Comparing Conventional and Organic Farming Crop Production Systems: Inputs, Minimal Treatments and Data Needs

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Abstract

Residues of synthetic pesticides food chain prompted the demand for "organic food," which is rapidly growing. Certified "organic food" is presently grown on about 31 million ha in the world (1.1 million ha in India). There are strong do's and dont's in the production of organic food as dictated by certification agencies operating globally (in India accredited by Ministry of commerce) for which farmers have to pay certification fee. Interactions with practitioners of organic farming (OF) revealed that reduced cost of production was a stronger reason for their conversion from conventional agriculture to OF. In addition, most farmers said that their yields were not lower than the yields of their neighbors who are conventional farmers. This is a researchable issue for mainstream scientists. The fact that nutrients needed for a crop can be met through plant biomass grown at the same field and the plant protection needs are met through innovative biological options are also important researchable issues, among several others. Some biological protocols of crop production and protection were used at ICRISAT-Patancheru, India, in an ongoing long-term experiment (completed seven years in March 2006). The research experience at ICRISAT and the experience collected from the OF practitioners have been shared. Suggestions for future demonstration cum verification experiments have been offered to facilitate statistically analyzable data on OF. Stakeholders are encouraged to use locally available natural resources for growing crops in a farming system perspective relevant to small and marginal farmers that form the bulk of farmers in developing countries (74% in India). Better still if the experiments are done on farmers' fields. Several unanswered questions and researchable topics on OF have been indicated.

Citation: Rupela, O.P., Humayun, P., Venkateswarlu, B. and Yadav, A.K. 2006. Comparing conventional and organic farming crop production systems: Inputs, minimal treatments and data needs. Organic Farming Newsletter, Vol 2: 3-17.

Introduction

Based on a UN survey, at least 130 countries produce organic food commercially (International Trade Center 1999). Total global area is now estimated at 31 million hectares (ha) in the world (www.orgprints.org, 23 Mar 2006) and 1.1 million ha in India (estimates based on contacts with accreditation agencies, operators of contract farming and www.apeda.com/organic/presentstatus.htm, 29 Mar 2006) and the market for organic food has swelled to an estimated US$27.8 billion a year (www.orgprint.org). This rapidly expanding market seems to be prompting farmers to shift to organic farming (OF) practices. By definition, a product can be labeled "organic" only when it has been certified by some accredited certification agency. About 20 such agencies operate globally. The certification process involves a visit by staff of the agency to a field growing the raw material and to the factory processing it. This third party verification process involves traceability of a product, implying that every batch of a product is labeled such that a consumer can learn where a given product originated. Unlike conventional agriculture, the process of growing crops under OF is dictated by market forces, mainly the certification agencies. The International Federation of Organic Farming Movement (IFOAM), a body of practicing organic farmers, with headquarters in Bonn, Germany, has been spearheading the development of protocols of crop production without without chemical fertilizers and synthetic pesticides (for more information, visit www.ifoam.org). The process of growing crops and even the conversion of a field from "conventional" to OF is a well-documented regulatory process. India is estimated to have over one million ha under conversion to organic (estimates based on personal communications with people on the field) of which more than half is in Maharashtra (SK Goyal, Commissioner of Agriculture, Maharashtra state, Pune, personal communication January 2006). It is important to note here that a certified organic farm has to produce most of the inputs *in situ*. Or it can import inputs e.g. compost from a neighboring certified farm. To remain economically viable, a farmer may have to produce most inputs on his own farm. Most OF practitioners have reported (including the thousands with whom we interacted) that it was not the premium price of the organic produce but the reduced expenditure on inputs and similar yields to their neighbor conventional farmers that was attracting them (Alvares 1996; Sharma 2005).

On the other extreme, most agricultural scientists believe that in the absence of chemical fertilizers, the large quantity of farm yard manure (FYM) and other biomass that will be needed to compensate for the fertilizers is unavailable. Also, they believe that different crops cannot yield high without agrochemicals, fertilizers in particular, and therefore practicing OF means food insecurity for the country (Chhonkar 2003). During visits to the OF practitioners, we noted fairly good crops without agrochemicals. Initially, we found it hard to believe. But over the years, when more and more farmers reported the same, we started believing them and felt a strong need of research to understand strengths of the alternative means of crop production and protection. More recently, we leant about the long-term experiments, on-going for 25 years in Switzerland (Maeder et al. 2002) and USA (Pimentel et al. 2005) where sustainable yields (though marginally reduced in some years) without agrochemicals have been reported in temperate climate conditions. In an on-going long-term experiment since June 1999, on a rainfed Vertisol at ICRISAT Patancheru, annual crop yields (total of two crops in the intercrops) in the two treatments without agrochemicals were comparable (in six out of seven years) to the treatment receiving recommended (by research institutes in the region for a given crop) levels of fertilizers and synthetic pesticides (Table 1).

National Project on Organic Farming (NPOF) under Ministry of Agriculture offers financial assistance for the evaluation of OF practices. Model Organic Farm Development scheme under NPOF can also become handy in evaluation of OF strategies. A seven years experience of growing crops at ICRISAT, without chemical fertilizers and synthetic pesticides, has been shared to facilitate the expected large number of evaluations under the NPOF. The relevant treatments in the experiment at ICRISAT (Rupela et al. 2005, 2006) did not follow the strict OF norms as determined by certification agencies, but focused on low-cost and biological approaches to learn how much a cash-poor but knowledge-rich farmer can harvest using the likely available natural resources, compared to the conventional agriculture treatment. This paper also shares lessons learnt from visits to a large number of the OF practitioners and published literature that tend to articulate science to some practices followed by organic farmers. The second half of the paper suggests treatments, inputs and data needs for relevant experiments in future to evaluate scope of producing high yield by using low-cost and biological approaches. The conventional agriculture using integrated nutrient and pest management practices is suggested as control. Interested may include more treatments of their choice. Focus should be on a farming system perspective and needs of small and marginal farmers owning <2 ha (74% farmers in India are marginal or small - Chadha et al. 2004) with access to low-cost eco-friendly inputs available around them or those that can be generated on their farm. The OF in this document should be viewed and practiced in such a scenario. If desired, the OF as dictated by certification agencies and crops receiving only agrochemicals can be the other two treatments in the same experiment.

Important features associated with OF

Of the 34 different nutrients that are needed in the formation of crop yield, four (carbon, oxygen, nitrogen and hydrogen) form bulk (92–98%) of the dry matter of a plant. And a plant can potentially derive these from environment. Of the other 30 that come from soil, 12 are vital and 18 are needed in traces. Two (potassium and chloride) of the twelve vital elements are non-constitutive and ten (phosphorus, boron, calcium, magnesium, sulfur, iron, manganese, molybdenum, copper and zinc) are constitutive (Bourguignon 1998). It is a widely known fact that some biological processes of a plant involved in acquiring nutrients such as nitrogen (eg, nitrogen fixation) are generally inhibited by adding fertilizer nitrogen (Streeter 1988). Soil scientists generally caution against non-judicious fertilizer use and encourage use of organic manures because otherwise it may lead to deficiency of micronutrients (NAAS 2005). Over the years, the OF practitioners have developed interesting and at times difficult to believe protocols of crop nutrition and protection based on traditional knowledge. The Society for Research and Initiatives for Sustainable Technologies and Institutions (SRISTI), a non-governmental organization (NGO), regularly scouts for such knowledge and has over 13,000 recipes relevant to rural trades (including crop production and protection) and a large number of these can be viewed on their website www.sristi.org. After scouting, a given recipe has to be endorsed by neighbor farmers and evaluated at least at one more place before listing it on their database (Anil K. Gupta, President SRISTI, Personal communications with OP Rupela). We noted the OF practitioners using several recipes close to those listed on the website of SRISTI. Instead of ridiculing as unscientific, the prevalent protocols used by the OF practitioners deserve to be examined critically by mainstream science. We list some features used by OF and noted by us as deserving attention of those interested in OF because they already have some sound scientific basis or may turn out to be so in due course, as and when studied.

1. Integrating animals, diverse crops/plants (eg, annuals and perennials) is important in OF. Trees bring nutrients from deep of soil and deposit them on soil surface. It is a kind of biological mining of nutrients from deeper layer to provide it for crop plants whose roots feed largely on top about 30 cm soil profile. Animals dependant on crop residues as feed produce partially digested biomass, an excellent food for earthworms. Cow dung has been reported rich in cellulose degrading (4.9×10^4 per g) phosphate solubilizing (1.4×10^5 per g) bacteria, and florescent Pseudomonas (2.0×10^5 per g, Nalajala 2006). In addition, unpublished studies at ICRISAT suggested up to 2.23×10^7 siderophore positive (indicators of plant-growth promoting rhizobacteria – PGPR) bacteria per gram (dry mass basis) fresh cow-dung.

2. Plants need nutrients for growth, be it from fertilizer bags or from soil enriched in organic sources indicated above. In OF, these can come from loppings of *Gliricidia* or other trees grown on field boundaries, farmyard manure (FYM), crop residues and weeds. Lopped at appropriate times during a year the obvious negative effect of shading on crop growth can be neglegible. Figure 1 has a sample lay out of an on-going field experiment at ICRISAT with four different treatments. It is growing *Gliricidia* on bunds of the four different treatment plots of 0.2 ha each, calculated to 612 m^2 out of the total one ha. Growing fruit trees amenable to lopping can also be considered in place of *Gliricidia*. About 50 m^2 has been devoted to biological services such as preparation of vermiwash (prepared using the method described by Ismail 1997), vermicomposting and growing botanicals as biopesticides. Thus only about 6.5% area of total devoted to producing inputs can meet crop's nutrient and biopesticides needs and relieve farmers from depending on purchased inputs.

3. Plant biomass seems to be the engine of crop productivity in OF. And adequate quantities can be produced in situ through the following strategies.

a. *Gliricidia sepium* grown on the boundary of the Vertisol field is a good source of plant biomass without seriously compromising on yield of the main crop. If grown at start of the experiment, from year 3, every 100-meter length of 1.5 m wide single row yielded at least 245 kg dry biomass equivalent to about 5.6 kg N (about 2% N in its foliage). And its biomass yield increased over years (Figure 2). A one ha field with 400 m boundary can thus have 22.4 kg N ha^{-1} from year 3 and may touch up to 77.2 kg ha^{-1} by year 7 in rainfed conditions (Figure 2). Yield may be much higher under irrigated conditions. In addition, the other nutrients in the plant tissue (Bourguignon 1998), will also become available for crops, over time. Yield of lopping may depend on soil type, its depth, rainfall and weather conditions of the region (reference to be sent to AKY by my colleague PVS Prasad ---- from ICRAF).

b. Weeds if removed before seed formation and added back to soil are also a good resource. Depending on rainfall, 0.65 to 1.62 t ha^{-1} was accounted annually in the long-term experiment at ICRISAT. These were either left on soil surface or composted with the help of earthworms and returned to field.

c. Crop residues can be returned to the plot in case of OF directly or indirectly. That is, cattle droppings may be returned to field (eg, as compost), if crop residues are needed as cattle feed. Depending on rainfall, even cotton sticks disintegrated in about a year when left as surface mulch (Rupela et al. 2005). Any plant biomass in excess of the needed as cattle feed and/or as firewood can be recycled for crop production. Also, as a strategy, the quantity of biomass removed for cattle feed or firewood from OF can be replaced (at least on weight by weight basis, if difficult on nutrients basis) with any other bio-waste on the farm. But it is important to account for it for preparing balance sheet of nutrients for each treatment of the experiment.

4. Some OF practitioners used products generally called Biodynamic or BD preparations based on traditional knowledge. These preparations are used for making compost, manage crop growth and pests. When studied at ICRISAT, some of these preparations had 3.24 $\log_{10}$ to 6.90 $\log_{10}$ g^{-1} bacteria antagonistic to disease-causing fungi (Rupela et al. 2003, Sriveni et al. 2004).

5. Experienced OF practitioners were noted to add value to plant biomass before application to crops. This was largely being done by (a) vermicomposting of the plant biomass instead of normal composting, (b) instead of using large quantity of FYM, used a preparation from cow dung locally called Amrit Paani [60 kg dung, 5 L urine, 250 g jaggery to make 200 L suspension, stirred for 3 days, about

6 times a day, applied to one acre (about 0.2 ha) with irrigation water or before rains]. Plant biomass dipped in Amrit Paani for vermicomposting was preferred over using large quantity of cow dung for compost preparation. Thus use of cowdung was minimal and addressed the general criticism that large quantity of FYM needed for OF is unavailable. Amrit Paani was noted to have large population of PGPR and the cow dung seemed the source of the PGPR (Table 2). Vermicompost prepared using Amrit Paani was noted to have large number of earthworms and was superior for population of PGPR than the compost from the conventional farms (Table 2). Excessive use of Amrit Paani was noted by farmers to cause etiolation of plants. Experienced farmers recommended its use once every week in year 1, twice a month in year 2, once a month in year 3 and only once in three months thereafter.

6. Using plant biomass as surface mulch in an on-going experiment at ICRISAT was also viewed as add-value option. Surface mulch has been reported to conserve soil and improve water use efficiency (Hajare et al. 1997). Applied in this manner it reduced soil temperature in the long-term experiment at ICRISAT. On the hottest day in 2002 (30 April) the soil temperature at 5 and 10 cm depth in the mulch applied plots was 6.5 to 7.3˚C lower than that in the control plot (Rupela et al. 2005).

7. Application of *Rhizobium* strains (from research institutes or trusted market sources) as relevant to a given crop is strongly recommended because population of these bacteria was noted low in most compost samples that were studied. This will also ensure reasonable population of desired bacteria that might have gone down with regular use of agrochemicals.

8. Crops chosen by the OF farmers was noted as very skillful activity. Besides choosing a crop with local demand, having a legume-nonlegume combination in a farming system perspective was given importance. Short duration legumes as vegetables and other vegetables where plants creep were noted as favorable choices of farmers near urban areas.

9. Natural enemies (predators and parasites) of insect-pests seem important allies in protecting crops on OF farms, besides the biopesticides. Just one insect *Helicoverpa armigera* (cotton bollworm or legume pod-borer) has at least 300 natural enemies (Sharma 2001). Methods for commercial multiplication of few natural enemies such as *Trichogramma* and *Chrysoperla* were available but we failed to find scientific literature on how to encourage large number of the predatory insects in farmers' fields through cultural practices. In the treatments receiving no chemical pesticides, population of coccinelids and spiders (viewed as indicators of natural enemies) was much more than that in the plots receiving chemical pesticides (Rupela et al. 2005).

10. Fertilizer nitrogen has been reported to encourage more egg-laying by some insect-pests (Kowalski and Visser 1979) in glasshouse studies. Thus OF may attract less insect-pests by default.

11. Use of trap crops (known to attract insect-pests more strongly than the main crop) and presence of multiple types of plants are believed by the OF practitioners to reduce damage by insect-pests. This was noted as widely practiced in Maharashtra both by organic and conventional farmers. Mainstream scientists also consider crop-diversity as key component in plant protection (Rao et al. 2002). Rupela et al. (2005) used every 5th row in cotton and pigeonpea as a 'Diversity row'. In that, at least five other crops known to farmers as encouraging natural enemies were grown in addition to the main crops. If needed, population of the main crop in this row can be reduced making space for the diversity crops. The different diversity crops noted on farmers fields in rainy season were pigeonpea (*Cajanus cajan)*, cowpea (*Vigna unguiculata*), coriander (*Coriandrum sativum*), marigold (*Calendula officinalis*), sorghum (*Sorghum bicolor*), maize (*Zea mays*), okra (*Abelmoschus esculentus*), Tulasi (*Ocimum sanctum*), black gram (*Phaseolus mungo*) and mung bean (*Vigna radiata*). And those in the post-rainy (winter) season were mustard (*Brassica juncea*), rajgira (*Amaranthus paniculatus*), clover (*Trifolium pratense*) and methi (*Trigonella foenum-graecum*). Use of biopesticides was the major direct plant protection tool in OF. Practitioners of OF use several recipes based on traditional knowledge. Several microbial and botanical biopesticides are available in market that can be tried, if from a trusted source.

12. Experienced OF practitioners preferred to have a tree cover on boundary of their farm. It not only serves as a source of extracting nutrients from deep in the soil but also as a shelter to predatory birds. At a research farm use of bird perches may do the desired job of encouraging the predatory birds.

13. Termites can be an issue particularly in the presence of large quantity of plant biomass in OF. In the long-term experiment at ICRISAT, these were successfully managed by digging termitaria, searching the queen and killing it. After the queen was killed in the eleven termitaria noted in the one ha field in year one of the experiment , only 1 to 3 new termitaria were noted annually in the subsequent seven years. No need of any chemical pesticide was felt to manage termites in the past seven years. Termites can be valuable not only in forest ecosystems but also in the crop production system. In Africa, farmers collect termite-mound soil and apply to cropped fields (Watson 1977) as it can be rich in available nitrogen (by about 20%), total P (by 2.25 times) and organic carbon (by 9.3%) than adjacent soil (Lopez-Hernandez 2001). Rupela et al. (2003) reported bacterial population of 4.72 $\log_{10}$ g^{-1} termitaria soil with ability to suppress disease-causing fungi. Termites are thus a biological resource with potential to enhance crop production and manage crop pests.

14. Plant growth promoting rhizobacteria (PGPR) are known to colonize the root system of plants and can modulate plant growth by enhancing the availability of nutrients, inducing metabolic activities by phytohormones, by inducing defense program such as systemic acquired resistance (SAR) and induced systemic resistance (ISR), or by reducing phytotoxic microbial communities (Kloepper et al. 1997, Ping and Boland 2004). Recently, a *Rhizobium* (widely known for forming nodules on legumes and provide atmospheric nitrogen to plants – biological nitrogen fixation) strain has been demonstrated to infect rice-roots, travel upward to stem and growing leaves, and improve its growth (Chi et al. 2005).

15. Most textbooks [eg, by Rangaswami (1988)] on plant-disease management generally recommend removal of crop stubbles from field as a measure of field sanitation and for destroying any dormant structures of fungal pathogens that may survive in the plant debris. Plant biomass used as surface mulch is perhaps a different type of niche where many fungi may not proliferate strongly. Using the OF protocol suggested here, plant diseases have not reduced crop production in the past seven years life of the long-term experiment at ICRISAT (Rupela et al. 2005), contrary to the expectation of peer scientists.

16. Insect-pests can be major yield reducers in OF and managing them without chemical pesticides is a big challenge. Presence of a large number of crops within a main crop (eg, in diversity rows stated in item 10 above) is an important feature in managing them. A protocol involving entomopathogenic microorganisms (developed at ICRISAT-Patancheru), wash of neem compost (prepared using a biological extraction method) and other two items based on traditional knowledge of farmers along with trap crops greatly helped to manage pests. This protocol has been successfully used in protecting cowpea, maize, sorghum, pigeonpea, and cotton from insect-pests at ICRISAT (Rupela et al. 2005) and in protecting cotton for 3 years and vegetables (tomato, onion and chilies) for one year at farmers' fields (unpublished studies). Protecting crops at research station proved more difficult than at farmers' fields. Perhaps long use of chemical pesticides at the research station might have greatly reduced the natural enemies of insect-pests. In at least six out of seven years damage from *Helicoverpa* was managed in the experiment at ICRISAT but other insect-pest were noted as important issue in different years. These were pod-sucking bugs (*Nezara viridula* in particular) in pigeonpea and cotton, red cotton bug in cotton and *Exelastis* in pigeonpea that adversely affected yield in different years. Confident solution to these insects by eco-friendly and low-cost means is a continuing endeavor. Some promising low-cost items for managing different insects-pests were *Calotropis gigantea* for managing aphids; 0.8% soap powder (Surf–Multi-action) for managing aphids, red spider mites and scale insects (soap is not permitted to protect crops in OF as per certification agencies); and neem fruit powder extract (5 kg powder soaked in boiled water and extract diluted to 100 L for spraying on 0.2 ha). Low-cost solution to manage other insects is still an issue.

17. Organic farming is widely criticized as labor intensive. Indeed we too felt that. But speaking to farmers suggested that it did not bother them so far as it was economically viable. Their major worry was an assured sale of produce at a price known to them at the time of sowing crops. Thus market forces were their major worries. Also, if OF is laborious it is a potential employment generation opportunity and may fit well with the present employment guarantee program of the Government of India.

Setting up the experiment

Treatments, plot size, replications etc.

More than two, minimal suggested treatments [(a) conventional agriculture (involving integrated pest management and integrated nutrient management) and (b) organic farming involving low-cost and biological inputs for growing and protecting crops (eg, biopesticides)] are encouraged for the proposed experiment. Only chemical inputs and OF as prescribed by certification agencies can be the other two treatments as per the interest of the concerned groups. But additional tratements should not be at the cost of the plot size. The plot size for one treatment should at least be about 0.2 ha (say 50 m x 40 m). Such a plot should allow operations at a level close to that of a small farmer. Drifts while spraying microbial biopesticides across treatments can be managed better when plot size is big. In the experiment of Rupela et al. (2005), shifting of some insect-pests such as aphids was noted at times from conventional plots to non-chemical plots soon after chemical spray. Therefore using a biggest possible plot size will be a good idea. Ideally a given location should have at least six replications for each treatment, but it will require over two ha area and the experiment will be expensive to conduct and difficult to manage. Because the National Center for Organic Farming (NCOF) is anticipating several locations where such an experiment can be conducted under the program "Model Organic Farm," each location can serve as a replication in a given season/year, at least for some parameters such as economics and soil biology across the different treatments and locations. And if the experiment continues for about six years at a given location, (a year can serve as a replication) and statistics-based conclusions can be drawn.

Each treatment should be divided into at least six subplots to be treated as six internal replications. For statistical accuracy, the experiment should be taken as a randomized block design, but due to reasons discussed above use of big plot is strongly recommended. Note the suggestion on Figure 1 of having a small area (650 m^2 out of every ha – 6.5%) for 'biological services' including for *Gliricidia* on farm boundary for production of crop nutrients. This area should generate much of the crop nutrients, at least from year 5 onward, and biopesticides needed for OF treatment on a rainfed Vertisol. With irrigation this may be achieved much earlier than year 5.

Inputs

The experiment may be rainfed or irrigated. For nutritional inputs, it is important to add same level of at least two major nutrients – nitrogen and phosphorus –

irrespective of the source as chemical fertilizers or compost/plant biomass. And the level of addition can be predetermined depending on crops used in the system. Quantity of plant biomass or compost for adding to a given treatment can be decided based on the concentration of N and P in the plant biomass chosen and/or compost for application. Similarly, the treatments receiving both chemical fertilizers and compost (integrated nutrient management) the total for N and P from both type of sources should be same as applied to the treatment receiving nutrients only through chemical fertilizers.

Conventional Agriculture (CA). This treatment should receive all agro-inputs including the use of FYM as done for integrated nutrient and pest management at rates applicable to a given crop and recommended by a university and/or research institute in the region where the experiment is being conducted.

Organic Farming (OF). The OF recommended for the proposed experiment under NPOF should receive low-cost and biological materials available locally to a small farmer. But the quantities for nutrients should remain similar (or even less) to that added to CA. Tillage and addition of large quantity of plant biomass of high CN ratio are not compatible. In such cases, conservation tillage is recommended. Alternatively, apply nutrients through compost of high microbiological quality.

Addition of large quantity of plant biomass is expected at initial stages until soil health improves, as indicated by presence of large number of earthworms. Later on, the system was noted to sustains even with partial recycling of biomass.

Minimal data needs

1. Initial characterization of field soil, in different treatment plots is a must. Divide each treatment into six sub-plots (treat as replication). Sample soil from at least three spots per sub-plot at 0-15, 15-30 and 30-60 cm depths by using a 40 mm diameter soil corer and pool the spots depth-wise. The resultant 18 soil samples (6 replication x 3 depth) per treatment be analyzed for total and available N, total and available P and non-exchangeable K (for areas/soils where K is a limiting factor). Soil samples from top 15 cm profile be analyzed for pH, EC, total and available N, total and available P, OC%, siderophore producing microorganisms, microbial biomass carbon, microbial biomass nitrogen and dehydrogenase activity. Soil samples from the other two depths be analyzed only for total and available N, total and available P. It is likely that researchers conducting the proposed experiment may not have facilities for these analyses. In such a case, they can identify relevant laboratories for the different analyses on charge basis, or develop some research linkages with other researchers.

2. Grain and stover yield of each crop in all the treatments/replications.

3. Preparing balance sheet of nutrients (at least N and P) inputs and outputs is also important. All the items added to the two treatment plots for crop production or removed from them (eg, grains at harvest) should be characterized for N and P.

4. Soil 'N' and 'P', both total and available, twice a year, preferably just before sowing in rainy season and soon after harvest of postrainy season crops. Analysis of 'K' can also be done at location(s) where this element is known to be limiting.

5. Measuring rainwater run-off and quantity of soil going with it are important and they should be measured where feasible. Where irrigated, water input should also be quantified per crop season in all the treatments.

6. Soil microbiology and soil biology related parameters stated above, should be studied at start of the experiment as part of site characterization (as stated in item 1 above) and subsequently after a gap of about two years say in year 1, 3, 5 etc.

7. Damage percent by insect-pest at crop growth stage and at harvest of each treatment and crop. At least ten plants per replication and six replications/plots per treatment should be observed at about 50 days age of crop and at harvest.

8. Determining population of predators/parasites per plant in each treatment is considered important. Spiders and Coccinellids can be readily counted at crop growth stage when insect activity is generally at its maximum. At least ten plants per replication (total 60 plants per treatment should be observed).

Discussions

The different features of the OF practices narrated in the proposed experiment are focused on small farmers. It is realized that several suggestions, particularly that of growing crops without tillage, are least researched areas. There is ample evidence that crops can be grown without tillage or just with conservation tillage (Hajare et al. 1997). The funding provided by the NPOF can therefore be used to develop this experience, data and then confidence in the value of such less explored features. Sowing crops in the presence of large quantity of plant biomass on soil surface in the OF treatment will remain an issue until a suitable planting device is developed. A method of quoting seeds with thick layer of soil and broad casing it for sowing has been tried with partial success and needs refinement. Punch planter, a recently developed concept, may help solve the problem. In the on-going experiment at ICRISAT, any fresh biomass addition is done soon after sowing (using bullock drawn equipment called tropicultor) of crops (done only in the rainy season, being a rainfed experiment). Seedlings emerged even from about 10 cm thick layer of plant biomass. Much of the applied biomass decomposed during the rains. Any un-decomposed biomass, (eg, thick-stems of *Gliricidia*) was manually removed just before sowing so that it does not interfere with tillage and placed back soon after sowing.

A reduced yield in the OF treatment plots, particularly in the initial about three years is widely observed and published. But most of these reports are from temperate climates. There are, however, indications from our limited experience that this period of reduced yield can be greatly minimized, if not eliminated, in tropical conditions. Liberal spraying of crops with wash of vermicompost prepared from leguminous plants such as *Gliricidia* and of those having biopesticide value such as neem (*Azadirachta indica*); growing high biomass producing cultivars of leguminous crops such as pigeonpea (medium to long duration) and cowpea as grain crops and returning their biomass to soil can be important in the endeavor to harvest high yield with OF, right from year 1.

Plant biomass and vermicompost, key sources for crop nutrients in OF treatments, should be produced on-farm, if it has to be economical for a farmer. Value of the beneficial microorganisms, another important input for OF, can be harnessed by involving earthworms and cow dung. Ideas and strategies to produce and use these two important inputs have been suggested.

Experiment model presented here is based on the experience at ICRISAT. There can be some variations in respect of cropping systems and crop husbandry practices depending on the local situations and local resources available to a researcher. But the broad guidelines on treatments should be observed.

Research stations are generally very different from farmers' fields, the way land and crops are managed. Interested researchers are encouraged to conduct the proposed experiment on a farmers' field. It may be treated as a researcher managed on-farm experiment. Location of the experiment may be nearest to the research station to reduce travel time and cost. Besides serving as a demonstration plot at farmers' fields, it may add value on scale-up phase of the technology of OF.

Overall we are convinced that some features such as recycling plant biomass and use of Vermicompost and botanicals used by the OF practitioners have sound scientific basis and there are reports in scientific journals. There are, however, several more features on which research by mainstream science is scanty and some others perhaps have not been addressed at all. OF as a farming system seems pro small and marginal farmers (owning less than 2 ha area) that are majority in India, and needs appropriate evaluations by the mainstream science.

***Acknowledgements**. Substantial information and knowledge shared in this document came from several farmers and organic farming enthusiasts. Subhash Sharma of village Doroli, Yavatmal district of Maharashtra, Manohar Parchure of Nagpur and Dipak Suchde of Panvel, Maharashtra, shared wealth of their knowledge and vast experience with us. JSS Jyothsna, M Kranthi, K Papa Rao and PVS Prasad helped us in collating information and data used in this paper. PVS Prasad and J Nalini typed the manuscript. We sincerely thank all for their inputs.*

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Table 1. Yield (t ha^{-1}) of crops in different years in the field experiment with four different crop husbandry systems, field BW3, ICRISAT, Patancheru.

	Year 2		Year 3		Year 4		Year 5		Year 6	
Treatments	Rainy (S)	Postrainy (P)	Rainy (C)	Postrainy (Co)	Rainy (M)	Postrainy (P)	Rainy (C)	Postrainy (Co)	Rainy (M)	Postrainy (P)
LC 1	2.82(0.140)	3.05(0.116)	0.28(0.020)	0.95(0.018)	3.80(0.048)	0.65(0.019)	0.46(0.016)	1.32(0.039)	5.12(0.158)	0.95(0.020)
LC 2	2.16(0.113)	2.87(0.106)	0.14(0.017)*	0.90(0.030)	3.30(0.095)	0.66(0.018)	0.52(0.015)	1.24(0.038)	4.89(0.167)	0.93(0.014)
MA	3.29(0.066)	1.45(0.124)	0.29(0.010)	0.44(0.020)	3.04(0.055)	0.72(0.022)	0.34(0.017)	1.42(0.035)	5.27(0.131)	0.89(0.014)
MA+biomass	3.19(0.126)	1.94(0.085)	0.39(0.014)	0.68(0.025)	3.68(0.081)	0.57(0.015)	0.38(0.015)	1.63(0.036)	6.06(0.127)	0.85(0.016)
Mean	2.87	2.33	0.27	0.74	3.46	0.65	0.43	1.40	5.34	0.90

S= Sorghum, P= Pigeonpea, C= Cowpea, Co= Cotton, M= Maize
*= extensive damage by aphids, Data in parenthesis are + SE's

Table 2. Stover yield (t ha^{-1}) of crops in different years in the field experiment with four different crop husbandry systems, field BW3, ICRISAT, Patancheru.

	Year 2		Year 3		Year 4		Year 5		Year 6	
Treatments	Rainy (S)	Postrainy (P)	Rainy (C)	Postrainy (Co)	Rainy (M)	Postrainy (P)	Rainy (C)	Postrainy (Co)	Rainy (M)	Postrainy (P)
LC 1	4.37(0.165)	7.21(0.339)	5.91(0.624)	2.63(0.058)	5.26(0.084)	1.70(0.043)	1.92(0.062)	3.83(0.095)	5.14(0.150)	1.65(0.073)
LC 2	3.74(0.108)	7.41(0.246)	5.79(0.412)	2.43(0.060)	4.91(0.125)	1.73(0.059)	2.27(0.066)	4.04(0.103)	5.72(0.190)	1.67(0.058)
MA	5.51(0.135)	5.07(0.347)	5.19(0.456)	5.09(0.165)	4.24(0.085)	2.04(0.042)	1.76(0.053)	4.32(0.134)	5.75(0.110)	1.94(0.066)
MA+biomass	4.65(0.176)	6.96(0.283)	6.81(0.421)	5.29(0.317)	5.18(0.103)	1.90(0.076)	2.59(0.083)	4.38(0.091)	5.99(0.229)	2.00(0.041)
Mean	4.57	6.66	4.92	3.86	4.90	1.84	2.14	4.14	6.15	1.82

S= Sorghum, P= Pigeonpea, C= Cowpea, Co= Cotton, M= Maize
Data in parenthesis are + SE's

Table 3. Microbial population (log_{10}cfu g^{-1}) in Amrit paani, cowdung and compost.

Types of Microorganisms	Amrit paani		Cow dung		Compost	
	Day 1	Day 3	ICRISAT study	CRIDA study	OF (n = 7)	CF (n = 14)
Total bacteria	6.96	7.07	7.35	9.8	7.12-7.03	5.21-6.68
Total fungi	4.00	4.00	6.25	3.8	4.64-6.45	5.04-6.27
Total actinomycetes	<4.0[1]	<4.0[1]	6.22	5.1	6.04-6.74	5.34-6.69
Siderophore producers	6.00	6.78	5.82 - 8.26	ND	6.07-8.11	4.29-6.76
Azotobacter like bacteria	5.00	<4.0[2]	<3.00	ND	ND	ND
Pseudomonas fluorescens	5.41	5.83	<3.00	5.3	5.30-6.89	5.47-6.66
P- solubilizers	5.85	<4.0[3]	<2.00	5.1	6.64-7.09	5.60-7.06
Cellulolytic bacteria	ND	ND	ND	5.15	ND	ND

cfu = colony forming units, OF =Organic Farming, CA = Conventional Agriculture, ND = Not determined, n = number of samples determined.

1. Bacterial population was very high ($>10^7$) that affected detection of actinomycetes by using Actinomycetes Isolation Agar (HiMedia lab. Ltd. Mumbai)
2. Population of non-azotobacter like organisms was high ($>10^7$) as a result it was difficult to detect the desired type.
3. Population of bacteria without hallow zone (a characteristic of P-solubilizing bacteria) were present in large number ($>10^6$), it made detection of hallow very difficult.

Note: All the microorganism present in cow dung should also be present in Amrit Paani, dung being one of its constituents. But it was not the case. It could be because batch of dung was different for the two studies. Also, Amrit Paani has other constituents and a different environment for growth of microorganisms. This aspect needs further studies.

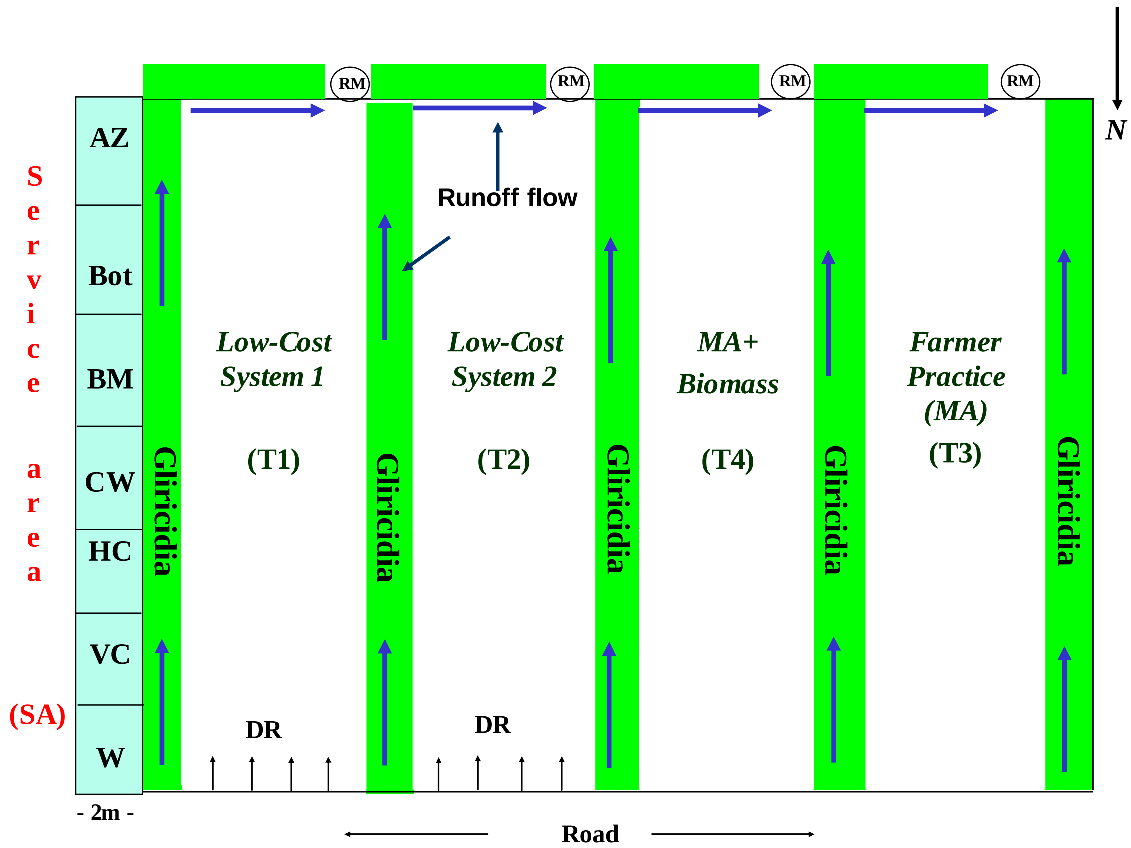

Figure 1. Layout of a field experiment ongoing at ICRISAT since June 1999 on a rainfed Vertisol. Each treatment is surrounded on three sides by one row of *Gliricidia* on a 1.5 m wide bund. The area occupied by Gliricidia and other features on left side can be viewed as service area for the organic farming treatment and is an important feature. The different items of services include CW = compost wash or vermiwash preparation tanks; W = area for placing weeds for future use as compost; AZ = water ponds (4 m^2) lined with polyethylene sheet, having 5 cm depth of water to grow Azolla as cattle-feed supplement; HC= Honeybee cages; VC = space for year-round preparation of Vermicompost; RM = Rainfall runoff meters to measure runoff water; DR = Diversity rows, one after every four rows of cotton, has at least five other crop plants known to farmers as promoting beneficial insects; BM = space for keeping any spare biomass for use as surface mulch in the experiment; Bot = Area for growing botanicals (eg, Dhatura, Adathoda, etc.) for use as biopesticides.

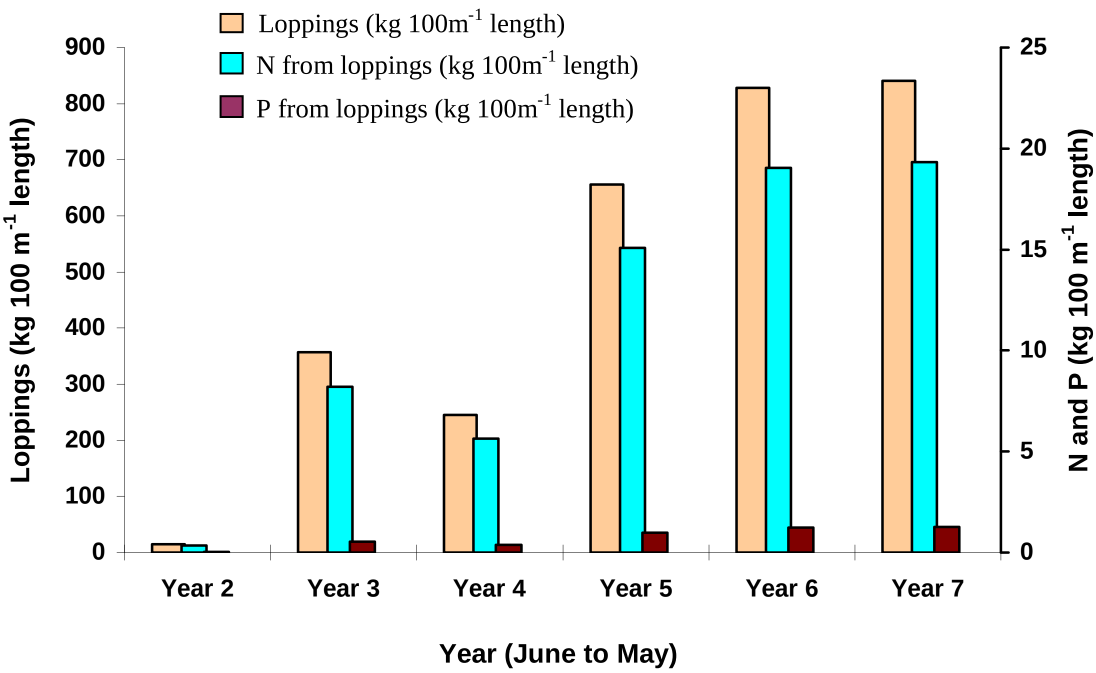

Figure 2. Yield of dry lopping and N and P through lopping of *Gliricidia* grown on boundary of an on-going long-term experiment (since June 1999) on a rainfed Vertisol, ICRISAT, Patancheru.