Note: the sections highlighted yellow have yet to be finalized.
Recasting of the interventions into classes/categories is strongly suggested

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Interventions that Make Agriculture Sustainably High Yielding, Eco-friendly and Empower Small-holder Farmers

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Protocols of modern agriculture production system has increased dependence of farmers on market purchased inputs. This has resulted in increased cost of production. There are evidences that productivity of some crops eg. rice in pre-British era was comparable to if not higher than those harvested today. Most of the production protocols used by those farmers have not been researched and are not the part of curricula in the education imparted by most agricultural universities. As a result, most agricultural scientists find it hard to accept that high yields are even possible without modern agro-chemicals. It is perhaps due to this scenario that despite the five decades of modern agriculture, India's food and nutrition security is still vulnerable. On the other hand a large number of farmers claim to be harvesting high yield without agro-chemicals which are comparable to or better than their neighbour conventional farmers using agro-chemicals. This chapter lists agro-practices that result in sustainable high yields and most of these are accepted by scientific community as good agriculture practices. It may be noted that several of the interventions given below have either been developed by or have been noted as meticulously used by successful farmers (generally small holders), or are a part of traditional knowledge of farmers.

There are ample evidences that good value of these protocols can be plausibly explained as scientifically sound. Scientists in agricultural research institutions are encouraged to evaluate these and articulate science to these methods where relevant.

Most of these protocols formed part of the two of the four methods of crop husbandry did not use agro-chemicals and are being evaluated at ICRISAT in a longterm experiment, since June 1999. Crop yields in these two treatments (called 'Low-cost Systems') were at par or better than conventional or modern agriculture in six out of eight years (for details see http://km.fao.org/fsn/fsn_home.html and Rupela 2008). Government programs aimed at helping small holder farmers are recommended to scale-up outcomes of this longterm experiment of ICRISAT to help small-holder farmers.

1. Contour bunding and trenching
It is a protocol to prevent soil erosion and promote more efficient use of rainwater. Farmers put stones/soil bund around the contours of slopes to keep rainwater and accompanying soil within the farming area long enough for it to soak in. This preserves land and makes it more productive. This technique has been in use in the 1980s. See more information on www.megphed.gov.in/knowledge/RainwaterHarvest/Chap7.pdf

2. Rainwater harvest
It is the gathering or accumulating and storing of rainwater. Traditionally, rainwater harvesting has been practiced in areas where water exists in plenty, and has provided rinking water, domestic water, water for livestock, water for small/little irrigation and a way to increase ground water levels. Globally lot of experience exists and farming communities can sustain better with such practices. Ideally each farmer should have a rainwater harvest structure – big or small. Information at www.fao.org/ag/ags/AGSe/agse_s/3ero/Namibia1/c21.htm should interest most.

3. Trees on field (in alleys) and/or on farm boundary:
Gliricidia (fast growing, serves as source of plant biomass for use as surface mulch) and fruit trees (are generally slow growers, supports economic health and nutrition of farm family) and on field boundaries. Direct seeded trees survive better than those from by cuttings. In the proposed strategy of drought proofing in rainfed areas, there should be at least one plant every 50cm within an alley row. Alley rows can be 10m to 15m apart. All trees (including fruit trees) should be lopped for biomass for in-situ generation of crop nutrients, fruits be viewed as bonus. Over years, fruit yield can be substantial and offers economic and nutritional security of farm family, particularly in arid and semi-arid areas. Other associated features of this strategy:

- Fruit trees: locally adapted tree species should be selected, saplings prepared from grafts one every 3 m within the 'alley row'', select only non-thorny species, maintain them as hedge and not as tall trees, major purpose: i) a source of biomass ii) determine time of lopping/pruning so that some fruit could be harvested. Note: Initially we need fast growing trees such as Gliricidia to generate biomass, but in due course – one should replace all Gliricidia with locally adapted fruit trees.
- Shade tolerant vegetables/spices/medicinal plants that can be grown below shade of the tree rows. Following plants have been identified for growing. In due course we need to learn their suitability. i) Citronella, ii) Ginger, iii) Turmeric, iv) Aloe vera, v) Shatavari. **Note:** Most of these are suitable for well endowed areas. Information for suitability of these or other crops for different areas has to be ascertained.

4. Main crop land (between 'Alley Rows') – Polycrops should be a rule and not exception when we want to grow crops at low-cost and without agro-chemicals. Main crops and diversity crops be selected as per the prevailing local farming system and should primarily address need of the farmer(s). Important points:-
a) Crops can be grown without tillage (sowing would of course need a bullock-drawn or tractor-pulled sowing drill) and covered with surface mulch,
b) All crops be sown in rows as intercrops and not as broad cast,
c) Diversity crops (see ***Appendix I***, 'Aurogreen crops) helps encourage natural enemies of insect-pests and enhances soil health due to enhanced population of agriculturally beneficial microorganisms.
Note: Rainfed agriculture offers bigger challenge than irrigated.

5. Surface Mulch:

a) Best value of plant biomass can be harnessed when used as surface mulch compared to composting. Eventually all plant biomass gets degraded and becomes part of soil thus saving lot of labor otherwise needed for composting or vermicomposting.

b) Lignolytic and wide C:N material serves longer (e.g., grass *Cynodon dectylon*) than narrow C:N materials (eg. *Gliricidia* lopping)
c) Once suitable fruit trees at least three for a given area have been identified, about 50% *Gliricidia* should be replaced with these fruit trees.
d) All farm waste (including that from cattle shed, and ash from rural kitchens) should come back to land

Note: Plant biomass/crop residues as cattle feed or as fuel may be used on priority over surface mulch.

Tillage versus Mulch

a) Land surface must not be left bare, particularly during rainy season.
b) Sowing manually or by bullock drawn implements (rake aside biomass at sowing, if essential, and place back after sowing) Note: soil below surface mulch having active roots has been noted to be rich in crop nutrients while the uncovered soil may remain poor. ***Appendix II*** has results of soil analyses indicating this.

6. Recycling

Recycling of all degradable material on a farm is a good agricultural practice but is ignored by most farmers. Much of these materials can be used as surface mulch. All successful farmers were noted to practice recycling but Mr Darshan Singh Tabiba of village Hiatpura, Maachhiwada, Ludhiana district Punjab was noted as ‘master recycler’. He was using press mud (waste from sugar factory) as cattle feed, vegetable waste (potato and other tubers in particular) for feeding pigs, cattle waste for making compost, pig excrements and vegetable waste as fish meal, pigs were made to walk through the fish ponds for aeration of ponds, water from ponds which got rich in nitrogen due to pig excrements was used for irrigating crops thus reducing expenses on fertilizers. Mr Tabiba was recognized by ICAR with Jagjivan Ram Award for his innovations. Unlike Mr Tabiba most Punjab farmers burn 12 million tons of rice and wheat straw annually and with it burn urea worth US Dollar 18 million and generate 23 million tons of carbon dioxide – a greenhouse gas. Like Punjab plant biomass is burnt or inadequately used by several farmers in all over India.

7. Earthworms

Introducing earthworms after purchasing from outside is not essential. Most fields have native population of earthworms. We need to learn and understand factors/conditions that enhances their population. Providing plant biomass as surface mulch, conservation tillage and application of bioproducts such as ‘Amritpaani’ have been noted to enhance population of the native earthworms. ***Appendix III*** has data generated at ICRISAT.

8. Cow dung ferment

a) Cow dung has been reported to have high population (10^4 to 10^6 per g) of at least four types of agriculturally beneficial bacteria
b) Fermentation of cow dung as ‘Amritpaani’ (a traditional knowledge recipe of liquid manure) further enhances their population by 10 to 100 times. Thus we do not need large quantity of dung for a farming without agro-chemicals, if we have surface mulch with biomass one cow is enough for one ha area. See ***Appendix IV*** for data generated at ICRISAT.

Ferments used by some organic farmers – Panchgavya, Jeevamrut, Amritpaani, Dashparni etc. have been reported by practitioners to enhance soil health and protect crops and need to be studied/researched by agricultural research institutes to articulate science to them.

9. Plant Protection

a) No serious threats from diseases (powdery mildew and downy mildew can be problems in some cases where relevant) were noted in the ten years experience at ICRISAT, or reported by practitioners of alternative agriculture.
b) Insect-pests and viruses were noted as major threats. Over years practitioners have developed protocols for managing them (see ***Appendix V***).

10. Weed management

a) After biomass generation and its use on-farm, managing weeds forms the next major effort as it has to be done manually. Aurogreen crops (see ***Appendix I***, item 11 below)
b) For effective management of weeds in a given crop (i) remove only those weeds that complete target plants for light, (ii) remove manually when weeds are about to form seeds. Note: weedicides are poisons and adversely affect soil health.
c) Over years cost of weeding goes down compared to conventional agriculture, because surface mulch suppresses weeds. It may be noted that tillage serves as a self sowing system for weeds.
d) Weeds offer a source of diversity in crops, by default.
e) Weeds can be more mycorrhizal than crop plants.
f) Some weeds are rich in micronutrients.
g) Weeding can contribute up to 2t of dry biomass per annum in a rainfed system (Rupela 2008) and this quantity can be substantially more in an irrigated system.

11. Seed treatment

a) Occasional problem of poor plant stand have been noted, largely due to poor germination. Therefore use of good quality seed is very important. Seed storage using low-cost approaches without agro-chemicals is possible.
b) Seed priming has been reported to enhance plant stand in water deficit situations (Harris et al. 1999)
c) Seed treatment with following can address problems due to ants and fungi and result in good emergence: Slurry of following, to be coated on seeds, shade dried before sowing. Slurry made using 25% each (by volume) of cow dung, ash, live soil – Amrit Matti (or high quality compost), in cow urine.

12. Aurogreen crops

This is an innovative method of introducing crop diversity in a mono-cropping and intercropping system and to produce green manure along with the main crop(s). In this method a mix of seeds of legumes, cereals, oilseeds and fiberous crops are broadcasted on a desired field. After 30 days growth, these are smothered (and not incorporated) and can give up to 12.5 t ha^{-1} wet mass. This practice enhances diversity of natural enemies of insect-pests and substantially increases population of agriculturally beneficial microorganisms in soil and thus improves soil and plant health (see ***Appendix I*** for details).

13. Pruning, root and canopy management for high yield of horticultural crops

(a) Root treatment to enhance productivity of grown-up/old trees:

It is a common observation that as trees age, their productivity decreases. Innovative practitioners have developed method of enhancing growth of feeder roots resulting in enhanced growth of trees. The method can be demonstrated on request. Note: some selected shade tolerating creepers can be grown in the root treatment area resulting in additional output of a crop of economic importance.

(b) Canopy management of selected fruit tree species for enhancing their yield:

Most horticultural trees are recommended to be planted in a given spacing (generally 30 ft – between rows and between trees within a row). Space between trees is generally sown to annual crops of the area until the trees grow big enough to cause shade and adversely affect yield of the annual crops. Practitioners have developed methods of lopping fruit trees that have been noted to enhance not only yield of trees but also, keep their height manageable for easy harvesting of fruits. The method can be demonstrated by successful farmers/practitioners.

(c) Pruning for enhancing yield of selected vegetable crops:

Practitioners have developed innovative methods of pruning certain creepers for enhancing yield. The method has been reported successful particularly for bottle gourd.

It would be apparent that the different interventions listed here would require labor more intensively than cash. Also, most would agree that for small holder farmers arranging labor (largely by family members) would be easier than cash. In addition, some of the interventions can be effectively implemented at watershed and/or community scale and should be undertaken through government programs such as NREG (see successful examples in the book by Centre for Environment Concerns 2009). Farmers using most or all protocols have been noted as prosperous ones even in suicide prone areas like Yavatmal of Maharashtra. Governments serious in helping farmers in achieving prosperity and living life with dignity are encouraged to invest resources in such interventions through structured rural development programs eg. producer company concept (a company of the farmers, for the farmers, by the farmers but managed by professionals and facilitated/financed by government) that would make small-holder farmer have stakes in their produce until it reaches consumers. Major investment will be needed on capacity building of farmers so that they properly learn and apply the interventions at their farms and successful farmers of different areas, masters in these interventions, can be hired as resource persons.

14. Set-row concept

This innovative method was prevalent among farmers in parts of Gujrat. All inputs, eg. compost and fertilizers (when farmers learnt to use) are added to this place only. Researchers (see papers by ---) from – and – evaluated it and reported that soil fertility in these rows was --- time better than the adjoining soil.

15. Humidity chamber

Ideally farmers should prepare their own planting material instead of depending on market. Yes, the propogation methods like grafting and gooting need specialized skill but rooting of cuttings is very simple and can be learnt by most farmers. In drier areas in particular, it will need a humidity chamber which can be prepared at low-cost using GI wire (3-4mm dia), transparent plastic sheet (low density plastic sheet of – gauze) and/or nursery net (depending on the intensity of summer temperature) and facility. A chamber of 3 feet x 5 feet may be sufficient for a small-farm holder and can be constructed at a low cost (approximately Rs. ----). Farmers with stronger/bigger needs can make multiple pieces of this facility.

15. **Field bunds** – selective weeding: Generally farmers leave very less space between fields thinking it will affect yield. It sounds logical but may not be true. These spaces should be raised from rest of the field and greened with plants (mix of grasses and legumes that trail on ground) that can serve as fodder for cattle. Plants that are not eaten by cattle, must be removed.

16. **Crops and varieties** known to convert 'non-available' elements to 'available' form. A crop needs at least 30 elements [3 major – N, P, K; 12 minor (---) and at least 18 trace elements (---) for its growth. And ideally in balanced form. A soil, good or poor, has all these elements but mostly in non-available form. Some crops and weeds exude some specific acids that help convert non-available to available form. For example, pigeonpea is known to exude 'piscidic acid that iron bound phosphate to ------- an available form of phosphate (Ae et al.)

Acknowledgements. I am grateful to (a) a large number of successful farmers of India who shared their experience and perspectives on the different interventions listed above, (b) Prof. Anil Gupta of the Society for Research and Initiatives for Sustainable Technologies and Institutions (SRISTI - see wws.sristi.org details) for sharing his confidence in the different agriculture protocols based on farmers traditional knowledge, (c) ICRISAT and its relevant staff for the opportunity to assemble key protocols into low-cost options of crop production and their evaluation in an on-going longterm field experiment.

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II: Sustaining soil fertility without agro-chemicals – a challenge to agriculture scientists.
III: Underground agents survive the searing SAT.
IV: Excerpts from ICRISAT Archival Report, GT-CI – 2005-06, Pages 366-367
V: Plant protection without agrochemicals.

Appendix I

Aurogreen – a New Method of Green-manure

This handout has been written based on discussion with Mr Manohar Parchure (phone: 9422152824, e-mail: manohar_bhau@yahoo.com) Chairman Advisory Committee of Maharashtra Organic Farming Federation (MOFF) in April 2009.

The positive effect of this practice is hypothesized due to a) enhanced above ground diversity that potentially brings in pests of different crops and therefore the natural enemies of these pests (provided no chemical pesticide is used), b) enhanced soil biology activity due to multiplication of highly diverse population of agriculturally beneficial microorganisms on root-rhizosphere of the different crops (note that one g of root rhizosphere soil can have at least one million agriculturally beneficial microorganisms), c) enhanced population of rhizobia of the different legumes that multiply on the root rhizosphere of the relevant legume (thus obviating the need of purchased rhizobial inoculants except where native soils lack it), d) amelioration of soil temperature due to plant biomass as surface mulch, e) reduced moisture loss from soil due to the resultant surface mulch. Scientists/research institutions with relevant resources are encouraged to test this hypothesis. The different steps of this method are described below. **Note**: As per experience of CG institutes in Asia, the practice of 'Green-manure' in general, has not been accepted by farmers. But 'Aurogreen' is a different concept where the recommended diverse crops can be grown along with the main crop and therefore substantially enhancing the scope of acceptability by farmers.

1. This is a new type of green manure method for me. It was perhaps developed by the Auroville community of Pondicherry, India.
2. In this type of green manure, diverse crops (see the section on seed requirement) are sown along with the main crop(s).
3. Mix the different types of seeds and broadcast them to achieve maximum possible germination. **Note:** Beejopchar[1] – ie. treating the seeds with a traditional recipe (see it in the footnote) will be a good idea for better emergence. Broadcasting time can be critical in a rainfed system and would require local skill/experience.
4. Smother the 'Aurogreen' crops at about 30 days age using reverse 'Bakhar' – a local tool used for interculture in Maharashtra and Madhya Pradesh.
5. Experienced practitioners tell that up to 5 t (wet mass) per acre (ie. 12.5 t ha^{-1}) has been measured in about 30 days. This practice has also been reported to help manage weeds better than otherwise.
6. Smothering is important because it provides biomass as surface mulch. Incorporation can potentially have issues of immobilizing crop nutrients and is therefore not recommended.
7. It is a highly convenient practice for wide-sown crops such as cotton. For other crops where smothering with interculture is not feasible, other options have to be considered.

[1] Make about one liter paste by mixing 250g each of ash, soil (from the field being sown), fresh (and not old) cow dung (has been reported to contain agriculturally beneficial microorganisms). Add old cow urine as much as needed to obtain a thick paste. Smear the 10kg seed with this paste a day before sowing and dry in shade. The treated seed can be used within a week.

8. Sowing of another round of 'Aurogreen' crops at any next opportunity should also be attempted before the main crop grows big to cause excessive shade on the Aurogreen crops.
9. Close-sown crops such as groundnut (rows 30cm apart) can take advantage of 'Aurogreen' concept by growing it before sowing the main crop. A modification of 'Aurogreen' that has been noted used by some practitioners. They call this Beej-Sanskaar which is potentially suitable for close sown crops and is described elsewhere.

Seeds used for the 'Aurogreen'

1. A total of 10kg seed is needed per acre = 6kg legumes, 2kg cereals, and one kg each of oilseed and fiber crops.
2. Attempt must be made to use locally adapted crops/varieties. Also, seed grown/preserved by farmers themselves should be used for the purpose. There is no need to purchase these from seed store. If a farmer does not have seed of the required crops it can be borrowed/purchased from neighbor farmers or even from a grocers, provided they have good germination percent. It is estimated that the required 10kg seeds may cost well within Rupees 150/- (one hundred and fifty only). Examples of the different types of crops/seeds are given below.
3. Legumes (6kg): mungbean, blackgram, cowpea, moth, chickpea
   Cereal (2kg): pearlmillet, sorghum, maize, wheat, raagi
   Oil seed (1kg): mustard, linseed, safflower, sunflower, seseme, soybean
   Fiber crops (1kg): Ambaadi/Gongura in Telugu (*Hibiscus cannabinus*), cotton, sunhemp
   Important: total quantities should remain around the recommended, but include as much diversity as feasible. For example, for one kg of oil seeds one can take 200g seed each of five of the six crops listed above. Thus one would ideally sow 10 to 15 different crops.

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Appendix II

Sustainable high soil fertility without chemical fertilizers, a challenge for agriculture scientists

OP Rupela et al.*

Background:

- This farm is in village Bajwada, district Dewas, Madhya Pradesh; owned by Malpaani Trust and managed by Mr Dipak Suchde, CEO of the trust (deepaksuchde@gmail.com, mobile: 9329570960). As I understand, Mr Suchde is also an important member of 'Prayog Parivar' – a non-institutional network of knowledge communication initiated by Prof. Shripad A. Dabholkar. The network involves several practicing farmers. More information on the network should be available at www.prayogpariwar.net. A book "Plenty for All" written by Prof. Dabholkar, published in 1998 (Mehta Publishing House, 1216, Sadashiv Peth, Pune; mehpubl@vsnl.com) tells us of a different outlook to farming and should be read by all students of agriculture.
- I know the group from April 2005 when I participated in a workshop by the group, organized to commemorate first death anniversary of Prof. Dabholkar. Surprisingly, quite a few farmers associated with the group were awarded by some states/organizations for harvesting highest yields for different crops, including sugarcane and grapes. Some of their views/concepts (in the book and/or on the website) may appear unscientific, but the fact that their farmers were harvesting high yields forced me to spend more time/interest in this direction.
- The group has developed several innovative protocols of crop production. The most fascinating for a microbiologist like me was 'the method of composting' which they called process of making 'Masala Matti' – Mr Dipak Suchde now calls it "Amrit Matti". Some samples of this compost had up to 100 million plant-growth promoting bacteria (siderophore producers) in every gram of the compost - highest ever measured in any compost in our lab.
- Mr Suchde believes that about 10 Gunta (one hectare = 2.42 acres, one acre = 40 Gunta) land is enough for not only feeding a family of four, but also providing other items of livelihood through selling the excess produce.
- Visit to crops at the Yusuf Meherally Centre (YMC) Tara, Panvel district of Maharashtra, where Mr Suchde used to work when I met him first, was an eye opener. The small area of 10 Gunta had over 100 crop species (mix of annuals like Papaya and perennials) and reminded me of several publications of Miguel A. Altieri (Professor of Entomology, University of Florida, 215 Mulford Hall Berkeley, California 94720; agroeco3@nature. berkeley.edu) where he argues in favor of designing agroecosystems mimicking the structure and function of natural ecosystems if we have to have sustainable high yields. Here at the YMC I was witnessing a working model of what perhaps Altieri was theorizing in his publications. The Alfisol soil at YMC did not seem fertile and had lot of pebbles. I was told that the crop was only 3-months plus. Still there were all signs of high productivity per unit area. It seemed much was happening in the heaps of "Amrit Matti" and needed explorations.

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* Co-authers will soon be contacted because of their intellectual contributions in educating me on aspects relevant to 'soil chemistry' and several sessions of discussions in the past one decade on interactions between microorganisms and soil chemistry. All the soil samples were analysed in the Soil Chemistry Laboratory at ICRISAT, headed by Dr KL Sahrawat, for NPK and OC%.

The key characteristics of this technology of growing crops, which the group calls 'Natueco Farming', were (a) plants growing on small 'heaps of Amrit Matti' covered with mulch, (b) the heaps were always kept moist (watering with rose cans at the rate of 1000L water per day per 10 Gunta), (c) spacing was wide, (d) not only the heaps, even the rest of the area was covered with grass mulch, (e) weeds were allowed to grow until flowering and were seen as a resource (again this reminded me of the work by Altieri), (f) need-based sowing and harvesting of crops – overall it looked a constructed forest.

- In Sept 2007, I visited at the Krushi Teerth, this time to spend five days. This was a new place of work for Mr Suchde. I was told that the Malpani Trust acquired these lands only recently and the 10-Gunta experiment was started only in June 2007 and thus the crops I was looking at were only about 3 months old. And again there were signs of high productivity per unit area as noted at the YMC. When dug out, most plants (including upland rice) had abundant roots and were white ie. highly active, as was true at the YMC. **Note:** *Yield data from the Krushi Teerth*.

On Studies/Data:
The signs of high productivity and other factors indicated above made me to take detailed soil sampling and we analyzed all possible parameters for which facility was available at ICRISAT. Results of the analyses along with comments are in the attached four data tables. The data indicate a system of crop husbandry that uses locally available natural resource, knowledge and labor to convert a soil with 'low' to 'high' available form of crop nutrients.

Overall:
Unfortunately, in the absence of any comparative treatment we cannot say that the yield with the Natueco Farming was or will be higher than conventional system of agriculture. But there were no signs of nutrient deficiency, diseases and insect-pests worth worrying. The fact that this method does not need agrochemicals, make it environment and farmers friendly, another 'low-cost biological option' that can help farmers. The method is worth exploring further and seems to have surprises for we scientists (plant pathologists, entomologists, soil fertility experts, agronomists, soil physics, crop physiologists, environmental economists, and ---?).

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Note : items highlighted yellow need confirmation

Table 1. Available P, total P, kjhel N, exchanglable K (ppm) and % organic carbon in the soil samples collected from Krishi Tirth, Bajwada, Dewas (MP).

Treatment	Available P (ppm)	Total P (ppm)	Kjehldahl (organic form) N (ppm)	Exchangable (available) K (ppm)	%OC (ppm)	pH
Original Soil	17.1	392	174	284	0.66	7.75
Between Heaps	20.5	362	198	315	0.74	7.59
Planted Heap	33.1	410	194	424	0.72	7.91
Below heap	247.7	500	798	770	2.61	7.89
Mean	79.6	416	341	448.25	1.1825	7.79
SE±	17.7***	58.4^{NS}	77.8**	87.0*	0.264***	0.036***

*= Differences across treatments are statistically significant at probability level (*P*) 0.05 **=Differences across treatments are statistically significant at *P* 0. 01; ***= Differences across treatments are statistically significant at *P* 0.001, NS= Differences across treatments are statistically non significant

Soil sampled on 19.09.07.
Original soil = soil sample from unplanted area on the farm
Between Heaps = Planting concept on the farm is grow horticultural crops on heaps and heaps are widely apart, soil sampling in this treatment was done between heaps.
Planted Heap = Sampling in this treatment was done at the heap, besides a growing plant on top of a heap
Below Heap = Sampling in this treatment was done after removing all the soil and plant roots from soil surface. Sampling was done from area just below the soil surface but below the heap.
Replications: each of the four treatments had three replications, and there were about three spots within a given replications.

On the different parameters that were measured:

A plant needs over 30 different elements for its growth/formation of leaves, stem fruits etc. all body parts. But we generally measure only selected few and largely **nitrogen (N), phosphorus (P) and potash (K)**. All the 30 about elements occur in a soil largely in two forms – **'available' and 'non-available' form**. Wherever it is stated as 'Total' it means it is total of available plus non-available form. The available form of a nutrient can be readily taken-up by a plant through its roots while the other form has to be processed by microorganisms, which are in maximum numbers on surface of roots and convert them into available form, through enzyme activities or production of organic acids. The process of conversion will generally be slow and would depend on type and numbers of different microorganisms. An element provided as a 'fertilizer' is essentially in available form and therefore when applied to soil, we generally notice a rapid response of plants, in terms of increased green color of foliage and/or growth/yield. pH tells us whether a soil is close to normal or a problematic soil. For a very good soil, pH should be around 7, and values more than 8 (salinity/alkalinity) and less than 6 (acidity) indicate problem. ***Note:*** *All these elements come from mother rock from which a soil has formed. Formation of soil is very long process. Few centimeters layer of soil might have taken thousands of years to get formed.*

Organic carbon (OC) is a biological and not a chemical parameter. Unlike the other biological parameters, this can be measured readily by a chemistry laboratory and is therefore generally lumped with the chemical parameters. **OC%** is like a bank of nutrients in soil and may contain all the nutrients needed for plant growth. More the value, bigger will be the bank balance. But like other elements in soil, much of these elements are also in unavailable form for a plant, but relatively easily degradable to become available for use by plants. These can be made available to plants by microbial activity and carbon in this component serves as food for the microorganisms.

Comments on data table 1: (a) fertility of the original soil was lower than the area under cultivation; (b) fertility was maximum below (15 cm) the heap indicating that roots from plants sown on heaps will tend to go deep in the soil to explore/take-up the nutrients; (c) organic carbon percent (OC%) below heap was at least 3 times more than that in the heap itself, indicating that smaller carbonaceous molecules of degrading biomass move down from heaps with water (rain or irrigation).

Table 2. Total B, S, Fe, Zn (ppm), and Available B, S, Fe, Zn and Mo (ppm), in the soil samples collected from Bajwada (MP), sampled on 19.09.07.

Treatment	Total B (ppm)	Available B (ppm)	Total S (ppm)	Available S (ppm)	Total Fe (ppm)	Available Fe (ppm)	Total Zn (ppm)	Available Zn (DTPA-Zn)	Available Mo (ppm)
Original Soil	29.7	0.27	93	7.17	40442	15.6	133	0.83	0.019
Between Heap	26.0	0.29	103	7.00	33550	11.7	108	1.08	0.009
Planted Heap	27.0	0.32	94	7.60	34625	9.1	77	0.97	0.012
Below heap	26.7	2.29	420	18.93	33300	21.0	97	6.10	0.020
Mean	27.3	0.79	178	10.18	35479	14.4	104	2.25	0.015
SE$\pm$	1.11^{NS}	0.215***	21.0***	1.054***	$1641.1^{NS(0.06)}$	2.48*	21.7^{NS}	0.293***	0.0031^{NS}
CV%	7	47	21	18	8	30	36	23	37

* = Statistically significant at 0.05, *** = Statistically significant at 0.001, NS= Statistically non-significant

NS (0.06) = Statistically nonsignificant at p=0.05 but the values are statistically significantly different at p=0.06.

On the different parameters that were measured:

As stated above, a plant needs over 30 different elements for its growth and good yield and these should be in balanced form. The three elements nitrogen (N), phosphorus (P) and potash (K) are called major elements because these are required in relatively large quantities compared to the others. Ten other elements [**B (boron), Ca (calcium), Mg (magnesium), S (sulphur), Fe (iron), Mn (manganese) , Mo (molybdenum), Cu (copper), Zn (zinc) and Cl (chloride)**] are regarded as vital elements for plant growth along with the P and K. These ten are widely known as micro-elements because these are needed in micro quantities - parts per million (ppm). Like the major elements these also occur in **'available' and 'non-available'** form. As stated above, an agricultural field would highly likely have all the over 30 elements needed for crop growth, but they would largely be in 'unavailable' form. But interestingly, much of the soil analyses done by scientific community is only for the 'available' form and not for the total amount of any given element in the soil. Also, it is worth noting that all the recommendations of a given fertilizer by the extension agencies or by fertilizer dealers is based on the available quantity of an element.

Note: For good crop growth, other 18 elements are also needed, but in very miniscule quantities and these are regarded as 'Trace Elements'.

Comments on data table 2: Only five of the ten micro-nutrients, widely noted as deficient in farmers' fields in semi-arid tropics [see paper by Sahrawat et al. 2007; Current Science 93(10):1428-1432], were analyzed. Salient comments follow: (a) quantities of available form of nutrients (B, S, Fe, Mo and Zn) were invariably significantly more below the heap than that at other sampling spots of the same field; (b) total concentration of all these elements was similar across sampling spots except for 'total S' indicating addition of 'S' with the items such as 'Amrit pani etc. being applied, and this needs to be studied; (c) the noted small differences across sampling spots in the total concentration of three elements -- B, Fe and Z were statistically non-significant. It was apparent that the heap method of cultivation has ability to continuously converting insoluble form of nutrients to soluble form (note: heap remains moist due to continuous application of water) and therefore potentially obviates the need of dependence on market purchased elements. Discussion with soil scientists indicated that most soils would have total form of most elements.

Table 3. Biomass carbon, biomass nitrogen and dehydrogenase activity in the soil samples collected from Krishi Tirth, Bajwada, Dewas (MP)

Treatment	Microbial Biomass C	Microbial Biomass N	Dehydrogenase activity
Original Soil	376	37	58
Between Heap	274	33	38
Planted Heap	208	34	63
Below heap	426	66	98
Mean	321	42	64
SE$\pm$	79.8^{NS}	19.3^{NS}	26.9^{NS}

NS= Differences across treatments are statistically non-significant

On the different parameters measured:

Microbial biomass carbon: this parameter tells us about the carbon held in body of microorganisms, and is an indirect measure of total population of microorganisms, irrespective of their culturability. ***Note:*** *microbiologists can only culture (in laboratory conditions) about 10% of microbial life in a given niche – a generalization. But this does not mean that the un-culture-able microorganisms are not functioning in nature. It only means that we do not fully understand their importance/value*.
Microbial biomass nitrogen: this parameter tells us about the nitrogen held in the body of microorganisms, an indirect parameter of total population of microorganisms, irrespective of their culturability.
Dehydrogenase activity: like the above two parameters, this also reflects all microbial life in a given niche, irrespective of culturability limitations. This reflection is recorded through activity of this enzyme having over 10 sub-types by oxidizing several different substrates of the several biochemical processes operating inside a living microorganism.

Comments on data table 3: (a) as indicated by microbial biomass carbon and nitrogen, the soil below heaps had most microbial activity/population followed by that in the original soil while the activity in the decomposing biomass in heaps was next highest, (b) activity of microorganisms as indicated by 'dehydrogenase' enzyme was also maximum in the sample collected below the heaps, followed by that in the heap itself, and lowest activity was noted in unplanted area between heaps which was covered with dry biomass, the noted high activity in the original soil is perhaps due to good growth of grass that would have allowed a good level of microbial activity in its root rhizosphere and needs further consideration.

Table 4: Population ($\log_{10}$ g^{-1} dry soil) and diversity (no. of colonies of different types) of different microorganisms in the soil samples collected from Krishi Tirth, Bajwada, Dewas (MP)

Treatment	Total bacteria pop.	Total bacteria diversity	Actinomycetes pop.	Actinomycetes diversity	Fungal pop.	Fungal diversity	Plant growth promoters (Ab)	Pseudomonas pop.,suppress diseases (Ab)	P-solubilizers pop. (Ab)	Org. Acid producers pop. (Ab)	N_2-fixers, AZO like pop (Ab).
Original	6.64	5	5.67	8	4.02	6	4.94	<4.0	<3.0	3.33	4.33
Between heaps	6.80	7	5.30	6	4.34	6	4.77	<4.0	<3.0	3.67	4.09
Planted heap	7.20	7	5.67	5	4.51	3	5.57	<4.0	<3.0	5.33	4.28
Below heap	6.86	11	5.58	7	4.18	6	3.85	<4.0	<3.0	4.00	4.16
Mean	6.87	8	5.55	6	4.26	5	4.79	<4.0	<3.0	4.08	4.22
SE$\pm$	0.099*	0.6***	0.103^{NS}	0.9^{NS}	0.152^{NS}	1.4^{NS}	0.482^{NS}	$<4.0^{a}$	$<3.0^{a}$	1.244^{NS}	0.135^{NS}

a=Population of *Pseudomonas* spp. and P-solubilizers could not be assessed due to presence of large numbers of other bacteria.
*= Differences across treatments are statistically significant at probability level (*P*) 0.05 **=Differences across treatments are statistically significant at *P* 0. 01
***= Differences across treatments are statistically significant at *P* 0.001 NS= Differences across treatments are statistically non significant

On the different parameters measured:

Total population of bacteria, actinomycetes and fungi: this parameter tells us about the population of these types of microorganisms that can grow on selected recipes (different for different microorganisms) where microbiologists believe that majority microorganisms will grow. It may, however, be noted that microbiologists can culture about 10% of total population of microorganisms in any niche, due to limitations of methods of culturing. ***Note:*** *all populations are log numbers and have to be taken accordingly. For example, log 3 means 1000 and log 6 means 10 lakh.*

Diversity of bacteria, actinomycetes, and fungi : this tells us the different types (due to size, color, texture etc. of the microbial colony) of microorganisms noted on the growth medium (recipes) used for population count (above parameter). Thus it does not account for the total microbial diversity in a given niche.

Agriculturally beneficial bacteria (Ab): All the five parameters (last five columns) indicated by (Ab) [the last five columns of this table] are the five different functional group of bacteria with functions as indicated with their names.

Comments on data table 4: (a) Population of bacteria inside heaps and below heaps was significantly more than the other treatments (range from 6.64 to 6.80 $\log_{10}$ per g of soil); (b) population of actinomycetes and fungi was similar across the four treatments and ranged from 5.30 to 5.67 ($\log_{10}$ per g of soil) in case of actinomycetes and from 4.00 to 4.51 ($\log_{10}$ per g of soil) in case of fungi; (c) maximum population of the plant growth promoters and organic acid producers was inside heaps where lot of roots were noted during sampling and lowest in the soil below the heaps where chemical fertility was the highest; (d) population of *Psuedomonas* (indicators of ability of soil to manage diseases) and P-solubilizers could not be counted due to methodology problems; (e) N_2-fixing bacteria (colonies that were looking like *Azotobacter*) was similar across the four treatments.

See separate pdf files for Appendix III and

Appendix V

Plant Protection without 'agro-chemicals'

Protecting plants from with agro-chemicals of the mainstream protocols is fraught with dangers. It needs lot of expertise to identify insect-pest followed by selection of pesticide. In the real world farmers have been noted to depend on pesticide suppliers in a rural shop. Most importantly hardly any farmer has been noted using protective clothing and other gears during spraying as recommended by agricultural research institutions and the manufacturers of the chemical pesticides. As oppose to this the natural farming based on 'organic principles' is very safe to use after a farmer has understood some basics. During my past ten years experience and interactions with organic farmers, threats from disease-causing fungi was only occasional. The major problem was noted from insect-pests. And among insect pests also, sucking pests caused most worries. Based on the experience so far, following steps would be of great help in managing insect-pest in general:

- Stop use of synthetic pesticides because they are all poisons (of respiratory system, endocrine glands and/or nervous system) and kill all insects, including the natural enemies of insect-pests (Note: as per a publication by HC Sharma (2001) of ICRISAT, just one insect – *Helicoverpa armigera* (cotton boll worm or legume pod borer) has about 300 natural enemies (includes a large number of beneficial insects). Also, these pesticides are potentially harmful to humans and environment.
- Stop using fertilizers, nitrogen in particular. Succulent plants with more nitrogen (be it from fertilizers or from excess use of compost) are preferred by some insect-pests for laying eggs (Phelan et al. 1995).
- Take all steps towards making soil very rich in agriculturally beneficial microorganisms and macro-fauna such as earthworms. **Note:** there is no need to buy vermicompost or even earthworms from external sources. But we need to learn how to increase population of agriculturally beneficial microorganisms and macro-fauna (including local earthworms). Once a soil is rich in beneficial microorganisms and macro-fauna there is very less likelihood that insect-pests will bother any crop to an extent that we have to take drastic measures of managing them, even with biopesticides. It may take one to three years for a soil to reach such a stage and will depend on knowledge and understanding of practising farmer.
- Resist temptation of growing crops in off-season in the hope of earning more money, because with time it will not be sustainable.
- Do not grow crops/trees that have been noted to have strong issues on insect-pests. This means that the natural enemies of that insect-pest is absent in your area.
- Increase diversity of crops (including trees where relevant) in a given field. It means instead of one crop we should have intercrop/polycrops. Say in a field of Groundnut we can grow other local crops as intercrop. In some situations several

grain crops (legume, cereal, fiber, oil) can be mixed and sown. Mixtures can be selected such that they could be separated by sieving after harvests. Indeed, a set of mixed crops can be such that their grains are of different sizes so that one could separate by sieving, even when they are harvested by a combine.

- If needed, locally available botanicals can be used as 'biopesticides'. At most locations in India, there may be 5 to 6 plants with ability to kill insect-pests. Most commonly noted plants during travel to these areas were Calotropis, Datura, Neem, Bakain (*Melia azadiracht*), Tridex (a common weed), Parthenium or carrot grass etc. In addition, there are several other options that have ability to trap, repel or kill insect pests eg. Diluted buttermilk (or Lassi in Hindi/Punjabi and Mazziga in Telugu), diluted cow-urine, yellow-color plastic sheets smeared with caster oil as sticky traps (can be made by farmers as a 'rural enterprise'). **Thumb rule:** plants on an unattended land that are not eaten by goats, highly likely have value as a 'potential biopesticide'.

Few selected recipes are given below:

Important: All the recipes are based on experience of successful organic farmers in India. To my knowledge, no verification has been done by any research institution.

Note: More recipes will be provided in due course.

For managing voracious feeders (eg. defoliators and even *Helicoverpa* – that feed on leaves and bores into fruits) can be managed as given below.

(A) **Cow-urine** (concentrated)
1. Dilute cow-urine 1:1 with water.
2. Apply the diluted urine to soil (not to plants – it is important because concentrated urine can burn plant foliage) at the rate of about 100L per ha per spray.
3. Smell of the urine has been noted to repel insect-pests in general – including *Helicoverpa* and *Exelastis*.
4. Once applied, smell of urine has been noted to persist for at least four days.

(B) **Cow-urine** (diluted)
1. Take relatively fresh cow-urine
2. Dilute it in clean water eight times (1:8).
3. Spray once in 7 to 10 days (it repels insects in general and promotes plant growth)

Note: ii) it can be sprayed even if there is no visible sign of insect damage.
ii) undiluted urine applied to soil between rows has been noted to repel several insect- pests.

(C) **Soap + Jaggary**

1. Buy Khadi soap (local and 501 or yellow bars available with grocers okay, do not use modern soaps and powders such as Surf Excel Blue because they have enzymes (eg.).
2. Take 0.5kg to 1.0kg soap and grate it in small pieces, as one will do for potato chips. Mix with about 3L water and boil (can be done in pressure cooker).
3. Take 2.5kg (for chickpea use 4 to 5 kg) Jaggary and break into small pieces using mallet. Boil it separately in about 3L water until dissolved.
4. Add both the items in a drum containing water. Make the volume to 100L and spray.

Note: *Spraying should be done in evening, so that larvae come out from hiding (below leaf canopy) and feed on the foliage.*

For Red spider mite: Use lime sulfur spray – composition as given below.

1. Take 1 kg lime powder and suspend in about 10 L of water.
2. In a separate container, take 1 kg wetable sulphur and suspend in about 10 L water.
3. Take a 100L drum and add the suspended sulphur. Make the total volume to about 50 L in water.
4. Add lime and make volume to about 100 L
5. Spray on affected field crops at the rate of 300L per ha.

Important: Always prepare fresh and use.

For managing fungal diseases using ferment butter milk in copper container:

1. Prepare curd from one L milk, using a copper container. Let it stay for 4 to 5 days. It will get greenish blue.
2. Prepare butter milk using this curd and dilute to 150L.
3. Spray to affected crops at the rate of 300L per ha.

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