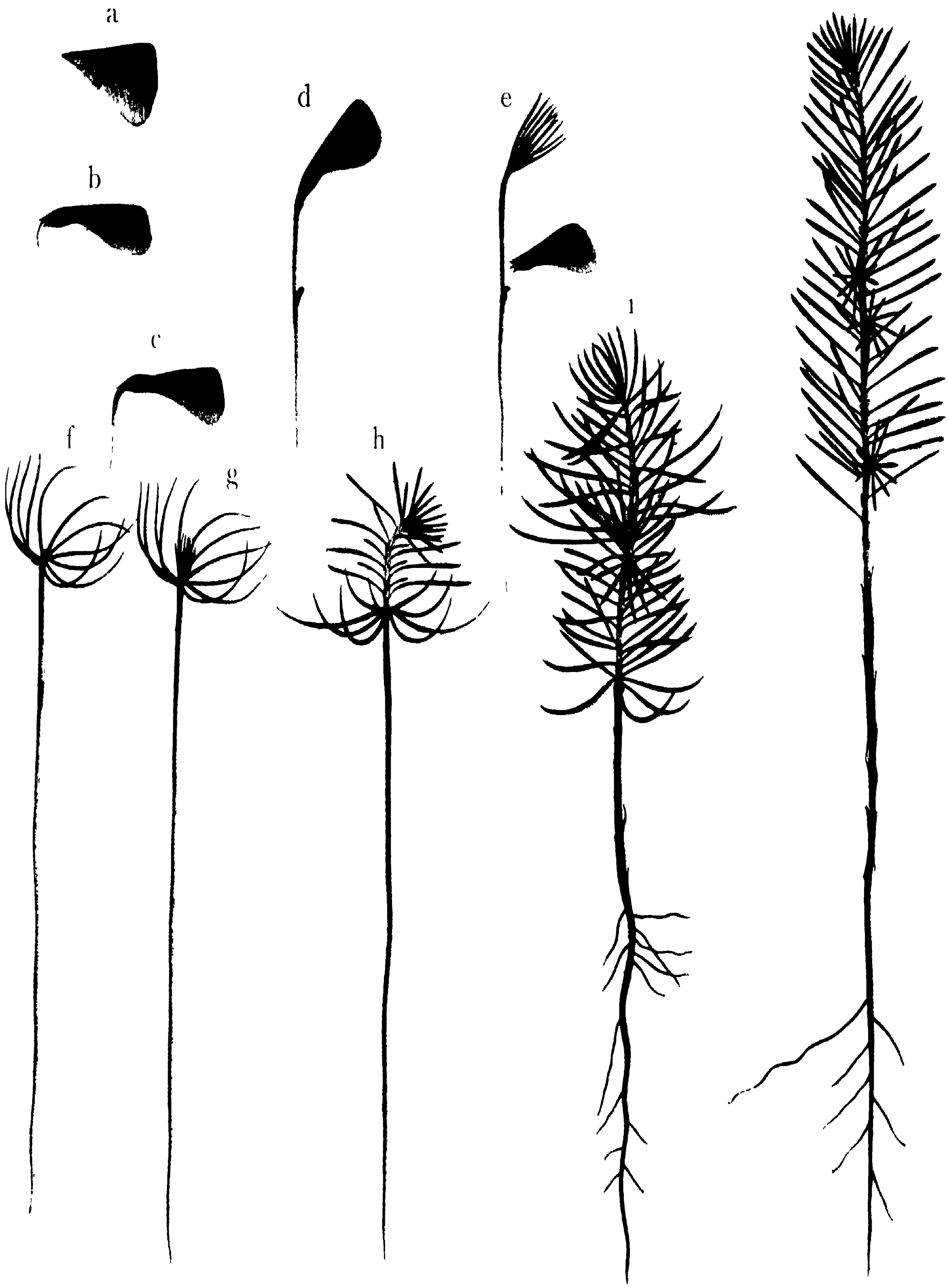


FIG. 449. *Cedrus Deodara* SEEDLING × ½

a Seed b - g—Germination stages (d and e show ruptured epidermis at base of hypocotyl)
h—Natural seedling at end of first season i Natural seedling at end of second season
j—Natural seedling at end of third season

Second year (Fig. 449, *i*). *Roots*: primary root tapering, wiry, thick in vigorous seedlings; lateral roots fairly numerous, short to moderately long, fibrous. *Hypocotyl* greyish brown, smooth or exfoliating in longitudinal strips. *Cotyledons* usually fallen by end of season, their position well marked by a raised ring. *Stem*: first year's shoot (above cotyledons) silvery grey to greenish grey, covered with spirally arranged green, not markedly glaucous leaves: second year's shoot pale yellowish or greenish buff, with numerous spirally arranged glaucous leaves 0·7–1·3 in. long, more crowded towards the apex. *Buds*: terminal bud small, light brown, that of previous year's shoot well marked by a ring of persistent brown recurved scales; lateral buds one or more in the axils of the leaves. *Branches*: one or more arrested branchlets bearing pseudo-whorls of leaves usually occur along the stem; one or more side branches frequently develop, especially on vigorous seedlings.

Third year (Fig. 449, *j*). *Roots*: primary root thick, tapering, woody, often not well marked in nursery seedlings, which have a strong bushy root-system; lateral roots numerous, fibrous, short to long. *Hypocotyl* greyish brown, smooth or exfoliating in longitudinal strips. *Cotyledons* absent, their position well marked by a raised ring. *Stem*: first year's shoot (above cotyledons) silvery grey to greenish grey with spirally arranged leaves either present in quantity or nearly all fallen, the shedding commencing at the bottom; leaves green, not glaucous, often turning yellow or brown; spiral raised leaf-insertions (pulvini) conspicuous after the leaves fall: second year's shoot silvery greenish grey, with spirally arranged leaves still present, green, not markedly glaucous, some leaves often shed: third year's shoot pale yellowish or greenish buff, with numerous spirally arranged glaucous leaves up to 1·5 in. long, more crowded towards the apex. *Buds*: terminal bud small, light brown, former terminal buds of first and second years' shoots well marked by rings of persistent brown recurved scales; lateral buds one or more in the axils of the leaves. *Branches*: arrested branchlets bearing pseudo-whorls of leaves usually occur at intervals along the main stem; vigorous seedlings often have side branches, sometimes in quantity.

The rate of growth of the seedling varies greatly according to the conditions under which it is grown. In the first season natural seedlings ordinarily produce shoots 0·5–1 in. long above the cotyledons, giving a total height of about 2–3·5 in., but vigorous nursery seedlings produce shoots 4–5 in. or more in length, giving, with the hypocotyl, a height up to 7 in. or more. Subsequent growth of natural seedlings is usually at the rate of about 1–2 in. per annum for a few years, while nursery plants three years old attain a height of under 1 ft. to over 2 ft., averaging about 15–18 in. Fig. 448 shows two nursery plants three years old. Seedlings show striking development on the ashes of burnt débris, where they may attain a height of as much as 8 in. in the first season. The age of seedlings can be determined without much difficulty, since the points of junction between the successive years' shoots are marked by the rings of recurved scales of the former terminal buds, which persist for a few years; the first of these rings will be found some little distance above the raised ring marking the insertion of the cotyledons. In determining the age of trees by ring-countings it is safe to add ten years for the time taken for a natural seedling to reach stump height.

The persistence of the leaves of seedlings varies; in vigorous plants they may be shed in part during the second year and wholly during the third year, while in plants of slower growth they may persist for four or even five years.

On rocky ground natural seedlings tend to form a long, wiry taproot. In the case of nursery plants, pricking out arrests the taproot and causes the formation of a strong, bushy root-system which attains a length of about 6–18 in. in three years.

Seedlings are very sensitive to drought, which is the cause of extensive mortality on dry sunny situations ; in such places a certain amount of protection from the sun is essential. Young plants endure moderate shade, but after establishing themselves they require full overhead light for their best development ; in cool, moist situations they grow best with complete light from the commencement.

In the Himalaya seedlings do not ordinarily suffer from frost except in frosty hollows, but in Britain they are somewhat tender. Hail has been known to kill large quantities of seedlings in sowings in Jaunsar.

Young plants suffer much from the attacks of insects, particularly cockchafer grubs, which destroy the roots, and cutworms (*Agrotis ypsilon*), which bite through the roots and stems.

SILVICULTURAL CHARACTERS. Although young deodar plants are capable of standing moderate shade and of persisting under it for some time, they are incapable of making satisfactory headway unless afforded complete overhead light. After the first two or three years, during which protection from the desiccating effect of the sun is advantageous on hot aspects, overhead light is essential to proper development. Plants in a state of suppression can at once be recognized by the absence of a vigorous leader and a characteristic flat-topped appearance ; such plants, although they may persist for many years, are too far gone to benefit by the admission of light. The deodar may be classed as a light-demander rather than a shade-bearer, in that it requires complete overhead light ; it will, however, stand much shade from the side, and in order to produce a clean bole it should be grown in a fairly dense crop. Some of the finest deodar timber is produced in mixture with the spruce, which affords dense lateral shade, causing the production of an exceptionally clean bole in the deodar.

The deodar is affected by drought chiefly in the seedling stage. If it survives the earlier years it has little to fear later, though on dry rocky ground it reaches physical maturity at an earlier age than elsewhere, and becomes dry-topped. Wind does not as a rule do much damage in deodar crops, as the tree has a massive root-system ; on loose, shaly soil, however, windfalls are not infrequent, while on exposed ridges the trees become stunted and misshapen. The deodar is seldom affected by frost in its natural home, but in England it suffers severely.

Snow is the cause of serious injury in many parts of the Himalayan region. Although not quite so fragile as *Pinus excelsa*, the deodar suffers considerably from snow, poles being bent, broken, or uprooted. This form of injury is commonest in pole crops which have been left unthinned too long. Thinnings deferred too long and then carried out only intensify the damage, and the only effective means of reducing snow damage to a minimum is to start thinnings at an early age and to execute them lightly and at frequent intervals.

Fire seldom enters the moister types of deodar forest, but it may do extensive damage in the drier types. Khan Bahadur Imam ud Din[1] notes the case of a dense forest of pure deodar at Sanjiret in Chitral, in which he

[1] Report on the Chitral Forest, 1908.

found some 10,000 dead trees of all sizes ; these had been killed by a fire which occurred eight years previously. Some remarkable effects of fire-protection may be seen in Jaunsar towards the lower limit of the deodar, where it meets the *Pinus longifolia* zone. Here the introduction of fire-protection has caused the spread of the deodar downwards in great quantity into the region of the pine, forming in places dense young crops, sometimes pure, sometimes mixed with blue pine (*Pinus excelsa*) and chir pine (*P. longifolia*), underneath somewhat open pure crops of large *P. longifolia* trees (see Fig. 450) ; this indicates that the deodar is more sensitive to fire than the chir pine, for as long as these areas were subject to burning the pine held the ground. The effect of fire on natural reproduction is discussed below.

Browsing by goats is the cause of much injury to young deodar. When the browsing is light and there is a plentiful supply of *Indigofera* and other palatable plants the deodar escapes without much harm, but where it is heavy, as is frequently the case, the deodar is browsed down to bush-like form and kept in this condition. Lopping for the sake of litter and manure is a very common form of injury to which the deodar is subjected. Trees which have been systematically lopped for some time present the appearance of straight poles covered throughout their length with bushy shoots ; cone-production is prevented and natural regeneration thus ceases, while the lopped trees die off by degrees, and treeless grassy slopes take the place of well-wooded hillsides. This process of destruction can be observed in all stages in many parts of the Himalaya.

Among wild animals, bears, porcupines, and monkeys are the most injurious. Bears remove the bark of deodar poles and saplings with their teeth and claws, presumably to lick the resinous surface beneath ; in some localities the damage done in this way is extensive, many young trees being completely girdled and killed. Porcupines do similar damage by gnawing off the bark round the base of the trees. In some localities langur monkeys do much damage by gnawing the bark from poles and saplings, while they, as well as brown monkeys, have a habit of pulling up germinating deodar seedlings.

Among climbers in deodar forest the worst is *Rosa moschata*, which scrambles into the crowns of young trees and suppresses them. *Vitis semicordata* and *Hedera Helix* as a rule do less damage, while *Clematis montana* is seldom luxuriant enough to be the cause of much injury.

Among parasitic fungi there are two which are particularly injurious to the deodar ; these are *Fomes annosus*, Fries (*Trametes radiciperda*, Hartig), and *Peridermium* (*Aecidium*) *Cedri*, Barcl. The former is considered by Hartig to be the most dangerous enemy of coniferous trees in northern Europe ; it is a serious menace to deodar crops in some parts of the Himalaya, and has been spreading in the plantations of Kulu within recent years. In the case of the deodar, young trees appear to be most prone to attack. This fungus spreads centrifugally, attacking the roots, which become rotten, the bark cracking and white bands and sheets of mycelium being found beneath the scales. The mycelium ascends from the roots along the cambium into the lower part of the stem, which shows an exudation of resin, and the needles turn yellow and fall ; when the mycelium has encircled the stem the tree dies. The wood is also attacked by fine hyphae, which disintegrate the tissues, reducing the value of the timber. The sporophores appear on the lower part of the stem in the form of brown rounded nodules, which increase and cohere into irregular brown incrustations with numerous ledges, the lower spore-bearing surface of which is at first white and later turns brown. According to Butler,[1] rhizomorphs are also produced, which is not the case in Europe; they are dark brown or nearly black, and resemble fine roots. These rhizomorphs, which are the organs of vegetative reproduction and are produced in large numbers, are probably the chief means by which the fungus spreads underground from root to root. The only practicable method of preventing the spread of the fungus appears to be by trenching round affected trees or groups of trees and isolating them.

Peridermium Cedri, Barcl., is the aecidial form of a fungus which does extensive damage in some localities.[2] The fungus attacks the young needles of the current year's shoots. The first sign of the attack is seen in the spring, when the affected needles are noticed to be shorter than the normal ones and curved backwards. About May and June numerous small yellow aecidia appear on the surface of the needles and subsequently burst, emitting clouds of yellow spores. The curved form of the needles persists throughout the year, long after the spores are shed. The foliage becomes thin, and the twigs and afterwards the branches die. One of the most characteristic results of an attack of this fungus is the production of 'witches' brooms', which are often the most conspicuous outward sign of the attack; these witches' brooms, however, are not always present.

When the attack consists of nothing more than a few witches' brooms on side branches, little or no damage results to the tree affected, although such a tree is always dangerous as a centre of infection. Extensive damage, however, sometimes occurs in young and middle-aged deodar crops. A mysterious disease, which had for years been killing off poles in large numbers in the plantations round Monali in the Beas valley, Kulu, I found in 1914 to be none other than a severe attack of this fungus; these plantations are situated in a rather moist valley at an elevation of 6,000 ft., a locality probably favourable to the spread of the fungus. Up to 1914 some hundreds of diseased stems had been cut out; in that year many more were observed to be dying, while of the survivors it was estimated that at least 80 per cent. were visibly affected. In these plantations the appearance of the attack is characteristic. The foliage becomes thin below the leader, and the twigs, and afterwards the larger branches, commence to die. The leader remains alive for a time but eventually dies, and as the attack spreads the whole tree dies. In Jaunsar damage almost as severe has been noticed in natural pole crops at Koti Kanasar, where numerous poles were found in 1911 to be badly forked and misshapen at the top, and had to be cut out in thinnings. Even young crops may be affected. A plantation only three years old at Kathiyan in Jaunsar was found some years ago to contain several plants so badly attacked as to have the appearance of witches' brooms growing out of the ground; the leading shoots had been destroyed, and the affected plants were doomed to perish.

This fungus requires further study. The spores, which escape in May

[1] Ind. Forester, xxxi (1905), p. 489.
[2] See *ibid.*, xxxviii (1912), p. 222, and xl (1914), p. 469.

and June and are wind-borne, apparently germinate on the young shoots; the mycelium probably spreads into the next year's young needles in the following spring, since the fructifications appear on these needles next May. Once the disease has gained a hold it is practically impossible to deal with it, since its facilities for spreading are so great. Where it first makes its appearance in a locality or plantation it could possibly be dealt with by cutting off and burning affected branches. Preventive measures would consist of avoiding damp valleys for deodar plantations and mixing deodar with blue pine or other suitable species.

So far as I have had an opportunity of observing the prevalence of this fungus, it is locally common in Jaunsar, the Simla hills, Bashahr, the Inner and Outer Saraj in Kulu, and the Kagan valley in Hazara, and is abundant in the Beas valley in Kulu.

Mr. J. S. Gamble informs me that his deodar plantations in Hampshire, England, have suffered much from the attacks of *Armillaria mellea*, probably the result of damage done to the roots by a bad storm soon after the plantations were formed; he says that plants mixed with broad-leaved species have suffered less than those mixed with other conifers.

NATURAL REPRODUCTION. The natural reproduction of the deodar can best be studied by considering the various factors which influence it, and these may be conveniently grouped under (1) seeding conditions, (2) germination, (3) climatic conditions, (4) conditions of soil and soil-covering, (5) light, (6) miscellaneous factors. Actual instances of the manner in which natural reproduction makes its appearance under different conditions can best be considered in connexion with regenerative measures, and these are accordingly dealt with later under 'silvicultural treatment'.

1. *Seeding conditions.* It has already been noted that normally one year in every three is a good seed-year, and the ratio of cone-bearing to male trees is large enough to ensure in good seed-years a plentiful supply of seed. Fertile seed is produced by comparatively young trees as well as by old trees; instances have been observed of abundant natural reproduction springing up under open pole crops (i) averaging 2½ ft. in girth at Koti Kanasar in Jaunsar, (ii) averaging 3 ft. in girth near Naggar in Kulu, (iii) averaging 4 ft. in girth in the same locality. Many similar instances could no doubt be quoted elsewhere. Crown development is of more importance than the actual size of the seed-bearers, since trees in open positions with well-developed crowns produce seed in greater abundance than those grown in close canopy or those subjected to systematic lopping. With a sufficiency of suitable seed-bearers seed is produced in quantity sufficient to carpet the ground in the vicinity with a thick growth of young plants if other conditions are favourable. Much of the seed produced falls along with the cone-scales beneath or close around the trees, and only a comparatively small proportion travels some distance before reaching the ground; in this respect the deodar differs from the pines associated with it, whose seeds escape singly from the cones and may be blown to considerable distances. In the case of the deodar natural seedlings may be found individually or even in moderate quantity at some distance from seed-bearers, particularly on the downhill side, but dense crops of natural reproduction spring up within a much more limited radius of the seed-bearers than is the

case with the pines. The actual radius within which dense natural crops are capable of springing up must depend on local circumstances such as the slope, and the strength and direction of breezes at the time of seeding.

2. *Germination.* Given the necessary minimum of moisture the seed, which has lain on the ground through the winter, germinates in the following spring, earlier than in the case of any other western Himalayan conifer. As a general rule germination takes place during March and April; under heavy shade or in cold situations it may be delayed until May, but in warm situations and in warm seasons it may commence in February or even as early as January. Germinating seedlings have been found beneath snow. Germination actually takes place under all conditions of cover, in the densest shade as well as in places completely exposed to the sun, in deep, moist, fertile soil as well as on bare rock, and in good seed-years germinating seedlings may be found in countless numbers in all kinds of situations in the neighbourhood of seed-bearers of all sizes; even under favourable conditions, however, numbers of these seedlings perish from one cause or another, and where the conditions are adverse, the holocaust of seedlings may result in not a single one remaining by the end of the season.

3. *Climatic conditions.* Drought is probably the most adverse factor with which the deodar seedling has to contend in its earlier stages; this factor is largely responsible for the high mortality so prevalent among natural seedlings during the first season. Where the monsoon influence is felt the critical times are from April to June and again from September to November; during these two periods seedlings may be found dying of drought in quantity in dry or exposed situations and in dry seasons, while similar mortality may be observed between June and September in seasons of scanty monsoon rain. In the dry regions beyond the influence of the monsoon the seedling has to rely for its existence on a heavy snowfall in the winter, which supplies sufficient moisture in the soil to tide over the intervening period of drought. Although the influence of snow on the natural reproduction of the deodar has as yet been insufficiently studied, it may be safely said that it is of great importance, not only in regions out of reach of the monsoon, but also in regions subject to monsoon influence. Its beneficial effect lies in protecting the seed from birds and animals during the winter and in supplying sufficient moisture to the soil, after it melts, to counteract the adverse effects of the subsequent period of drought. It has been noticed in the case of artificial sowings that a year of scanty snowfall may be followed next spring by early germination and the subsequent wholesale death of the seedlings during the dry weather from April to June. The natural reproduction of deodar in the inner dry regions is often profuse. Although the rainfall there is so scanty as to be quite incapable of securing the survival of natural seedlings to any extent, the winter snowfall is heavy, and the inference is that the natural reproduction must owe its success to a large extent to the effect of the snow, though the absence of heavy undergrowth no doubt also favours it.

To summarize, it may be stated that a season of heavy snowfall or plentiful and well-distributed rainfall following a good seed-year is of great benefit to natural reproduction, whereas a season of drought may nullify all the effects of an abundant seed-year.

4. *Conditions of soil and soil-covering.* It has just been pointed out that a desiccated condition of the soil, which may be due to climatic or to other causes, is probably the most adverse factor with which the deodar seedling has to contend; it follows that anything which will either reduce soil desiccation or so stimulate the growth of the seedling as to cause the rapid penetration of the taproot to the moister layers of the mineral soil at some depth below the surface, will act favourably on the establishment of natural reproduction. The profusion with which deodar reproduction springs up and establishes itself on newly exposed mineral soil—for instance on abandoned cultivation, road cuttings, landslips, taluses, and occasionally on the sand and shingle of river-beds—demonstrates the advantages secured by the direct contact of the young taproot with, and its unimpeded development in, the mineral soil. Free porous soil, provided there is sufficient moisture present, is favourable, while stiff, hard soil is the reverse, for in the former a vigorous development of the root-system is possible, whereas in the latter its feeble development greatly enhances the risk of death from drought. Soil hardened by the tread of grazing animals is particularly unfavourable to natural reproduction. The effects of desiccation in preventing natural reproduction are well exemplified on shallow soil where the underlying rock is near the surface, particularly on hot aspects; here reproduction may be abundant all round, but all efforts will fail to induce it to appear where the rock is only thinly covered with soil. Some rocks are more inhospitable than others in this respect; limestone, which decomposes slowly and is very permeable, producing a dry surface soil, is one of the worst, while friable mica schist and soft shale are more favourable.

The effects of desiccation are intensified where the young taproot has to make its way through a thick layer of raw humus in the shape of undecayed needles. Raw humus absorbs water readily, but parts with it rapidly, and in dry situations and in periods of drought it constitutes a dry stratum through which the taproot of the seedling is unable to make its way before it perishes from lack of moisture. The effect of the removal of raw humus is strikingly illustrated in some of the forests of Kulu, where the right exists to remove litter for the manuring of rice-fields. This removal is effected by scraping off the layer of needles with an iron rake, the mineral soil being completely exposed. On such ground young deodar seedlings appear in vast quantities after a good seed-year; these are regularly destroyed within a year or two by the scraping action of the rakes, but if the removal of litter is prevented for some years after a good seed-year, complete regeneration can be secured at once if the crop is opened out to give favourable light conditions.

Apart from the action of raw humus, there are other adverse soil factors whose nature is not clearly understood. It has often been noticed that reproduction fails in moist depressions, although it may be abundant on better drained ground in close proximity; it is likewise often absent in moist types of forest such as those in which deodar is mixed with spruce or silver fir on cool aspects. Such a condition has been variously attributed to bad drainage, and to excess of organic matter, of carbon dioxide, or of moisture. The injurious factor, although possibly connected with an excess of moisture, cannot be merely water as such, for an instance has been observed in a valley below

Simla, in which numerous deodar seedlings about three years old were growing vigorously along the side of a perennial running stream on ground constantly saturated with water and covered with bog moss. Whatever the precise nature of the injurious factor may be, it can be dissipated by the action of fire and by the aeration of the soil. During the rainy season seedlings tend to rot off in damp situations where the weed-growth is heavy.

Failure in natural reproduction is often attributable to the mechanical action of an accumulation of refuse resulting from felling and conversion, in the shape of chips of wood, fragments of bark, and heaps of sawdust and brushwood; germination may take place on heaps of such refuse, but the seedlings quickly perish. Where fellings are heavy these accumulations of refuse may account for a good deal of failure to secure reproduction. The measures adopted with success in Kulu for removing this refuse, by burning and thereby producing an excellent germinating bed, are described later.

A soil-covering of herbaceous or shrubby plants may be injurious or beneficial. A dense growth of grass with a matted root-system may prevent the taproots of deodar seedlings from penetrating readily to the mineral soil, and may thus cause their death from drought. The presence of grass, however, is by no means always an adverse factor; on hot slopes it may exercise a protective influence provided it is not too dense and matted, and cases are often to be found of deodar reproduction establishing itself well on grassy areas. In moist localities heavy weed-growth causes suppression or produces unfavourable soil conditions, preventing the establishment of reproduction. On hot aspects, however, the protection afforded by a soil-covering of shrubs is of great benefit, and may be essential to the survival of deodar seedlings. Among the most useful shrubs in this respect are species of *Indigofera* and *Desmodium*, while the bracken fern is also a useful protection. The protective effect of tree-growth is dealt with below under 'silvicultural treatment'.

5. *Light.* If light were the only factor to be considered, then it might be said at once that the best results would be obtained by complete exposure from the time of germination onwards; wherever conditions will permit of this, deodar plants grow more vigorously when free from all cover than when even lightly shaded. It is only the fear of desiccation that renders shade necessary at all during the first few years of the seedling's life, and it is only in places where desiccation is to be feared that any form of cover which impedes the admission of abundant light is necessary, while even then the cover should not be retained longer than it is required. On cool aspects and moist fertile porous soil the natural reproduction of deodar is often all that can be desired where there is no sort of cover from the commencement. Some of the best deodar reproduction to be found anywhere is that which has sprung up on abandoned fields in the open; here the well-tilled ground produces favourable soil conditions, that is, good aeration and conservation of moisture, promoting vigorous development in the seedlings and thus ensuring them against injury from desiccation without the aid of any protective cover. Mr. Trevor[1] notes that in the Jutlikalwala plantation in Kulu the height of deodar growing in the full enjoyment of light was found to be double that of plants growing under a light overwood of blue pine; also

[1] Ind. Forester, xli (1915), p. 451.

that in the Trai Jakar plantation deodar plants seven years old growing under a heavy overwood of blue pine were less than 2 ft. high. The case of the Nankhari Dhar plantation in Bashahr, referred to below, further illustrates this point; indeed, wherever deodar reproduction exists plants in all degrees of suppression may be found under even a moderate canopy, many of them with tops bent over and flattened, exhibiting that stage of suppression at which they are past any possible aid by the admission of light. The important question of light will be alluded to again in dealing with the silvicultural treatment of the deodar.

6. *Miscellaneous factors.* Animals, birds, and insects which destroy deodar seed and seedlings have already been alluded to. Among these perhaps the worst enemies of natural reproduction are the insects, including cockchafers and cutworms, which destroy young seedlings; the damage done by them may be so extensive as to destroy all the seedlings over considerable areas. Much damage is sometimes done by hail, which strips the needles off young seedlings or cuts the seedlings in two, killing them in either case. Erosion by snow is the cause of absence of reproduction on the snow-slides so common in depressions running down the mountain sides at the higher elevations; such places are the natural drainage channels for masses of snow, and as such are not suitable for tree-growth, although broad-leaved species sometimes make their appearance in such glades. The raking of litter, already alluded to, is the cause of a complete absence of natural reproduction in some of the forests of Kulu; such areas, however, if closed to this practice, regenerate freely owing to the absence of raw humus. Grass-cutting is decidedly injurious, and accounts for the destruction of numerous seedlings.

In the majority of cases grazing is injurious to natural reproduction. Goat browsing in areas under regeneration is under no circumstances permissible, while the admission of buffaloes is incompatible with successful reproduction owing to the damage they do by trampling seedlings, injuring saplings, and hardening the soil where it is inclined to be stiff. Ordinary cattle grazing in strict moderation is less harmful, particularly where there is much shrubby growth, in which case it may even act beneficially in reducing cover which would otherwise suppress young deodar. In the great majority of cases, however, strict closure to all kinds of grazing is the safest course in areas under regeneration, and heavy grazing of any kind is inadmissible if only on account of the damage done by the trampling of seedlings. Some good examples of the adverse effects of unrestricted grazing on natural reproduction and the beneficial effect of strict closure are to be found in the forests of Kulu. Mr. Trevor quotes the following instances:

'In 1913 it was found in Nagri, Reunsigarh, and Marig that the seedlings growing in burnt patches were being destroyed by the feet of cattle; they were at once excluded from Nagri, where the seedlings have been saved; but the entire crop in Marig has been destroyed, and it has now been necessary to close the area to grazing. Similarly in Bohara, in which the burnt patches were sown in 1913, cattle have done a certain amount of damage in the portion not closed, and the growth of the plants in the fenced portion is 25 per cent. better than those outside. In the spring of 1913, when the experimental area in Bajraundi was closed and fenced, there were thousands of seedlings both inside and outside this area. Those inside still persist and are in a most flourishing condition (1915), while outside under exactly similar conditions of soil and light nearly all have perished.'

Fire is a decidedly injurious factor where the natural reproduction of deodar has already been secured, since it may completely destroy the whole young crop, particularly in dry types of forest or where there is much inflammable undergrowth present. The spread of deodar reproduction into the region of *Pinus longifolia* as a result of the introduction of fire-protection has already been alluded to as illustrating the greater sensitiveness to fire of the deodar as compared with the pine. Fire, nevertheless, is an important agent in securing reproduction, which often fails unless measures are taken to burn felling refuse and troublesome undergrowth. As with most other conifers, so with deodar, natural reproduction sometimes appears in quantity as a direct result of a severe fire, owing to the admirable germinating bed formed by the ashes and to the removal of undergrowth. Mr. A. F. Broun [1] in 1886 recorded a case of abundant natural reproduction of deodar which had sprung up in the Kathiyan forest, Jaunsar, after a destructive fire caused in 1871 by villagers in order to propitiate their deity on an outbreak of small-pox. In 1886 there were still numerous dead blackened trees on the ground, while the natural reproduction of deodar was in many places very abundant ; on a patch 10 ft. square 86 saplings, averaging 8 ft. in height, were counted, of which 62 were alive and 24 had been killed by suppression. The excellent pole crops now to be found in this forest are doubtless the result, in part, of the fire in question. In the working plan for the Dalhousie range forests, Chamba,[2] Mr. R. McIntosh, discussing the question of absence of deodar reproduction owing to heavy undergrowth, mentions that extensive conflagrations are said to have occurred many years previously at the time when the present mature crop had its origin, and that the introduction of fire-protection forty years prior to the time of writing synchronizes with the stoppage of extensive deodar reproduction. He thus surmises that the occurrence of periodic fires is not inconsistent with the regeneration of the deodar, and advocates that if grazing and cutting of undergrowth do not result in reproduction then the effect of repeated firing for a few consecutive years should be tried where reproduction fails.

ARTIFICIAL REPRODUCTION. *General considerations.* Deodar may be raised either by direct sowing of various kinds or by transplanting from the nursery. It may be noted that deodar has been successfully raised from cuttings in South Africa, though this method of propagation has not been resorted to in India. Sowing and transplanting from the nursery both have advantages, and both have been carried out with complete success in many localities. Direct sowings on a large scale, however, are not possible except in years when seed is tolerably plentiful, and hence, if artificial reproduction is to be carried out regularly on an extensive scale, it may be necessary to maintain a stock of nursery plants for transplanting purposes. There has sometimes been a tendency to employ methods of forming plantations which are so costly as to be quite unjustifiable ; provided the cost is kept within reasonable limits, however, there is no reason why deodar plantations should not be made remunerative besides being culturally successful. Small isolated plantations are more

[1] Notes on Plantations and other Operations, 1886.

[2] Revised Working Plan for the Dalhousie Range Forests, 1913, paras. 16–20.

costly than those formed in extensive compact blocks, owing to the higher expenditure on the tending and upkeep of the former. The choice of site and the methods of formation to be adopted for different sites are of importance. Cases of failure are not infrequently due to attempts to grow deodar on ground unsuited to its favourable development, particularly on shallow rocky soil where the plants either die of drought when young or remain stunted if they survive.

In cool, damp situations, sowing and planting succeed best if carried out entirely in the open. On situations which are even moderately hot and dry, however, advantage should be taken of any shade that is available, though such cover should be removed as soon as the young plants are well established. In all but the coolest and dampest places seed should be sown, or seedlings planted, on the shady side of bushes, rocks, or clumps of grass. Shrubby growth should not be cleared more than is necessary, but only sufficiently to give sowing or planting room, light being given immediately overhead but side shade being retained. *Indigofera* and *Desmodium* are among the most useful shrubs under which to raise deodar; plantations are usually successful also in areas covered with *Parrotia Jacquemontiana*, though frequent cleaning is necessary to keep the *Parrotia* in check until the deodar is safe from suppression. Experiments in Jaunsar have shown that if *Indigofera* and *Desmodium* have to be introduced artificially they should be sown a few years in advance of the deodar in order that they may reach sufficient size to afford protection, since their growth at first is slow. Sowing or planting under the shelter of bushes can be most conveniently carried out along contour lines cleared through shrubby growth, the width of the clearing depending on the height and density of the shrubs and the degree of protection required; ordinarily clearing to a width of 2 to 4 ft. suffices.

Sowing and planting of deodar are not unattended by risks of various kinds. The dangers to which seedlings are exposed have already been referred to. Insects, particularly cockchafers and cutworms, often do extensive damage in sowings and in the nursery. Birds, including pheasants, devour the seed during the winter and the germinating seedlings during the spring, and where this form of damage is prevalent direct sowing may have to be discarded in favour of transplanting from the nursery, where protection can be afforded. The same applies in cases where monkeys have acquired the habit of pulling up young seedlings or where hail is specially destructive; in the latter case the young plants require to be protected in the nursery by screens. Plantations require careful protection from grazing, and where this cannot be effected otherwise, fencing is necessary, in which case the formation of plantations in compact blocks of fair size is essential in the interests of economy.

The success or otherwise of sowing and planting, and particularly the former, depends largely on the state of the season. Good results may be expected if the monsoon rains are timely and copious, or if sowings are followed by a heavy snowfall. Failing this there may be high mortality from drought. Tending operations in plantations are described on pp. 1023–4.

Mixtures. Some very successful deodar plantations have been formed under the shelter of tree nurses, of which the most important are blue pine and oak (*Quercus incana* and *Q. dilatata*). The nurses should be well opened out or lopped before the deodar is introduced, and should not be retained longer than is necessary. Deodar has been successfully introduced in spruce forest in Kulu by means of horizontal line sowings, the spruce having first been opened out ; the spruce overwood, however, requires to be removed very early. The effect of introducing deodar artificially under blue pine can be studied in parts of Kulu, Bashahr, and Jaunsar. The results show that deodar can be introduced successfully under pine crops in the tree or pole stage, provided the overwood is well opened out first and is not kept over the young deodar crop longer than is necessary. Pole crops are more liable to cause suppression than crops of tall trees. The effect of leaving blue pine standing too long over a young deodar crop, as illustrated by the Nankhari plantation in Bashahr, is explained below under ‘ tending operations ’. Another instructive plantation is that of Ramgarh Kundi in Kulu, situated at an elevation of 7,500 to 8,000 ft. on an isolated hill presenting varying aspects. Here in 1902 deodar was planted in pits spaced 10 ft. by 5 ft., and was also sown in lines, partly in the open and partly under a pole crop of blue pine previously opened out and lopped to some extent. In 1914, when the plantation was twelve years old, it was found that on every aspect except south and south-west the deodar planted in the open was far more vigorous than and about twice the height of that under the blue pine. On south and south-west aspects the results varied, though on the whole the deodar plants were most promising where protected by the side shade of young blue pine. In the open parts young blue pine was filling up gaps naturally in a most promising manner. In this plantation it would have been well to have removed the whole of the blue pine overwood within five years on all but the hottest aspects.

The best results in an artificial mixture of deodar with a natural crop of blue pine have been attained by sowing or planting the deodar in young sapling crops of pine a few feet high ; in such cases the two grow up together, the pine affording useful side shade to the deodar, and all that is necessary is to keep the deodar free from overhead suppression. Perhaps the greatest advantage to be gained by introducing deodar under a tree crop of blue pine is that the latter if well opened out regenerates naturally and fills up gaps, affording a useful mixture ; in such cases a wider spacing of the deodar plants suffices than would otherwise be the case. Under a young pole crop of blue pine, however, where natural reproduction of the pine is not anticipated, a pure deodar plantation must be allowed for. Figs. 451 and 452 show portions of the Jutli Kalwala deodar plantation in Kulu, fifteen years old, in which natural reproduction of blue pine, from seed-bearers in the neighbourhood, has appeared in great abundance, filling all gaps and growing up to form an ideal even-aged mixed crop with the deodar.

Direct sowing. In direct sowing the best results are attained by following Nature and sowing deodar seed in November and allowing it to lie through the winter, when it germinates early next spring. In case of failure, resowing may be carried out about April, and this occasionally gives good results. The chief disadvantages of spring sowing are that seed if stored for any length of time is liable to insect attacks, and that germination is usually delayed. Sowings may be carried out broadcast or in contour lines, broken or continuous, in patches of various sizes including elongated patches running along the

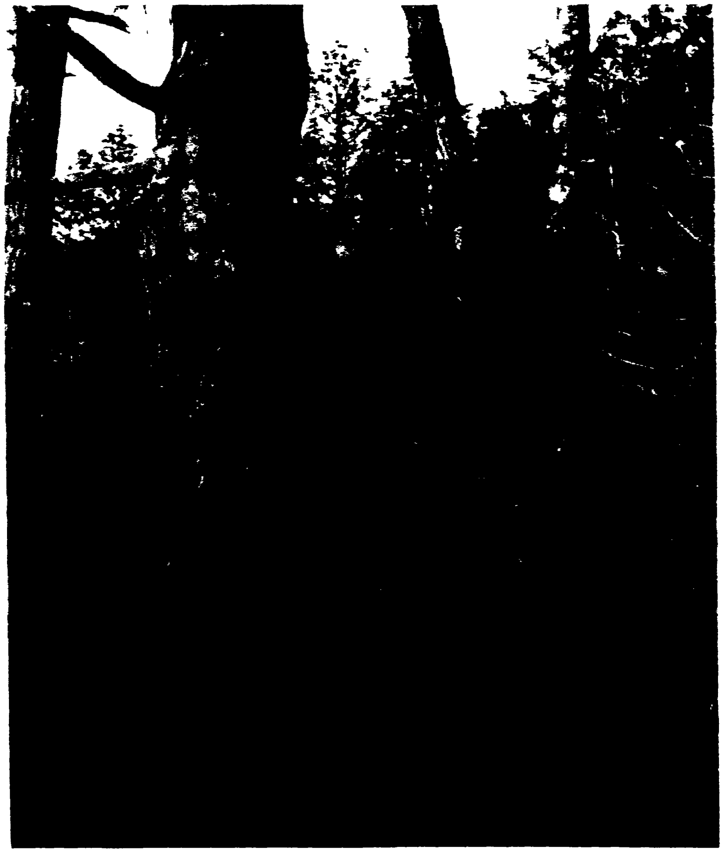


FIG. 450. Natural reproduction of deodar, with some blue pine and chir pine, establishing itself beneath an open overwood of chir pine as a result of fire-protection, Jaunsar, elevation 6,000 ft.

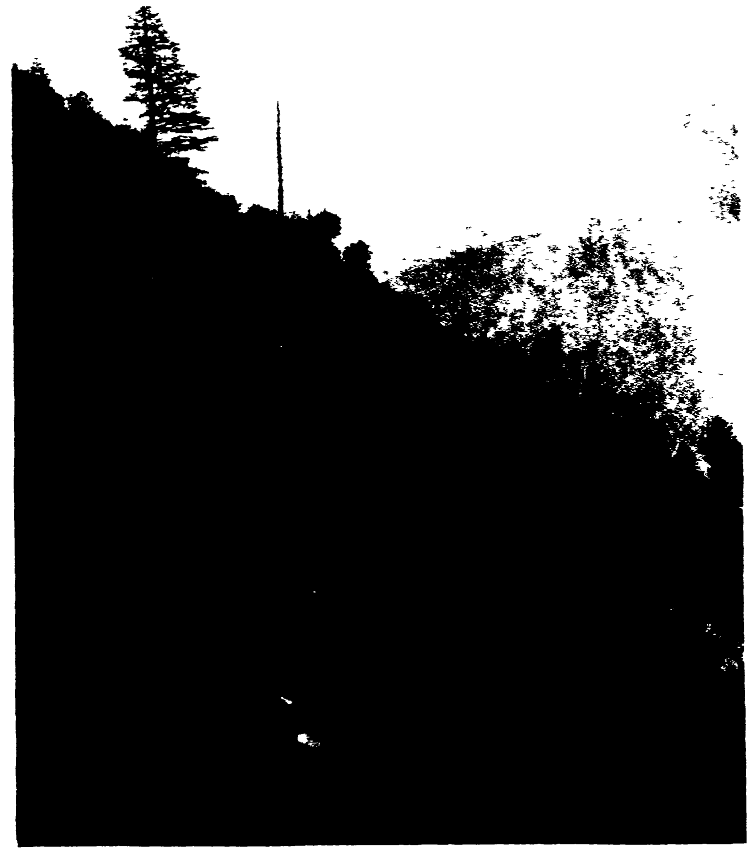


FIG. 451. General view over portion of Jutli Kalwala plantation, Kulu, 15 years old, showing mixture of deodar with *Pinus excelsa*, which has appeared naturally and is filling up gaps.

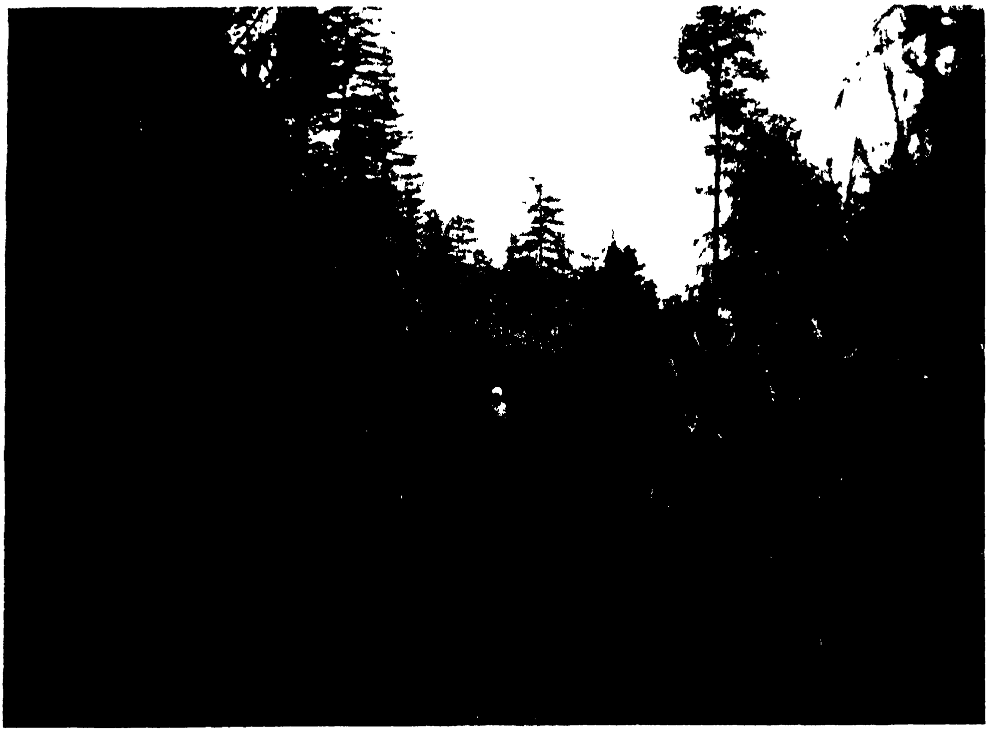


FIG. 452. Deodar plantation, 15 years old, in which *Pinus excelsa* has regenerated naturally in abundance, Juth Kalwala, Kulu.

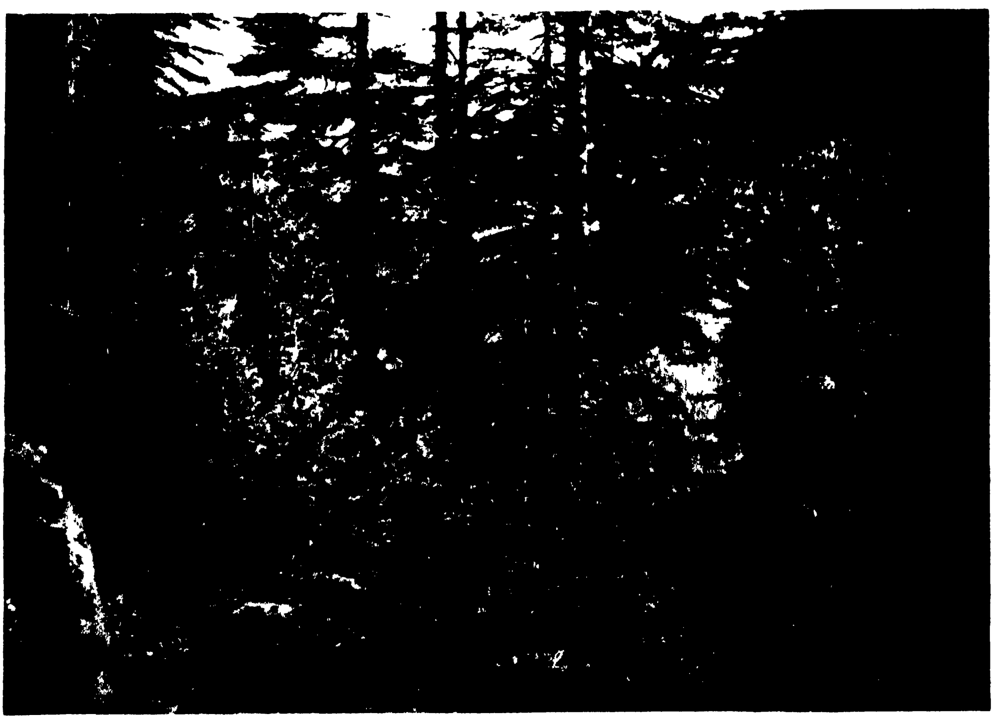


FIG. 453 Deodar forest, showing tendency for natural reproduction to spring up in groups where there are gaps in the canopy, Jaunsar.

contour, or by dibbling. Where line, patch, or broadcast sowing is adopted, thorough preparation of the soil is necessary by hoeing to a depth of several inches, preferably after collecting and burning all refuse. After sowing the seed should be lightly covered with earth.

Broadcast sowings over large areas are somewhat expensive, but they are particularly useful in sowing up abandoned cultivation and gaps where felling refuse has been collected and burnt. The quantity of seed required per acre actually sown is about 20 to 25 lb. Where much weeding is anticipated, or where the sowings have to be carried out in areas covered with shrubs and other growth, contour line sowings are the most suitable. A distance of 10 ft. between lines has been found by experience to give good results. If the distance is greater the crowns do not meet in time to prevent the formation of strong branches. The lines should be made in the form of terraces 1 ft. wide, well hoed up, one line of seed being sown along the centre of the terrace; 20 lb. of seed suffices for one acre. Weeding along contour line sowings is easy, but such sowings are particularly liable to the attacks of insects and other pests, and if grazing animals gain access they use the contour terraces as paths and do much damage. Sowings in hoed patches varying in size from 1 ft. square upwards are simple and cheap, but are unsuitable where weed-growth is heavy. They are useful for filling gaps in young crops of blue pine 2 or 3 ft. high. Great success has been attained in Kulu by sowing in patches in gaps where felling refuse has been thoroughly burnt. The seed is stirred up in the patches of ashes, and the resulting seedlings show rapid growth. The patches are used next year as temporary nurseries, surplus seedlings being planted throughout the gap during the rainy season. The thinning out of seedlings in line and patch sowings is a very necessary operation. Excess plants should be employed as far as possible for filling up gaps, after which the remainder should be thinned out with a pruning knife not later than the third year, failing which the plants become congested and weakly. Dibbling should be carried out only in loose soil; it is useful for introducing deodar in young blue pine crops.

Planting. The nursery treatment of the deodar presents no special difficulty. The nursery should be free from overhead shade, though side shade is an advantage on hot aspects. The seed-beds, about 4 ft. wide, composed of light, porous soil preferably with an admixture of leaf-mould and wood-ashes, should be well hoed up and raised. The seed should be sown in November, soon after collection, in drills 4 to 6 in. apart, and the beds should be covered with thorny twigs to keep off birds, the twigs being removed when germination begins. Germination takes place early next spring, and in hot situations or where hail is to be feared the seed-beds should be protected by light shades until the rainy season. Watering, which should be carried out sparingly, is not as a rule necessary except in May and June; regular weeding, however, is advisable. It is usually customary to prick the seedlings out in the nursery in July of the year of germination with a spacing of 6 in. by 4 in., and again in July of the second year with a spacing of 9 in. by 6 in., finally planting them out in July of the third year, after the rains have well set in, by which time they are 12 to 18 in. high. The less vigorous plants may be pricked out again and planted out in the fourth year. In Kulu planting is carried out the year after sowing, with seedlings averaging 8 in. high ; these are transplanted direct from the seed-beds without any pricking out in the nursery. By this method much expense is saved and the results are quite successful.

During the transfer of seedlings from the nursery to the planting site the roots should never be exposed to the sun. Cloudy or rainy weather should be selected if possible, and the seedlings should be packed in bundles with wet moss round the roots, placed in a basket, and carried thus to the planting site. Planting, which commences as soon as the rainy season has well set in, should be pushed on rapidly in order to obtain the full benefit of the rains. Winter transplanting has been tried in different localities with variable results, the success depending a good deal on the snowfall. In regions beyond the reach of the monsoon, winter planting has to be resorted to as a matter of course. Deep wide planting holes are unnecessarily expensive ; provided they are large enough to admit the roots freely, this is sufficient. Unnecessary width in particular should be avoided, since there is a danger of the plants becoming loosened by heavy rain where the holes are too wide. The earth filled into the holes should be well pressed down, care being taken not to sink the plant below its original level. On hot aspects advantage should be taken, in planting, of the shade afforded by bushes, rocks, or tufts of grass. In the case of basket planting the seedlings are pricked out in the nursery during the first rains, transferred to baskets during the second rains and planted out with the baskets in the following year. These baskets, which are made of ringal bamboo, are 4 to 6 in. in diameter and 8 or 9 in. long, and in Jaunsar cost Rs. 1–8–0 to Rs. 2–8–0 per 100. Their use adds very materially to the cost of the plantation, and cannot be justified where less expensive methods can be employed ; basket planting, however, usually results in a high percentage of success.

The most usual spacing for deodar is 5 ft. by 5 ft., or in the case of contour lines, 3 or 4 ft. apart in lines 8 to 10 ft. apart. Spacings of 4 ft. by 4 ft. or 6 ft. by 6 ft. have also been employed to some extent. The former produces very dense crops with clean stems, but is perhaps unnecessarily close, since a spacing of 5 ft. by 5 ft., if the plantation is successful, gives all the density required. Where deodar is to be planted in an area being regenerated naturally for blue pine with the view of obtaining a mixed crop, a spacing of 10 ft. by 5 ft. is ample. Planting in cleared contour lines is the most satisfactory method to adopt where the growth of shrubs and weeds is heavy, since weeding is greatly facilitated.

Cost of sowing and planting. The actual cost of sowing and planting in different localities has varied greatly. Planting, including all nursery charges and transplanting, should not exceed Rs. 20 per acre, and in the Nogli range of Bashahr the average for some years was as low as Rs. 9 per acre. Under the system now followed in Kulu, in which seedlings are not pricked out in the nursery but are planted out the year after germination, the planting holes being no larger than is necessary, the cost works out at Rs. 4 to Rs. 5 per acre for a spacing of 5 ft. by 5 ft. The cost of basket planting in Jaunsar has averaged about Rs. 60 per acre with a spacing of 5 ft. by 5 ft., excluding the cost of subsequent tending. Broadcast sowing in Bashahr, though successful, has proved somewhat expensive, the cost of digging being Rs. 20, and of

Fig. 454. Natural reproduction of deodar in a blank round a seed-bearer, Jaunsar.

Fig. 455. Result of seeding felling in deodar forest; area fully regenerated with a young natural crop of deodar and blue pine, now ready for final felling; Kulu.

FIG. 456. Group of young deodar poles about 30 ft. high sprung from a seed-bearer recently removed, leaving a blank (in foreground): seed-bearer should have been removed many years previously. Jaunsar.

FIG. 457. Natural reproduction of deodar and blue pine, with a little spruce, resulting from an even spacing of seed-bearers 20 per acre: young crop chiefly 5–8 ft. high and ready for freeing completely from overhead cover: Bashahr.

sowing Rs. 5 per acre. Direct sowing in lines or patches should not exceed Rs. 10 per acre, and patch sowing can be done for Rs. 3 per acre or less. In Kulu sowing in prepared contour lines 10 ft. apart costs Rs. 10 per acre, including the preparation of terraces and sowing, or Rs. 16 to Rs. 20 per acre, including subsequent weeding, cleaning, and early thinning. In the same division heaping and burning felling refuse, sowing up the burnt patches, transplanting surplus plants from the patches and subsequent weeding, resulting in the complete regeneration of the area operated over, costs on an average Rs. 10 per acre. The cost of weeding and cleaning varies greatly with the extent of the weed-growth. As a general rule these tending operations up to about the fifteenth year cost about Rs. 8 to Rs. 15 per acre, though the cost may be less where weed-growth is not heavy.

SILVICULTURAL TREATMENT. The treatment of the deodar may be conveniently considered under three separate heads: (1) regenerative measures, (2) tending operations, and (3) silvicultural systems.

1. *Regenerative measures.* The chief factors, so far as they are known, which bear on the natural reproduction of the deodar have already been considered. Where conditions are favourable the natural tendency of the deodar is to regenerate in groups or masses of more or less even age in the neighbourhood of seed-bearers, either in gaps of sufficient size or in completely isolated situations. Fig. 453 shows a typical instance of a group of reproduction springing up in a gap. Where, as is often the case under the present condition of the forests, the old crop consists of somewhat scattered branchy deodar trees, often of considerable size, this tendency, which is illustrated in successive stages in Figs. 454 and 456, is very marked; these two photographs were taken in the same locality. In such cases reproduction first appears partly underneath the tree and partly in a fringe of varying breadth extending for a distance often of many yards round it, particularly on the downhill side. As the young crop grows the seedlings beneath the spreading branches of the seed-bearer become killed off, partly by suppression, and partly perhaps because they get little rain and snow, and a complete blank results beneath the tree. In Fig. 454 this stage is commencing, while in Fig. 456 the blank beneath the seed-bearer, recently removed, is complete, and in the fringe of reproduction round it the dominant stems have reached a height of 30 ft.

Regeneration in small groups, patches, or fringes arising in gaps or round isolated seed-bearers has had to be relied on to a considerable extent in the past, and in the open condition of so many of the existing deodar crops it will play a prominent part for some time to come. Crops which originate in this way, however, are far less satisfactory than crops of even age extending over considerable areas, for whereas the latter produce clean straight timber, small groups of trees standing alone produce strong branches and knotty timber. The same applies to solitary seedlings or small patches of seedlings, which often appear under other species such as oak or blue pine considerably older than themselves, and eventually establish themselves in gaps. Such isolated plants develop into branchy trees. The ideal, therefore, should be to aim at producing even-aged crops of considerable density over as large an area as possible, affording complete overhead light as soon as the seedlings are safe from the desiccating effects of the sun. Fig. 445 shows an even-aged pure pole crop which has originated from a mass of even-aged natural reproduction of some extent, and the clean appearance of the stems may be compared with the branchy appearance of those which are produced by the small group shown in Fig. 456. The details of the crop shown in Fig. 445 are as follows: age, 45 years; mean height, 61 ft.; mean girth, 34 in.; stems per acre, 517; volume per acre, 7,929 cubic ft., of which 6,049 cubic ft. is timber down to 24 in. in girth. It is clear that in order to take advantage of natural reproduction appearing in small groups and at the same time to link these groups together into an even-aged crop, no undue delay should occur in removing seed-bearers which have already done their work and in completing the stocking of the area artificially if necessary. In Fig. 454 the young crop has already reached the stage at which it should be freed from the seed-bearer, any resulting blank being filled up artificially.

Dense even-aged pure crops of deodar, such as that shown in Fig. 445, are common in many localities, and are as well represented in Kulu as anywhere. Many of them have doubtless arisen with the introduction of fire-protection in areas previously subject to frequent fires, and some at least have arisen on abandoned cultivation (Fig. 446). Such crops not only produce better and cleaner timber than that produced by small groups of trees or uneven-aged crops, but they lend themselves more satisfactorily to thinnings and other tending operations. Provided the crops are more or less even aged, however, it is not necessarily advisable that they should be pure. Excellent results are obtained by the regeneration of deodar in even-aged mixed crops with blue pine or spruce. A mixture of deodar with oak is likewise a good one, but as the deodar grows much more rapidly than the oak the deodar crop should be sufficiently dense to clean itself after it has overtopped the oak, or should have a sufficient quantity of blue pine or spruce mixed with it to produce a completely stocked crop. As is the case with other conifers, deodar often regenerates with great freedom beneath the oak, the soil conditions being particularly favourable, and where the cover of the oak is light, as in places where it is subject to lopping, deodar crops of considerable density may make their way through the oak. Cases may sometimes be observed where in oak forest subject to lopping a deodar crop is slowly but surely taking the place of the oak. Deodar likewise regenerates well beneath the light shade of the blue pine, and provided the latter is removed in good time the deodar establishes itself without difficulty. It happens frequently that isolated deodar plants establish themselves in this way, and are duly freed in cleaning operations by the removal of large blue pine trees standing over them; such operations are not as a rule to be commended, for at the best the isolated deodar plants, unless there is a sufficiency of other young growth with them to produce a fairly dense crop, can only produce branchy trees.

Granted that the ideal is to secure even-aged regeneration, whether in pure or in mixed crops, this ideal is not always easy of attainment, since a combination of factors favourable to reproduction is not always present. This is due to some extent to the state of so many of the existing mature crops of deodar, which have grown up in an open and irregular condition, with the result that there is often a matted growth of grass or a dense growth of weeds on the ground, or the soil has become hardened by excessive grazing. Completely stocked even-aged crops approaching maturity are not at present available in sufficient number to study the effect, under different conditions, of an even opening out of the canopy by a definite spacing of selected seed-bearers. Judging by such instances as are available, however, there is every indication that one of the best methods of regenerating deodar crops, where conditions lend themselves to it, will be by an even spacing of seed-bearers in seeding fellings—the actual spacing depending on the radius of seeding and the degree of protection required—followed by the final removal of the overwood in one or more fellings as soon as regeneration has been secured and protection for the young crop is no longer required. The selection of cone-bearing trees with well-developed but not too spreading crowns will be an important consideration in the execution of the seeding fellings.

A few instances may be quoted of the observed results of an even spacing of seed-bearers. In 1911 a dense pure pole crop of deodar, in which the trees averaged less than 3 ft. in girth, was observed in which numerous small gaps were made in the canopy by snow-break which occurred a few years previously, resulting in places in a more or less even opening of the canopy, the gaps varying from about 5 to 10 yds. wide from crown to crown. The result was the appearance in every gap of large numbers of seedlings, which at the time of observation were four years old, and could have been freed with perfect safety. This example indicates that even in pole crops the opening of the canopy by even spacing may result in the complete regeneration of the area in one good seed-year. Better examples of dense young even-aged crops of deodar, sometimes pure, sometimes mixed with *Pinus excelsa* and *P. longifolia*, under an open canopy, could hardly be obtained than in the case, already quoted, of the ingress of deodar into the region of *P. longifolia* as a result of fire-protection in areas previously burnt (see Fig. 450).

Some of the best examples of even-aged natural reproduction of deodar obtained by a more or less uniform spacing of the canopy are to be found in mixed forest of deodar and blue pine, with or without spruce. In Kulu, where Mr. Trevor has done much experimental work in the regeneration of the deodar, are to be found some good examples of successful reproduction, both in pure deodar crops and in mixed crops of deodar and blue pine, obtained by an even opening of the canopy. Fig. 455 shows in the background a crop opened out in a seeding felling, with natural reproduction making its appearance, and in the foreground a regenerated crop with the removal of the overwood almost completed. Reproduction in this coupe was probably favoured by the regular removal of litter prior to the commencement of regeneration fellings, when this practice was prohibited ; closure to grazing is here found to be essential to the establishment of reproduction. In this locality a spacing of the mother trees of 30 to 50 ft., giving about 17 to 48 trees per acre, is found to be suitable in seeding fellings. The actual spacing of seed-bearers must vary considerably according to circumstances ; thus on hot aspects a closer spacing is required than on cool aspects, while caution is necessary in opening the canopy where a heavy growth of weeds is feared. Figs. 411, 457, and 458 show excellent reproduction of deodar mixed with blue pine and a little spruce obtained with a spacing of seed-bearers to 5 or 6, 20 and 10 per acre respectively. In such cases the overwood should be removed rapidly after reproduction has appeared, and its final removal should be effected by the time the young crop is five to ten years old.

In the instances just quoted the conditions for obtaining natural reproduction have not been unfavourable, and reproduction has been effected without any other measures than opening the canopy sufficiently and closing to grazing and the removal of litter. In many cases, however, reproduction cannot be obtained so easily owing to unfavourable conditions of soil and soil-covering. Here Mr. Trevor's experiments in Kulu have shown that regeneration can be effected with complete success, after fellings have been completed, by collecting and heaping the felling refuse in gaps, at the same time cutting and heaping undergrowth where necessary, and burning the whole thoroughly. The collection of refuse into heaps without burning, in order to clear the ground for the reception of seed, has been tried without success ; the essential operation is the burning, which results in an excellent germinating bed and the thorough clearing and enrichment of the soil. It will be of interest to describe briefly the methods employed with success in Kulu. The collection and burning of refuse should be carried out soon after the forest has been exploited, preferably in a good seed-year and before the seed has fallen. The burning of refuse can be carried out with safety to the surrounding crop only if gaps of fair size are created. The refuse, consisting of felling débris and cut undergrowth, is collected in the centre of these gaps away from trees or advance growth ; special iron rakes have been found useful for collecting the smaller chips of wood. The heaps should be as large as possible, the small chips, which do not burn well by themselves, being mixed with the larger pieces. As a rule the heaps should be fired in the evening and allowed to burn all night. The burning is best carried out during or immediately after the rainy season, in order to avoid risk of firing the forest ; in damp forest, however, it is better to burn in the spring. Burning should begin at the top of the slope, otherwise the ascending smoke renders work difficult on the uphill side. Where the refuse has not been completely consumed by one burning it is collected and burnt again, and after complete burning has been effected the ashes are scattered if necessary over the gap. The cost of collecting and burning refuse averages Rs. 1–8–0 per acre, but in some forests in Kulu the work is done free of charge by villagers in return for grants of unsaleable material which is cut in opening out the crop, and which would otherwise be burnt. After the burning has been completed the area appears as if a severe ground fire had passed over it, and in place of a mass of wood chips, tops, and branches, which prevent reproduction, an excellent soft germinating bed of wood-ashes is produced, in which seedlings grow with abnormal vigour. Fig. 459 shows a gap in which the collection and burning of refuse has just been completed. Where the number of seed-bearers is insufficient, or when the seed-year is a poor one, these burnt gaps are sown broadcast at a cost which averages 1 anna 8 pies per acre. This system of collecting and burning refuse, followed by sowing, has proved successful in effecting complete regeneration in areas which had long defied all attempts to obtain it.

Hoeing the ground in the vicinity of seed-bearers has been found to give very variable results in different localities, but the conditions under which

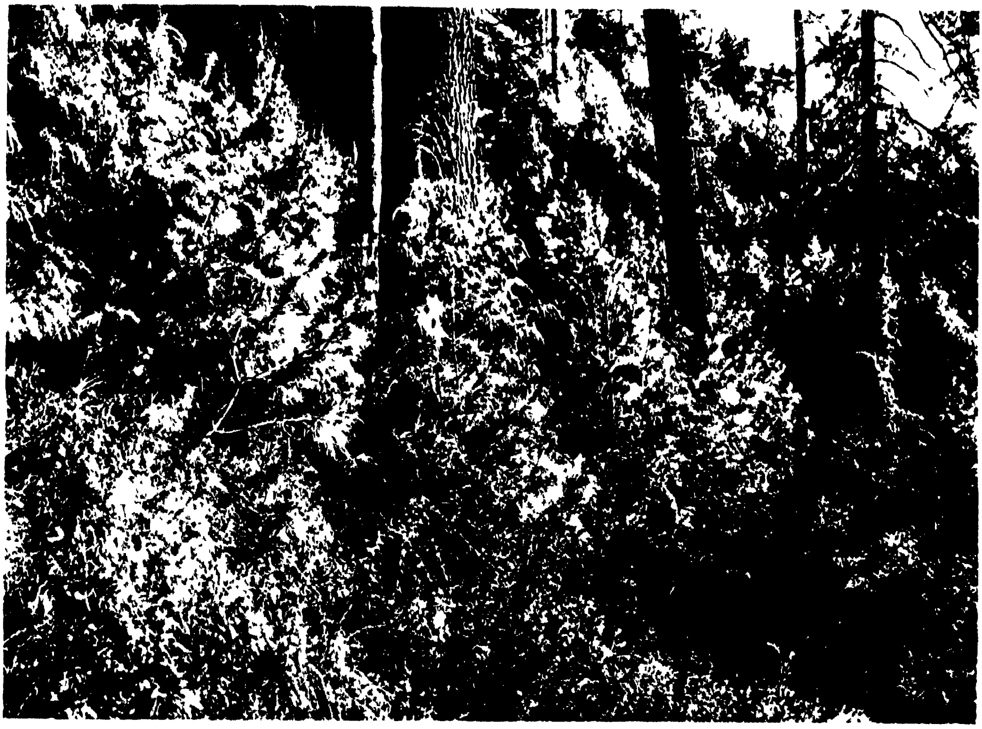


FIG. 458. Natural reproduction of deodar and blue pine, with a little spruce, resulting from an even spacing of seed-bearers, 10 per acre ; young crop well established and in need of freeing from overhead cover ; Bashahr.

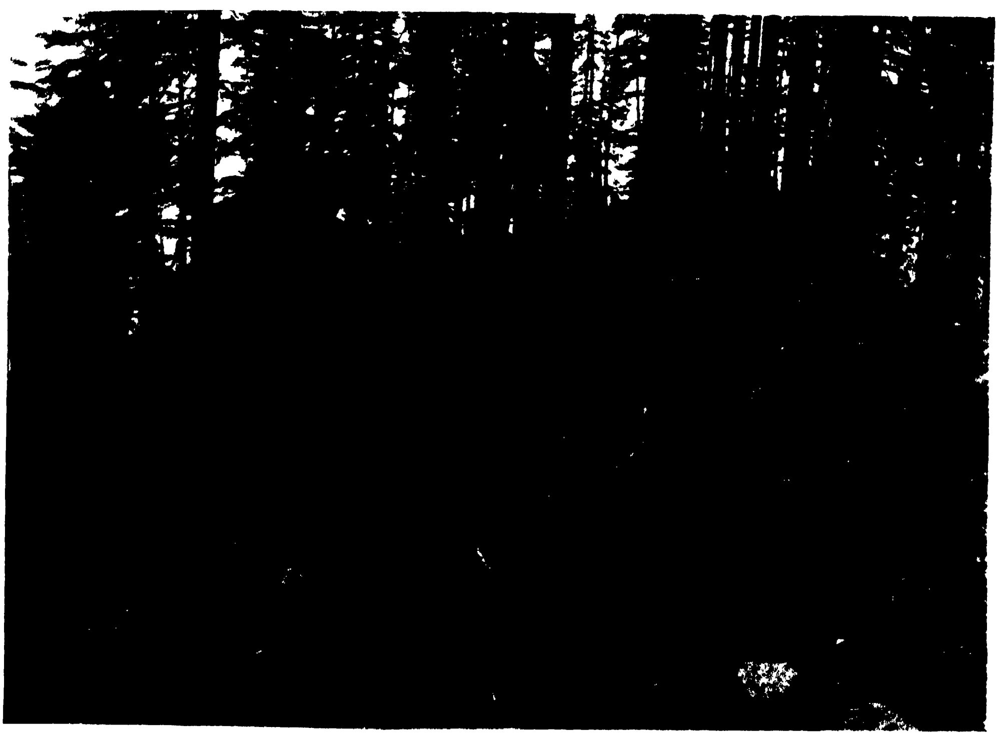


FIG. 459. Deodar forest opened out for regeneration, and burning of refuse completed, Kulu.

Fig. 460. Tending operations in young deodar crops; oak and rhododendron girdled

the work has been carried out have not been recorded in sufficient detail to draw definite conclusions. In an experiment at Taprog in Bashahr it was found that thorough hoeing in the autumn in a good seed-year, before the fall of the seed, produced a plentiful crop of natural reproduction. In this case the seed was found to fall in sufficient quantity to a distance of 200 ft. on the downhill side of the seed-bearers.

The value of side shade as a protection against desiccation is now well understood in European forestry, and the question of utilizing it on hot aspects deserves further study in connexion with the establishment of deodar reproduction. Various cases have been observed in which reproduction springs up in masses where it receives side shade from the sun, but this does not always happen, and the direction from which side shade is most beneficial under different conditions remains to be determined. In Jaunsar cases of profuse reproduction on hot southerly aspects have been observed where side shade was afforded from the south-east, and here the morning sun would appear to be the unfavourable factor. In gap fellings in Chamba, where the openings are sufficiently large, the best reproduction is found round the edges of the gaps, not immediately under the surrounding trees, but at some little distance from them, while in the centre of the gaps the seedlings tend to die from drought. In Kulu, however, the most vigorous saplings are usually found in the centre of a gap, and not round its edges; this indicates that side shade may not be beneficial under all conditions.

2. *Tending operations.* In young deodar crops, whether natural or artificial, tending operations begin with the weeding of rank herbaceous growth and undershrubs; this is particularly necessary in direct sowings. Where weed-growth is heavy, two weedings in the first year are usually required, one in June and the other in August, but where the weeds are not luxuriant a single weeding in August suffices. Where weeds are plentiful, weeding may have to be continued for three or four years. In hot situations the removal of shrubs requires to be carried out with caution, for although the freeing of the leaders of the young plants is always desirable, the removal of weeds, and particularly of shrubs, to the extent of exposing the soil to desiccation, should be avoided. Hoeing the soil round young plants during weeding is dangerous if snow is prevalent, since this increases the risk of their being bent down by snow. A subsequent and most important operation is that of freeing young deodar saplings from the overhead cover of other trees beneath which they are growing, of which the most important are probably blue pine and oak. This operation is variously termed a cleaning or an improvement felling; in carrying it out the important points to remember are that the sooner full overhead light can be safely admitted and the leader completely freed the better, while on the other hand side shade should be retained as far as possible, since isolation produces branchy trees. Some of the most promising young deodar crops are to be found in places where the systematic lopping of blue pine or oak is carried out, and where natural reproduction of deodar has appeared under the lopped overwood; the lopped trees tend to form a bushy growth, affording side shade with plentiful gaps overhead, and the young deodar crop profits greatly by these conditions.

In actual practice it is often the custom, instead of felling the trees whose removal is desired, to kill them by girdling, in order to save the expense of felling. Lopping or topping these trees in place of felling or girdling them is usually preferable wherever this can be done conveniently, since it frees the leaders of the deodar while tending to prevent the development of side branches. Fig. 460 illustrates the freeing of natural deodar saplings by the girdling of oak.

The Nankhari plantation in Bashahr affords some instructive lessons in the removal of blue pine over a young deodar crop artificially introduced under it. The elevation is between 7,000 and 7,500 ft., and the aspect is mainly east ; the plantation was formed chiefly between 1904 and 1907 by sowing and planting deodar under an overwood of blue pine. The results have shown that the deodar is more liable to suppression under a pole crop than under a crop of tall trees, and that in either case the total clearance of the overwood should be effected within a few years of introducing the deodar. This plantation was visited in 1914, when it was seven to ten years old, and it was found that the deodar crop was vigorous only in large gaps where the pine had been completely cleared, and that where the overwood was at all dense the young crop had become suppressed or exterminated. Figs. 461, 462, and 463 give some idea of the condition of the young deodar crop under various degrees of overhead cover.

Cleanings should be repeated at frequent intervals, particularly where blue pine is concerned, since this tree outgrows the deodar in its earlier stages. The freeing of badly suppressed deodar plants which have become flat-topped and bent over is a useless operation, since plants which have reached this stage do not respond to the admission of light.

Thinnings are a very necessary operation in deodar crops. These should begin early and be repeated at intervals of not more than ten years ; among other advantages the gradual opening of the crop in this way is the surest safeguard against damage by snow. A system of thinning young deodar thickets by the agency of forest guards, which was devised by Mr. Trevor in Kulu, has been found to work well in practice. A stick, the length of which varies with the average spacing required, is employed to measure the distance between stems ; when held horizontally, as long as it passes between two adjacent saplings, nothing is removed, but if it does not the worse specimen is felled and the better one retained. It has been found that if a stick 4 ft. long is employed an average spacing of 6 ft. is obtained. By this means large areas of congested sapling crops are operated over which could not otherwise be dealt with satisfactorily.

Subsequent thinnings are carried out on recognized silvicultural lines. They include the removal of inferior species and of deodar stems which are snow-broken, attacked by *Peridermium Cedri*, misshapen, and otherwise undesirable. Owing to the tendency of the deodar to produce strong branches in open crops, care should be taken not to break the canopy severely, but to thin sufficiently to cause the crowns to touch and no more. The last thinning should be in the form of a preparatory felling to stimulate crown development and seed production. Improvement fellings in the shape of the removal or girdling of spruce, silver fir, blue pine, oak, and other trees which are interfering with promising deodar are regularly carried out in many of the existing forests. These fellings, if intelligently carried out, are most useful, but the

FIG. 461. Plantation of deodar 7–10 years old under pole crop of blue pine, Nankhari, Bashahr (1) blue pine, insufficiently opened out, and deodar, where not already killed by suppression, only 2 to 4 ft. high and becoming suppressed.

FIG. 462. Plantation of deodar 7–10 years old, under pole crop of blue pine, Nankhari, Bashahr (2) young deodar completely freed in large gap in pine crop, but suppressed in foreground where cover is denser.

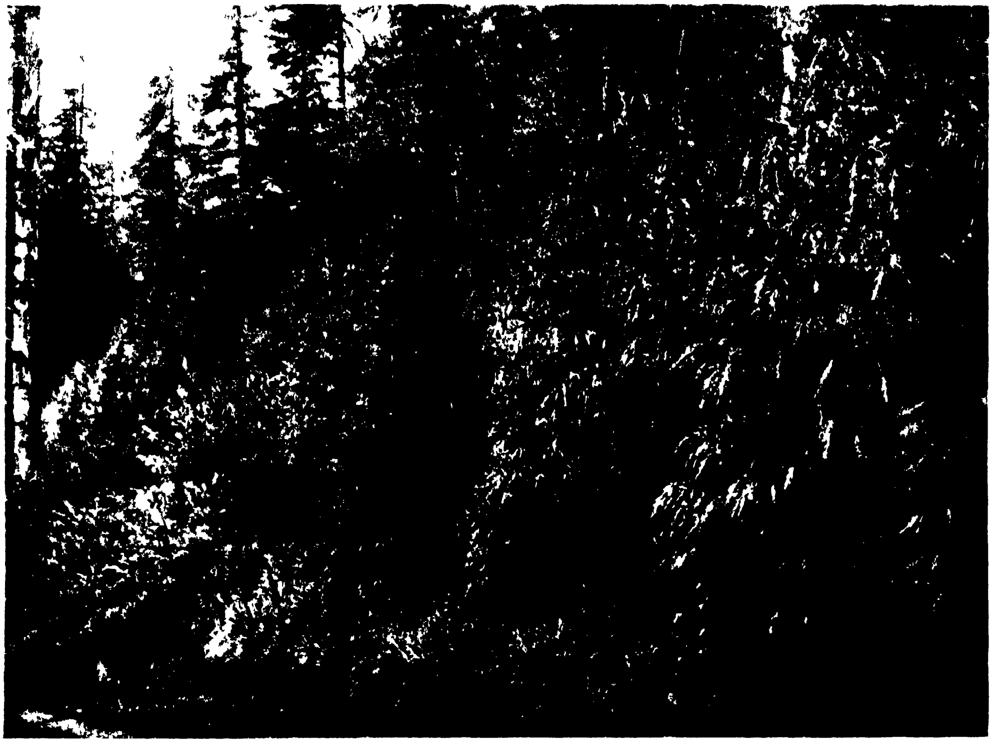


Fig. 463. Plantation of deodar 7–10 years old, under pole crop of blue pine, Nankhari, Bashahr: (3) deodar crop completely freed at an early stage, in vigorous condition, 7–10 ft. high, with young blue pine filling up gaps naturally.

Fig. 464. *Abies Pindrow* forest at 9,500 ft., with some *Quercus semecarpifolia*, Kulu.

wholesale removal of trees of prospective value in the interests of small isolated and often suppressed or branchy deodar trees cannot be justified.

3. *Silvicultural systems.* The treatment adopted generally for the deodar forests at the time when attempts were made to introduce systematic working where no system had previously been in force, was that of selection fellings under a definite felling cycle, and with a minimum exploitable girth or diameter for sound trees ; the opportunity was also taken to carry out improvement fellings with the object of removing unsound or badly shaped deodar as well as accessory species interfering with promising deodar stems. As a means of improving the existing crop this treatment has had beneficial results, but here its utility has ended. Experience everywhere has shown that the selection system has failed both to effect reproduction to the extent desirable or to bring the forests into a more normal condition, and this is not surprising considering the light-demanding character of the tree and the necessity for paying special attention to regenerative operations. The tendency of the deodar to regenerate in groups, where gaps of sufficient size are created, led in some cases to the prescription that the trees should be felled not singly, but as far as possible in small groups with the object of creating gaps. This takes into account the silvicultural requirements of the species to some extent, but the diffusion of work has rendered it impossible in practice to pay sufficient attention to regenerative measures in each gap. Natural reproduction, if it happens to appear at all, stands a strong chance of disappearing through suppression, for it is impossible to attend systematically to large numbers of small gaps scattered over extensive stretches of mountainous country ; in many cases, again, nothing but a heavy growth of weeds appears in the gaps. This uncertainty in obtaining reproduction can hardly be held to warrant the sacrifice involved in felling undersized trees with the object of creating gaps, while apart from silvicultural considerations, concentration as apart from diffusion of working is of special significance in difficult country where it may be necessary to construct export works.

The need for concentration accordingly led some years ago to the proposal that the group system should be applied to all the important deodar forests of the Punjab ; fortunately this proposal was not acted on, for the rigidity with which it was proposed to apply it would have foredoomed it to failure. A working plan prescribing the group system was actually framed in 1911 for the Upper Ravi forests of Chamba, but so far the results attained have not been altogether satisfactory, natural reproduction often failing from one cause or another. Although it is too soon to form a definite opinion as to the results of the group system in Chamba, it seems doubtful if the adoption of this system in itself is likely to lead to successful results, for it would be impossible under Indian conditions to apply it with the detailed attention with which it is applied in Europe, and as a system it is somewhat complicated.

There can be no doubt that in the future treatment of the deodar forests, concentration of working and of regenerative and tending operations must form the basis of successful management. The details of treatment will vary with local conditions. The freeing of promising advance growth by the creation of gaps will no doubt form an important item in the fellings, but this should be combined with the uniform opening of the canopy in the form of seeding fellings with the object of creating even-aged young crops wherever conditions lend themselves to this treatment. On hot aspects there may yet be scope for the adoption of fellings in strips against the sun, with the object of securing the advantages of side shade. In general, however, the successful establishment of the young crop will depend largely on the amount of detailed attention given to regenerative and tending operations such as those described above, and provided these are carried out over definite manageable areas a fair degree of success should be attained. *It is not advisable to prescribe any rigid form of fellings such as group, strip, or uniform fellings ; a study of the ground and the crop will generally indicate how the fellings should be carried out. Natural* reproduction will almost certainly require to be supplemented by artificial reproduction, but care should be taken not to attempt to stock ground which Nature never intended to support a crop of deodar.

A working plan on the elastic lines just indicated has recently been prepared by Mr. Trevor for the deodar forests of Kulu. The rotation is fixed at 120 years, and is divided into four periods of thirty years each. The regeneration fellings in any year may be carried out in any part of periodic block I ; their number and periodicity, and the method of executing them, are not rigidly laid down. After the first regeneration felling all refuse, bushes, inferior trees, raw humus, and suppressed advance growth will be collected and burnt, and the soil will be brought into a suitable condition to receive the seed, if necessary by hoeing. All low spreading branches will be pruned off the mother trees in order to admit light and rain to the ground. The yield is fixed by volume.

STATISTICAL. *Thickness of bark and sapwood.* The following table, based on 250 measurements made in Jaunsar, gives the average thickness of bark in that locality :

Cedrus Deodara : bark thickness, Jaunsar.

Girth of tree over bark.	Bark thickness.	Girth allowance for bark.	Girth of tree over bark.	Bark thickness.	Girth allowance for bark.
	in.	in.		in.	in.
1 ft. and under	0·2	1·3	5 ft. 1 in.–6 ft.	0·7	4·4
1 ft. 1 in.–2 ft.	0·3	1·9	6 ft. 1 in.–7 ft.	0·9	5·7
2 ft. 1 in.–3 ft.	0·4	2·5	7 ft. 1 in.–8 ft.	1·0	6·3
3 ft. 1 in.–4 ft.	0·5	3·1	8 ft. 1 in.–9 ft.	1·1	6·9
4 ft. 1 in.–5 ft.	0·6	3·8	Over 9 ft.	1·2	7·5

As regards sap-wood, there does not appear to be any very definite relationship between the size and age of the tree and the thickness of sap-wood, the latter varying considerably for trees of the same size and age, particularly in the case of small trees. An average of 220 measurements in Kulu and Jaunsar gave the following results :

Cedrus Deodara : measurements of sap-wood.

Girth of stump over bark.	Corresponding radius without bark.	Thickness of sap-wood. Minimum.	Maximum.	Mean.
ft.	in.	in.	in.	in.
1–4	1·7–7·1	1·2	3·0	1·6
4–6	7·1–10·8	1·3	2·2	1·7
6–12	10·8–21·8	1·5	2·8	2·2

This shows a somewhat greater thickness of sap-wood for the larger sized trees, but as the number of measurements on stumps under 6 ft. in girth was considerably less than in the case of larger stumps it is possible that the figures for the former do not represent very correct averages.

Rate of growth in young plantations. Measurements in 33 plantations in Jaunsar showed the following average :

Age (from seed).	Mean girth.	Mean height.
years.	in.	ft.
10	2	4
15	6	9
20	..	15
25	..	23

Individual plantations showed great variation in the rate of growth. Many of these plantations, again, were formed on somewhat unfavourable sites and were not regularly tended ; the growth therefore is slower than what might be expected under more favourable conditions. The Kawaragarh plantation in Kulu, formed by line sowings, had a maximum girth and height of 2 ft. and 25 ft. when seventeen years old. The Bindraban plantation, also in Kulu, had a mean girth of 10–12 in. and a mean height of 45–50 ft. when thirty-two years old.

Girth increment. The statement opposite has been compiled from measurements recorded for the most part in working plans. These measurements are recorded in different ways, some by girth and some by diameter, some inclusive and some exclusive of bark ; in some working plans a number of years are added to the age to allow for the time a seedling takes to establish itself, while in others no such addition is made. In order to place all the results on the same footing all measurements have been converted to girth over bark, and no allowance has been made for the time required for the seedling to establish itself ; this period is usually taken at ten years, and this or some other suitable period should be added to the age in each case if the measurements are to be applied in practice.

General quality classes. The table below shows a tentative allotment to general quality classes according to height-growth, based on 83 separate measurements of even-aged fully stocked sample plots laid out by the Forest Research Institute in Jaunsar, Bashahr, Kulu, and Chamba. This allotment may be regarded for the present as merely provisional, pending the collection of more exhaustive data.

Cedrus Deodara : allotment to quality classes according to height-growth

Age.	Height. I quality.	Height. II quality.	Height. III quality.
years.			
20	21 feet and over	9 feet to 21 feet	Under 9 feet
30	36 ,, ,,	17 ,, 36 ,,	,, 17 ,,
40	50 ,, ,,	26 ,, 50 ,,	,, 26 ,,
50	65 ,, ,,	36 ,, 65 ,,	,, 36 ,,
60	78 ,, ,,	46 ,, 78 ,,	,, 46 ,,
70	90 ,, ,,	55 ,, 90 ,,	,, 55 ,,
80	101 ,, ,,	65 ,, 101 ,,	,, 65 ,,
90	111 ,, ,,	74 ,, 111 ,,	,, 74 ,,
100	120 ,, ,,	83 ,, 120 ,,	,, 83 ,,
110	126 ,, ,,	89 ,, 126 ,,	,, 89 ,,
120	131 ,, ,,	93 ,, 131 ,,	,, 93 ,,
130	134 ,, ,,	96 ,, 134 ,,	,, 96 ,,
140	137 ,, ,,	97½ ,, 137 ,,	,, 97½ ,,
150	138 ,, ,,	98½ ,, 138 ,,	,, 98½ ,,
160	139 ,, ,,	99 ,, 139 ,,	,, 99 ,,
170	139½ ,, ,,	99½ ,, 139½ ,,	,, 99½ ,,
180	140 ,, ,,	99½ ,, 140 ,,	,, 99½ ,,
190	140 ,, ,,	100 ,, 140 ,,	,, 100 ,,
200	140 ,, ,,	100 ,, 140 ,,	,, 100 ,,

Form factors. The following table of timber form factors has been prepared tentatively for trees growing in even-aged fully stocked crops of I and II qualities :

Cedrus Deodara : timber form factors for trees in I and II quality crops.

Height. ft.	Form factor.	Height. ft.	Form factor.
41–50	0·17	81–90	0·34
51–60	0·23	91–130	0·36
61–70	0·29	131 and over	0·35
71–80	0·32	..	..

These form factors have been obtained from the formula $f = \frac{v}{sh}$, where

f = form factor.

v = solid volume of timber in the round (excluding bark) down to a girth (measured over bark) of 2 ft.; volume calculated from quarter-girth-squared measurement.

s = sectional area at 4½ ft. from ground-level.

h = total height of tree.

Statistical results obtained from measurements in Research Institute sample plots. The table opposite summarizes the results obtained so far from measurements made in even-aged fully stocked sample plots laid out by the Forest Research Institute in Jaunsar, Bashahr, Kulu, and Chamba. These results may be regarded as purely tentative and only roughly approximate, since the data at present available are insufficient for the compilation of accurate statistics. The quality classes adopted are those quoted above; statistics are at present insufficient to warrant the preparation of volume figures for crops of quality III or to enable estimates of intermediate yields to be formed for crops of any quality.

Local out-turn statistics. Extensive measurements have been made for many years past in different localities with the view of preparing out-turn statistics of felled trees of various sizes. The trees felled grew under varying conditions in untended and usually irregular crops; many of the trees, having grown in open positions, were branchy, while some were over-mature and unsound. Figures deduced from these measurements, therefore, although applicable locally in respect of trees growing under past conditions, mainly in irregular crops, cannot be taken as typical of trees grown in even-aged, tended, normal crops such as will be produced in future under scientific treatment. Some of the results of these measurements may be quoted.

Hazara. The following statement (p. 1130) has been compiled from out-turn figures based on 1,518 measurements recorded by Mr. A. V. Monro in the Kagan range working plan of 1900 :

Cedrus Deodara: statistical results of deodar sample plot measurements in even-aged fully stocked crops.

Age.	Mean height. I quality.	Mean height. II quality.	Mean height. III quality	Mean girth at 4½ ft. from ground. I quality.	Mean girth at 4½ ft. from ground. II quality.	Mean girth at 4½ ft. from ground. III quality.	Number of stems per acre. I quality.	Number of stems per acre. II quality.	Number of stems per acre. III quality.	Volume of timber per acre in main crop.[1] I quality.	Volume of timber per acre in main crop.[1] II quality.	Mean annual increment per acre, timber in main crop.[1] I quality.	Mean annual increment per acre, timber in main crop.[1] II quality.	Age.
years.	ft.	ft.	ft.	ft. in.	ft. in.	ft. in.				cub. ft.	cub. ft.	cub. ft.	cub. ft.	years.
20	28	15	6	1 2	0 6	0 4	950	1,380	1,700	..	..	..	..	20
30	47	26	12	1 10	1 0	0 8	610	1,050	1,400	1,000	..	33	..	30
40	64	38	18	2 6	1 6	1 0	400	750	1,100	2,800	..	70	..	40
50	79	50	26	3 3	2 0	1 4	280	500	800	4,500	1,100	90	22	50
60	88	62	34	4 0	2 6	1 8	200	360	550	6,300	2,400	105	40	60
70	106	73	42	4 8	3 0	2 0	160	280	420	8,000	3,700	114	53	70
80	118	83	50	5 4	3 6	2 3	130	220	340	9,600	5,000	120	62	80
90	126	92	57	6 0	4 0	2 6	110	190	290	11,300	6,300	125	70	90
100	134	101	64	6 7	4 6	2 9	100	170	250	12,900	7,700	129	77	100
110	140	107	70	7 2	5 0	3 0	90	150	230	14,300	9,000	130	82	110
120	144	112	75	7 8	5 6	3 3	85	130	200	15,900	10,100	*132*	84	120
130	147	115	78	8 2	6 0	3 6	80	120	180	17,100	11,100	131	*85*	130
140	150	117	80	8 8	6 5	3 9	75	110	160	18,000	11,900	129	*85*	140
150	153	118	81	9 1	6 10	3 11	70	100	140	18,800	12,400	125	83	150
160	155	119	82	9 6	7 3	4 1	..	90	120					160

[1] Solid volume of timber in the round (excluding bark) down to a girth (measured over bark) of 2 ft.; volume calculated from quarter-girth squared.

Cedrus Deodara : out-turn statistics, Hazara.

Diameter of tree at breast height.	Average out-turn. Logs.	Average out-turn. Scantlings.	Diameter of tree at breast height.	Average out-turn. Logs.	Average out-turn. Scantlings.
in.	cub. ft.	cub. ft.	in.	cub. ft.	cub. ft.
25	85	50	35	170	92
26	92	53	36	180	98
27	100	56	37	190	104
28	108	60	38	202	110
29	115	64	39	216	116
30	122	68	40	230	123
31	130	72	41	245	130
32	140	77	42	260	136
33	150	82	43	275	142
34	160	87	..	..	..

Chamba. In the Upper Ravi working plan of 1910, Mr. C. G. Trevor records the following scantling out-turn figures based on measurements of 176 trees :

Cedrus Deodara : scantling out-turn statistics, Upper Ravi forests.

Diameter of tree at breast height.	Out-turn of scantlings.	Diameter of tree at breast height.	Out-turn of scantlings.
in.	cub. ft.	in.	cub. ft.
24–25	38	32–33	83
26–27	45	34–35	94
28–29	55	36–37	100
30–31	75	..	..

The following actual scantling out-turns of 87 felled deodar trees are recorded by Mr. R. McIntosh in the Dalhousie range working plan :

Cedrus Deodara : scantling out-turn statistics, Dalhousie range forests.

Diameter of tree at breast height.	Number of trees measured.	Average out-turn of scantlings.	Diameter of tree at breast height.	Number of trees measured.	Average out-turn of scantlings.
in.		cub. ft.	in.		cub. ft.
18–19	4	25	28–29	14	71
20–21	6	33	30–31	12	68
22–23	7	37	32–33	7	74
24–25	24	45	34–35	4	88
26–27	8	52	36	1	80

Mr. J. Copeland recorded the following actual out-turns of felled trees in the revision felling statement for the Pangi forests, 1917 :

Cedrus Deodara : out-turn statistics, Pangi forests.

Diameter of tree at breast height.	Average out-turn. Logs.	Average out-turn. Scantlings.	Diameter of tree at breast height.	Average out-turn. Logs.	Average out-turn. Scantlings.
in.	cub. ft.	cub. ft.	in.	cub. ft.	cub. ft.
18–19	40	..	34–35	193	112
20–21	56	..	36–37	205	110
22–23	64	36	38–39	231	122
24–25	84	51	40–41	277	164
26–27	99	61	42–43	314	147
28–29	109	66	44–45	355	185
30–31	137	78	46–47	368	215
32–33	152	88	..	..	..

Kulu. The following yield table has been prepared by Mr. C. G. Trevor from measurements of 7,700 trees exploited in Kulu over a period of twenty years :

Cedrus Deodara : yield table, Kulu.

Diameter at $4\frac{1}{2}$ ft.	Age.	Mean annual increment in sawn scantlings (general average).	Local quality I. (Trees attaining maximum height of over 120 ft.) Logs.	Local quality I. Scantlings.	Local quality II. (Trees attaining maximum height of 90 to 120 ft.) Logs.	Local quality II. Scantlings.	Local quality III. (Trees attaining maximum height of less than 90 ft.) Logs.	Local quality III. Scantlings.	Average. Logs.	Average. Scantlings.
in.	years.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.
12	57	0·16	26	13	20	10	15	7	20	9
13	61	0·18	31	15	24	12	18	8	24	11
14	65	0·20	37	18	28	14	21	9	28	13
15	68	0·22	43	21	32	16	24	11	32	15
16	71	0·25	50	24	38	18	28	13	37	18
17	75	0·28	58	28	44	21	33	15	43	21
18	80	0·30	66	33	51	24	38	17	49	24
19	85	0·32	76	38	59	27	44	19	56	27
20	90	0·33	86	43	68	31	50	22	63	30
21	95	0·36	100	48	74	35	56	25	70	34
22	100	0·39	114	54	82	40	63	28	77	39
23	105	0·42	126	61	93	45	70	31	86	44
24	110	0·44	140	68	103	50	78	35	95	49
25	115	0·47	158	75	114	55	83	39	105	54
26	120	0·49	170	82	123	60	90	43	115	59
27	127	0·50	183	89	133	65	97	47	126	64
28	135	0·52	191	96	142	71	104	51	137	70
29	147	0·52	200	102	150	77	111	55	147	76
30	159	0·51	207	109	160	83	119	60	157	82
31	171	0·51	215	115	168	89	127	65	167	88
32	205	0·46	223	120	178	94	134	70	177	95
33	..	..	229	126	185	99	142	75	187	102
34	.	..	234	131	193	104	150	80	197	109
35	..	..	238	136	202	109	159	85	209	117
36	..	.	243	141	208	114	168	90	221	125
37	..	..	248	145	214	118	177	93	233	133
38	..	..	253	149	220	122	186	96	244	140
39 and over	..	..	258	153	226	126	192	100	255	150

The standard loss in converting from logs to scantlings is taken locally to be 45 per cent.

Bashahr. Measurements of 439 trees felled in Bashahr between 1892 and 1910 gave the following results :

Cedrus Deodara : out-turn statistics, Bashahr.

Girth of tree at breast height.	Corresponding approximate diameter.	Average age.	Average out-turn. Logs.	Average out-turn. Scantlings.
ft.	in.	years.	cub. ft.	cub. ft.
6–7	23–27	97	84	38
7–8	27–31	112	123	59
8–9	31–34	128	168	..
9–10	34–38	162	223	..

Simla hills. The following statement shows the average out-turn obtained from 358 deodar trees felled in the Simla forest division during a series of years prior to 1914, and converted mainly into sleepers :

Cedrus Deodara : out-turn statistics, Simla hills.

Diameter.	Corresponding girth.	Logs.	Average out-turn. Sawn timber. Broad-gauge sleepers. Number.	Volume.	Other sawn timber.	Total sawn timber.
in.	ft. in.	cub. ft.		cub. ft.	cub. ft.	cub. ft.
24	6 3	96	11	45	7	52
26	6 9	104	12	49	9	58
28	7 4	114	13	53	12	65
30	7 10	125	14	57	15	72
32	8 5	137	16	66	13	79
34	8 11	151	18	74	13	87
36	9 5	166	20	82	13	95
38	9 11	182	22	90	13	103
40	10 6	200	25	102	10	112
42	11 0	220	27	111	11	122
44	11 6	240	29	119	13	132
46	12 1	265	31	127	15	142
48	12 7	290	33	135	18	153
50	13 1	320	35	143	22	165
52	13 7	350	37	152	25	177
54	14 2	380	38	156	34	190
56	14 8	415	39	160	43	203

The following table of measurements is contained in Mr. Hart's working plan of 1897 for the Simla municipal forests :

Cedrus Deodara : out-turn statistics, Simla municipal forests.

Diameter.	Age.	Gross volume.	Mean annual increment.
in.	years.	cub. ft.	cub. ft.
12–15	77	32·66	0·42
15–18	88	49·49	0·56
18–21	100	73·34	0·73
21–24	112	92·26	0·82

3. ABIES, Juss.

The silver firs are evergreen trees with leaves flattened, except in a few species which have leaves quadrangular in section, always with a pair of white or greyish lines, one on either side of the midrib on the ventral surface. Flowers monoecious. Male flowers solitary in the axils of the leaves of the previous year's shoots ; female flowers erect on the upper sides of the branches, usually near the top of the tree, composed of numerous spirally arranged imbricate ovuliferous scales with two ovules on each scale, and an equal number of longer mucronate bracts. Cones ripening in one season, erect, breaking up on the tree when ripe, the scales falling with the seeds and leaving the erect central axis of the cone, which persists for some time on the tree.

The specific distinction between the Himalayan silver firs is not yet a matter of certainty. *A. Pindrow*, Spach, is the low-level silver fir of the western Himalaya, and *A. Webbiana*, Lindl., is the name commonly given to the eastern form as well as to the high-level western form. Brandis,[1] who differentiates between (1) the western low-level form (*A. Pindrow*, Spach), (2) the western high-level form (*A. Webbiana*, Lindl.), and (3) the eastern form (*A. densa*, Griff.), doubts whether the three are specifically distinct.

[1] Indian Trees, p. 692.

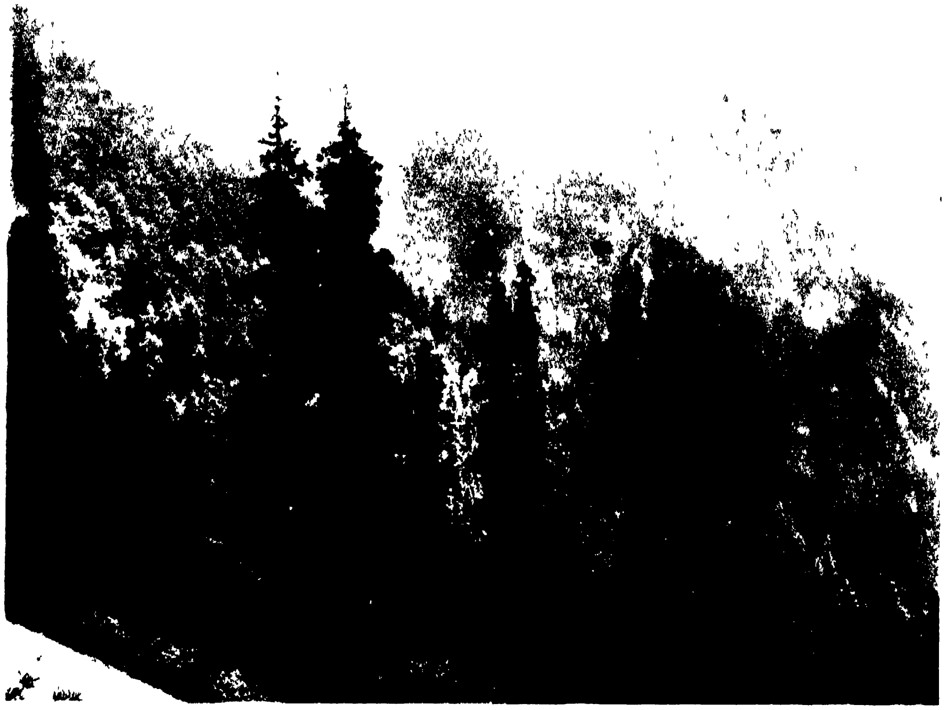


FIG. 465. *Abies Pindrow* with *Quercus semecarpifolia* at 10,000 ft., Kulu.

FIG. 466 Pure mature forest of *Abies Pindrow*, upper Siran valley, Hazara

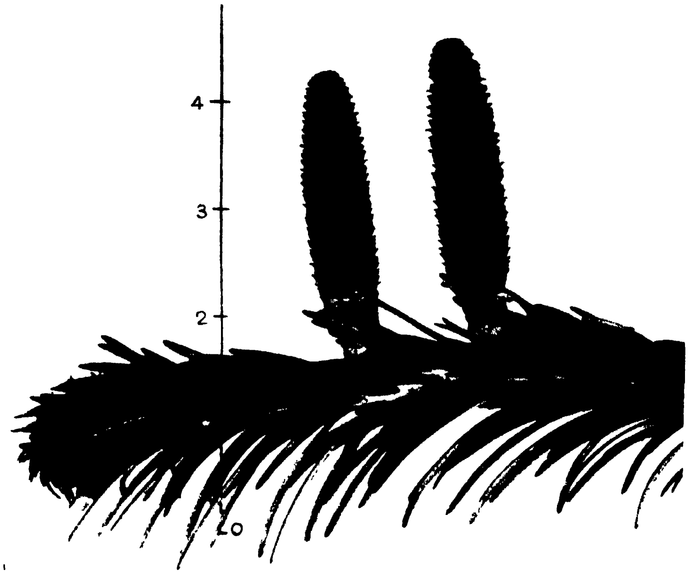


FIG. 467. *Abies Pindrow*, female flowers at time of pollination, May. Scale shows inches

FIG. 468. *Abies Pindrow*, cones at time of ripening, October

He says that in his experience the low-level form gradually changes into the high-level form on ascending to the higher ranges, and that he has never seen the two growing together. He mentions, however, that the two western forms have hitherto come true to seed when cultivated in England and Ireland. Henry[1] distinguishes two species, *A. Pindrow*, Spach, the western low-level fir, and *A. Webbiana*, Lindl., the eastern fir, and considers the high-level western form to be a variety (var. *brevifolia*) of the latter.

The low-level western silver fir is markedly different from the eastern form in general appearance, as will be seen on comparing Figs. 465 and 473. The main differences in the three forms are as follows :

1. Western low-level form (*A. Pindrow*): a tall tree with a dense narrow conical crown and distichous leaves, 1–2·5 in. long or even longer ; young shoots glabrous ; cone erect, cylindrical-ovoid, 4–7 in. long by 2–2·5 in. in diameter ; bracts in the mature cone less than half the length of the scales, with emarginate apex.

2. Western high-level form : very similar to *A. Pindrow*, but usually more stunted and gnarled ; leaves 0·5–1 in. long, densely covering the upper sides of the twigs ; young shoots with short brown hairs ; cones shorter and thicker than in *A. Pindrow*.

3. Eastern form : a tall tree with thick spreading horizontal branches and leaves 1–2 in. long, more or less distichous, but more crowded than in *A. Pindrow* ; young shoots hairy ; cones shorter and thicker than in *A. Pindrow* ; bracts in the mature cone nearly as long as the scales, with a stiff acuminate apex.

Species 1. *A. Pindrow*, Spach ; 2. *A. Webbiana*, Lindl. ; 3. *A. Webbiana*, Lindl. (?), (*A. densa*, Griff.).

1. **Abies Pindrow,** Spach. West Himalayan low-level silver fir. Vern. *Paludar*, *rewar*, Haz. ; *Tós*, Kulu ; *Rai*, Chamba ; *Pindrau*, *rau*, *kalrai*, Simla hills ; *Span*, *krok*, Bashahr ; *Morinda*, Jaunsar ; *Ragha*, Kumaun.

A tall evergreen tree with a dense conical crown of dark green foliage, which frequently extends the whole length of the bole almost to the ground ; upper branches horizontal, lower ones usually drooping with ends curving upwards, branchlets stiff, spreading horizontally. Leaves 1–2·5 in. long, sometimes longer, 0·1 in. broad or less, flat, narrow linear, dark green and shining above, with two whitish lines below, one on either side of the midrib, apex usually bifid. Leaves spirally arranged, declinate into a pectinate arrangement on barren shoots, but on cone-bearing shoots shorter, not pectinate but arranged more or less round the shoot, especially on the upper side, and pointing somewhat forward. Bark on young trees brown to silvery and smooth or scaly, on old trees greyish brown to light grey with deep vertical fissures and long, narrow scales. Wood white, used for building, planking, boxes, shingles, &c.. and suitable for match-manufacture and wood-pulp. The lower part of the bole often contains brown wood in the centre, as in the case of the spruce (see p. 1143). Although commonest in large trees it is sometimes found in trees of moderate size.

The tree reaches large dimensions. The following have been recorded in Jaunsar :

[1] Elwes and Henry, The Trees of Great Britain and Ireland, iv. 750, 755.

Near Mundali: (1) height 206 ft., girth 18 ft. 9 in.; (2) height 202 ft., girth 26 ft.; (3) height 188 ft., girth 19 ft. 9 in.; (4) girth 26 ft.

Near Kathiyan: (1) height 195 ft., girth 13 ft.; (2) height 189 ft., girth 16 ft.; (3) height 181 ft., girth 15 ft. 8 in.

Distribution and habitat. This fir extends throughout the western Himalaya from Afghanistan to Nepal, chiefly at 7,500 to 11,000 ft., but sometimes descending below 7,000 ft. in cool ravines or ascending to 12,000 ft. It is commonly found mixed with spruce (*Picea Morinda*) and sometimes with deodar or blue pine; in the latter case the silver fir usually seeks the cooler and moister slopes and the pine the warmer and drier situations. There are certain localities where the usual spruce mixture is absent and the silver fir forms pure forests or is mixed with broad-leaved species. Such is the case almost throughout the Galis forests of Hazara, on the Dhaula Dhar in Kangra, in parts of Kumaun, as on Badkot mountain, and in many other localities on cool aspects at the higher elevations. The silver fir is also frequently found associated with various broad-leaved species, such as *Quercus dilatata*, *Q. semecarpifolia* (at the higher elevations), *Acer caesium* and other maples, *Aesculus indica*, *Prunus Padus*, *Ulmus Wallichiana*, *Juglans regia*, and other trees. This broad-leaved mixture is well represented in Hazara, where also a very common associate of the silver fir is the yew (*Taxus baccata*). In areas not subject to grazing there is often a dense undergrowth of shrubby and herbaceous plants, among the commoner shrubs being species of *Rubus*, *Rosa*, *Viburnum*, *Salix*, and *Strobilanthes*, and the gregarious aromatic shrub *Skimmia laureola*; bamboos, particularly *Arundinaria spathiflora*, are plentiful in some localities. The trees are often festooned with the so-called Himalayan Virginia creeper (*Vitis semicordata*). The fir forests, however, are very often used as summer grazing grounds, in which case undergrowth is kept down.

Figs. 472 and 475 show the common type of spruce and silver fir mixture. Figs. 464 and 465 illustrate the pure type of silver fir forest commonly found at the higher elevations, with *Quercus semecarpifolia* growing wherever there is sufficient light; in Fig. 464 is sèen a portion of one of the high-level pasture grounds which frequently adjoin the fir forests. Fig. 466 shows the interior of a pure silver fir forest in Hazara. Well-stocked silver fir forests are of considerable density, admitting little light to the ground owing to the thick dark green foliage. The stately appearance of the lofty trees, coupled with their heavy shade, gives an air of grandeur to these forests which is not equalled in any other type of forest in the Himalaya.

The silver fir prefers cool, moist situations with deep, rich soil, and is found most commonly on northerly aspects, though at the higher elevations it is found on all aspects. It avoids dry, shallow soil, and though sometimes found on the tops of ridges it is usually stunted in such situations. The silver fir forests occur within the region of heavy snowfall, and the depressions running down the mountain sides are filled for several months with deep snow or scoured by snow-slides; the fir avoids these depressions, occupying the intervening spurs, while the depressions are either devoid of tree-growth or clothed with broad-leaved trees. Within the natural habitat of the silver fir the rainfall, including the winter snowfall, varies for the most part from 45 to 100 in.; most of the rain falls during the monsoon, from July to September,

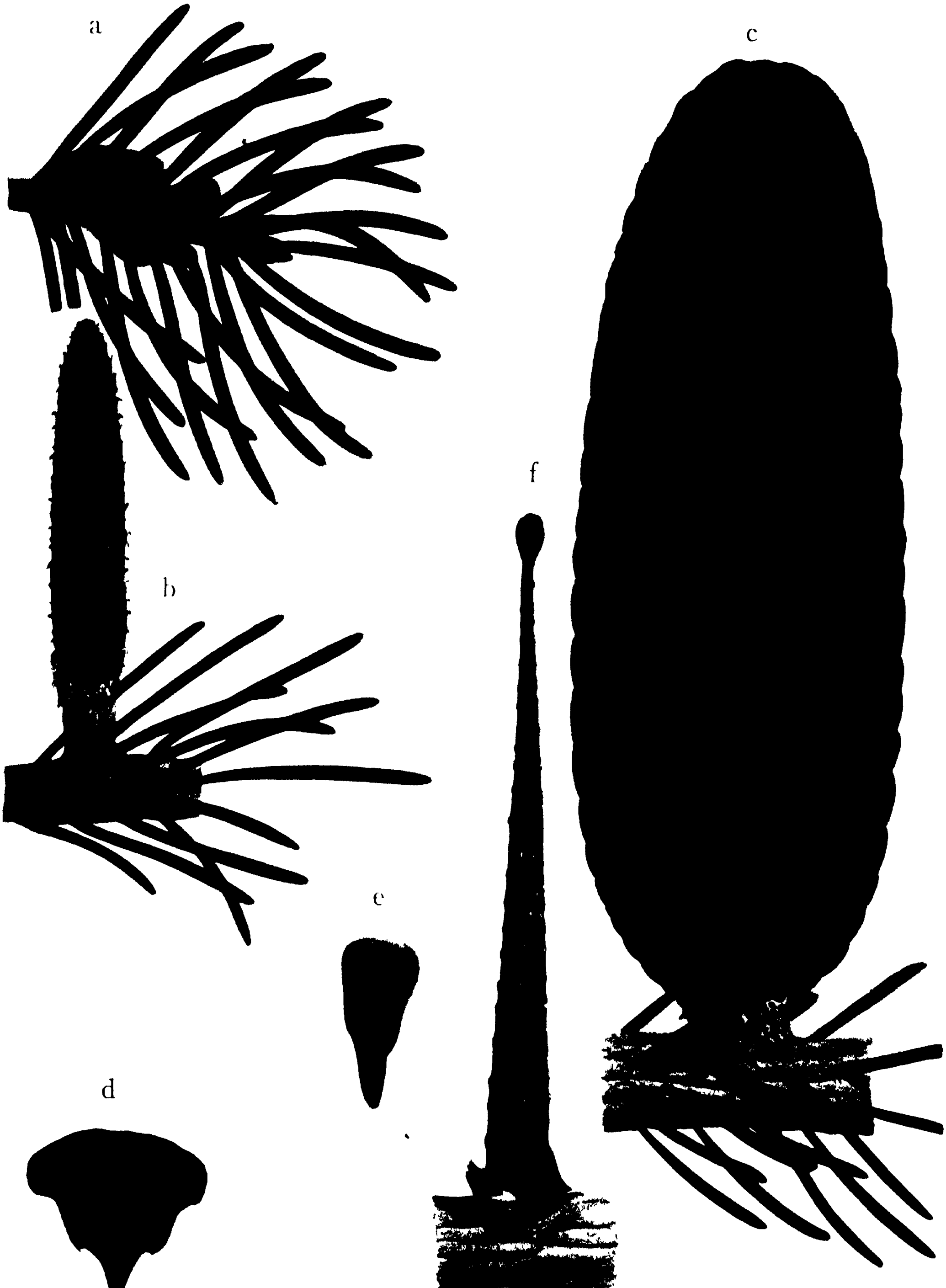


FIG. 469. *Abies Pindrow*—FLOWERS AND FRUIT × $\frac{7}{8}$

a—Male flowers, April-May b—Female flower at time of pollination, April-May
Mature cone, October-November d—Cone scale e—Seed f—Persistent cone axis

and the snow falls from December to April. The maximum shade temperature probably seldom, if ever, reaches 90° F. The fir does not extend into the dry regions of the upper Sutlej valley.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The needles persist for three to six years, and sometimes in part for seven or eight years. The old needles fall chiefly in May and June. The new shoots appear in April–May, their bright green colour contrasting strongly with the dark green of the older foliage ; the young needles and shoots are soft, not stiff like the older ones.

Male flowers (Fig. 469, *a*) sessile in the axils of the leaves on the lower side of the previous year's shoots, cylindrical-ovoid, 0·3–0·5 in. long by 0·2 in. in diameter immediately before ripening, enlarging to 0·5 to 0·8 in. by 0·2 to 0·3 in. after shedding pollen, yellow, often with a light purplish colour, subtended at the base by a cup of brown imbricate scales which persist after the flowers have fallen. The pollen is shed chiefly towards the end of April and in the first half of May, and the flowers fall soon after.

Female flowers (Figs. 467 and 469, *b*) on stout scale-covered stalks 0·4–0·5 in. long, erect on the horizontal branches, chiefly on the upper part of the tree, 1·5–2 in. long by 0·4–0·5 in. in diameter, cylindrical, dark purple, with ovuliferous scales and longer bracts with minutely fimbriate margins arranged in spirals of 5 × 3. Pollination takes place chiefly towards the end of April or in the first half of May, at which time the scales are open to receive the pollen. They close soon after, and the growth of the young cone is rapid. At low elevations by the end of June the cones are about 4–5 in. long by 1·75 in. in diameter.

Cones (Figs. 468 and 469, *c*) when mature erect cylindrical-ovoid, 4–7 in. long by 2–2·5 in. in diameter, dark purple. Scales (Fig. 469, *d*) 1–1·2 in. long by 1·2–1·5 in. broad, fan-shaped, bearing two winged seeds (Fig. 469, *e*) about 1–1·3 in. long, including the wing and 0·5–0 6 in. long without it ; wing 0·5–0·8 in. wide. Bracts broadly obovate emarginate, less than half the length of the scales. The cones ripen in October or early November, breaking up on the tree, and the seeds and scales fall together, leaving the central axis (Fig. 469, *f*), which persists for some years on the tree.

Seeding. The period which elapses from the pollination of the female flower to the ripening of the cone is thus six to seven months, and a probable good seed-year can be foretold by that length of time by examining the upper branches of the trees in April or May with the aid of field-glasses, care being taken not to confound the flowers with the old cone-axes ; the former are usually found in quantity nearer the top of the tree than the latter.

In order to obtain seed for sowing purposes the cones have to be collected before they break up, towards the end of September or early in October ; the cones break up on being placed in the sun for a few days, and the seeds may be separated from the scales by shaking and winnowing. Tests have been carried out to ascertain the effect of the age and size of the tree on the fertility of the seed, but so far as they go they have not shown any definite relation between age or size and fertility. In Kulu seed from trees 12 to 18 ft. in girth gave an average fertility of 69 per cent. Nevertheless large trees often tend to become dry-topped, and such trees produce few or no cones even in good seed-years. Special observations in this direction were made during an exceptionally prolific seeding in Hazara in 1918. It was noticed that cones were produced in greatest abundance by moderate-sized trees about 3 to 7 ft. in girth, while large dry-topped trees were as a rule poor seed-bearers. It was further ascertained that cones began to be produced in fair quantity at thirty years of age, though on exposed ridges and other unfavourable situations the age was higher; younger trees, however, were occasionally found to produce a few cones.

Seed-year records in Jaunsar for twenty-five out of twenty-eight consecutive years, 1887 to 1914, showed good seeding seven times, moderate seeding five times, and bad seeding thirteen times, from which it would appear that a good seed-year may be expected about once in every three to four years.

GERMINATION (Fig. 470, *b–h*). Epigeous. The radicle emerges from the apex of the seed, opposite the wing, and descends. The hypocotyl, at first curving downwards, straightens in elongating, and raises above ground the cotyledons enclosed in the shell of the seed. The latter, with the endosperm, remains enclosing the tips of the cotyledons as they elongate, eventually falling to the ground, when the cotyledons, 5–7 in number, spread outwardly in a whorl, from the centre of which the young shoot subsequently develops.

THE SEEDLING. The following is a description of the natural forest seedling during the first three years:

First year (Fig. 470, *i*). *Roots*: primary root short or moderately long, terete, tapering, wiry, brown; lateral roots absent or short. *Hypocotyl* distinct from root, 1–2·2 in. long, terete, glabrous, red or reddish green turning brown; point of junction between hypocotyl and root marked in early stages by the loose ruptured epidermis. *Cotyledons* 5–7, whorled, 0·8–1·3 in. long, 0·06–0·08 in. broad, linear, flattened, often curved laterally, entire, apex emarginate, at first pale green, turning dark green with whitish stomatic lines on either side of the midrib on the upper surface. *Stem* (above cotyledons) consisting of nothing more than a whorl of leaves equal in number to the cotyledons and alternating with them, and a winter bud of brown imbricate scales in the centre. *Leaves* 0·3–0·6 in. long, linear, narrowed at the base, flattened, entire, apex rounded or acute or emarginate, upper surface smooth and shining, lower surface with a pair of silvery stripes, one on either side of the midrib, composed of parallel lines of stomata.

Second year (Fig. 470, *j*). *Roots*: primary root moderately long, wiry, brown; lateral roots moderate in number, short or moderate in length. *Hypocotyl* dark brown, wiry, smooth or peeling longitudinally. *Cotyledons* still present and green throughout the season, or sometimes turning yellow or brown. *Stem*: first year's shoot (above cotyledons) represented by a whorl of leaves much shorter than the cotyledons and the winter bud scales immediately above them; second year's shoot erect, pale yellowish grey, with numerous spirally arranged leaves 0·4–1·2 in. long, the silvery stripes on the under surface more conspicuous than those on the first year's leaves. *Buds*: terminal bud prominent, globose or ovoid, greenish reddish or purplish brown, often white with resin; sometimes two terminal buds together, both of which produce shoots next year, of which one eventually takes the lead; one or more axillary buds sometimes produced.

Third year. *Roots*: primary root elongated somewhat; lateral roots often numerous, short to moderately long, fibrous. *Hypocotyl* brown, peeling in longitudinal strips. *Cotyledons* usually dropped, their position clearly marked by a raised ring; sometimes a few left, yellow or brown. *Stem*: first year's shoot (above cotyledons) with whorl of needles usually present, in part at least, often turning yellow, and winter bud scales distinct immediately

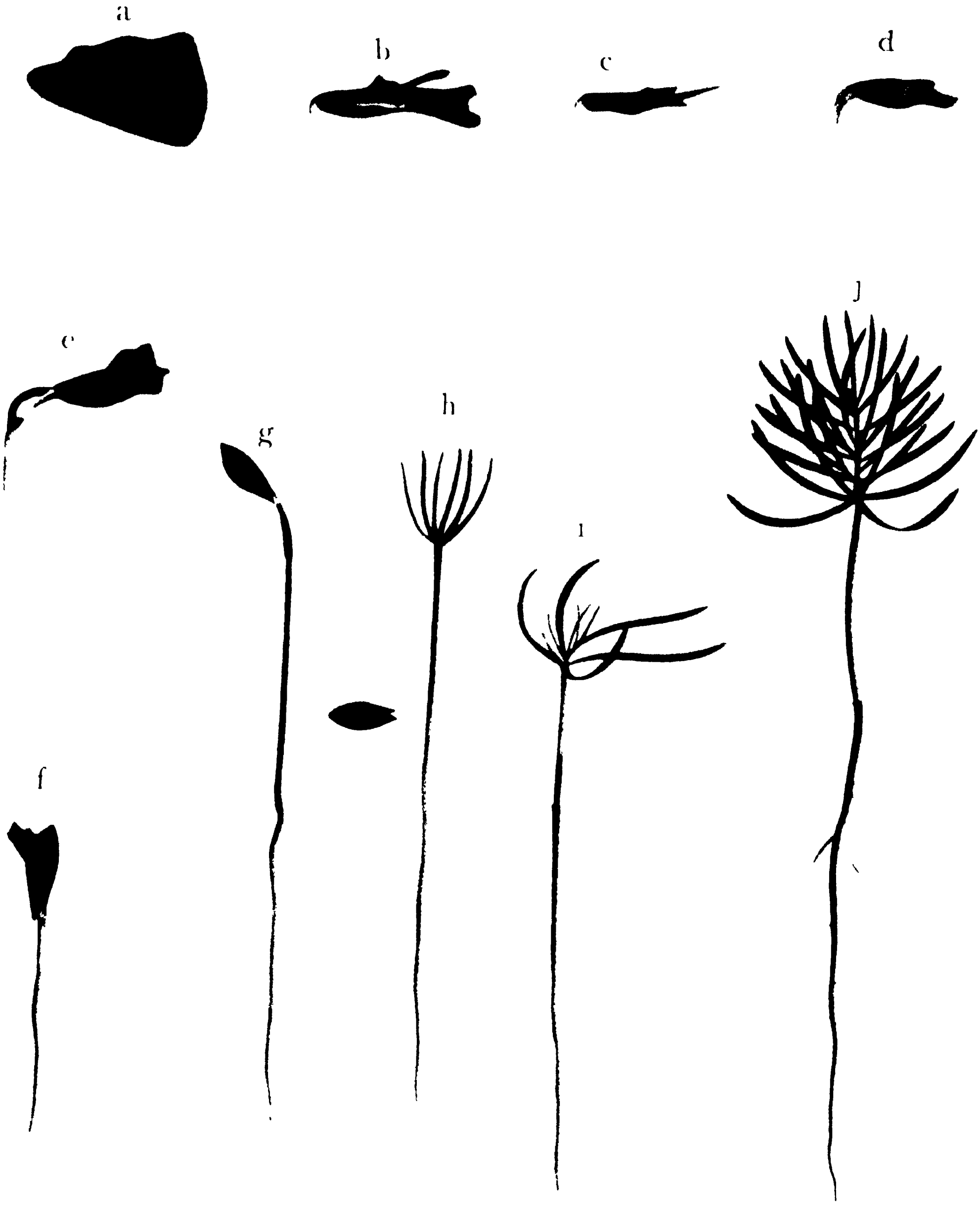


FIG. 470. *Abies Pindrow*—SEEDLING × $\frac{3}{4}$

a—Seed b - h—Germination stages (e shows ruptured epidermis at base of hypocotyl)
i Seedling at end of first season j—Seedling at end of second season

exceptionally prolific seeding in Hazara in 1918. It was noticed that cones were produced in greatest abundance by moderate-sized trees about 3 to 7 ft. in girth, while large dry-topped trees were as a rule poor seed-bearers. It was further ascertained that cones began to be produced in fair quantity at thirty years of age, though on exposed ridges and other unfavourable situations the age was higher; younger trees, however, were occasionally found to produce a few cones.

Seed-year records in Jaunsar for twenty-five out of twenty-eight consecutive years, 1887 to 1914, showed good seeding seven times, moderate seeding five times, and bad seeding thirteen times, from which it would appear that a good seed-year may be expected about once in every three to four years.

GERMINATION (Fig. 470, *b–h*). Epigeous. The radicle emerges from the apex of the seed, opposite the wing, and descends. The hypocotyl, at first curving downwards, straightens in elongating, and raises above ground the cotyledons enclosed in the shell of the seed. The latter, with the endosperm, remains enclosing the tips of the cotyledons as they elongate, eventually falling to the ground, when the cotyledons, 5–7 in number, spread out radially in a whorl, from the centre of which the young shoot subsequently develops.

THE SEEDLING. The following is a description of the natural forest seedling during the first three years:

First year (Fig. 470, *i*). *Roots*: primary root short or moderately long, terete, tapering, wiry, brown; lateral roots absent or short. *Hypocotyl* distinct from root, 1–2·2 in. long, terete, glabrous, red or reddish green turning brown; point of junction between hypocotyl and root marked in early stages by the loose ruptured epidermis. *Cotyledons* 5–7, whorled, 0·8–1·3 in. long, 0·06–0·08 in. broad, linear, flattened, often curved laterally, entire, apex emarginate, at first pale green, turning dark green with whitish stomatic lines on either side of the midrib on the upper surface. *Stem* (above cotyledons) consisting of nothing more than a whorl of leaves equal in number to the cotyledons and alternating with them, and a winter bud of brown imbricate scales in the centre. *Leaves* 0·3–0·6 in. long, linear, narrowed at the base, flattened, entire, apex rounded or acute or emarginate, upper surface smooth and shining, lower surface with a pair of silvery stripes, one on either side of the midrib, composed of parallel lines of stomata.

Second year (Fig. 470, *j*). *Roots*: primary root moderately long, wiry, brown; lateral roots moderate in number, short or moderate in length. *Hypocotyl* dark brown, wiry, smooth or peeling longitudinally. *Cotyledons* still present and green throughout the season, or sometimes turning yellow or brown. *Stem*: first year's shoot (above cotyledons) represented by a whorl of leaves much shorter than the cotyledons and the winter bud scales immediately above them; second year's shoot erect, pale yellowish grey, with numerous spirally arranged leaves 0·4–1·2 in. long, the silvery stripes on the under surface more conspicuous than those on the first year's leaves. *Buds*: terminal bud prominent, globose or ovoid, greenish reddish or purplish brown, often white with resin; sometimes two terminal buds together, both of which produce shoots next year, of which one eventually takes the lead; one or more axillary buds sometimes produced.

Third year. *Roots*: primary root elongated somewhat; lateral roots often numerous, short to moderately long, fibrous. *Hypocotyl* brown, peeling in longitudinal strips. *Cotyledons* usually dropped, their position clearly marked by a raised ring; sometimes a few left, yellow or brown. *Stem*: first year's shoot (above cotyledons) with whorl of needles usually present, in part at least, often turning yellow, and winter bud scales distinct immediately

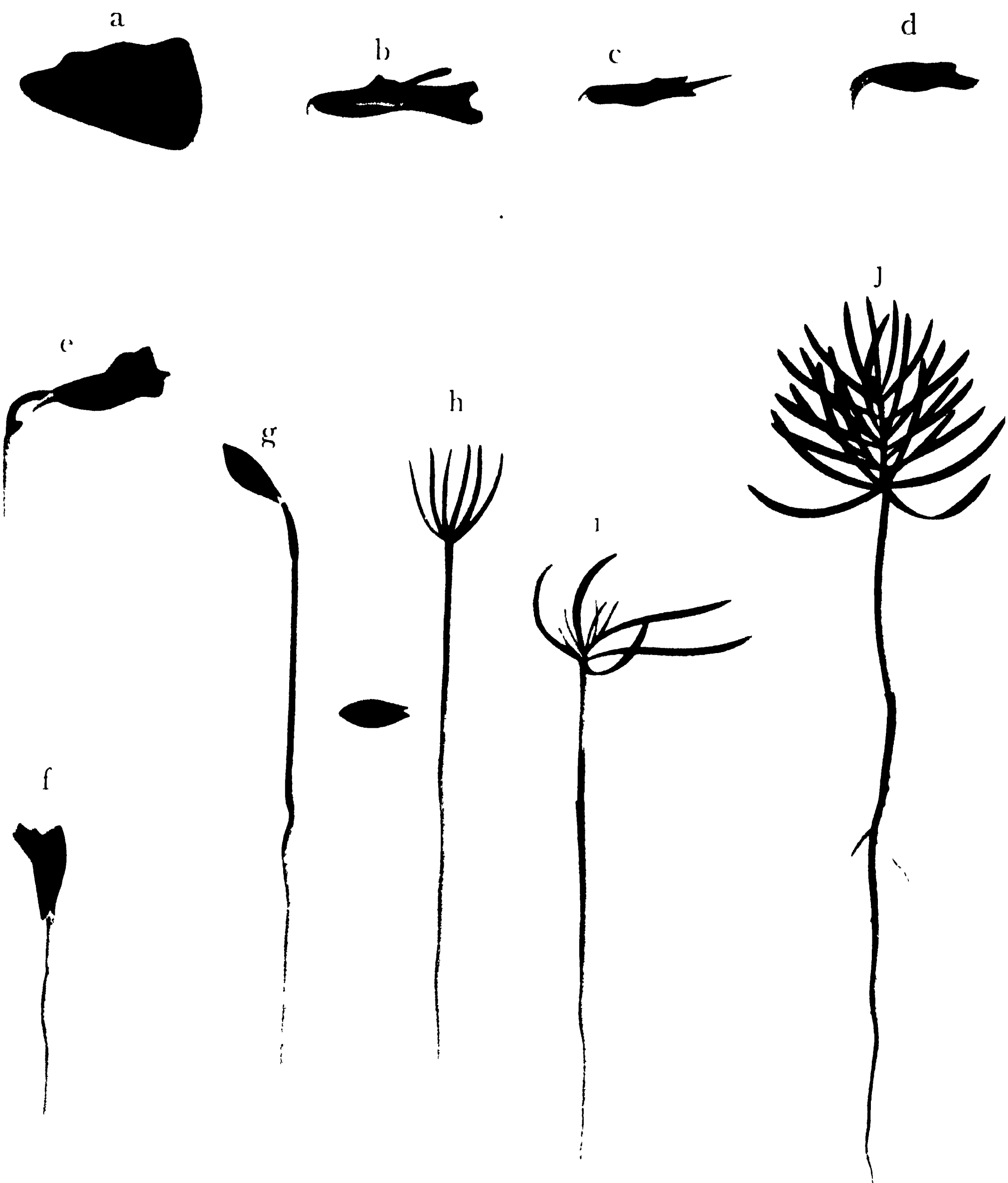


Fig. 470. *Abies Pindrow*—Seedling × $\frac{3}{4}$

a Seed b-h Germination stages (e shows ruptured epidermis at base of hypocotyl)
i Seedling at end of first season j—Seedling at end of second season

above them; second year's shoot greyish brown, with leaves usually all present, sometimes a few fallen on lower part of shoot; third year's shoot pale yellowish grey, covered with spirally arranged leaves 0·7–1·5 in. long, silvery stripes on lower surface more conspicuous than on leaves of previous year's shoot. *Buds*: terminal buds one or two, as before; lateral axillary buds usually also present.

The leaves of seedlings persist for at least three and often four years, and sometimes in part for five years. They increase slightly in size with each succeeding year, attaining a length of about 1–1·7 in. in the sixth year. Each year's growth is clearly marked by the rings of terminal winter bud-scales, which persist for some years. The season's growth commences in April or early May, and is practically completed by the end of June. The growth of natural seedlings is slow. The first year's growth is very little more than the length of the hypocotyl, that is, a maximum of a little over 2 in. The second year's growth ordinarily varies from 0·4 to 1·3 in., and that of the third year from 0·5 to 2·8 in., according to vigour; subsequent growth is usually somewhat faster, but even under favourable conditions a height of barely 3 ft. is attained in ten years. Thus in counting rings on stumps a period of at least ten years should be added for the time required for the seedling to attain stump height.

Seedlings require a moist fresh soil for their best development. They are sensitive to drought and frost. They stand a considerable amount of shade, but when once established are apt to become suppressed under heavy shade, and grow most vigorously with complete overhead light. They are readily browsed in the spring, particularly by goats.

SILVICULTURAL CHARACTERS. The silver fir is a shade-bearer. Saplings persist for many years under fairly heavy shade, and suffer less thereby than those of any other conifer of the western Himalaya except the yew, but they put on little growth unless a fair amount of overhead light is admitted; the admission of complete overhead light after the young plant is established results in vigorous upward growth if other conditions are favourable. For the production of clean timber, however, side shade is essential, owing to the great tendency of the tree to form branches low down on the bole. In a mixed forest of spruce and silver fir the latter may be found with leafy branches down the bole under conditions of shade in which the spruce boles are kept clean.

The root-system of the silver fir is somewhat superficial, spreading, and not very massive. Trees on exposed situations are apt to be thrown by wind, but as a rule the fir grows in sheltered situations. In its natural home the tree does not appear to suffer to any extent from frost, though young plants are sometimes affected; in Britain it is a tender species. It suffers little from snow-break, owing to its short branches, though on steep slopes curvature at the base is frequently caused in the sapling stage by sliding snow. Fires do not often occur in the silver fir forests of the western Himalaya, but when it is subjected to fire the fir is more sensitive to injury than any other conifer of that region, trees which are badly scorched being usually killed outright.

NATURAL REPRODUCTION. Under natural conditions the seed which falls in October and November germinates for the most part during the following May and early June. The seed may be found germinating under fairly heavy shade. The question of seed-bearers may be of importance in over-mature forests in which the trees are old and dry topped ; the quantity of seed produced by such trees, as already mentioned, is small.

The chief requirements for successful reproduction, apart from the question of seed-production, are a germinating bed consisting of fresh well-drained porous soil, preferably newly exposed mineral soil, an absence of sour humus or excessive soil-moisture, protection in the earlier stages from the desiccating effect of the sun, protection from grazing and from fire—though the latter is seldom to be feared—and a fair amount of overhead light after the seedling is established. The value of newly exposed mineral soil may be seen by the manner in which seedlings spring up in cuttings, and on places where the soil has been exposed by the felling and extraction of timber or otherwise ; in some of the Kashmir forests thickets of silver fir spring up on newly formed islands of sand, shingle, and boulders in the beds of streams running through the forest. Drought is a fruitful cause of mortality among natural seedlings, which die off in quantity during or shortly after germination on ground which is exposed to the sun for any length of time during the day ; shade, at all events from the side, is essential under most conditions.

Perhaps the most general cause of failure in natural reproduction is attributable to unfavourable soil conditions, possibly the result of an excess of carbon dioxide produced by an accumulation of dead needles in the presence of an excess of moisture in the soil. These unfavourable conditions are sometimes indicated by the presence of an undergrowth of *Skimmia Laureola*. To this cause is probably due the almost complete failure of reproduction in some of the moister fir forests, for example in the Dungagali range of Hazara. Here reproduction is almost entirely absent in the moister depressions, though it appears on the better drained spurs, while in places where the soil has been worked up, reproduction sometimes appears in quantity where it was previously absent. This, together with the experience gained in the Kanjatra block, near Deoban, in Jaunsar, indicates that the unfavourable soil conditions do not go deep, and that they can be dissipated by the simple process of exposing the soil and hoeing it up. The Kanjatra block consisted at one time of dense mature spruce and silver fir forest which showed no signs of regenerating, and accordingly in 1877–8 it was opened out in the form of a heavy seeding felling, but the only result was a dense crop of weeds without any natural reproduction. Artificial reproduction was then tried, and the silver fir seedlings established themselves without difficulty in the prepared lines where the soil was dug up. The result has been a complete success, there being now a promising young crop of silver fir under the mature and somewhat open overwood, which is ready for removal. In this case the unfavourable soil conditions were evidently removed without difficulty by the mere hoeing up of the soil, otherwise the seedlings, of which some were the result of direct sowing and some were transplants, could not have survived. In cases where reproduction fails owing to unfavourable soil conditions, these unfavourable conditions could no doubt be removed by measures similar to those which have been found so successful in the case of the deodar, namely, cutting the undergrowth and burning all refuse ; in the case of the silver fir, however, more caution would be required in opening the canopy than in the case of the deodar, owing to the sensitiveness of the seedlings to drought.

Except in special cases such as those just noted, in which the reproduction of the silver fir fails owing to unfavourable soil conditions, natural reproduction is usually all that can be desired provided the ground is not exposed for any length of time to the desiccating effect of the sun. Thickets of young silver fir are often to be found in small gaps in which side shade to the ground is afforded, or under a moderately light canopy of broad-leaved species, blue pine or deodar, or on cool northerly slopes. There are many instances in which broad-leaved or other crops are being gradually converted to silver fir crops owing to the readiness with which the fir establishes itself on suitable ground under a light canopy of other species or in small gaps. Fig. 471 shows the typical manner in which thickets of young silver fir often appear in gaps in broad-leaved forest.

Moderate shrubby weed-growth does not as a rule impede the natural reproduction of the fir, and may be beneficial in sheltering the ground from the sun. Where the weed-growth is very dense, however, it is inimical; this applies particularly to rank herbaceous growth, which is specially noxious. A dense matted growth of *Strobilanthes* impedes natural reproduction in some localities. *Skimmia Laureola*, as already noted, usually denotes unfavourable soil conditions.

Natural reproduction has little or no chance of establishing itself in areas which are at all heavily grazed, as the young plants are very susceptible to damage, while apart from actual browsing the seedlings, owing to their small size, are very liable to be uprooted and destroyed by trampling.

ARTIFICIAL REPRODUCTION. Experience regarding the artificial reproduction of the silver fir is somewhat limited, as this tree has not been raised in plantations to any great extent. So far as is known transplanting from the nursery has generally proved more successful than direct sowing. Fresh seed should be sown in October or November, and it is usual to keep the plants three or four years in the nursery, which should be in a cool well-drained situation on fresh fertile loamy soil. The restocking of the Kanjatra block referred to above was commenced in 1885 and continued for some years ; it took the form of contour line sowings and basket planting under an opened-out overwood of spruce with a little silver fir. Actually spruce and silver fir were sown in alternate lines 6 ft. apart, but very few of the spruce plants survived, though the silver fir plants have succeeded well over a considerable portion of the area. The cost, which is not accurately known, is said to have been high, but this was due partly to the experimental nature of the work and partly to the failure of the spruce, necessitating much restocking of gaps. Fig. 472 shows a portion of this plantation at the age of twenty-one years.

SILVICULTURAL TREATMENT. The silver fir forests of the western Himalaya have hitherto been worked under the selection system, but this system has not proved successful except under conditions specially favourable to natural reproduction. Such conditions do not as a rule exist in the purer types of silver fir forest where there is an excessive accumulation of fir needles on the ground. In mixed forests of silver fir with blue pine or broad-leaved species the fir usually reproduces with freedom, and the only course necessary as a rule is to open the canopy sufficiently to enable the young fir to establish itself. In the purer types of silver fir forest or in mixed forests of spruce and silver fir, where conditions for natural reproduction are so often unfavourable, the plan indicated for securing reproduction is to open the canopy moderately and in good seed-years to cut the undergrowth and burn it thoroughly together with all felling refuse in the manner described for the deodar (p. 1122). It may prove difficult, however, to burn such material in the moister types of forest, in which case possibly hoeing the ground may have the desired effect. The question of side shade, as afforded by fellings in narrow strips, is worth pursuing experimentally in connexion with the natural reproduction of the silver fir. Fig. 482, which is explained on p. 1150, shows a successful case of reproduction of silver fir, spruce, and oak springing up on a cleared strip sheltered laterally from the morning sun. In places where reproduction cannot be secured by natural means artificial reproduction has to be resorted to in order to ensure complete stocking. In a species like the silver fir, which has such a tendency to branch low down, the cleanest timber will be produced by growing the trees in dense even-aged crops. The silver fir is well adapted for growing in such crops, and under natural conditions they are not infrequently met with.

In the more recent working plans the tendency now is to abandon the selection system in favour of successive regeneration fellings, under which special measures such as cutting and burning the undergrowth are to be carried out where natural reproduction cannot be obtained otherwise. For the silver fir a fairly long regeneration period is indicated owing to the sensitiveness of the young plants to exposure to the sun at too early a stage. In the latest working plan for Kulu a rotation of 150 years, with five periodic blocks of thirty years each, has been adopted. In Hazara a regeneration period of thirty years has also been proposed.

STATISTICAL. 1. *Girth and height increment.* For several years the rate of growth of the silver fir is slow, but after normal height-growth begins it is maintained fairly constantly at about 1–1½ ft. per annum up to an age of about 100–120 years, after which it usually slows down. The height-growth of the young plants in the Kanjatra plantation in Jaunsar was approximately as follows :

Abies Pindrow : rate of growth in Kanjatra plantation.

Age.	Mean height.	Age.	Mean height.
years.	ft.	years.	ft.
8	1·5	16	5·3
10	2·1	18	6·5
12	3·1	20	7·8
14	4·1		

Specially vigorous plants showed considerably faster growth. The statement below, showing the rate of growth of natural silver fir in girth and height, has been prepared from measurements recorded in working plans and based on ring-countings on stumps. The girth figures include bark, and in order to make the figures uniform for comparison nothing has been added to allow for the time required for a seedling to attain stump height ; in using the figures in practice, at least ten years should be added to the age to allow for this.

FIG. 471. Natural reproduction of *Abies Pindrow* establishing itself in a gap in forest of broad-leaved species, Hazara. *Acer caesium* in centre.

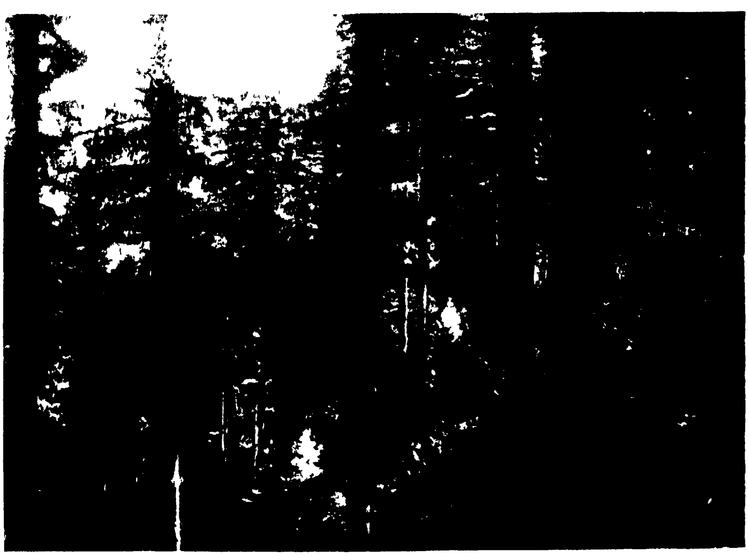


FIG. 472. Forest of *Picea Morinda* and *Abies Pindrow* opened out and underplanted with *Abies Pindrow*; young crop 21 years old; Jaunsar

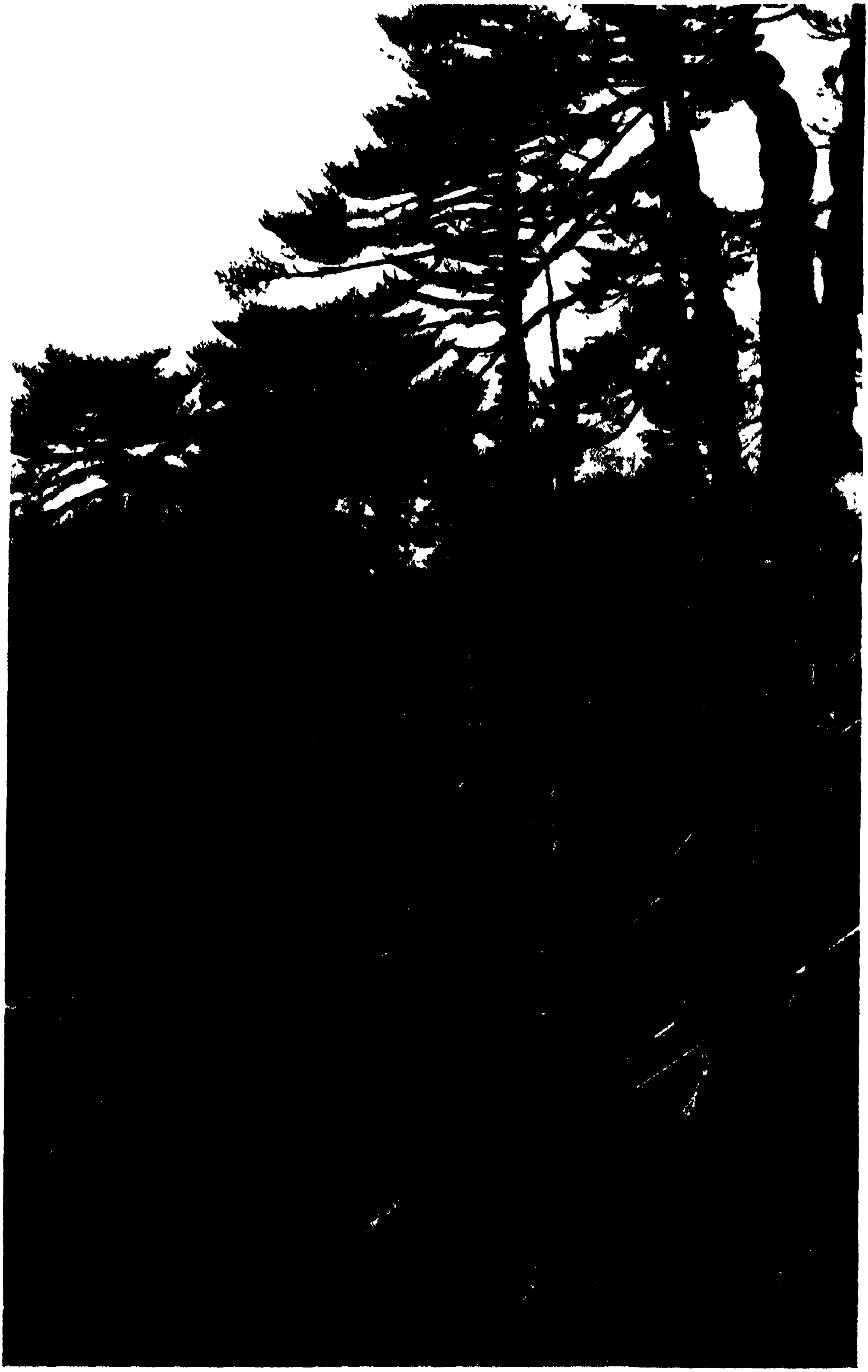


Fig. 473. Forest of *Abies Webbiana*, 11,000 ft. British Sikkim.

Abies Pindrow : rate of growth in girth and height in natural forests.

Age.	Mean girth. Kulu.[1] Inner Saraj (20 trees).	Outer Saraj (19 trees).	Kulu (25 trees).	Rupi (29 trees).	Hazara. Dungagali and Thandiani[2] (72 trees).	Kashmir. Batot range.[3]	Jaunsar.[4]	Mean height. Jaunsar.[4]
years.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft.
20	..	..	..	..	..	0 10	1 4	20
40	2 6	..	..	2 11	1 8	1 10	2 9	40
60	3 7	2 10	..	4 4	2 10	2 9	4 2	60
80	4 6	3 9	3 3	5 6	3 11	3 9	5 6	80
100	5 4	4 8	3 11	6 8	4 11	4 9	6 10	100
120	6 1	5 6	4 7	7 8	5 11	5 9	8 2	120
140	6 10	6 5	5 3	..	6 11	6 10	..	..
160	7 8	7 3	5 9	..	7 10	7 11	..	..
180	..	8 1	6 3	..	8 6	9 2	..	..
200	..	..	6 9	..	9 0	..	..	..
220	..	..	7 3	..	9 4	..	..	..
240	..	..	7 9	..	..	..	..	..

In the working plan for the Dalhousie range forests, Chamba,[5] it is estimated that an average tree takes 150 years to reach a diameter of 24 in. (girth, 6 ft. 3 in.), and shows no marked diminution of growth until after reaching a diameter of 36 in. (girth, 9 ft. 5 in.).

2. *Out-turn.* There are very few out-turn figures available for the silver fir. The following local yield table for Kulu has been compiled by Mr. C. G. Trevor for silver fir and spruce combined :

Abies Pindrow and *Picea Morinda* : yield table, Kulu.

Diameter at 4½ ft.	Age of spruce.	Age of silver fir.	Average age of the two species.	Mean annual increment of sawn scantlings.	Average volume. Logs.	Average volume. Scantlings.	Volume of trees for calculation of the yield.
in.	years.	years.	years.	cub. ft.	cub. ft.	cub. ft.	
12	57	73	65	0·15	20	10	35
13	61	80	70	0·20	26	14	
14	65	86	75	0·24	32	18	
15	69	90	79	0·26	38	21	
16	73	96	84	0·29	44	25	
17	77	100	88	0·32	52	29	
18	81	104	92	0·36	60	34	90
19	85	112	98	0·40	70	40	
20	89	118	103	0·44	82	46	
21	93	122	107	0·49	96	53	
22	97	128	112	0·54	110	61	
23	101	134	117	0·59	126	70	
24	105	139	122	0·65	144	80	162
25	111	146	128	0·70	162	90	
26	115	150	132	0·75	180	100	
27	120	158	139	0·79	200	110	219
28	125	164	144	0·81	220	118	
29	129	172	150	0·84	236	126	
30	133	178	155	0·86	250	134	263
31	137	186	161	0·87	264	141	
32	143	194	168	0·87	276	147	
33	150	..	..	..	288	153	299
34	155	..	..	..	300	159	
35	160	..	..	..	310	165	
36	165	..	..	..	320	170	328
37	170	..	..	..	328	175	
38	175	..	..	..	336	180	
39 and over	183	..	..	..	344	185	350

[1] Working Plan for the Kulu Forests, Punjab, C. P. Fisher, 1898.
[2] Working Plan for the Dungagali and Thandiani Ranges, Hazara, A. V. Monro, 1908.
[3] Working Plan for the Batot Range Forests, Riasi Division, Kashmir, Hans Raj, 1917 (these measurements include both spruce and silver fir).
[4] Working Plan for the Jaunsar-Bawar Forests, P. H. Clutterbuck, 1901.
[5] Revised Working Plan for the Dalhousie Range Forests, Chamba, R. McIntosh, 1913.

In the 1913 working plan for the Dalhousie range forests, Chamba, the average out-turn in sawn scantlings from 14 trees 24 to 30 in. in diameter at 4½ ft. from ground-level is stated to be 57 cubic ft.; it was found, however, that the out-turn varied greatly in individual trees, owing to the presence of decay in some of them.

2. **Abies Webbiana,** Lindl. West Himalayan high-level silver fir. Vern. as for *A. Pindrow.*

A tree resembling *A. Pindrow* but usually more stunted and gnarled, with leaves 0·5–1 in. long (see introduction to this genus).

This fir is found in the western Himalaya at higher elevations than *A. Pindrow,* occurring towards the upper limits of tree-growth, sometimes associated with *Betula utilis* and *Rhododendron campanulatum,* ascending to 14,000 ft., and rarely descending below 11,000 ft.

3. **Abies Webbiana,** Lindl. (?). Syn. *A. densa,* Griff. East Himalayan silver fir. Vern. *Gobre salla,* Nep.; *Dunshing,* Bhutia.

A tall evergreen tree, attaining a height of 200 ft., with thick spreading horizontal branches and leaves 1–2 in. long (see introduction to this genus).

This fir is found in the eastern Himalaya, in Sikkim and Bhutan, at 9,000–13,000 ft., sometimes descending in Bhutan to 8,000 ft. It probably extends into Nepal. Above 10,500 ft. it often forms pure forests of considerable extent (see Fig. 473); below this elevation it is sometimes mixed with spruce or hemlock spruce. At the higher elevations it becomes stunted, and is often associated with juniper. Characteristic undergrowth species are various rhododendrons or the *maling* bamboo (*Arundinaria racemosa*).

If protected from fire the silver fir forms crops of considerable density, but where fires rage the crop tends to become open, as the fir is sensitive to damage by fire, which often burns with great intensity owing to the dense growth of *maling* bamboo, and trees of fair size are killed outright by it.

The silver fir forests are situated for the most part in a very humid region characterized by heavy rain and dense mists from June to October, and the trees bear evidence of this in the growth of mosses, ferns, and other epiphytes with which their branches are often laden.

Measurements by Mr. E. Marsden in 1917 in three sample plots in the Darjeeling hills gave the following results:

Abies Webbiana: sample plot measurements, Darjeeling hills.

	Standing crop (after thinning).						Yield from thinning in 1917.		
				Solid volume per acre.					
Age.	Number of stems per acre.	Mean girth.	Mean height.	Timber over 24 in. in girth.	Small-wood.	Total.	Number of stems per acre.	Solid volume per acre, timber and small-wood.	Particulars of san plot.
years.		in.	ft.	cub. ft.	cub. ft.	cub. ft.		cub. ft.	
20	638	12·3	17	..	484	484	181	89	Plantation, Senc
115	294	35·5	62	4,530	778	5,308	187	1,623	Natural, Sandakı
151	286	47·1	95	11,130	907	12,037	..	..	Natural, unthinr below Sandakı

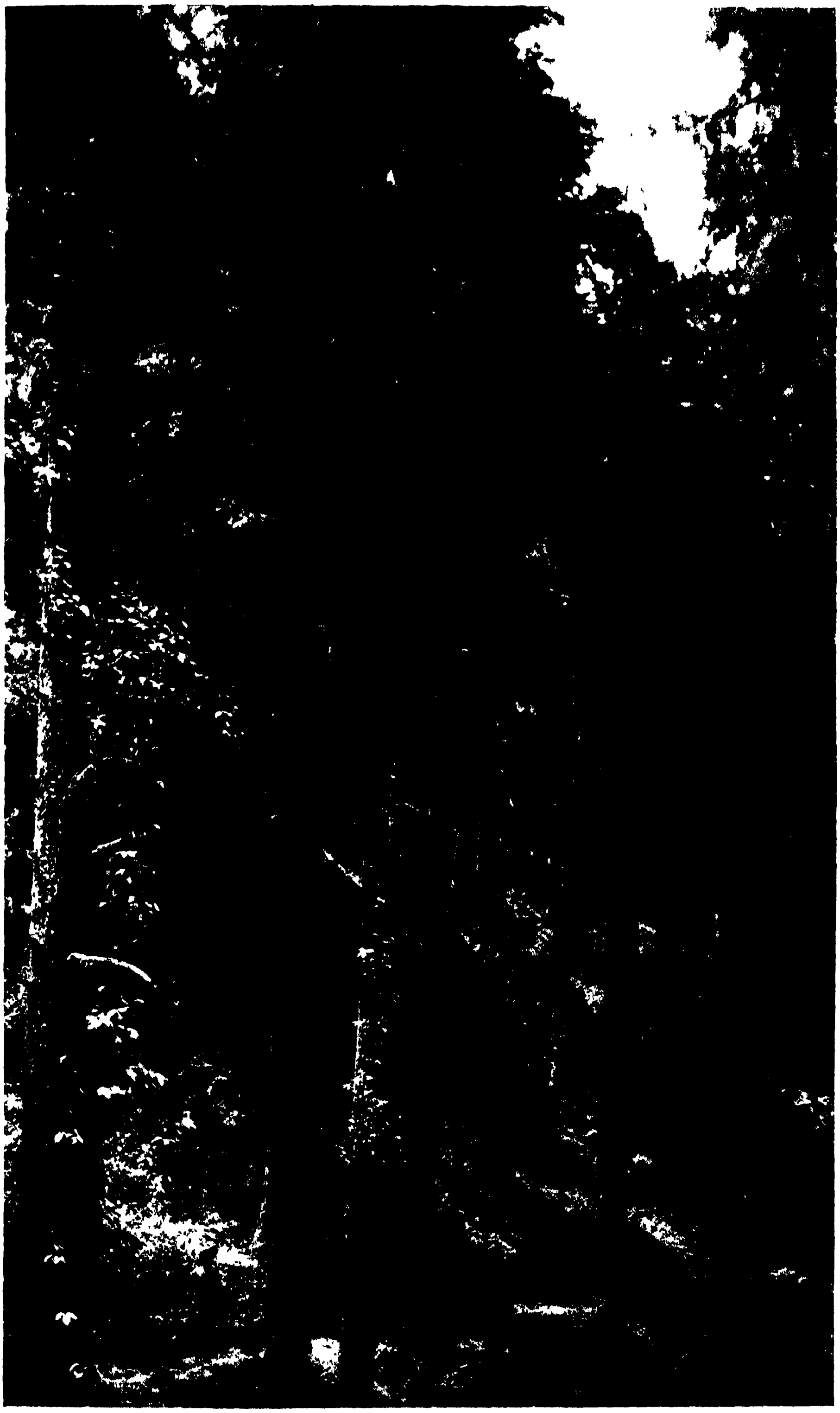


FIG 474. Forest of *Picea Morinda*, 8,500 ft , Jaunsar.

FIG 475. Forest of *Picea Morinda* and *Abies Pindrow* opened out by felling, Bashahr.

FIG 476. Good natural reproduction of *Picea Morinda* under a light underwood of *Pinus excelsa*, in an area subject to moderate grazing, where the spruce has survived at the expense of the pine. Bashahr.

4. PICEA, Link.

The spruces are tall evergreen trees with needle-like leaves arranged singly in spiral order on small persistent projections along the shoots. Leaves needle-like, tetragonal or flattened in section, persisting for some years. Flowers monoecious. Male flowers solitary in the leaf-axils of the previous year's shoots, with an involucre of scales at the base; female flowers solitary, terminal, erect, on the previous year's shoots. Cones usually pendulous, always so in the Indian species, with persistent scales each bearing two-winged seeds, ripening in one season.

The spruces are divided into two main sections: *Eu-picea*, with leaves quadrangular in section and bearing stomatic lines on all four surfaces, and *Omorica*, with flattened leaves bearing stomata only on their dorsal surface. Henry points out that there are two Indian species: *P. Morinda*, Link, the west Himalayan spruce, belonging to the former section, and *P. spinulosa*, Griffith, the east Himalayan or Sikkim spruce, belonging to the latter.

Species 1. *P. Morinda*, Link; 2. *P. spinulosa*, Griff.

1. **Picea Morinda,** Link. Syn. *P. Smithiana*, Boiss.; *P. Khutrow*, Carr.; *Pinus Smithiana*, Wall.; *P. Khutrow*, Royle; *Abies Smithiana*, Lindl. West Himalayan spruce. Vern. *Rai, re, riar, rau, raiang*, W. Him.; *Tós*, Chamba; *Kachal*, Hazara.

A very tall evergreen tree with a conical crown, horizontal or drooping branches and slender pendulous tassel-like branchlets usually 1–3 ft., but occasionally up to 5 ft. long. Leaves spirally arranged, 1–1·5 in. long, acicular, obscurely quadrangular, with usually two lines of stomata on each of the four sides. Bark grey to greyish brown, exfoliating in small thin rounded scales. Measurements of bark-thickness are given on p. 1151. Wood white, often becoming brown in the centre in large trees, soft to moderately hard, used for planking, shingles, tea-boxes, packing-cases, &c.; has been pronounced very suitable for match manufacture and wood-pulp. Mr. W. Raitt, who has examined the wood for pulping purposes, found that it has a longer fibre than any other spruce hitherto examined. If, as is hoped, the wood proves after impregnation to be suitable for railway sleepers, these should be obtainable in large quantities.

The tree reaches very large dimensions. The following measurements have been recorded near Mundali, Jaunsar, elevation about 8,500 ft.:[1] (1) height 215 ft., girth 19 ft.; (2) height 202 ft., girth 19 ft.; (3) height 195 ft., girth 23 ft.; (4) height 177 ft., girth 20 ft. A tree which I measured in 1907 at Konain, Jaunsar, elevation 7,800 ft., was 202 ft. high and 23 ft. 10 in. in girth; it was growing on the side of a moist ravine on a northerly aspect.

The larger trees very frequently have a mass of brown wood in the centre resembling heart-wood, which often fills the greater portion of the cross-section near the base. This is not true heart-wood, since it extends only a certain distance up the stem, sometimes as much as 25 ft. or more; it is often full of moisture and shows signs of rot, while trees with brown wood tend to become hollow. This brown wood may therefore be regarded as a sign of incipient rot: it greatly reduces the value of the tree. Its formation may

[1] F. Gleadow, Forest School Tour in Jaunsar, 1898–99, p. 49.

commence early ; in Bashahr I found two freshly felled trees 4 ft. and 4 ft. 3 in. in girth and ninety-two years of age with brown wood in the centre. This formation of brown wood is a strong reason against growing spruce on a long rotation.

DISTRIBUTION AND HABITAT. This spruce occurs throughout the western Himalaya from Afghanistan eastwards at least as far as Kumaun, chiefly at elevations of 7,000–11,000 ft., though occasionally descending lower and ascending higher. Scattered trees may sometimes be found as low as 5,000 ft. on cool aspects, and under the influence of fire-protection young spruce trees in some localities are making their appearance at elevations lower than those at which mature forests are to be found. Although a gregarious tree it is not often found pure over large areas, but is more commonly mixed with silver fir, or with deodar, blue pine, oak—chiefly *Quercus dilatata*, and at the higher elevations *Q. semecarpifolia*—and other broad-leaved species such as maple, horse-chestnut, walnut, bird-cherry (*Prunus Padus*), elm (*Ulmus Wallichiana*), and others. In some localities the yew is a common underwood species. The spruce stands less heat and requires more moisture than the deodar, and, unlike that tree, does not extend into the drier parts of the inner valleys. On the other hand, although a frequent companion of the silver fir it is capable of thriving on drier ground and in warmer situations than that tree. Some of the finest spruce is found on moist rich soil in association with *Quercus dilatata* of large size. The spruce occurs on various geological formations, perhaps the commonest within its region being mica schist, shale, gneiss, and limestone. Climatically the spruce belongs to the cool, temperate regions of the Himalaya, where there is comparatively heavy snowfall between December and April. The maximum shade temperature probably seldom if ever reaches 90° F., while the rainfall is for the most part between 40 and 100 in., of which the great bulk falls either in the season of the monsoon rain or in the form of winter snow.

Although the spruce forms extensive forests over wide stretches of country its local distribution is at times curiously restricted. Thus in Hazara, although common in the Kagan and upper Siran forests, where silver fir is also common, the spruce is absent in the forests of the Galis, where the silver fir is abundant, except over a very limited area in the Bakot forest, where it grows well. Again, on the Dhaula Dhar of Kangra the spruce and the silver fir occupy separate areas, the former occurring above Palampur and the latter farther west near Dharmsala.

The tall stately trees with their drooping evergreen foliage render the spruce forests sombre in aspect ; the trees themselves are often festooned with the so-called Himalayan Virginia creeper (*Vitis semicordata*), which turns bright red in the autumn. Situated as they usually are on somewhat moist cool slopes, the forests, if closed to grazing, are characterized by a luxuriant undergrowth of shrubs and herbaceous plants ; but as they are much used as summer grazing grounds for sheep, goats, and buffaloes, the ground is often grazed bare. Fig. 474 shows a typical spruce forest closed to grazing ; the climber on some of the trees is *Vitis semicordata*. Fig. 475 shows mixed forest of spruce and silver fir (*Abies Pindrow*) recently opened out by felling.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The needles usually persist

FIG. 477. *Picea Morinda* FLOWERS AND FRUIT × $\frac{7}{8}$

a—Male flowers immediately before shedding pollen, April-May b—Male flower after shedding pollen, April-May c—Female flower at time of pollination, April-May d—Female flower (young cone) shortly after pollination, May e—Ripe cone, Oct.-Nov. f—Cone scale g—Seed

in full for three to six years, and often persist in part for seven or eight years. They are shed for the most part in the hot season, in May and June. The new shoots, with light green needles, appear in April; the bud-scales adhere in the form of a conical cap which often remains on the tips of the new shoots for a time before falling to the ground.

Male flowers (Fig. 477, *a* and *b*), solitary in the leaf axils towards the end of the previous year's shoots, before ripening ovoid, greenish yellow, 0·5–0·7 in. long by 0·25–0·5 in. in diameter. Anthers in distinct spirals, base surrounded by an involucre of light brown imbricate scales. After shedding their pollen they elongate considerably, and a distinct petiole 0·2–0·3 in. long forms; the flowers become 0·7–1·3 in. long, excluding the petiole, by 0·25 to 0·5 in. broad. The pollen is shed from the latter part of April to the middle of May, according to locality, after which the male flowers fall with their petioles, the cup-like involucre of scales remaining on the tree.

Female flowers and cones. Female flowers (Figs. 477, *c*, and 479) solitary, erect, terminal on the previous year's shoots, at the time of pollination 1·5–1·8 in. long by 0·5–0·7 in. in diameter, cylindrical ovoid, reddish green, with scales in spirals. Scales of two kinds, small membranous bracts and the ovuliferous scales bearing two inverted ovules at their base. Pollination takes place from the latter part of April to the middle of May; at this time the ovuliferous scales are open, their upper parts being bent outwards perpendicular to the axis. Soon after pollination the scales close and fertilization is completed, the young cone increasing in size and weight and becoming pendulous (Figs. 477, *d*, and 480). Subsequent growth is rapid, and by July the cones reach full size though they are still green. They ripen in October and November. The ripe cone (Fig. 477, *e*) is terminal, pendulous, 3–7·5 in. long by 1·5–2 in. in diameter, cylindrical, brown; scales (Fig. 477, *f*) in spirals of 8 × 5, broadly ovate with a thin edge and a cuneate base, each subtending two winged seeds. Seed (Fig. 477, *g*) without wing 0·15–0·2 in. long, greyish brown, with wing 0·6–0·8 in. long; wing oblique spathulate, 0·3 in. wide, light brown.

The time taken from the pollination of the female flower to the ripening of the cone is thus about six to seven months, and probable good seed-years can be foretold only so long in advance, the erect female flowers being visible in April or early May at the ends of the branchlets with the aid of field-glasses.

Seeding. Various tests have been carried out recently to ascertain the effect of the age and size of the tree on the production of fertile seed. These are not yet conclusive, but so far they indicate that fertile seed is produced by large and small trees alike. Moderate-sized trees about 3–8 ft. in girth with vigorous well-developed crowns, however, have usually been found to produce cones in greatest abundance. Well-developed cones are often found on trees about twenty years old. The seed retains its vitality, to some extent at least, if stored for a time. Seed kept for eighteen months was tested at Dehra Dun, and showed 25 per cent. of fertility. Tests of fresh seed have shown fertility varying from 22 to 65 per cent.

Good seed-years are the exception rather than the rule. In Jaunsar records for twenty-nine out of thirty-two consecutive years, 1883 to 1914, show good seeding six times, moderate seeding six times, and poor seeding seventeen times. Thus good seeding may be expected only about once every five years.

Many unripe cones are destroyed by nutcrackers (*Nucifraga hemispila*) and by flying squirrels (see under *Pinus excelsa*, p. 1022); the former also extract and devour the seeds from ripening cones.

Pseudo-cones. The flowers and cones of the spruce should not be confounded with the pseudo-cones formed by aphides (*Chermes*). These pseudo-cones are found in the green state about May and June, when they are of various sizes up to 1·3 in. long by 0·6 in. in diameter, ovoid, with pseudo-scales with sharp points (the aborted needles) in regular spirals of 8 × 5. If cut through longitudinally they present the regular appearance of cones, but instead of containing ovules, they contain small chambers in which the minute reddish brown aphides can be seen.

GERMINATION (Fig. 478, *b–g*). Epigeous. The radicle emerges from the end of the seed and descends. The hypocotyl elongates, raising above ground the cotyledons enclosed in the shell of the seed. As the cotyledons elongate the shell remains enclosing their extremities in the form of a cap, eventually falling to the ground, when the whorled cotyledons, eight to ten in number, separate somewhat and the young shoot develops from the centre of the whorl.

THE SEEDLING. The following is a description of the natural forest seedling, grown under average conditions, during the first three years:

First year (Fig. 478, *h*). *Roots*: primary root short, terete, tapering, thin, flexuose, light brown; lateral roots small or almost absent. *Hypocotyl* distinct from root, 1·5–2 in. long, thin, cylindrical, light green turning brown. *Cotyledons* 8–11, whorled, 0·7–1·1 in. long, acicular, triquetrous, compressed laterally, entire, curved inwards, the whole usually bending to one side, bright green, tender when young, becoming stiffer later. *Stem* (above cotyledons) at most scarcely 0·5 in. long, often consisting of nothing but a tuft of needles and a terminal bud. Leaves up to 0·5 in. long, acicular, obscurely quadrangular, minutely and somewhat widely serrulate, with a sharp pointed apex, spirally arranged and situated on small peg-like projections (pulvini). *Terminal winter bud* yellowish grey.

Second year (Fig. 478, *i*). *Roots*: primary root rather short, tapering, wiry, brown; lateral roots few or moderate in number, short to moderately long. *Hypocotyl* greenish brown, smooth or peeling longitudinally. *Cotyledons* still present, sometimes green, sometimes turning brown by the end of the season. *Stem*: first year's shoot (above cotyledons, if present) with leaves still green, but lower ones often turning yellow or brown; upper extremity well marked by persistent brown scales of winter bud: second year's shoot pale yellowish grey, somewhat drooping, with spirally arranged leaves 0·4–0·8 in. long, more thickly clustered towards apex, with light brown terminal bud, and on vigorous specimens one or more axillary buds.

Third year (Fig. 478, *j*). *Roots*: primary root not much elongated; lateral roots moderate in number and length or short. *Hypocotyl* greenish or greyish brown, smooth or peeling longitudinally. *Cotyledons*, if present, dead and falling, their position well marked by a ridge. *Stem*: first year's shoot (above cotyledons, if present) greenish grey, with leaves present or absent, usually brown if present, their raised points of insertion (pulvini) conspicuous; second year's shoot yellowish grey, leaves present, green or partly yellow and sometimes falling near base; third year's shoot pale yellowish grey, somewhat drooping, with bright green spirally arranged leaves 0·5–1 in. long, more densely clustered towards apex. *Buds and lateral shoots*: terminal winter bud yellowish grey; axillary buds usually present at various points on the stem, from which one or more side branches have sometimes developed.

FIG. 478. *Picea Morinda*—SEEDLING × $\frac{3}{4}$

a—Seed b-g—Germination stages h—Natural seedling at end of first season
i—Natural seedling at end of second season j—Natural seedling at end of third season

The season's growth of natural seedlings usually commences about April, and the rate of growth is slow, but it depends much on the amount of light and on the fertility of the soil. Often the growth is not more than about half an inch a year for some years, but under specially favourable conditions, on moist ground with side shade and full overhead light, natural seedlings have been found attaining a height of 1 ft. 4 in. in five years, which, however, is quite exceptional. Under natural conditions an average annual height-growth of about 1 in. for the first five years is usual, the growth thereafter increasing to about 2 to 3 in. per annum for a few years. Thus in counting rings on stumps in natural forest it is necessary to allow at least ten years for the time required for the seedling to attain stump height.

The leaves of seedlings usually persist, in whole or in part, for two or three years. The persistent leaf-cushions, in the form of spirally arranged raised dots after the leaves are shed, are very characteristic of spruce seedlings. The roots are generally short, often attaining a length of only 1 to 2 in. in the first year, and 5 to 6 in. in the third year. For this reason the young plant has little chance of establishing itself in hot, dry situations, but requires a fairly moist soil. It does not, however, persist under heavy shade, and the ideal conditions for its growth are abundance of overhead light combined with side protection from the desiccating effect of the sun. Although sensitive to drought the seedling is frost-hardy in its natural home.

Nursery-raised seedlings, as might be expected, grow more vigorously than natural seedlings under average conditions, but their growth is also comparatively slow, a yearly average of only about 2 to 3 in. in height being attained during the first few years. A height of 4 ft. in ten years is above rather than below the average even for artificially raised seedlings, but thereafter growth is more rapid.

SILVICULTURAL CHARACTERS. The spruce is a moderate light-demander, ranking more or less equally with the deodar in this respect. In early youth it requires protection from the sun, and stands a certain amount of shade, but once established its growth is most vigorous when it obtains complete overhead light, and under shade which is at all heavy it becomes suppressed. The root-system is spreading, somewhat superficial and not very massive, and the tree is not wind-firm. The spruce is not so subject to snow-break as the blue pine or the deodar, owing chiefly to its more pendulous branches and branchlets. Saplings, however, are frequently bent down by sliding snow, and as a result curvature at the base may persist throughout the life of the tree; the risk of this form of damage is aggravated where the saplings are isolated, and hence growing in dense crops is beneficial, while unnecessary removal of surrounding growth and undergrowth should be avoided. Fire does not ordinarily occur in spruce forests, but when it does the spruce suffers more than any of the other west Himalayan conifers except the silver fir. Young spruce plants are less subject to damage from browsing than young blue pine plants; goats, it is true, browse on the young shoots, but if other fodder is plentiful they usually avoid spruce. In grazed areas, however, great damage is done to spruce seedlings owing to their small size, for the plants are readily destroyed by trampling and by being uprooted along with grass and other herbage.

No dangerous fungus attacks have yet been reported in spruce areas. *Trametes Pini* has been found on lopped spruce in Kulu, but it does not appear to be the scourge which it is in the case of *Pinus excelsa*. *Peridermium Thomsoni*, Barcl., is the aecidial stage of a fungus which attacks the needles, causing them to become swollen and curled and to burst open and emit orange-coloured spores in May and June, at which time evidence of the attack can be seen in the form of long orange-coloured tassels sometimes over a foot long. The same fungus also attacks green cones, the scales becoming soft and swollen and covered with orange flecks. This fungus does not appear to be very common. I have found it locally common in Kulu. *Barclayella deformans*, Dietel, is the teleuto stage of the same fungus, and is much commoner ;[1] it produces short orange tassels 1–2 in. long, the needles being less swollen than in the case of *Peridermium Thomsoni*. The spores ripen in May and June. *Peridermium Piceae*, Barcl., is another rust, recorded by Mr. Oliver from Jaunsar, of which only the aecidial stage is known.[2] The young shoots are attacked, long narrow spore-cases appearing somewhat irregularly along the upper surface of the affected needles, which turn yellow. Regarding this fungus, Dr. Butler says : 'Mr. Oliver informed me that he had seen trees in Chakrata Cantonment in 1902 dying or dead from the effects of this fungus. This was due to the loss of all infected needles in 1901, when the attack was very severe. The trees were so weakened in consequence that they were unable to make new shoots or only put out feeble ones.'

NATURAL REPRODUCTION. The natural reproduction of the spruce is handicapped to some extent by the comparatively long intervals at which good seed-years take place. So far as is known the best seed-bearers, that is, those producing the largest quantity of well-developed cones, are trees of moderate size, not those of very large size. Under natural conditions germination begins about the end of May or during June, and may continue during July, August, and part of September.

The chief requirements for successful natural reproduction are a germinating bed consisting of recently exposed mineral soil, which should be porous and fresh, protection from fire and grazing, freedom from troublesome weeds, protection in the earlier stages from the desiccating effect of the sun, and an abundance of overhead light. Spruce seedlings often spring up in abundance on mineral soil exposed by small landslips and road cuttings and on abandoned cultivation. A thick accumulation of dead needles is decidedly unfavourable, since the young seedling does not produce a long taproot, and readily dies of drought if the root is unable to penetrate quickly to the mineral soil ; the adverse effect of raw humus, which may possibly be due to chemical as well as to physical action, is seen in the difficulty which spruce reproduction experiences in establishing itself under a parent crop of spruce. Young spruce has considerable power of penetrating a moderate growth of weeds, but where the weed-growth is dense and matted, as in the case of *Strobilanthes Wallichii*, the seedlings are unable to establish themselves. As in the case of the blue pine, spruce reproduction is favoured by the presence of *Indigofera*, *Desmodium*, and bracken.

Grazing is fatal to the establishment of seedlings in their earlier stages,

[1] E. J. Butler, Ind. Forester, xxxi (1905), p. 611. [2] Butler, *loc. cit.*, p. 614.

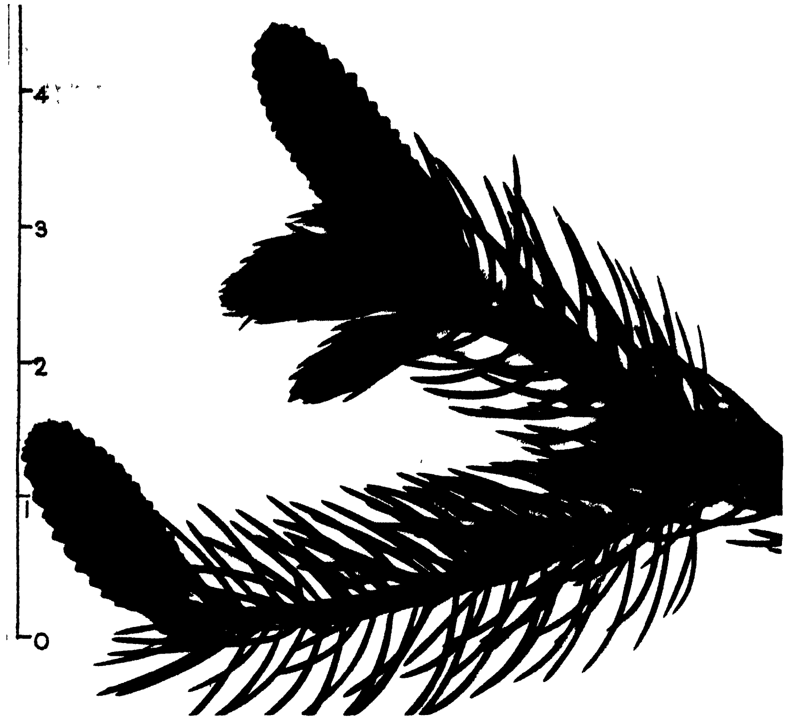


FIG. 479. *Picea Morinda*, female flowers at time of pollination, May. Scale shows inches

FIG. 480. *Picea Morinda*, young cones shortly after pollination, end of May. Scale shows inches.

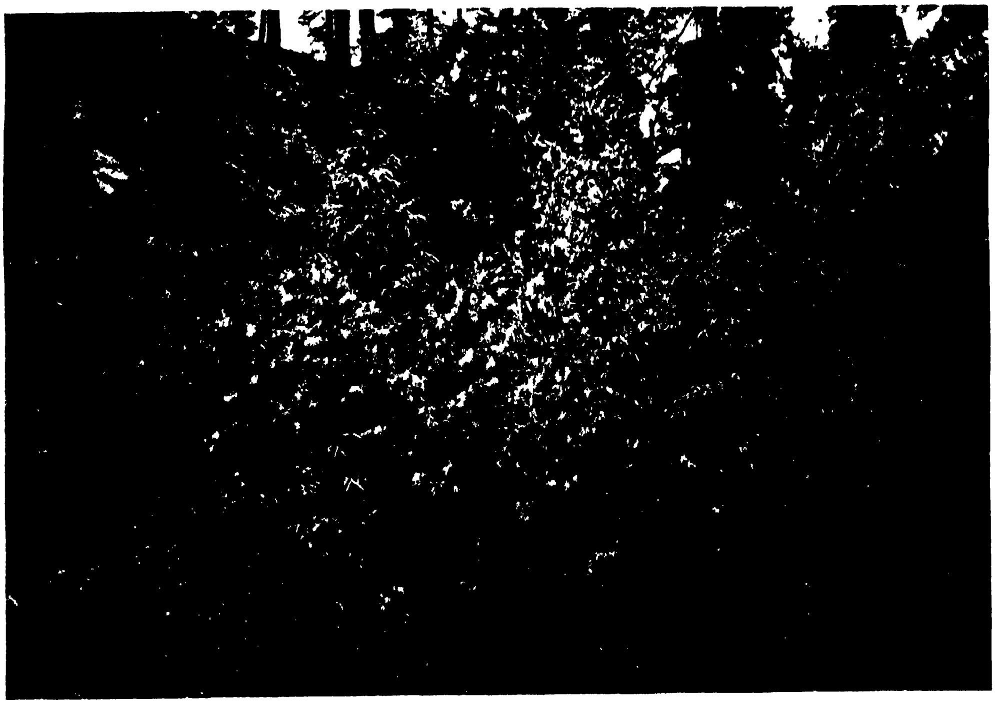


Fig 481. Good natural reproduction of *Picea Morinda* and *Pinus excelsa* in a large gap with much shrubby undergrowth affording protection from browsing, Bashahr.

Fig. 482. Dense natural reproduction of *Picea Morinda*, *Abies Pindrow*, and *Quercus semecarpifolia* on an open strip receiving lateral shade from the south-east, Kulu.

since owing to their small size they are easily destroyed by trampling or are easily uprooted. Goat browsing is particularly harmful, as the young plants are eaten by these animals. Nevertheless if the young spruce is able to survive the first few years by reason of the protection afforded by bushes, it has a better chance of ultimate establishment than the blue pine, which is more readily browsed. Fig. 476 shows a dense mass of spruce reproduction establishing itself, owing to the protection of bushes, under a light overwood of blue pine and spruce in an area open to moderate grazing ; blue pine reproduction is kept back by the grazing, whereas the young spruce is establishing itself successfully in spite of it. As in the case of the deodar, the thorough clearing of the ground by means of fire has a beneficial effect on spruce reproduction. In the Surd forest of the Nogli range, Bashahr, an excellent young crop of spruce, mixed with blue pine, has established itself on an area overrun by a severe fire many years ago. In regenerative operations fire will no doubt be found to play an important part in inducing spruce reproduction by consuming débris and raw humus and bringing the soil into a suitable condition ; mere opening out of the canopy too often results in the appearance of a heavy growth of weeds.

The question of light is a most important one in connexion with spruce reproduction. The best reproduction is usually found in open gaps where complete overhead light is obtained, though it also appears readily under a light overwood of blue pine. Spruce regeneration is often excellent in mixture with that of the blue pine, the conditions favourable to the one being to a large extent favourable to the other (see Fig. 481). In moist ravines and cold, damp situations it is usually scarce or absent, as is also the case in ravines scoured by snow-slides.

The question of side shade in early youth is one which requires further study. Wagner has demonstrated the value of side shade from the morning sun in the case of the European spruce, and so far as observations have been made its beneficial effects, in preventing desiccation, are no less apparent in the case of the Himalayan spruce, though observations are as yet incomplete. The following cases may be cited :

1. In the late autumn of 1909 four experimental plots were laid out near Mundali in Jaunsar, in an open area subject to grazing, on which there were two belts of spruce forest giving lateral shade to part of the area. The slope was moderate, and the aspect varied from west to north. Two of the plots were fenced and two were left open to grazing, while in one of each pair the soil was hoed up, the other being left unhoed. Throughout the fenced area, and in the hoed portion of the grazed area, spruce seed was sown. These plots were inspected in the autumn of 1914, that is, five years after being laid out, and the following observations were recorded :

(i) Under cover of the spruce belts there was a dense growth of *Strobilanthes* and no young spruce ; (ii) in the open, but with complete lateral shade from the morning and midday sun, i. e. from east to south, the soil was moist and spruce seedlings were plentiful, in the fenced plot attaining a height of 1 ft. 4 in., with vigorous growth, and in the unfenced plot attaining a height of 5 in. and much browsed ; (iii) in the open, with protection from the morning sun but not from the midday sun, spruce seedlings were not plentiful, and attained a maximum height of only 5 in., even when protected from grazing; (iv) in all portions exposed to the sun throughout the day the ground was dry, herbaceous weeds had died down by October, and spruce seedlings were absent; (v) a moderate growth of weeds was found to act as a protection, but a dense growth of *Strobilanthes* prevented the survival of any seedlings; (vi) closure to grazing proved decidedly beneficial; (vii) spruce seedlings were more plentiful and more vigorous in the hoed than in the unhoed areas, but as the former were also the areas best protected from the sun, no conclusion can be based on this.

2. Mr. Marsden has furnished me with the following note recorded in May 1915 in the Kundi forest, Chamba, at an elevation of 6,950 ft.: 'A small gap in mixed deodar, spruce, and blue pine forest shows good spruce regeneration of all ages up to 20 ft. high where there is shelter from north-east round to south, but nothing on the other sides; it extends about 80 ft. into the gap and no more.'

3. In Kulu in June 1914, at an elevation of 9,000 ft., a cleared strip about 20 yds. wide on a northerly aspect, protected laterally on the south-east by a mature crop of spruce, silver fir, and brown oak (*Quercus semecarpifolia*), had filled up with a dense mass of natural reproduction of these three species, as shown in Fig. 482. The origin of the cleared strip could not be traced; the clearing, which may have been due to an abnormal snow-slide or to wind, had evidently been made at least fifteen to twenty years previously.

These instances serve to indicate that protection from the morning and midday sun is beneficial to the establishment of spruce reproduction, though further experiments and observations are required to determine this definitely.

Artificial reproduction. The spruce has not been grown artificially to any extent in the Himalaya, but where it has been grown transplanting from the nursery has usually proved more successful than direct sowing. Fresh seed should be sown in the nursery in October or November. Germination commences towards the end of the following May or in June and continues during July and August. The seedlings may be pricked out in the nursery when two years old and planted out at an age of three or four years; some plantations in Jaunsar, however, have been formed with plants two years old. Care is necessary during transplanting not to injure the roots or to expose them to the sun, for which reason the young plants, when removed from the nursery to the planting site, should be bundled together with their roots wrapped round with damp moss.

Silvicultural treatment. The spruce has hitherto been worked as a rule under selection fellings, but, as in the case of the deodar, this system has proved unsuitable, since the spruce is not sufficiently shade-bearing for such treatment. The most suitable method of regenerating the spruce naturally under different conditions requires further study. The factors influencing natural reproduction have been dealt with above, and it may be agreed that some form of opening of the canopy, combined where necessary with cutting and burning undergrowth and collecting and burning felling refuse in good seed-years, as in the case of the deodar (see p. 1122), should effect reproduction in most cases.

Some good examples of spruce reproduction appearing as a result of an even spacing of the canopy are to be found in Kulu and Bashahr. The trees retained as seed-bearers should be of moderate size, large over-mature trees being felled. In Kulu a spruce crop between fifty and sixty years of age, the trees having a mean girth of about 3½ ft., was opened out heavily in 1912 in order to introduce deodar by line sowings ; the trees of the overwood were spaced about 50 ft. apart, giving seventeen trees per acre, and the result after two years was a plentiful crop of young spruce seedlings, the appearance of which was no doubt helped by the working of the soil in order to sow deodar. Where seed-bearers exist there is little difficulty in regenerating spruce along with blue pine, and some good examples of such mixed young crops, often with deodar, are to be found in the Nogli range of Bashahr as a result of an even spacing of seed-bearers, about five to twenty to the acre (see Figs. 457 and 458). In such areas some of the best reproduction is to be found where the majority of the seed-bearers are about 4½ to 6 ft. in girth.

The instances already given of the beneficial effect of side shade from the morning and to some extent from the midday sun indicate that where desiccation is feared there may be scope for working by means of strip fellings proceeding from north-west to south-east. Such fellings have not yet been tried in practice. The best regeneration period for the spruce under different conditions remains to be ascertained by experience. A period of thirty years is proposed tentatively for the future working of the forests both in Hazara and in Kulu.

The tending of spruce crops is a matter to which little attention has so far been given. In its natural condition the spruce is capable of forming very dense crops, and in such a condition produces clean timber. The correct method of tending such crops would appear to be to keep them dense, thinning them regularly but with caution, as in the case of the European spruce.

STATISTICAL. 1. *Bark thickness.* Numerous measurements in Jaunsar gave the following average bark thickness for different girths :

Girth.	Bark thickness.	Girth.	Bark thickness.
ft.	in.	ft.	in.
1–2	0·3	5–6	0·8
2–3	0·45	6–7	0·9
3–4	0·6	Over 7	1·0
4–5	0·7	..	..

2. *Growth in youth.* Measurements made at different times in thirteen young plantations in Jaunsar showed the following mean growth in girth and height :

Age.	Mean girth.	Mean height.
years (from seed).	in.	ft.
8	2·8	2·8
10	3·3	3·5
12	3·9	4·3
14	4·6	5·3
16	5·4	6·5
18	..	7·8
20	..	9·5

3. *Girth and height increment.* The statement below, showing the rate of growth in girth and height, has been compiled from such data as are available. In order to obtain uniform figures for comparison, nothing has been added

for the time taken for a seedling to establish itself, while in each case the means have been determined from curves plotted by the aid of rectangular co-ordinates. The girth includes bark in each case.

Picea Morinda: rate of growth in girth and height.

	Mean girth.							Mean height.
	Kulu.[1]				Jaunsar.		Kashmir.	
Age.	Inner Saraj (18 trees).	Outer Saraj (36 trees).	Kulu (33 trees).	Rupi (34 trees).	Konain, alt. 7,800 ft.[2]	General average.[3]	Batot range.[4]	Jaunsar.[3]
years.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft.
20	1 9	1 7	1 2	1 8	1 11	1 2	0 10	18
40	3 6	3 3	2 4	3 3	3 10	2 8	1 10	39
60	5 5	4 7	3 5	4 8	5 7	3 11	2 9	56
80	7 4	5 10	4 4	6 1	6 11	5 1	3 9	73
100	9 1	7 0	5 2	7 6	8 1	6 1	4 9	89
120	..	8 2	6 0	..	..	7 1	5 9	105
140	..	..	6 10	..	..	..	6 10	..
160	..	..	7 8	..	..	..	7 11	..
180	..	..	..	..	..	..	9 2	..

In order to allow for the time taken for a seedling to establish itself, at least ten years should be added to the age in each case.

Ring-countings in the Kotkhai-Kotguru forests of the Simla hills showed an average of 11·5 rings per inch of radius, giving a mean annual girth increment of 0·55 in.[5] In the working plan for the Kulu forests [1] the spruce is estimated to attain on an average a diameter of 2 ft., or a girth of 6 ft. 3 in., in 100 years, after which the rate of growth diminishes rapidly. In the leased forests of Tehri Garhwal it is estimated to reach a girth of 6 ft. in 122 years.[6]

4. *Volume production.* No comprehensive general statistics of volume production are yet available for the spruce. Perhaps the most complete local yield table yet compiled is the combined yield table for the silver fir and spruce recently prepared by Mr. C. G. Trevor in Kulu and given under *Abies Pindrow* (see p. 1141). Except in the case of young trees, representative average figures giving the volume of utilizable timber are often difficult to compile with any degree of accuracy owing to the frequent presence, in varying quantity, of decayed wood in the centre of the bole. For this reason the yield of scantlings from trees of the same size may vary enormously, although the form of the bole is more constant than in the case of most species. This point is illustrated by the following results of detailed measurements of twelve spruce trees felled in Jaunsar in 1914 with the idea of forming a rough preliminary idea of the probable yield of timber suitable for match manufacture in fully stocked crops :

[1] Working Plan for the Kulu Forests, Punjab, C. P. Fisher, 1898.

[2] Ring-countings by J. Donald, 1913.

[3] Working Plan for the Jaunsar-Bawar Forests, P. H. Clutterbuck, 1901.

[4] Working Plan for the Batot Range Forests, Riasi Division, Kashmir, Hans Raj, 1917 (these measurements include both spruce and silver fir).

[5] Working Plan for the Kotkhai-Kotguru Forests, Simla Division, E. M. Coventry, 1903.

[6] Working Plan for the Leased Deodar Forests, Tehri Garhwal, J. C. Tulloch, 1907.

Picea Morinda : measurements of individual trees, Jaunsar, 1914.

No.	Age.[1]	Girth at br height.	Total height.	Solid volume per tree. Gross volume of bole down to 24 in. girth (bark excluded from volume).	Estimated volume of brown or rotten wood.	Utilizable timber after deducting rotten or dark wood (bark excluded).	Top piece down to 6 in. girth (bark included).	Utilizable match-wood down to $3\frac{1}{2}$ ft. girth, after deducting dark wood (bark excluded).	Estimated number of trees per acre in fully stocked crop.	Estimated * volume of utilizable match-wood per acre in fully stocked crop.
	years.	ft. in.	ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.		cub. ft.
1	175	6 10	145	148	82	66	2	54	90	4,840
2	185	7 5	151	199	121	78	1	66	76	5,016
3	165	6 4	153	144	39	105	3	91	99	9,609
4	120	5 0	125	65	21	44	3	25	222	5,550
5	125	5 0	132	70	23	47	2	23	222	5,106
6	180	6 3	126	108	58	50	3	39	109	4,251
7	180	5 4	124	83	25	58	1	38	134	5,092
8	200	5 11	141	115	58	57	2	39	121	4,719
9	106	4 1	100	42	1	41	3	22	360	2,920
10	101	4 8	94	48	5	43	3	30	302	9,060
11	160	5 3	125	83	25	58	3	38	134	5,092
12	97	5 1	86	46	8	38	3	26	194	5,044

The trees selected for measurement were felled in well-stocked, even-aged crops, and were typical stems of average growth ; the number of trees per acre was estimated from the average spacing of trees in such crops. It is interesting to note the results obtained by plotting the figures in the above statement by rectangular co-ordinates and constructing a mean curve. These results are tabulated in the following statement, which must be taken to be nothing more than a very rough preliminary estimate based on a few measurements only :

Picea Morinda : estimated out-turn of match-wood in well-stocked, even-aged crops, Jaunsar.

Age.	Girth at breast height.	Volume of utilizable match-wood per acre.	Mean annual increment of utilizable match-wood per acre.
years.	ft. in.	cub. ft.	cub. ft.
90	4 4	5,000	55
100	4 7	7,800	78
110	4 10	7,400	67
120	5 1	5,900	49
130	5 4	5,500	42
140	5 7	5,200	37
150	5 10	5,100	34
160	6 0	5,000	31
170	6 2	4,900	29
180	6 4	4,850	27
190	6 6	4,800	25
200	6 8	4,750	24

* From this it would appear that the mean annual increment per acre for utilizable match-wood culminates at about one hundred years, the corresponding girth being roughly $4\frac{1}{2}$ ft.

[1] Ten years added for time taken for establishment of seedling.

The Kulu working plan, 1898, gives the following out-turn figures based on measurements of over 100 trees :

Girth of tree at 4½ ft. from ground.	Volume in the round.
ft.	cub. ft.
6–6½	93
6½–7½	121
7½–8½	154

The average out-turn in sawn scantlings from 14 spruce and silver fir trees 2–2½ ft. in diameter in the Dalhousie range forests was 57 cubic ft.[1]

2. **Picea spinulosa,** Griff. Syn. *P. morindoides,* Rehder. East Himalayan or Sikkim spruce. Vern. *Sehshing,* Bhutia.

A tall evergreen tree attaining a height of over 200 ft. The spruce of the eastern Himalaya was until comparatively recently considered to be identical with the west Himalayan spruce, *P. Morinda,* Link. Henry [2] points out, however, that it is not only a separate species but belongs to a different section of *Picea.* The following is taken from his description of the tree :

'Bark rough and scaling off in small quadrangular plates. Young branchlets slender, glabrous, yellowish grey. . . . Leaves, in an imperfect radial arrangement, covering in closely imbricated ranks the upper side of the branchlets, those on the lateral sides directed outwards and forwards, those on the under side pointing downwards and forwards ; ¾ to 1¼ in. long, $\frac{1}{20}$ in. broad, slender, acute at the apex, which is tipped with a sharp point ; flattened but keeled on both surfaces, so that the section is rhomboid-elliptic ; ventral surface green without stomatic lines and directed towards the light ; dorsal surface with two stomatic bands, each of four to six lines. . . .

'Staminate flowers pink, ¾ in. long. . . . Cones about 2½ in. to 3 in. long on cultivated trees, up to 4 in. long on wild trees, 1 to 1¼ in. in diameter, cylindric, obtuse at the apex, green with a purple border to the scales when growing, shining brown when mature ; scales thin and flexible, suborbicular with a cuneate base, about ½ to ⅝ in. wide, bevelled in the upper margin, which is rounded (in some wild specimens truncate), entire, undulate or slightly denticulate ; bract ovate, acute, ⅙ in. long. Seed ⅕ in. long, greyish brown ; seed with wing ½ in. long ; wing broadest above the middle, rounded or denticulate at the apex.'

The tree is indigenous to Sikkim and Bhutan in the inner valleys at 8,000 ft. and over, and has been recorded from the Chumbi valley at 9,000–10,000 ft. In Sikkim it occurs with *Tsuga Brunoniana* at 8,000–11,000 ft., with *Abies Webbiana* at 9,000–11,000 ft., and sometimes with *Larix Griffithii.* In Bhutan it is commonest at 9,000–11,000 ft., and is often associated with *Pinus excelsa* at the lower elevations. Mr. W. R. Jacob [3] says that in Bhutan extensive areas of spruce and blue pine forest have been cleared away permanently, but where sufficient seed-bearing trees are left in the vicinity the ground is again covered with young trees in a remarkably short space of time.

The size to which the tree grows under favourable conditions may be gathered from the following account of it by Elwes : [4] 'Though I saw this tree in the Lachen valley of Sikkim during my first journey to the Tibetan

[1] Revised Working Plan for the Dalhousie Range Forests, Chamba, R. McIntosh, 1913.
[2] Elwes and Henry, The Trees of Great Britain and Ireland, vi. 1392.
[3] Report on the Forests of Bhutan, 1912, para. 25.
[4] Elwes and Henry, *op. cit.*, vi. 1393.

Fig 483 *Tsuga Brunoniana* at 9,400 ft Darjeeling.

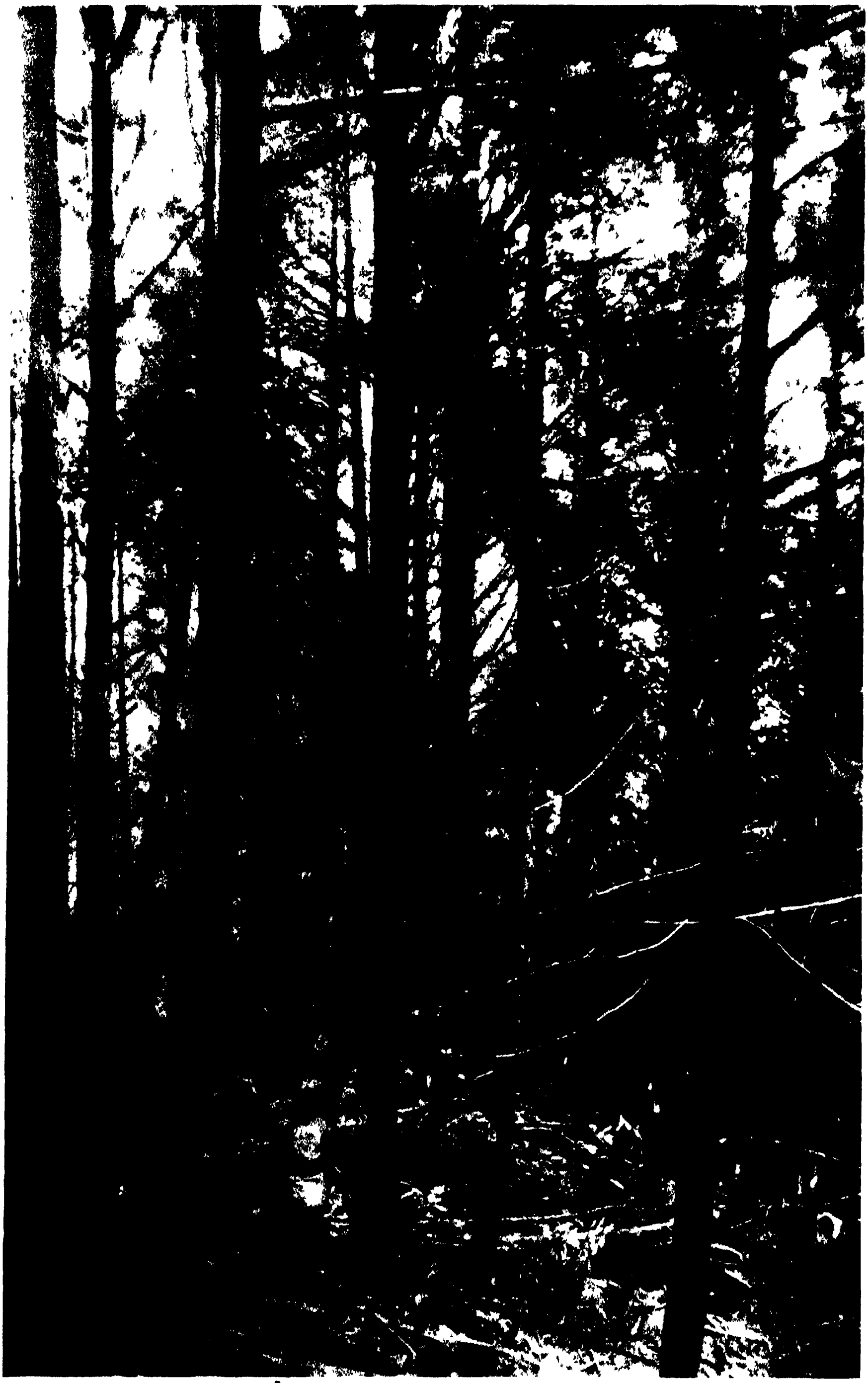


FIG. 484 *Tsuga Brunoniana*, pole forest recently thinned, Darjeeling

frontier in 1870, I did not take special notice of it at the time, and certainly saw no such wonderful trees as are described by Mr. J. Claude White in his recently published book.[1] These grow in the Sebu valley, a tributary of the Lachung, and must be among the tallest trees in India. Mr. White says: "One fallen giant, a spruce that I measured, was 220 ft. from the roots to where it had broken off short, and there it measured 6 ft. in girth. What had become of the top I do not know, but it was a magnificent specimen."

'To confirm this, I may say that I have since heard from Mr. A. D. Hickley, who visited and remeasured the same tree. He informs me that it grew at a place called Chu-par-rab-dong on the left bank of the river just opposite Yakchi, at an elevation of about 10,000 ft. Five lengths of the fallen stem were missing, having been probably used by the natives; but without counting these he made the length 207 ft., and the girth as follows: at the base, 12 ft. 7 in.; at 50 ft., 13 ft.; at 100 ft., 12 ft.; at 139 ft. (the place where the tree was first broken in its fall), 9 ft. 4½ in. The thinnest piece, without the bark, was 5 ft. 2 in. in girth. In the same valley not far away, Mr. Hickley measured another spruce, also with the top broken, 197 ft. long; and there were many like it still standing.'

5. TSUGA, Carrière.

The hemlock spruces are evergreen trees with horizontal or pendulous branches and pectinately arranged leaves. The leaves persist for some years, and the foliage is dense in consequence. Flowers monoecious. Male flowers in the axils of the previous year's leaves; female flowers terminal on the previous year's lateral shoots. Cones small, with persistent scales, ripening in one season. One Indian species.

Tsuga Brunoniana, Carr. Syn. *Pinus Brunoniana*, Wall.; *Abies dumosa*, Loudon. Himalayan hemlock spruce. Vern. *Tengre salla*, Nep.; *Tangshing*, Bhutia.

A large, handsome evergreen tree with a pyramidal outline and spreading branches which droop gracefully. Leaves 0·5–1 in. long, linear, distichous, dark green and grooved above, silvery white beneath. Bark thick, rough. Wood whitish, soft, not of very good quality, used for shingles. In Sikkim the bark is used for roofing. The tree ordinarily attains a height of 100 to 120 ft. and a large girth. Trees up to 170 ft. in height have been recorded, and Mr. E. Marsden in 1917 measured a tree 17 ft. 9 in. in girth in the Singalila range, Darjeeling.

DISTRIBUTION AND HABITAT. Central and eastern Himalaya from Kumaun to Bhutan, chiefly at 8,000–10,000 ft., but ascending to about 11,000 ft. and descending to 6,500 ft. Duthie[2] says it forms beautiful forests near Sosa in north-eastern Kumaun at 9,000–10,000 ft. Gamble says that in British Sikkim it is found in the Siri valley mixed with or just below the silver fir (*Abies Webbiana*), and associated with yew, oaks (especially *Quercus pachyphylla*), rhododendrons, and the *maling* bamboo (*Arundinaria racemosa*).

On the Singalila and Chola ranges it occurs at 8,000–11,000 ft., sometimes with *Picea spinulosa*, *Abies Webbiana*, or *Larix Griffithii*. Fig. 483 shows a group of old trees, and Fig. 484 a pole crop.

[1] Sikkim and Bhutan, p. 79 (1909).

[2] Gard. Chron., Mar. 1886.

year for some years, but occasionally they elongate and become long shoots or produce flowers. Flowers monoecious. Cones erect, with persistent imbricated woody scales ; seeds winged. One Indian species.

Larix Griffithii, Hook. f. and Thoms. Sikkim larch. Vern. *Sah, saar,* Lepcha ; *Boargasella,* Nep.

A moderate-sized or large deciduous tree with a pyramidal shape and long pendulous branches. Needles light green, 1–1·3 in. long. Bark brown. Wood soft to moderately hard with a red heart-wood, durable.

The tree is generally said to reach a height of 60 ft., but Elwes [1] mentions that Mr. Hickley measured one growing between two spruces in the Sebu valley, a tributary of the Lachung, with a height of well over 125 ft., which is much taller than any previously recorded. Trees found in eastern Nepal by Sir Joseph Hooker in 1848 were only 20 to 40 ft. high.[2]

DISTRIBUTION AND HABITAT. As far as is known the tree has only a limited distribution in the Himalaya in eastern Nepal, Sikkim, and Bhutan at 8,000–12,000 ft., but commonest from 9,500 to 11,000 ft. Also in the Chumbi valley, Tibet. In Bhutan it is often mixed with *Pinus excelsa,* or forms pure forests above it, or occurs in small groups, frequently with an undergrowth of rhododendron. It is sometimes associated with *Abies Webbiana, Picea spinulosa,* or *Tsuga Brunoniana.* It does not appear to be found in British Sikkim. Hooker says it attains a height of 60 ft. in deep valleys, but prefers the dry rocky ancient moraines formed by glaciers, and also grows on grassy slopes where the drainage is good. This corresponds exactly to the habit of the European larch (*L. europaea,* DC.) in the Alps ; this tree is found on well-drained grassy slopes, and regenerates freely in pure crops on fresh débris in the open, particularly on the taluses formed at the base of precipices, on new ground exposed by landslips or snow-slides, or on the diluvial cones formed by mountain torrents where they issue into the valleys.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The needles are shed in the autumn, the new foliage appearing in the spring. The flowers appear in May and the cones ripen in October the same year (Brandis). Cones cylindrical, 2–3 in. long or more, with persistent scales, erect (reversed) on the pendulous branchlets ; seeds winged, in pairs on each scale, 0·4–0·5 in. long including the wing.

RATE OF GROWTH. A specimen from the Chumbi valley, Tibet, examined by Mr. Gamble, showed 21 rings per inch of radius, giving a mean annual girth increment of 0·29 in., which is slow.

7. CUPRESSUS, Linn.

The cypresses are evergreen trees with small scale-like, opposite, closely adpressed leaves ; primordial leaves, as in seedlings, needle-like, spreading, in whorls of three or four. Flowers monoecious, terminal on the ultimate branchlets. Male flowers cylindrical, with numerous decussate peltate stamens. Female cones with decussate scales which become peltate and woody on maturing. Seeds small, compressed, winged.

The only indigenous species is *C. torulosa,* Don, but other species are

[1] Elwes and Henry, *op. cit.,* vi. 1394. [2] Him. Journ., i. 255.

occasionally cultivated in India. *C. cashmeriana*, Royle, *ex* Carrière, is possibly a form of *C. torulosa.*

Species 1. *C. torulosa*, Don; 2. *C. sempervirens*, Linn.; 3. *C. funebris*, Endl.; 4. *C. macrocarpa*, Hartweg; 5. *C. lusitanica*, Miller; 6. *C. Lawsoniana*, Murray.

1. **Cupressus torulosa,** Don. Himalayan cypress. Vern. *Devidiar, galla, leori, surai, raisal,* W. Him.

A large evergreen tree with a pyramidal crown; branches ascending, horizontal or drooping, curving markedly upwards towards the ends. Leaves triangular, closely imbricate (Fig. 486, *e*). Bark greyish brown, peeling off in narrow, longitudinal strips, often running somewhat spirally up the tree from left to right. Wood moderately hard; heart-wood light brown, fragrant, of excellent quality and very durable. If the tree were commoner it would be an important timber tree; it is, however, so local that the timber is unobtainable in any quantity. The wood is used chiefly for building, often for temples: it is also burnt as incense.

The tree reaches large dimensions. In the vicinity of the Deota temple, Tehri Garhwal, two trees were measured in 1885 and found to be (1) 155 ft. in height and 23 ft. 6 in. in girth, (2) 140 ft. in height and 24 ft. in girth.[1] At Naig, south of Lobha, Stewart records one 27 ft. in girth near the ground.

Distribution and habitat. Outer ranges of the western Himalaya at 6,000–9,000 ft., from Chamba to Nepal. The tree is decidedly local in its distribution, occurring in patches of varying extent, sometimes pure, sometimes associated with deodar, spruce, silver fir, blue pine, or oaks. Among localities where the cypress is found wild may be mentioned the slopes of China hill at Naini Tal, on shale but not far from limestone, in Jaunsar on the limestone cliffs of Moila and Lokandi, at 8,000–9,000 ft., and below Karamba peak, in the Simla hills on the Shali and Tikka ridge on limestone and in the Simla catchment area on shale, as well as in various localities in Chamba, Kulu, Garhwal, Kumaun, and other parts of the western Himalaya. There is a fine group of cypress trees on the ridge above Bamsu village in Tehri Garhwal. The tree is found commonly on limestone, though occasionally on other rocks. Fig. 485 shows its typical occurrence on limestone cliffs; in such places it has a remarkable capacity for growing on the sides of sheer precipices, sending its roots into the crevices, the stem growing vertically parallel to the side of the precipice. Within its habitat it is sometimes found on hot, dry slopes where few other species will grow.

Although in its wild state it is found principally on limestone, the tree is by no means particular as to soil or climate. It is frequently planted in the Himalaya on various rock formations and soils, and grows well in many other parts of India. At Dehra Dun (2,000 ft.) it grows rapidly and attains very fair dimensions on deep loam. It is grown in various stations on the plains, including Saharanpur, Calcutta, and some of the plains stations of the Punjab, where, if irrigated, it stands a shade temperature of 120° F. It is grown in some parts of the Indian Peninsula, at Poona, at Chikalda in Berar at 3,000 ft., and in the Nilgiris at about 7,000–8,000 ft. It has shown much promise in the Sanniyasimalai plantation in North Salem, where it has recently been planted to a considerable extent. In its natural habitat the absolute maximum shade

[1] Notes on Sowing, Planting, &c., in Jaunsar, 1885.

FIG. 486. *Cupressus torulosa*—FLOWERS AND FRUIT

a—Male flowers at time of ripening, January, × ⅞ b—Single male flower × 5 c—Female flowers at time of fertilization, January × ⅞ d—Single female flower at time of fertilization × 3½ e—Portion of branchlet showing arrangement of scales × 3½ f—Full-sized cones in second year, not yet ripe, January-July × ⅞ g—Old cones remaining on tree the year after ripening × ⅞ h—Single seed × 2½

temperature is probably about 90° F., the absolute minimum about 15° F., and the normal rainfall varies from about 45 to 95 in.

Flowering and fruiting. The male flowers first become visible, as small pale green dots at the ends of the branchlets, in September–October. They ripen and shed their pollen in January or early February, the trees at this time being conspicuous with their golden yellow covering of male flowers. These flowers are 0·1–0·3 in. long, yellow, with opposite decussate peltate scales, the anthers near the edge (Fig. 486, *a* and *b*).

The female flower at the time of pollination in January is a somewhat inconspicuous club-shaped structure, about 0·3 in. long, consisting of a thick quadrangular stalk covered with green imbricate scales and surmounted by the flower proper, which is about 0·2 in. long by 0·1–0·2 in. in diameter, composed of 6–10 purplish green to dark purple scales enclosing the numerous naked erect ovules. These flowers are found at the ends of the ultimate newest branchlets (Fig. 486, *c* and *d*).

After pollination the young female cones gradually change their form and colour. By May they become pale bluish green, and about 0·3 in. long. From then onwards they grow rapidly, becoming full-sized by September or October, when they are globose, about 0·5–0·6 in. in diameter, pale bluish green, covered with a glaucous bloom, with fleshy scales, green inside. The succeeding months are occupied in the gradual ripening of the seeds within the apparently fully-developed cones, and by April or sooner the seeds are quite ripe and loose within the cones, although the cone-scales are still soft and green inside, and are easily cut with a knife. The cones remain in this condition during the early part of the rainy season, and commence opening and shedding their seeds in August, continuing to do so during sunny weather until November or even December.

Thus although the seeds ripen in about a year from the time of pollination of the female flower, the cones do not open and shed the ripe seeds until one year and seven to ten months from the time of pollination. This tardy shedding of the seed, which is noticeable in other species of cypress, is interesting. Ripe seed of good quality can be readily obtained, for the purpose of sowing, by collecting the cones in June and placing them in the sun until they open.

The cones when fully developed are globose, 0·5–0·6 in. in diameter, with 8–12 thick peltate 4- to 6-sided scales, each with a small pointed process in the centre, greenish brown with a pale bluish bloom before opening, becoming brown and woody on opening (Fig. 486, *f* and *g*). The open woody cones remain some time on the tree after shedding their seed.

The seeds (Fig. 486, *h*) are compressed, with an orbicular somewhat obscure wing, 0·15–0·2 in. in diameter including the wing, light reddish brown. Many are smaller, but these are usually abortive. Each cone contains about 45–80 seeds, but a considerable proportion are infertile. About 5,000 to 6,000 good seeds weigh 1 oz. The tree begins to produce seed at an early age. In Jaunsar natural plants 5½ ft. high, and estimated to be about fifteen years old, have been observed bearing seed. At Dehra Dun planted trees have borne cones at an age of seven years, but the seed has not been tested. Good seed-years are frequent.

Germination (Fig. 487, *b*–*e*). Epigeous. The radicle emerges from the apex of the seed. The hypocotyl then elongates, often with slight arching, carrying above ground the testa, which falls with the expansion of the cotyledons.

THE SEEDLING (Fig. 487).

Roots: primary root long, wiry, flexuose, terete, brown; lateral roots few to moderate in number in first season, afterwards more numerous, fibrous. *Hypocotyl* distinct from the root, 0·7–1·4 in. long, cylindrical, soon becoming woody, red turning brown. *Cotyledons* two, sessile, 0·3–0·4 in. by 0·04–0·05 in., linear, acute, entire. *Stem* erect, terete, green, glabrous; internodes in first season 0·1–0·2 in. long; side branches commence forming in first season. *Leaves*: primordial leaves acicular, 0·25–0·4 in. long, in decussate whorls of 4, sometimes 3; triangular scale-like adult leaves usually begin to be formed in the third year.

The growth of the seedling during the first season is slow, a height of only about 1–3 in. being ordinarily attained. Subsequent growth is faster. Seedlings raised at Dehra Dun showed the following growth from the second to the sixth year:

End of season.	2nd.	3rd.	4th.	5th.	6th.
Height . .	7–12 in.	1 ft. 6 in.–2 ft. 1 in.	3 ft. 3 in.–5 ft. 5 in.	5 ft. 0 in.–7 ft. 6 in.	7 ft. 2 in.–10 ft. 11 in.
Girth . .	..	..	..	..	3¼–5¼ in.

This growth is faster than is ordinarily the case at the cooler elevations where the tree is found naturally; here an average height of about 2 ft. is ordinarily attained in four years in the case of artificially raised seedlings. The seedling requires a porous soil, rapidly damping off in soil which is stiff and saturated with moisture.

SILVICULTURAL CHARACTERS. The cypress is somewhat similar to the deodar in its light requirements, if anything standing rather more shade. In India it is frost-hardy; on the plains it remained unaffected by the severe frost of 1905. In Britain, however, it is not hardy, and does not grow well except in places where severe frosts are absent. In the Himalaya it is subject to snow-break: the snow lodges in quantity among the ascending branches near the tops of the trees, and the tops are often broken off. A fungus, *Gymnosporangium Cunninghamianum*, Barcl., attacks the branches of the cypress, appearing in wet weather in the form of yellow gelatinous masses. The alternate generation, the aecidial form, is on the leaves of *Pyrus Pashia*.

NATURAL REPRODUCTION. Under natural conditions the seed, which falls from August to December, remains on the ground until the beginning of the following rainy season, about July, when germination commences; heavy rain may stimulate germination earlier, but if a spell of dry, hot weather ensues the seedlings tend to die of drought if in an exposed position. Natural seedlings spring up most readily on bare, loose ground such as that formed by the accumulation of débris at the bases of cliffs through the disintegration of the rocks, or by small landslips. Natural seedlings have been found springing up readily on recently abandoned fields. On loose, fresh soil the taproot develops quickly and soon establishes itself, but under less favourable conditions the seedling requires such protection from the sun as is afforded by rocks, shrubs, or tussocks of grass. Natural seedlings are sometimes found growing out of the crevices of rocks.

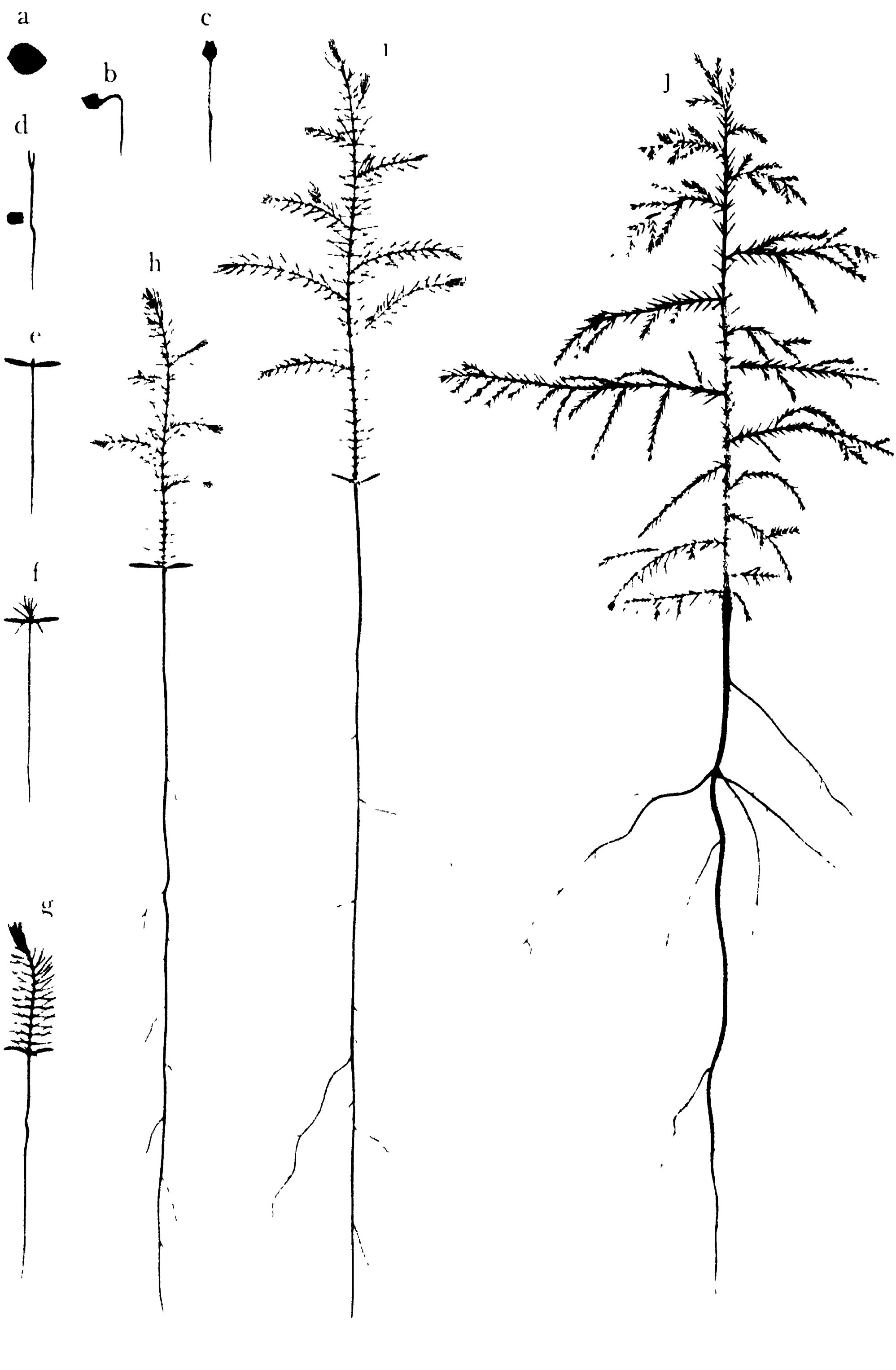


FIG. 487. *Cupressus torulosa*—SEEDLING × ½

a—Seed × 1½ b - e—Germination stages × ½ f - i—Development of seedling to end of first season × ½
j—Seedling in middle of second season × ½

ARTIFICIAL REPRODUCTION. Mathura Prasad Bhola [1] found from experiments at Pauri, Garhwal, in 1917, that in order to promote early germination the best time to sow seed, whether direct or in the nursery, is soon after the break in the monsoon rains, when germination takes place in two to three weeks. In Jaunsar seedlings are successfully raised by sowing in boxes either in June or in November ; in the latter case germination commences about May of the following year. Boxes are found preferable to seed-beds, but in either case light porous soil is necessary, and protection from heavy rain is required. The seedlings are pricked out in the nursery when large enough, and finally planted out in the third season, small plants being kept for another year. Direct sowings are not likely to be successful, owing to the small size of the seed and its poor germinative power.

Seedlings have been raised successfully at Dehra Dun by sowing in boxes in November or December, keeping the boxes under shade and watering regularly but sparingly ; germination began in March and continued till July. The seedlings were pricked out in beds the following year and planted out successfully during the rainy season the year after.

SILVICULTURAL TREATMENT. The cypress is so restricted in its distribution that it is seldom possible to work it as a crop by itself, and in practice it has usually been worked as an auxiliary species to deodar. Possibly it might be worked under regeneration fellings in the few places where it occurs in sufficient quantity, but of this we have no experience. It has been planted to some extent in the Himalaya, for instance in Jaunsar in mixture with deodar. Where its cultivation on any scale is desired clear-felling and artificial reproduction would be the only feasible method.

RATE OF GROWTH. In its natural region the growth of the cypress is only moderate, but at Dehra Dun it is fast, at all events in youth. In the mixed plantations of deodar and cypress in Jaunsar the former usually outgrows the latter. The following are measurements of three cross-sections at Dehra Dun :

(1)	Girth 2 ft. 3 in.	Age (from annual rings) 12 years :	mean annual girth increment	2·25 in.
(2)	„ 3 ft. 11 in.	.. „ 76 „	.. .. „	0·62 in.
(3)	„ 5 ft. 10 in.	.. „ 59 „	.. „ ..	1·19 in.

No. (1) was from a tree grown at Dehra Dun.

2. **Cupressus sempervirens,** Linn. Mediterranean cypress. Vern. *Sara*, Hind.

A large evergreen tree, often with a fluted stem. Bark thin, smooth or with slight longitudinal fissures, greyish brown, peeling off in thin strips which often run spirally up the stem. There are two well-marked varieties of this tree : (1) var. *horizontalis*, Gordon (*Cupressus horizontalis*, Miller), with spreading branches, the common wild form ; (2) var. *stricta*, Aiton (var. *pyramidalis*, Nyman ; var. *fastigiata*, Hansen), with erect branches running more or less parallel to the stem, giving the tree a narrow pyramidal shape ; the form most commonly met with in cultivation.

The tree in its wild form (var. *horizontalis*) is indigenous to the mountains of northern Persia, to Syria, Asia Minor, Crete, and Cyprus. It is extensively cultivated, especially the fastigiate variety, throughout the Mediterranean

[1] Ind. Forester, xliv (1918), p. 175.

region as well as in many other parts of the world, including Britain, where, however, it does not stand severe frost. This variety is largely cultivated in India on the plains, in the outer Himalaya, and in Kashmir. The spreading variety is grown in India, particularly in the hills, to a lesser extent.

The cones are larger than those of *C. torulosa*, sub-globose or ovoid, 0·8–1·2 in. long. The flowers appear from February to April, the seeds becoming ripe early the following year, though the cones do not open until the following autumn. The seeds have a very narrow wing. They keep fertile a long time ; Elwes [1] records a case of seeds collected at Scutari in 1884 which remained fertile for eleven years. Seedlings can be best raised in boxes, from which they are pricked out when a few inches high and transplanted when three or four years old. The tree requires well-drained soil.

3. **Cupressus funebris,** Endl. Weeping cypress.

A large evergreen tree with ascending or horizontal branches and long, slender, pendulous branchlets. Bark smooth, brown, fibrous. A native of central China. Cultivated in India, chiefly near temples and monasteries in the eastern Himalaya. There are several trees at Dehra Dun, growing fairly well. Gamble mentions that trees planted in 1886 in the Dhobijhora plantation near Kurseong had a girth of over 4 ft. in 1899. Cones globose, 0 3–0 5 in. in diameter.

4. **Cupressus macrocarpa,** Hartweg. Monterey cypress.

A large evergreen tree with thick, scaly bark. In youth it has a narrow, pyramidal crown, which becomes broad and flattened in old trees. Under cultivation it tends to produce a fastigiate and a spreading form, like *C. sempervirens*. This species has a very restricted distribution, near Monterey along the sea-coast in California and on the island of Guadalupe It is grown in the Nilgiris. There is a small plantation near Ootacamund, which gives an extremely dense shade. Cones ellipsoidal, 1–1·5 in. long by 0·75 in. in diameter.

Elwes [2] says it seems indifferent to the nature of the soil in a well drained situation, and grows well on limestone, sand, and peat. He adds that it is easy to raise from seed, and grows faster than any other cypress when young, but that its timber appears to be so coarse and knotty that it is not likely to be of any economic value ; it is, however, a good tree for ornamental purposes, stands clipping well, and is very useful for making hedges, growing much faster for this purpose than the yew. It has great power of withstanding storms and saline winds on the sea-coast, and in suitable climates it is a useful tree for planting for shelter-belts in coastal regions.

5. **Cupressus lusitanica,** Miller. Syn. *C. glauca*, Lam. Mexican cypress, Goa cypress.

A large evergreen tree with widely spreading branches and pendulous branchlets. Bark reddish brown, exfoliating longitudinally in long, thin strips. Leaves bluish, ovate acuminate, slightly free at the apex, not so closely adpressed as in *C. torulosa*. Cones globose, about 0·5 in. in diameter, dark reddish brown, covered with a glaucous bloom. Possibly a native of Mexico, where it occurs at 4,000–10,000 ft., chiefly near streams and on moist slopes. It is cultivated in Western India on deep, rich soil ; it does not thrive

[1] Elwes and Henry, *op. cit.*, v. 1156. [2] Elwes and Henry, *op. cit.*, v. 1168.

below the *ghats*. It is known there and elsewhere as the Goa cypress, and may have been introduced by the Portuguese, as it is commonly grown in Portugal.

6. **Cupressus Lawsoniana,** Murray. Lawson's cypress.

A large evergreen tree with very thick reddish brown spongy bark forming ridges covered with small scales; bark on young stems thin, with narrow longitudinal cracks. Leaves acute, usually with whitish streaks on the under surface. Male flowers crimson. Cones 0·35 in. in diameter, reddish brown, covered with a glaucous bloom. A very variable tree under cultivation, fastigiate, spreading, pendulous, dwarf and coloured varieties being known. A native of south-west Oregon and north-west California, in an equable, moist climate, at elevations chiefly below 3,000 ft., occasionally up to 5,000 ft. A shade-bearing species, demanding shade and moisture when young, and requiring to be planted close to produce a clean bole. In Britain it has proved not only very hardy, but also decidedly accommodating as regards soil. It is easily raised from seed sown in boxes, which should be kept shaded; it grows also from cuttings. Its timber is highly valued in Oregon and California. The tree is occasionally planted in Indian hill stations, as at Darjeeling, and deserves further attention. It may prove a useful species for underplanting deciduous broad-leaved trees at suitable elevations. The growth is fairly fast, and owing to the close spacing which the tree will stand, the volume per acre should be comparatively high.

8. JUNIPERUS, Linn.

The junipers are evergreen shrubs or trees, the leaves on young plants acicular and spreading, those on older plants either acicular or adpressed and scale-like. Flowers monoecious or dioecious. Male flowers in small catkins; female flowers composed of a few pointed scales bearing one or two ovules at their base or alternate with them. Cone succulent and berry-like, composed of the united fleshy scales enclosing one or more seeds, in Indian species ripening in the second (or third ?) year. Four Indian species, all at the higher elevations and ascending to the limit of tree-growth; they grow in dry, barren regions with scanty rainfall, and exhibit marked xerophilous tendencies. Economically some of the junipers are important as furnishing pencil cedar wood, the two most important being *J. virginiana*, Linn., of North America, and *J. bermudiana*, Linn., of the West Indies. Two of the Indian species, *J. recurva*, Ham., and *J. macropoda*, Boiss., have been tried by a Calcutta firm and found suitable, but it is doubtful if they can be obtained readily enough and in sufficient quantity to support a regular industry. The latter is found in some quantity in Baluchistan, but the supply is required for local use.

Species 1. *J. macropoda*, Boiss.; 2. *J. Wallichiana*, Hook. f. and Thoms.; 3. *J. communis*, Linn.; 4. *J. recurva*, Buch. Ham.

1. **Juniperus macropoda,** Boiss. Syn. *J. excelsa*, Brandis. Himalayan pencil cedar. Vern. *Appurz*, *ghushki*, Baluch.; *Obusht*, Pushtu; *Shúr*, *chalai*, *dhup*, W. Him.

A moderate-sized tree with light open foliage. Leaves dimorphous, the acicular leaves opposite or in whorls of three, the scale-like leaves usually opposite, closely adpressed. Bark reddish brown in young trees, reddish brown to grey in older trees, exfoliating in long fibrous strips. The bark at the base of old trees is of great thickness, and is removed for roofing huts. Wood moderately hard, fragrant, used for building, utensils, and other purposes, and for fuel and charcoal. It has been pronounced suitable for pencil manufacture.

The tree does not ordinarily attain a height of more than 50 ft., and seldom reaches a height of 80 ft., but Lala Mul Raj mentions having met with an exceptionally tall tree 100 ft. in height in the Chotair forest, Baluchistan. He has supplied me with the following measurements made in Baluchistan in 1916:

Gohar forest	(1)	Height 80 ft.,	girth 15 ft.
	(2)	,, 75 ft.,	,, 14½ ft.
Batsirgi forest		,, 40 ft.,	,, 18 ft.
Chotair forest	(1)	,, 100 ft.,	,, 11½ ft.
	(2)	,, 65 ft.,	,, 10 ft.
	(3)	,, 75 ft.,	,, 12 ft.
Shaidan forest		,, 57 ft.,	,, 21 ft. near base; branched at 2½ ft. from ground.

Brandis mentions a tree 33½ ft. in girth in Lahoul. The trunk is often crooked and gnarled, and sometimes exhibits 'twisted fibre', the twist in some cases running in one direction and in others in the opposite direction. The tree rarely forms a clean bole, but usually branches to the base, the lowest branches being often buried in leaf débris near the trunk, and their extreme ends taking an upward turn, giving them the appearance of young trees surrounding the old one.[1]

Distribution and habitat. Inner arid ranges of the Himalaya from Nepal westwards, at 5,000–14,000 ft., growing more or less gregariously in open crops or in the form of scattered trees on dry rocky or stony ground in regions of scanty rainfall; Chitral, above 8,000 ft.; Kurram valley, common at 9,000 ft.; Baluchistan. It is cultivated at Saharanpur on the plains of northern India.

The most important juniper tracts occur in Baluchistan, where they are estimated to cover a total area of not less than 1,500 square miles, including the forests of the Kalat State. The tree occurs at elevations of 6,500 to 10,000 ft., but is commonest between 7,500 and 9,000 ft. It is usually found more or less gregariously in open forest, frequently with an underwood of *Prunus eburnea*, *Caragana Gerardiana*, *Fraxinus xanthoxyloides*, *Pistacia mutica*, and *P. Khinjak*. Only where the conditions are specially favourable, that is, in sheltered situations with a moderate amount of moisture in the soil, does the juniper crop tend to become fairly dense. The prevailing rock in the Baluchistan juniper tracts is limestone, though shale, grey sandstone, conglomerate, and other rocks occur locally. Topographically the country consists of barren mountain ridges separated by valleys or plateaux where the soil is deep and fertile, consisting of the accumulations of the detritus from the ridges, and where the juniper attains a large size and is well shaped. It occurs sometimes on bare rocks, but here it is stunted. The moister valleys are occupied by ash and other broad-leaved species. Fig. 488 shows a typical

[1] J. H. Lace, Journ. Linn. Soc., xxviii. 307.

Fig. 488 Forest of *Juniperus macropoda*, Baluchistan

FIG. 489. Plantation of *Callitris rhomboidea*, Ootacamund.

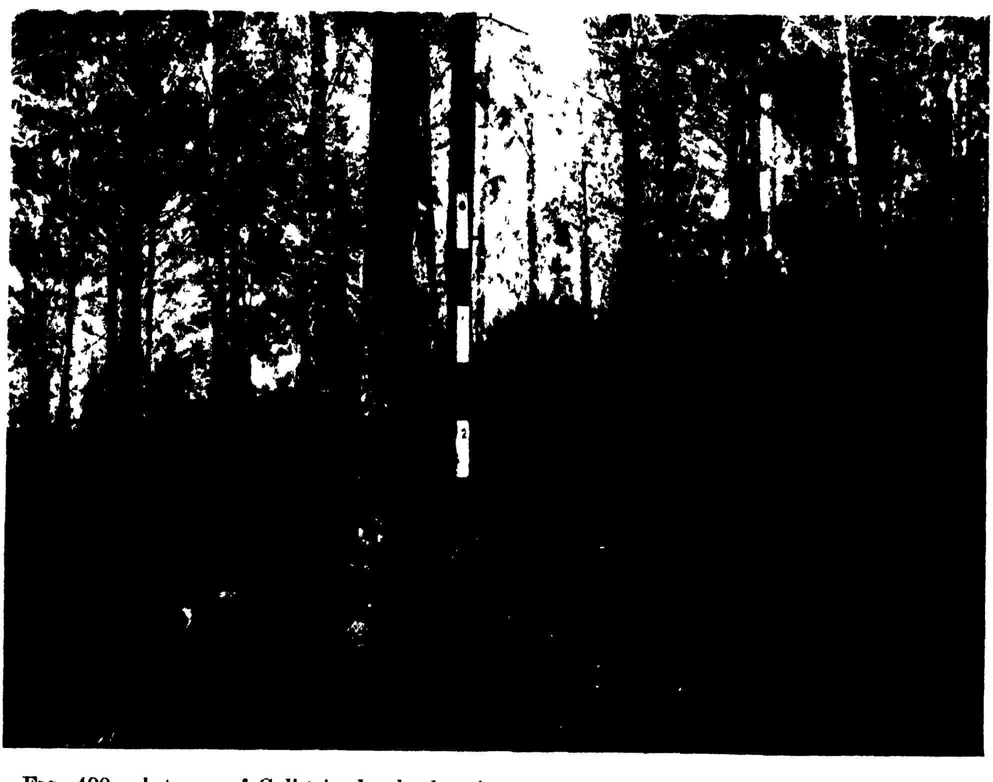


FIG. 490. Interior of *Callitris rhomboidea* plantation, showing dense natural reproduction, Ootacamund.

juniper tract in Baluchistan. Climatic statistics within the juniper regions are scanty. Generally speaking the rainfall probably never exceeds 12 in., while the minimum temperature may fall to well below zero Fahr.; in the winter the snowfall may be considerable.

FLOWERING AND FRUITING. The flowers appear in the spring and the fruits ripen in September–October in the second year. Male flowers 0·1–0·2 in. long. Berries sub-globose, 0·25–0·35 in. in diameter, bluish black when ripe, 2- to 5-seeded. Some seed is produced as a rule every year, but good seed-years occur at less frequent intervals. In Baluchistan the seeds appear to be disseminated chiefly by the agency of a bird named by the Pathans *obusht khawarak* (juniper eater), which feeds on the ripe fruits.

SILVICULTURAL CHARACTERS. The tree has a strong spreading root-system, particularly on dry rocky ground, where the roots spread far in search of moisture; it is therefore wind-firm, though it becomes gnarled and stunted in exposed situations. It is hardy both to drought and to frost, enduring very low temperatures. In unprotected tracts it suffers much from the hand of man, by lopping and by stripping of the bark. The custom, apparently commoner at one time than it is now, of setting fire to standing trees for the protection of flocks from beasts of prey at night, has been responsible for the destruction of large numbers of trees in Baluchistan. Owing to the scantiness of the grass and undergrowth in many of the juniper forests the trees are not exposed to much damage from ordinary fires, but injury by grazing is accentuated from the same cause, for which reason grazing is excluded from the state forests of Baluchistan wherever conditions permit. Rats and porcupines do a certain amount of injury to young plants. Trees are frequently struck by lightning in the juniper forests, and may be completely destroyed from this cause.

NATURAL REPRODUCTION. Seedlings appear naturally to a varying extent, but the great majority perish, probably from drought. A heavy snowfall has been found to assist reproduction by increasing the moisture in the soil, while in fairly moist, sheltered situations seedlings occasionally spring up in some quantity. Protection from fire and grazing is necessary for the successful establishment of natural reproduction, which, however, is at the best a very slow process.

SILVICULTURAL TREATMENT. At present the working of the state juniper forests of Baluchistan consists in removing dead trees and only such living trees as are necessary to supply right-holders when dead trees are not available.

RATE OF GROWTH. The annual rings are distinctly marked by a narrow dark line. The rate of growth is very slow. Lala Mul Raj informs me that in 1915 he made ring-countings on eight stumps on deep fertile soil in a valley, and found the average growth to be 20·38 rings per inch of radius, giving a mean annual girth increment of 0·3 in., while a slow-grown specimen in the Quetta sale dépôt showed 92 rings per inch of radius, giving a mean annual girth increment of 0·07 in. Mr. Lace, by ring-countings on five stumps, obtained an average of 26·46 rings per inch of radius, giving a mean annual girth increment of 0·23 in. The sections recorded by Stewart gave 24, 40, and 44 rings per inch of radius, giving a mean annual girth increment of 0·26, 0·15, and 0·14 in. respectively.

Thus the mean annual girth increment varies from under 0·1 to 0·3 in., and probably exceeds the latter figure only under more than ordinarily favourable conditions. A tree may therefore be expected as a rule to attain a girth of 6 ft. in anything from 240 to 720 years.

2. **Juniperus Wallichiana,** Hook. f. and Thoms. Syn. *J. pseudo-sabina*, Fisch. and Mey. Black juniper. Vern. *Bhil,* Hind.

An evergreen tree with spreading branches and bushy foliage, attaining a height of 60 ft. in Sikkim ; in the western Himalaya only a shrub. Leaves dimorphous, both acicular and scale-like, the latter opposite decussate in four rows, making the branchlets quadrangular. Himalaya from the Indus to Bhutan, at 9,000–15,000 ft. ; in the north-west a large gregarious shrub covering extensive areas at the limit of tree vegetation, associated with *Betula utilis.* Flowers April–May ; fruits August (Brandis). Berries ovoid, acute, 0·25–0·5 in. long, blue when ripe, one-seeded.

3. **Juniperus communis,** Linn. Common juniper. Vern. *Páma*, *betar*, *thelu*, W. Him.

An evergreen shrub, sometimes a small tree, procumbent at high elevations. Leaves all acicular, usually 0·4–0·6 in. long, in whorls of three. Bark reddish brown, smooth, peeling off in papery sheets.

A widely distributed plant, occurring throughout the northern and central part of Europe, at the higher elevations of the Mediterranean region, and eastward through Siberia, Persia, Afghanistan, Kurram valley at 11,000–13,000 ft., and the western Himalaya at 5,500–14,000 ft., extending eastward to Garhwal and Kumaun, where it occurs only at the higher elevations. In Europe it is frequently gregarious and is often abundant on heath land, on rocky mountain slopes, or on peat overlying a sandy subsoil. The flowers appear in March–April, and the fruit, a sub-globose, bluish black, usually three-seeded berry, ripens in August–September of the second year (Brandis). In Europe the fruits are used in the manufacture of gin.

Elwes [1] says the seeds lie for one year before germinating, even when freshly sown, and that they keep for some years in the berry without losing their vitality. Under natural conditions the seeds are freely spread by birds, which devour the fruits.

4. **Juniperus recurva,** Buch.-Ham. Weeping blue juniper. Vern. *Betar*, *thelu*, *guggal*, W. Him.

An evergreen straggling shrub or small graceful tree with curved or drooping branches and glaucous blue foliage. Leaves all acicular, decurrent, densely imbricated in whorls of three, turning brown after three or four years and persisting for a time after that.

Inner ranges of the Himalaya, at 7,500–15,000 ft., extending east to Bhutan and west to Afghanistan. The plant is very gregarious, often extending over large areas pure or mixed with *J. communis*. In the west it is represented by the procumbent variety (var. *squamata*, Parlat. ; *J. squamata*, Buch.-Ham.), the stems of which creep over the ground, rooting freely and sending up numerous short, erect branches which form dense thickets. This procumbent variety is frequently grown as a low dense shrubby border in gardens at low elevations. It thrives at Dehra Dun (2,000 ft.) and grows even on the

[1] Elwes and Henry, *op. cit.*, vi. 1405.

plains. It is propagated by taking cuttings of the prostrate stems with the bushy foliage attached, planting them in nursery beds and watering them regularly until well rooted, after which they are planted out early in the rainy season.

Flowers chiefly June–July; fruits July–October of the second year (Brandis). Berries ovoid, 0·3–0·5 in. long, one-seeded.

9. CRYPTOMERIA, Don.

A genus of eastern Asia, containing only one species.

Cryptomeria japonica, Don.

A large evergreen tree attaining in Japan a height of 150 ft. or more and a girth of 20 to 25 ft. Trunk with a broad base, tapering upwards. Bark reddish brown, peeling off in long strips. Needles awl-shaped, quadrangular, with decurrent bases, arranged spirally in five ranks. Flowers monoecious. Male flowers clustered at the ends of the branchlets; female flowers at the ends of the branchlets, globose, cone-like, covered with small awl-shaped leaves. Cones woody, globose, brown, 0·7–0·8 in. in diameter, with scales bearing acuminate bracts partly adnate to them. Seeds 0·15–0·25 in. long, compressed, angular. The growth of the shoot is often continued through the cone. Wood soft, fragrant, with a reddish brown heart-wood. Gamble says it makes excellent tea-boxes, and as it grows rapidly it is worth cultivating for this purpose and for box-planking generally. In Japan it is extensively used, particularly for building, staves, tubs, and casks.

The tree is indigenous to China, as far as is known only in the mountains of the Chekiang and Fokien provinces, and to Japan, also in mountainous country, and is much planted in both countries.

Seeds were first brought to India in 1844 by Mr. Fortune on his first mission to China for tea seed, and since then the tree has been planted to a considerable extent in suitable localities. In the Darjeeling hills it has been successfully grown at elevations varying from 3,000 to 7,000 ft., but appears to thrive best between 4,000 and 6,000 ft. At 7,500 ft. on Jalapahar the trees are stunted and the growth is slow. In the neighbourhood of Shillong it thrives between 4,000 and 6,000 ft. on moist soil, growing far more rapidly than the indigenous pine (*Pinus Khasya*). It is planted to a certain extent in the western Himalaya, in Simla and other hill stations, but does not seem to grow so well as it does farther east in a moister climate.

In the Darjeeling hills the cones ripen in July–August at the lower elevations and somewhat later at the higher elevations. Seeds sown in the winter germinate as a rule in April or May. Experience in the Darjeeling hills has shown that the seed-beds require to be sheltered under mats until the seedlings are about 6 in. high, when the mats are removed for two or three weeks in order to harden the young plants before transplanting. It is usual to prick out the seedlings in the nursery and to plant them out when about 1½ to 2 ft. high. Young plants are said not to be eaten by cattle; they succeed well in the open or under very slight shelter. The trees seed freely in the Darjeeling hills. Gamble says that the trees in a plantation formed about 1866 at Dhobijhora near Kurseong had attained a girth of 43 in. in 1899, that is, at an age of about thirty-five years from seed. Elwes [1] gives the following account of the planting of cryptomeria in Japan :

'The trees are planted out at three years old after being twice transplanted in the nursery, where they are raised from seed and kept shaded during the first year. This, at least, is the rule in the Kisogawa district, though I was told that in the south cryptomerias are more cheaply and quickly raised from cuttings, and that these produce as good trees as seedlings.

'About 4,000 per acre are usually planted, and weeded once or twice a year for three years, when they suppress the weeds by their shade. The plantations grow very fast, and are pruned from the eighth to the twenty-third year after planting out. Thinning is done at the earliest at twelve years, and the thinnings form such a profitable source of revenue that income is probably returned quicker by such a cryptomeria plantation than by any other tree. The final felling takes place at about 120 years old, when as many as 180 trees, containing 15,000 cubic feet, may be found on an acre. The previous thinnings are estimated at 16,000 cubic ft., making the total product per acre in 120 years over 30,000 ft. This result, which appears astonishing, is perhaps exceptional, but all the plantations I saw gave evidence of extremely rapid growth, and showed a larger proportion of clean useful poles and timber than any plantations I have seen in other countries.'

The method of treatment commonly followed in Japan is that of clear-felling followed by replanting.

Measurements made in 1917 by Mr. E. Marsden in four sample plots in the Darjeeling hills and one at Ootacamund in the Nilgiris gave the following results :

Cryptomeria japonica : measurements in sample plots.

Serial No.	Locality.	Age.	Number of stems per acre.	Mean girth.	Mean height.	Solid volume per acre. Timber over 24 in. in girth.	Small-wood.	Total.	Yield per acre from thinning in 1917. Number of stems.	Solid volume Timber over 24 in. in girth.	Small-wood.	Total.	Rem
		years.		in.	ft.	cub. ft.	cub. ft.	cub. ft.		cub. ft.	cub. ft.	cub. ft.	
1	Darjeeling	22	296	36·4	63	3,577	802	4,379	408	467	1,241	2,208	
2	,,	24	119	43·7	64	2,074	261	2,335	..	..	..	..	Heavil ned at vals: o not re
3	,,	28	104	44·2	76	2,951	266	3,217	..	..	..	..	d
4	,,	50	157	84·1	78	12,710	202	12,912	..	..	..	..	Unthin
5	Ootaca-mund	31	322	40·0	66	4,114	865	4,979	..	..	..	..	d

10. CALLITRIS, Vent.

A genus of the tribe Cupressineae, the Australian species of which are usually known as 'cypress pine'. No species indigenous to India; one introduced.

Callitris rhomboidea, Br. Syn. *Frenela rhomboidea,* Endl. Oyster Bay pine.

A moderate-sized tree with feathery cypress-like foliage, sometimes attaining a height of 70 ft., but usually a good deal smaller. Indigenous to the rocky coastal regions of New South Wales, Victoria, South Australia, and Tasmania, seldom growing far inland. The tree was introduced into the Nilgiris in the years 1885 to 1891 by Mr. Gamble, who planted it extensively

[1] Elwes and Henry, *op. cit.*, i. 135.

about Ootacamund and Coonoor; the plantation at Aramby is a feature of the environs of Ootacamund. The wood is soft, easily worked and very resinous, and appears to be used in Australia mainly for cheap furniture, planking, and weather-boarding. In the Nilgiris it has been found to be very soft and full of turpentine, and there is little demand for a wood of this type. It gives an excellent firewood of the fragrant resinous kind.

In the Nilgiris the tree has been found to grow best in pure plantations; mixed with pines or *Cryptomeria* it has been found to get the upper hand, and mixed with cypress the latter suppresses it. It requires a sheltered situation, as it is liable to be broken by wind; light but frequent thinnings tend to produce tolerably wind-firm trees. One of its most marked characteristics is the extraordinary profusion with which it regenerates naturally from seed wherever the canopy is slightly broken and light is admitted. Fig. 489 gives a view of a portion of the Aramby plantation, along the edge of which a dense line of natural reproduction up to 10 ft. high is seen. Fig. 490 shows a portion of the interior of the same plantation, in which the ground is covered with a dense crop of natural seedlings up to 3 or 4 ft. high. These seedlings frequently bear cones when only 2 or 3 ft. high.

In the Nilgiris the growth is somewhat slow but very regular. The rings, which have been ascertained to be annual, are quite distinct. The following table, based on numerous measurements, gives the average rate of growth and volume production per tree: [1]

Callitris rhomboidea: rate of growth and volume production, Nilgiris.

Age.	Mean height.	Mean diameter.	Corresponding girth.	Mean volume per tree.
years.	ft.	in.	in.	cub. ft.
5	10·5	1·05	3·1	..
10	21	2·55	8·0	..
15	30	4·15	13·0	0·60
20	38·5	5·48	17·2	1·90
25	45·5	6·55	20·6	3·75
30	51·5	7·40	23·2	5·80
32	54	7·80	24·5	6·70

11. PODOCARPUS, L'Hérit.

Trees or shrubs, usually with linear lanceolate or elliptical lanceolate leaves; flowers dioecious, rarely monoecious. Three Indian species.

Species 1. *P. neriifolia*, Don; 2. *P. latifolia*, Wall.

1. **Podocarpus neriifolia,** Don. Syn. *Nageia bracteata*, Kurz. Vern. *Gunsi*, Nep.; *Jinari*, Cachar; *Thitmin*, Burm.

A large evergreen tree with whorled branches and linear coriaceous leaves 5–10 in. long. Bark greyish brown, thin, fibrous. Wood yellowish, even grained, of good quality, used for general carpentry.

The tree occurs up to 3,000 ft. in the eastern Himalaya from Nepal eastwards in the evergreen forests of the outer hills, Assam, Khasi hills, Chittagong, the tropical forests of Martaban and Tenasserim, and the Andamans. In the Andamans it is sometimes common on the higher hills in evergreen forest on

[1] Working Plan for the Nilgiri Plantations, S. Cox, 1914.

serpentine and micaceous sandstone along with *Mesua ferrea* and other trees.

Gamble gives the rate of growth at fifteen rings per inch of radius, representing a mean annual girth increment of 0·42 in., which is slow.

2. **Podocarpus latifolia,** Wall. Syn. *Nageia latifolia*, Gordon.

An evergreen tree of Assam, Martaban, and Tenasserim, and the Tinnevelly *ghats* at 3,000–5,000 ft. The only conifer of the Indian Peninsula.

12. TAXUS, Linn.

This genus consists of one species, *T. baccata*, Linn., of which there are several varieties which have been described as species, but are now usually recognized as geographical forms. The genus differs from all other conifers in the arilloid fleshy fruit.

Taxus baccata, Linn. Yew. Vern. *Barma, barmi, thunu, thuner*, W. Him.

An evergreen shrub or tree, sometimes attaining large dimensions in the Himalaya, usually much branched, with spreading branches and dense foliage. Needles distichous, 1–1·5 in. long, flat, dark green and shining above, light green below. Flowers dioecious, rarely monoecious. Bark thin, reddish brown, scaly. Wood hard, close and even grained, requiring long seasoning, tough and elastic. In England the wood is used for bows for archery, and a few years ago a small consignment of Himalayan wood was sent home for the purpose, and was well reported on.

In the Himalaya the yew sometimes reaches large dimensions. In Jaunsar girths of 9 ft. 1 in., 11 ft. 2 in., 11 ft. 9 in., 12 ft. 6 in., and 14 ft. 6 in. have been recorded. According to Brandis, Madden has recorded a tree at Gangutri 100 ft. high and 15 ft. in girth. Mr. Gamble[1] measured two trees in the Darjeeling hills, one 20 ft. in girth, broken at the top, the other 16 ft. in girth with a straight cylindrical stem 30 ft. high. In Hazara, where large trees are common, I have measured trees up to 14 ft. 3 in. in girth; the tallest tree found was 60 ft. high. Large trees are almost invariably hollow.

Distribution and habitat. The yew is widely distributed through the northern hemisphere. In India it is indigenous to the Himalaya at 6,000–11,000 ft., but chiefly above 7,000 ft., the Khasi hills, and the hills of the Ruby Mines district of Upper Burma at 5,000 ft. and over. It is particularly common in the forests of Hazara, where it reaches a large size. It is found as a rule in moist, shady places, often as an underwood to broad-leaved species or other conifers. Fig. 185 shows it growing under *Prunus Padus*.

Leaf-shedding, flowering, and fruiting. In the Himalaya the needles are shed chiefly in May and June. The flowers appear from March to May, and the fruits ripen from September to November. The male flowers consist of a globose head of stamens on a common stalk, and the female flowers of a single erect ovule surrounded by a disk, on a peduncle covered with imbricate scales. The fruit consists of a solitary seed more than half enclosed in a red juicy arillus formed of the enlarged disk. The seed has a white albumen and a minute embryo. Cotyledons two in number.

Silvicultural characters. The yew is a pronounced shade-bearer,

[1] Ind. Forester, i (1875–6), p. 97.

reproducing and growing well under fairly dense shade. The leaves contain an alkaloid poison which appears to vary in virulence under different conditions, but if taken in sufficient quantity is fatal to man and to live stock. In Europe browsing animals have been known to die of the effects of yew poisoning if the leaves are devoured in any quantity. In the Himalaya, animals appear to avoid browsing on the tree. Nevertheless in parts of Hazara, particularly in the Siran and Kagan valleys, the yew is extensively lopped for cattle fodder, perhaps more so than any other conifer, and trees are frequently killed by repeated lopping.

ARTIFICIAL REPRODUCTION. The yew can best be raised from seed, but varieties are propagated by cuttings planted in sandy soil and kept under shade until they are well rooted. Seed usually takes a long time to germinate, and the growth of the seedling is very slow. The seedlings bear transplanting well.

RATE OF GROWTH. The growth is very slow, and the tree lives to a great age. Gamble's specimens varied from 12 to 44 rings per inch of radius, giving a mean annual girth increment of 0·14 to 0·52 in. Brandis gives 20 to 32 rings per inch of radius, representing a mean annual girth increment of 0·19 to 0·31 in. A cross-section in the silvicultural museum at Dehra Dun showed 133 rings for a girth of 2 ft. 9 in., giving a mean annual girth increment of 0·25 in.

INDEX TO VERNACULAR NAMES

VOLUMES I, II, AND III

INDEX TO ENGLISH NAMES

VOLUMES I, II, AND III

INDEX TO SCIENTIFIC NAMES

VOLUMES I, II, AND III

PRINTED IN ENGLAND
AT THE OXFORD UNIVERSITY PRESS