# Organic Farming in Rainfed Agriculture

## Opportunities and Constraints






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Based on invited papers from faculty of ICAR Winter School on "Organic Farming in Rainfed Agriculture" held at CRIDA, 1 - 21, November, 2007

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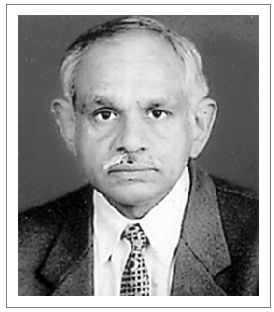
# Foreword



Organic Farming has emerged as an important priority area globally in view of the growing demand for safe and healthy food and concerns on environmental pollution associated with the indiscriminate use of agro-chemicals. Though the use of chemical inputs in agriculture is inevitable to meet the growing demand for food in India, there are opportunities in selected crops and niche areas where organic production could be encouraged to tap the domestic and export markets. Keeping this in view, the Government of India initiated the National Programme on Organic Production (NPOP) in Xth Five Year Plan under which many promotional and policy initiatives were taken up. The Indian Council of Agricultural Research (ICAR) also initiated a network project on organic farming and data is being generated on the feasibility and economics of organic production of important crops in various agro-ecological regions of the country.

Farmers in rainfed areas grow a large variety of crops with negligible inputs. Through proper training and organization of farmers groups, some of the areas and crops with good market potential can be encouraged to go organic. However, there exist several research gaps both in nutrient and pest management in different production systems which need to be bridged to enable farmers to produce crops organically. The main challenge is to evolve a package of practices by using inputs permitted in certified organic farming without compromising on the yield levels. I am happy to note that CRIDA has organized a Winter School on Organic Farming in Rainfed Agriculture during November 1-21, 2007 during which a large number expert faculty shared their experiences. The invited papers from the faculty have been reviewed and brought out in the form of a book by Dr. B. Venkateswarlu, the Course Director and his colleagues.

This book contains very useful information on the scope of organic farming in different rainfed crops and cropping systems, opportunities in nutrient management through green leaf manuring, bio-fertilizers, vermicompost and other permitted inputs, role of cropping systems in soil fertility build up; use of bio-pesticides and bio-agents for non-chemical pest management, organic horticulture, dairy farming, policy and promotional activities in different states and certification aspects of organic farming. I am confident that this publication will be useful to researchers, development department officials, extension staff, policy makers and all those interested in organic farming.

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# Contents

# Status of Organic Farming in India and the World

**A.K. Yadav***

## Introduction

During the last two decades, there has been a significant sensitization of the global community on environmental conservation and safe food. Organic Agriculture (OA) is now becoming mainstream all over the world. While OA has a long history, the modern organic movement is radically different from its original form. Now it has environmental sustainability at its core in addition to the concerns for healthy soil and healthy food.

In India, organic farming has started simultaneously from two streams. While the commercial growers of spices, basmati rice and cotton adopted organic for premium prices in export market, resource-poor farmers in rainfed marginal lands adopted it as an alternative livelihood approach, which not only promises clean environment and healthy food but also ensures soil fertility, long-term sustainability and freedom form debt and market forces. What is unique with this growing concept of organic farming in India is that, it holds the last hope to the farmers.

### The World Status

As per the latest survey conducted by IFOAM and SOEL Association (Willer and Yussefi 2007), almost 31 million hectares (m.ha) are currently managed organically by more than 6,00,000 farmers worldwide. This constitutes 0.7 per cent of the agricultural land of these countries according to the 2007 survey. Countries with most organic land are Australia / Oceania with 11.9 m.ha, followed by Europe with 7 m.ha. Latin America (5.8 m.ha), Asia (2.9 m.ha), North America (2.2 m.ha) and Africa (0.9 m.ha).

Currently countries with more organic lands are Australia (11.8 m.ha), Argentina (3.1 m.ha), China (2.3 m.ha) and US (1.6 m.ha). The number of farms and the proportion of organically managed land compared to conventionally managed one is highest in Europe. There has been major growth of organic area in North America and Europe. Both have added over half a million ha each during 2005-06. In North America, it represents an increase of almost 30%, an exceptional growth. In most other countries, organic farming is on the rise. There are also some decreases of organic land (extensive pastoral land) in China, Chile and Australia.

As per 2007 survey, land use information was available for 27 million hectares. More than half of the organic agricultural land is used for permanent pastures/grassland, one quarter is used for arable cropping, 10% for permanent crops, followed by other crops (5%) and other land use (1%). On a global level, permanent pastures / grassland (19.8 m.ha) account for almost two third of the world's organic land. More than half of this grassland is in Australia. Furthermore, large areas of permanent pastures are in Latin America and Europe.

The main crop categories for arable land are cereals followed by fodder crops, other arable crops, set-aside/green manuring, protein crops, vegetables, oilseeds, industrial crops, medicinal and aromatic plans, root crops, seed production etc. Besides the above, there

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is about 62 m.ha of organic wild collection area with 979 organic wild collection projects, world over. The largest collection areas are in Europe an Africa (almost 27 m.ha each). In terms of quantities, the important wild collected products are: bamboo shoot (36%), fruits and berries (21%) and nuts (19%).

The global sales of organic food and drinks have increased by 43% from 23 billion US$ in 2002 with sales reaching 33 billion US$ in 2005. Although, organic agriculture is now present in most parts of the globe, demand remains concentrated in Europe and North America. These two regions are experiencing under supply because the production is not meeting the demand. Thus large volumes of imports are coming in from other regions. Production in developing world is rising at much faster rate than that in the industrial countries. For example, the amount of organic farm land increased in triple digits in Asia, Africa and Latin America since 2000, whereas only double digit growth has been observed in other regions.

Demand for organic products mainly comes from affluent countries. Six of the G-7 countries comprise 84% of global revenues. This disparity between production and consumption of organic foods puts the industry in a fragile condition. A dip in demand from Europe and /or North America would have a major impact on global production of organic food. The industry could lose confidence as export markets close, causing oversupply and organic food prices to drop. The organic food producers in Asia, Africa and Latin America have been advised to become less reliant on exports and develop internal markets for their products. By developing internal markets, the business risks can be reduced to minimum. Consumers can also benefit by having the access to locally produced organic foods.

## Standards and Regulation – Global View

Currently, more than 60 countries have a regulation on organic foods. Worldwide, 395 organizations offer organic certification services. Most certification bodies are in Europe (160) followed by Asia (93) and North America (80). The countries with the most certification bodies are US, Japan, China and Germany. 40% of the certification bodies are approved by the European Union, 32% have ISO 65 accreditation and 28% are accredited under the US National Organic Programme. Under India's National Programme on Organic Production (NPOP), 11 certification bodies have been authorized to oversee and certify the organic products.

## Organic Agriculture in India

Since January 1994 "Sevagram Declaration" for promotion of organic agriculture in India, the organic farming has grown many folds and number of initiatives at Government and Non-Government level have given it a clear direction. While National Programme on Organic Production (NPOP) defined its regulatory framework, the National Project on Organic Farming (NPOF) has defined the promotion strategies and provide necessary support for area expansion under certified organic farming. Nine states have formulated organic promotion programmes and are trying to formulate the organic policies. Three years ago states, like Uttarakhand moved to make organic farming a thrust area for agricultural development. States of Mizoram and Sikkim declared their intention to go totally organic. In March 2007, the Government of Nagaland has also declared its intension to work for total organic and defined organic pathway and policies. Under NPOFs service provider scheme, more than 300 farmer groups have been developed throughout the country to spread organic farming. Various other schemes of NPOF being operated through the state Governments and many non-government agencies have also contributed significantly to the growth of organic agriculture.

## Growing certified area

Before the implementation of NPOP during 2001, and introduction of accreditation process for certification agencies, there was no institutional arrangement for assessment of organically certified area. Initial estimates during 2003-04 suggested that approximately 42,000 ha of cultivated land were certified organic. By 2005, India had brought more than 2.5 million ha of land under certification. Out of this, while cultivable land was approximately 76,000 ha, remaining area was forest land for wild collection. Growing awareness, increasing market demand, increasing inclination of farmers to go organic and growing institutional support have resulted into more than 200% growth in certified area during the last two years. The state wise area brought under certification process during 2005-06 and 2006-07 are given in Table-1.

**Table 1 : Total area under organic certification process (certified and under conversion) during the year 2006-07**

| Sl. No. | State | Area in ha. | | |
|---|---|---|---|---|
| | | Certified Area | Under Conservation | Total |
| 1. | Andhra Pradesh | 5561.17 | 4925.90 | 10487.07 |
| 2. | Arunachal Pradesh | 65.87 | 632.77 | 698.64 |
| 3. | Assam | 2526.61 | 540.24 | 3066.85 |
| 4. | Bihar | 0 | 0 | 0 |
| 5. | Chhattisgarh | 279.16 | 28.72 | 307.88 |
| 6. | Delhi | 3632.63 | 1830.35 | 5462.98 |
| 7. | Goa | 4100.50 | 2849.80 | 6950.30 |
| 8. | Gujarat | 7102.31 | 658.51 | 7760.82 |
| 9. | Haryana | 3382.54 | 15.78 | 3398.32 |
| 10. | Himachal Pradesh | 69.03 | 9507.70 | 9576.73 |
| 11. | J & K | 32541.79 | 0 | 32541.79 |
| 12. | Jharkhand | 10.50 | 2253.35 | 2263.85 |
| 13. | Karnataka | 8735.06 | 2976.78 | 11711.84 |
| 14. | Kerala | 11631.93 | 3112.73 | 14744.66 |
| 15. | Manipur | 913.68 | 5105.87 | 6019.55 |
| 16. | Maharashtra | 41390.48 | 72238.44 | 113628.92 |
| 17. | Madhya Pradesh | 87536.03 | 59875.81 | 147411.84 |
| 18. | Mizoram | 0 | 16802.50 | 16802.50 |
| 19. | Maghalaya | 0 | 304.40 | 304.40 |
| 20. | Nagaland | 0 | 878.89 | 878.89 |
| 21. | Orissa | 66625.42 | 7959.69 | 74585.11 |
| 22. | Punjab | 347.60 | 698.36 | 1045.96 |
| 23. | Rajasthan | 15034.26 | 9697.53 | 24731.79 |
| 24. | Sikkim | 274.82 | 1531.91 | 1806.73 |
| 25. | Tripura | 0 | 0 | 0 |
| 26. | Tamilnadu | 3414.09 | 1652.39 | 5066.48 |
| 27. | Uttar Pradesh | 5589.56 | 1700.57 | 7290.13 |
| 28. | Uttaranchal | 3178.63 | 5250.88 | 8429.51 |
| 29. | West Bengal | 7332.75 | 3147.18 | 10479.93 |
| 30. | Other | 510.52 | 966.32 | 1476.84 |
| | **Total** | **311786.94** | **217143.40** | **528930.31** |

## Decreasing cost of certification

High cost of certification had always been a matter of concern for small and marginal farmers. But with the increasing competition, increasing number of producers and introduction of Grower Group Certification (GGC) system, per farmer costs have come down drastically. The costs which were ranging from Rs.1.5 to 2.0 lakh per individual project and Rs.500 to 2500 per farmer in groups have come down to Rs.45,000 to 75,000 in case of individual projects and Rs.100 to 150 per farmer in groups. Recently, the initiatives taken up by Government of India to promote State Government bodies as certification agencies has further reduced the prices. The Uttaranchal State Organic Certification agency is offering certification at a price of Rs.10,000 to 15,000 per project.

## Role of National Project on Organic Farming in Promotion of Organic Farming

Department of Agriculture and Cooperation, Ministry of Agriculture, Govt. of India has launched a Central Sector Scheme "National Project on Organic Farming" during X five year plan w.e.f. 1st October, 2004. Main objectives of this scheme are as follows:-

1. Capacity building through service providers.
2. Financial support to different production units engaged in production of bio-fertilizers, compost and vermi-compost etc.
3. Human resource development through organizing training on Certification and Inspection. Production and Quality Control of Organic Inputs, Training of Extension Officer / Field Functionaries, Farmers Training on Organic Farming etc.
4. Field demonstration on organic inputs and enriched biogas slurry.
5. Setting up of Model Organic Farms.
6. Market development for organic produce.
7. Development of Domestic Standards
8. Support to new initiatives on technology related to organic farming.
9. Awareness programmes etc.
10. Quality control of various bio-fertilizers and organic fertilizers as per fertilizers control order.

Details of total achievements in respect of different components during the two and half year period of 10th plan are given in Table-2. Details of funds released to different states during the same period are given in Table-3.

**Table 2: Physical Targets and Achievements under the National Project on Organic Farming during 10th Five Year Plan**

| S.No. | Components | | Total Achievements (no.) |
|---|---|---|---|
| **A.** | **Capacity Building through service providers** | | **308** |
| **B.** | **Organic Inputs Production Units** | | |
| | 1. | Fruit / vegetable compost units | 15 |
| | 2. | Bio-fertilizer production units | 24 |
| | 3. | Vermiculture hatcheries | 521 |
| **C.** | **Training Programmes** | | |
| | 1. | Training on certification and inspection agencies | 52 |
| | 2. | Training on production & quality control of organic farming | 169 |
| | 3. | Training of extension staff | 302 |
| | 4. | Training of farmers on organic farming | 1356 |
| **D.** | **Field demonstrations** | | |
| | 1. | Field demonstrations on organic inputs | 3344 |
| | 2. | Setting up of Model organic farm | 232 |
| | 3. | Field demonstration on enriched biogas slurry | 782 |

**Table 3: Details of funds sanctioned and released during the period from 2004-06 to 2006-07 under National Project on Organic Farming (Rs in lakh)**

| Sl.No. | Name of the States | 2004-05 | 2005-06 | 2006-07 | Total |
|---|---|---|---|---|---|
| | **North Eastern States** | | | | |
| 1. | Assam | 1.0725 | 66.71 | 3.68 | 71.47 |
| 2. | Arunachal Pradesh | 4.4875 | 30.16 | 41.28 | 75.93 |
| 3. | Manipur | 6069 | 5.74 | 101.58 | 114.02 |
| 4. | Meghalaya | 2.34 | 38.07 | 0.78 | 41.19 |
| 5. | Mizoram | 45.3125 | 22.50 | 166.59 | 234.4 |
| 6. | Nagaland | 0 | 86.69 | 88.31 | 175 |
| 7. | Sikkim | 1034 | 49.11 | 32.58 | 92.03 |
| 8. | Tripur | 8.975 | 25.84 | 30.00 | 64.81 |
| | **Other states** | | | | |
| 1. | Andhra Pradesh | 0 | **34.6625** | **39.60** | **74.265** |
| 2. | Bihar | 0 | 1.13 | 69.36 | 70.49 |
| 3. | Chhattisgarh | 14.975 | 0 | 119.24 | 134.21 |
| 4. | Delhi | 0 | 6051 | 1.82 | 8.335 |
| 5. | Goa | 0 | 4039 | 4.13 | 8.52 |
| 6. | Gujarat | 2.0 | 59.74 | 0 | 61.75 |
| 7. | Haryana | 0 | 4040 | 48.23 | 52.63 |
| 8. | Himachal Pradesh | 2.0 | 12.78 | 50.56 | 65.335 |
| 9. | Jharkhand | 0 | 6.96 | 93.0 | 99.96 |
| 10. | Karnataka | 1.78 | 25.43 | 57.10 | 84.31 |
| 11. | Kerala | 1.71 | 69.56 | 50.20 | 121.74 |
| 12. | Lakshdweep | 0 | 2.30 | 0 | 2.30 |
| 13. | Madhya Pradesh | 6.885 | 31.81 | 149.45 | 188.14 |
| 14. | **Maharashtra** | **5.385** | **102.22** | **169.93** | **277.535** |
| 15. | Orissa | 0 | 7.20 | 197.11 | 204.31 |
| 16. | Punjab | 0.24 | 0.08 | 16.16 | 16.48 |
| 17. | Rajasthan | 0 | 13.74 | 17.56 | 31.30 |
| 18. | Tamilnadu | 1.00 | 87.01 | 72.96 | 160.57 |
| 19. | Uttar Pradesh | 9.35 | 44.34 | 51.88 | 105.57 |
| 20. | Uttaranchal | 48.20 | 0.88 | 332.72 | 381.80 |
| 21. | West Bengal | 0 | 24.39 | 99.13 | 123.52 |
| 22. | NABARD | 150.0 | 732.5 | 0 | 882.50 |
| 23. | NCDC, New Delhi | 0 | 100.0 | 0 | 100.0 |
| | **Total** | **322.43** | **1698.34** | **2106.89** | **4126.167** |

## Growing organic food market

During the last seven years, there have been many estimates on the size of the organic food market in India: some say "organic foods are the super rich man's food and have negligible or no market, while some have speculated to be a market of about 2-3 million consumers with estimated potential of Rs.96 billion based on a modest spending of Rs.4,000/- per month. Recently, International Competence Centre for Organic Agriculture (ICCOA) conducted a survey in top 8 metro cities of India (which comprise about 5.3 % of the households) to assess the organic food market potential and

Table 4: Market potential for organic foods by study products in top 8 metros in India

| Study products | Accessible potential | | Market potential | |
|---|---|---|---|---|
| | Rs Million | % | Rs Million | % |
| Vegetables | 1030 | 18 | 3220 | 22 |
| Fruits | 710 | 13 | 2460 | 17 |
| Milk | 520 | 9 | 1660 | 11 |
| Dairy product | 500 | 9 | 1110 | 8 |
| Bakery products | 480 | 9 | 1860 | 13 |
| Oils | 320 | 6 | 590 | 4 |
| Rice | 270 | 5 | 460 | 3 |
| Ready to eat | 260 | 5 | 360 | 2 |
| Wheat – Atta | 250 | 5 | 4700 | 3 |
| Snacks | 220 | 4 | 560 | 4 |
| Frozen foods | 220 | 4 | 300 | 2 |
| Dals | 180 | 3 | 320 | 2 |
| Health drinks | 170 | 3 | 340 | 2 |
| Canned foods | 170 | 3 | 230 | 2 |
| Tea | 120 | 2 | 230 | 2 |
| Coffee | 100 | 2 | 170 | 1 |
| Condiments | 50 | 1 | 120 | 1 |
| Spices | 40 | 1 | 80 | 1 |
| Sugar | 2.8 | 0 | 4.8 | 0 |
| Baby food | 0.1 | 0 | 0.3 | 0 |
| **Total** | **5620** | **100** | **14520** | **100** |

Source: Rao *et al*., 2006. The market for organic foods in India, ICCOA Publication

consumer's inclination and behavior towards the organic food. The market study estimates the accessible market potential for organic foods in 2006 in top 8 metros of the country at Rs.562 crores taking into account the current purchase patterns of consumer in modern retail format. The overall market potential is estimated to be around Rs.1452 crores, the availability will however be a function of distribution, retail penetration and making the product available to the customer.

## Future prospects

Although India has traditionally been a country of organic agriculture, but the growth of modern scientific, input intensive agriculture has pushed it to wall. But with the increasing awareness about the safety and quality of foods, long-term sustainability of the system and only hope for rainfed – resource poor farmers, organic farming has emerged as an alternative system of farming which not only addresses the quality and sustainability concerns, but also ensures a debt free, profitable livelihood option. With in a short span of five years, organic agriculture has grown from a controversial niche subject to a mainstream agriculture. It has grown at a rate of nearly 200% in the last two years and is likely to grow by more than 100% in the next five years to come. Institutional mechanisms and Governmental support has ensured its sustained growth during the 11$^{th}$ plan period. But to keep the hopes of these farmers, efforts are necessary to link them to market. For this efforts need to be made on the same scale, as has been initiated for increasing the area.

# Organic Farming in Rainfed Agriculture: Prospects and Limitations

**B. Venkateswarlu***

## Introduction

The rainfed agro-ecosystem in India covers arid, semi-arid and sub humid zones which represents more than 70% of the geographical area. Sixty six per cent of the 142 m.ha. cultivated area is rainfed. Unlike irrigated areas, where homogenous, high intensive cropping systems are common, rainfed farming systems are more diverse and heterogenous. Coarse cereals, pulses, oilseeds and cotton are the major cropping systems. Livestock farming plays an important role in farmer's livelihood. Historically, rainfed farmers followed a low intensive sustainable farming system with excellent integration of crops-trees-pastures and livestock. However, from 70s, with the introduction of hybrids and high yielding varieties particularly in sorghum, pearlmillet and oilseeds, a shift of cropping pattern towards monoculture took place and a corresponding increase in the use of chemical inputs in crop production. The various developmental schemes of the Government of India under different missions have also contributed towards increased use of chemical inputs and higher production.

## Rainfed Agriculture: Low Input Farming

However, the vast majority of rainfed farmers in remote areas still practice low external input or no external input farming which is well integrated with livestock, particularly small ruminants. The average use of chemical fertilizers in rainfed areas based on a survey of non-irrigated SAT districts was found to be 18.5 kg as against 58 kg in the irrigated districts (Katyal and Reddy, 1997). Based on several surveys and reports, it is estimated that up to 30% of the rainfed farmers in many remote areas of the country do not use chemical fertilizers and pesticides. Thus, many resource poor farmers are practicing organic farming by default. The Government of India task force on organic farming and several other reviewers have identified rainfed areas and regions in north east as more suitable for organic farming in view of the low input use (GOI, 2001; Dwivedi, 2005; Ramesh *et al 2005)*.

Based on research data generated under the All India Coordinated Research Project on Dryland Agriculture and related projects during the last 25 years, it is evident that chemical fertilizers have significantly contributed to improved productivity in rainfed crops, even in areas where legumes are part of the cropping systems. However, long-term data suggest that even in drylands, sustainability of higher yields over a period of time is possible only when optimum nutrients are supplied through organics or a combination of organics and chemical fertilizers but not when supplied as chemical fertilizers alone (Hegde, 1988). Similarly in the area of pest management also, significant yield benefits were reported in a number of pulse and oilseed crops with the use of chemical pesticides initially but more recent data across the country particularly from the network projects on IPM under the National Agricultural Technology Project

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(NATP) clearly showed that sustainable yields are achieved only with integrated pest management (CRIDA, 2003). However, there have been many, but isolated examples of realizing on par yield levels (with that of IPM or using chemicals) in cotton, pulses and oilseed crops with non pesticidal management (NPM), particularly from trials conducted by NGOs across the country. But most often such data are not systematically analysed with cost benefit ratios.

However, all rainfed areas can not be treated at par. Crops like cotton, hybrid sorghum and millets, ground nut, pigeon pea receive relatively higher levels of chemical fertilizers and pesticides all over the country. The chemical input use increased where the varietal replacement was high and greater accessibility to farmers for surface or ground water for protective irrigation. Therefore, it is essential to delineate different regions and crops within rainfed areas depending on the nature and level of input use, so that a proper research and policy initiative can be taken up for identifying prospective regions/commodities

## Available Knowledge Base

Very few well replicated field trials were conducted on organic farming involving major rainfed crops, except for a six year trial on cotton in Maharashtra which showed reduction in cost of cultivation and increased gross and net returns compared to conventional cotton cultivation (Rajendran *et al* 2000). However, extensive information is available on the yield and economics with a number of rainfed crops and cropping systems where complete organic manures or organics as part of INM packages have been used (Lomte *et al* 2004). In most such trials however, no attention was paid on the method of pest management. In large number of on-farm trials conducted under the National Agricultural Technology Project (NATP), farmers practice was included as one of the treatments for comparison. In twenty five per cent of the 3000 on-farm trials conducted during 3 years in 5 production systems viz., rainfed rice, oilseeds, pulses, cotton and nutritious cereals, the farmers practice did not include any application of chemicals either as nutrients or for pest management. However, such no input treatments invariably resulted in 40-50% lower yields than the plots that received recommended level of inputs (CRIDA, 2003). The INM treatments however produced higher yield and better cost benefit ratios.

Extensive literature is also available on the usefulness of legume based inter and sequence cropping systems in the context of organic production. In general, the benefits from legume crop in the system to other component crop in terms of nutrient transfer are not found significant but the succeeding cereal crop benefitted due to the residual effect (Katyal and Reddy, 1997). Intercropping systems have also recorded low pest loads and emerged as a key component of IPM modules in pulse and oilseeds based cropping systems in large number of trials conducted under NATP (CRIDA, 2003). Therefore the cropping systems concept has to be built in, while designing the organic production protocols for rainfed crops. Vermicomposting, use of biomass raised on the bunds as source of nutrients and biofertilisers are other approaches that showed promise tried in rainfed areas across the country. Vermi composting in particular has been accepted by the rainfed farmers and gained momentum during the last 5 years.

Adoption of soil and water conservation measures, a key component of rainfed farming is also one of the pillars of organic farming. Mulching or mulch cum manuring, residue management, green leaf manuring, cover cropping are other strategies that conserve moisture and improve nutrient use efficiency in drylands which are also the essential components of organic production methods. The use of FYM or other organic nutrient sources during aberrant rainfall years in particular have an additional advantage of protecting the crop from drought besides the nutritional benefits, so critical in drylands. While there is no contradiction between these established rainfed farming technologies and the objectives of the organic farming, the only issue will be the labour and capital intensive nature of some of these technologies and its ultimate impact on the cost of production.

## Constraints in Scaling Up

Besides the well known limitation of the availability of FYM and other organic forms of nutrients in desired quantities as highlighted by Chhonkar (2004), water availability also is an important constraint for adoption of organic farming, particularly in arid and dry semi-arid tropics. Absence of surplus rainwater for harvesting and long periods of low soil moisture can limit the overall biomass production for recycling, green leaf manuring and on-farm composting. Application of 5-10 t FYM/ha is required in most crops to produce on par yields with recommended chemical fertilizers. Such level of inputs use can only be possible in limited areas for specific crops. However, biomass production during the off season (without competition with the *kharif* crop) through a legume cover cropping and its incorporation in the soil can be another strategy to over come the limitation of organic matter availability (Venkateswarlu *et al* 2007). Since the overall biomass production is linked to rainfall, using crop biomass either by composting or through recycling should be a major strategy in relatively high rainfall receiving areas in moist semi-arid and dry subhumid regions (750 - 1200 mm) while the dry semi-arid and arid areas (300 - 750 mm) may depend on use of FYM as the principal source, since live stock is a strong component in these regions.

Considering the low organic matter and fertility status of Indian soils, the yield decline during conversion period could be sharp in the absence of external inputs. In view of the limited biomass and organic resources available for use in rainfed areas, organic production either for domestic or export markets should be encouraged in highly selected areas and commodities. This strategy alone can sustain the production and marketing of organic food on a long term basis.

## Focus on Niche Areas and Commodities

Rainfed areas are reported to have relative advantage to go for organic farming primarily due to i) low level of input use, ii) shorter conversion period and iii) smaller yield reductions compared to irrigated areas, but no one can suggest any large scale conversion in view of the limitations referred above. Moreover, following WTO agreement, and expected free trade of commodities both within and outside the country, the cost of production is sure to play a major role in the profitability. Hence, rainfed farmers producing same commodity as in irrigated areas need to realize high yields in order to remain competitive. Moreover, large yield gaps still exist between research station productivity and farmers fields. Therefore, it is necessary that farmers have to increase the quantum and efficiency of input use and achieve higher productivity.

However, the inherent advantages of rainfed areas should be capitalized by encouraging organic farming in highly selected areas and commodities with edapho-climatic and price advantages. The primary focus should be on commodities which have export potential with price premiums. A list of such crops and the suggested areas are given in Table 1. Having selected the commodities, a two pronged strategy need to be followed for popularising organic farming. Firstly, areas where relatively low or no inputs are used and which are climatically well endowed with reasonable productivity levels may be identified. Farmers in contiguous areas can be encouraged to adopt farm management practices that are required in organic production. Yield levels in such areas may be further enhanced by using permitted inputs. A commodity and area oriented group certification system may be possible with the support of the Government

**Table 1 : Selected list of commodities with potential for organic production in rainfed regions**

| Commodity | Scope/Opportunity | Potential Area |
|---|---|---|
| Cotton | Demand for organically produced lint. To cut down on chemical use | Maharashtra, AP., Karnataka, Gujarat |
| Sesame | Demand for organic sesame seed for medicinal and confectionery uses | Gujarat, Rajasthan |
| Niger | Demand for niger seeds produced organically for bird feed in Europe | Tribal areas of different states, in particular Orissa and Chhattisgarh |
| Lentil | Preference for Indian lentil in world markets; organic product to fetch price premium | U.P. |
| Safflower | Growing market for safflower petals as natural food dye and herbal products | Maharashtra |
| Fingermillet | Scope to export fingermillet flour as health food ingredient | Karnataka, Orissa, Jharkhand |
| Medicinal herbs | Need for residue free crude drugs | All over India |
| Ginger/Turmeric | Demand for residue free spices/natural colours | Orissa |
| Groundnut | To produce residue/toxin free table varieties | Gujarat |
| Soybean | Demand for organically produced DOC for livestock feed | M.P. |

agencies and service providers. As a second strategy, areas where farmers are already realizing higher yields but using chemical inputs need to be identified and a systematic conversion protocols need to be introduced based on research data. Besides training and capacity building of farmers on production of inputs required for organic farming at farm level, the availability of other bio inputs like biofertilisers and bio pesticides need to be increased in selected areas by encouraging the setting up of bio resource centers. Forward linkages with certifying agencies and markets will be essential to sustain the initiative.

## Recommendations

While rainfed regions undoubtedly offer good scope for organic production atleast in niche areas and commodities, a number of research, development and policy issues need to be addressed before realizing the potential.

- Prepare an enlarged list of crops, herbs and livestock products which can be sourced from rainfed regions considering the international trade in organic food and allied products.
- Carry out a country wide survey/ inventorisation of areas in arid, semi-arid and dry sub humid regions about the level of chemical input use, productivity in selected commodities which have potential to fetch price premiums in international markets.
- Identify contiguous blocks of areas with little or no chemical input use and where productivity can be enhanced by using permitted inputs to enable group certification to farmers.
- To develop protocols for organic production of important commodities through farmers participatory network research. These protocols should be based on the entire cropping system approach and not on individual seasonal crops.
- To create awareness and capacity building of different stakeholders on different

aspects of organic production like cultivation, harvesting, certification and marketing.

- Develop preferential policy instruments for rainfed farmers particularly in terms of providing market information, subsidized supply of inputs and group certification.

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# Organic Farming Research in Madhya Pradesh

**P. Ramesh***

## Introduction

Green revolution technologies involving greater use of synthetic agro-chemicals such as fertilizers and pesticides with adoption of nutrient responsive high yielding varieties of crops has boosted the production per hectare in most cases. However, this increase in production has slowed down and in some cases there are indications of decline in productivity. Moreover the success of the green revolution in recent decades has often masked significant externalities, affecting natural resources and human health as well as agriculture itself (Subba Rao, 1999). Environmental and health problems associated with intensive agriculture have been increasingly well documented, but it is only recently that the scale of the costs has attracted the attention of planners and scientists.

Organic farming is often understood as a form of agriculture with use of only organic inputs for the supply of nutrients and management of pest and diseases. In fact it is a specialized form of diversified agriculture wherein problems of farming are managed using local resources alone. The term organic does not explicitly mean the type of inputs used rather it refers to the concept of farm as an organism. Often organic agriculture has been criticized on the grounds that with organic inputs alone farm productivity and profitability might not be improved because the availability of organic sources is highly restricted. True, organic resources availability is limited but under conditions of soil constraints and climate vagaries, organic inputs use have proved more profitable compared to agro-chemicals (Huang *et al*., 1993).

## Concept of organic farming

Organic farming/agriculture is one among the broad spectrum of production methods that are supportive of the environment. Organic production systems are based on specific standards precisely formulated for food production and aim at achieving agro ecosystems, which are socially and ecologically sustainable. It is based on minimizing the use of external inputs through use of on-farm resources efficiently compared to intensive agriculture involving the use of synthetic fertilizers and pesticides.

"Organic" in organic agriculture is a labeling term that denotes products that have been produced in accordance with certain standards during food production, handling, processing and marketing stages and certified by a duly constituted certification body or authority. The organic label is therefore a **process claim rather than a product claim**. Number of definitions have been proposed for organic agriculture. All the definitions however primarily focus on ecological principles as the basis for crop production and animal husbandry. To promote organic agriculture and to ensure fair practices in international trade of organic food, the Codex Alimentarius Commission, a joint body of FAO/WHO framed certain guidelines for the production, processing, labelling and marketing of organically produced foods with a view to facilitate trade and prevent misleading claims.

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Codex Alimentarius Commission defines "*organic agriculture as holistic food production management system, which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles and soil biological activity. It emphasizes the use of management practices in preference to the use of off-farm inputs, taking into account that regional conditions require locally adapted systems. This is accomplished by using, where possible, agronomic, biological and mechanical methods, as opposed to using synthetic materials, to fulfill any specific function within the system*" (FAO, 1999).

## Principles of soil fertility management in organic farming

Organic farming systems rely on the management of soil organic matter to enhance the chemical, biological and physical properties of the soil. One of the basic principles of soil fertility management in organic systems is that plant nutrition depends on "**biologically derived nutrients**" instead of using readily soluble forms of nutrients; less available forms of nutrients such as those in bulky organic materials are used. This requires release of nutrients to the plant via the activity of soil microbes and soil animals. Improved soil biological activity is also known to play a key role in suppressing weeds, pests and diseases (IFOAM, 1998).

There are several doubts in the minds of not only farmers but also scientists whether it is possible to supply the minimum required nutrients to crops through organic sources alone and even if it is possible how are we going to mobilize that much of organic matter. At this juncture, it is neither advisable nor feasible to recommend the switch over from fertilizer use to organic manure under all agro-ecosystems. Presently only 30 per cent of our total cultivable areas have irrigation facilities where agro-chemicals use is higher compared to rainfed zones. It is here that ingenuity and efforts are required to increase crop productivity and farm production despite of recurrence of environmental constraints of drought and water scarcity (Ramesh *et al*., 2005 b).

The basic requirement in organic farming is to increase input use efficiency at each step of farm operations. This is achieved partly through reducing losses and partly through adoption of new technologies for enrichment of nutrient content in manures. Technologies to enrich the nutrient supply potential from manures including farm yard manure three to four times are being widely used at organic farms (Subba Rao and Ramesh, 2007). According to a conservative estimate around 600 to 700 million tonnes of agricultural waste is available in the country every year, but most of it is not used properly. We must convert our filth/waste into wealth by mobilizing all the biomass in rural and urban areas into bioenergy to supply required nutrients to our starved soil and fuel to farmers (Veeresh, 1997). India produces about 1800 mt of animal dung per annum. Even if two-third of the dung is used for biogas generation, it is expected to yield biogas not less than 120 m $m^3$ per day. In addition the manure produced would be about 440 mt per year, which is equivalent to 2.90 mt N, 2.75 mt $P_2O_5$ and 1.89 mt $K_2O$ (Ramaswami, 1999).

Organic farm and food production systems are quite distinct from conventional farm in terms of nutrient management strategies. Organic systems adopt management options with primary aim to develop whole farm like a living organism with balanced growth in both crops and livestock holding. Thus **nutrient cycle is closed as far as possible**. Only the nutrients in the form of food are exported out of the farm. Crop residues burning are prohibited so is the unscientific storage of animal wastes and its application in fields. It is therefore, considered as more environmental friendly and sustainable than the conventional system. Farm conversion from high input chemical based system to organic system is designed after undertaking a constraint analysis for the farm with primary aim to take advantages of local conditions and their interactions with farm activities, climate, soil and environment so as to achieve as far as possible, the closed nutrient cycles with less dependence on off-farm inputs. **As far as possible** implies that only nutrients leaving the farm unit are those for human consumption (Subba Rao and Ramesh, 2006).

Crop rotations and varieties are selected to suit local conditions having potential to sufficiently balance the crops nitrogen demand. Requirements for other nutrients like phosphorus, sulphur and micronutrients are met with local, preferably renewable resources. Organic agriculture is therefore often termed as **knowledge based rather than input based agriculture**. Furthermore, organic farms aim to optimize the crop productivity under given set of farm conditions. This is in contrast with the concept of yield maximization through the intensive use of agrochemicals, irrigation water and other off farm inputs (Subba Rao *et al*., 2005). There are ample evidences to show that agrochemical based high input agriculture is not sustainable for long period due to gradual decline in factor productivity with adverse impact on soil health and quality (Stockdale *et al.*, 2000).

## Components of soil fertility in organic farming

### Using crop rotations

Crop rotation is a system where different plants are grown in a recurring defined sequence. Crop rotations including a mixture of leguminous fertility building and cash crops are the main mechanism for nutrient supply within organic system. Rotations can also be designed to minimize the spread of weeds, pests and diseases. The development and implementation of well-designed crop rotations is central to the success of organic production systems (Stockdale *et al*., 2000). White (1987) gives the range of amounts of nitrogen fixed by modulating crops in tropical and sub-tropical regions (100 kg N/ha/year) and temperate regions (200 kg N/ha/year). However, the actual amount of nitrogen fixed in any year is dependent on climatic conditions and choice of variety or cultivar.

### Green manures

Traditionally India has been using green manures like dhaincha, sunnhemp, wild indigo, cowpea, cluster bean, greengram, blackgram, berseem, etc either as a catch crop, shade crop, cover crop or forage crop. The green manure contributes about 60-200 kg N in about 45 to 60 days (Palaniappan, 1992). Some promising green manures are *Crotolaria juncea* (sunhemp), which is quick growing, more succulent and easy to produce seed, could accumulate 16.8 t/ha biomass with 159 kg N/ha. *Sesbania aculeata* (dhaincha), which could accumulate high biomass of 26.3 t/ha and is widely adapted could contribute about 185 kg N/ha. Similarly, the stem nodulating, water logging tolerant *Sesbania rostrata* could add biomass of 24.9 t/ha with N accumulation of 219 kg/ha. The drought tolerant self seeding *Tephrosia purpurea* could produce biomass of 16.8 t/ha which contribute 115 kg N/ha. The multipurpose green manure cum fodder cum cover crop *Phaseolus triobus* could generate biomass of 19.6 t/ha contributing 126 kg N/ha/season.

### Biofertilizers

Biofertilizers are microbial inoculants, which contain live cells of efficient nitrogen fixing microorganisms, which fix atmospheric nitrogen either symbiotically with host plant or free living as well as phosphate solubilizing microorganisms. Besides, many microbes also produce phytohormones which increase crop growth. Different types of biofertilizers like Rhizobium, Azotobacter, Azospirillum, Acetobacter, Blue Green Algae (BGE), Azolla, and Phosphate Solubilizing Microorganisms (PSM) are being largely used in India either for nitrogen or phosphorus nutrition. These microbial inoculants supply crop nutrients in soil habitat through microbial transformations.

### Managing crop residues

Crop residues can be an important source of nutrients to subsequent crops. It is well documented that different quantities of N, P, K and other nutrients are removed from and returned to the soil depending on crop species concerned. The quantity and quality of crop residues will clearly influence the build up of soil organic matter and the subsequent availability and timing of release of nutrients to following crops. Cereal straw, for example, contains only around 35 kg N/ ha compared to more than 150 kg N/ha for some vegetable residues. Residues also contain variable amounts of lignin and polyphenols, which influence decomposition and mineralization rates. Incorporation of N rich, low C: N ratio residues leads to rapid mineralization and a large rise in soil mineral N, while residues low in N such as cereal straw can lead to net immobilization of N in the short to medium term. The latter can be advantageous in preventing N leaching between crops. The inclusion of crops with a diverse range of C: N ratios can help to conserve N within the system (Watson *et al*., 2002).

### Application of composted animal manures

Animal manures are the most common amendments applied to the soil. Cattle account for about 90 % of the total animal dung and nutrients. Organic manures produced from non-organic farms may be brought onto the holding but there are restrictions. The quantity of nutrients in manures varies with type of animal, feed composition, quality and quantity of bedding material, length of storage and storage conditions. In organic systems, it is particularly important to conserve manure nutrients for both economic and environmental reasons. Composting is recommended in organic farming as a management tool for control of weeds, pests and diseases. Development of several compost production technologies like vermicomposting, phosphocomposting, N-enriched phospho-composting, etc improves the quality of composts through enrichment with nutrient bearing minerals and other additives. These manures have capacity to fulfill nutrient demand of crops adequately and promote the activity of beneficial macro- and micro-flora in soil. (Mohan Singh, 2003).

### Use of Agro-industry wastes

Press mud, coir pith, sea weed residues, cotton wastes, bagasse, biogas slurry, mushroom spent waste etc contribute substantial quantities of NPK besides secondary and micro nutrients.

### Oil cakes and other organic manures

Oil cakes of non-edible types like castor, neem and karanji (*Pongamia pinnata*) as well as edible cakes like groundnut, mustard are widely used in India as organic manures due to their high NPK content. Nimbin and Nimbicidin is said to inhibit nitrification processes. Animal wastes like bone meal, fish meal etc are also rich in nutrients and are often used in organic farming. Tapping and proper utilization of such locally available organic resources could provide substantial quantity of crop nutrients in organic farming.

### Naturally occurring mineral amendments

Some naturally occurring mineral amendments are allowed in a restricted manner in organic farming to supplement the crop nutrient requirements. These include rock phosphate, potassium sulphate, basic slag, gypsum (calcium sulphate), Epsom salt (magnesium sulphate), calcitic lime, dolomite lime, etc.

## Organic farming research at IISS, Bhopal

Experiments conducted at IISS, Bhopal to study the effect of organic and inorganic source of nutrients on the productivity and soil quality of soybean + red gram – chickpea sequential cropping indicated that application of farm yard manure @ 10 t/ha in combination with phosphocompost @ 3 t/ha recorded significantly higher productivity in terms of soybean equivalent yield compared to that of 100 % NPK through inorganic fertilizers. In general application of organics or the combination of organic and inorganic nutrients resulted in the improved nitrogen status of soil compared to that of inorganic fertilizers alone. The phosphorus and potassium status of soil was not affected due to treatments. However, there was a slight improvement in the P status of soil with the application of organics especially in phosphocompost-applied treatments (Ramesh *et al*., 2004).

Application of poultry manure @ 5 t/ha was found to give higher grain yields of both macaroni and bread wheat varieties compared to the vermicompost @ 7.5 t/ha or cattle dung manure @ 10 t/ha. On an average, macaroni wheat performed better than bread wheat in terms of grain yield, protein content and water use efficiency in both chemical and organic input based cropping system (Ramesh *et al*, 2005 a).

Under rainfed conditions of IISS, Bhopal, pigeon pea was taken up as a test crop to find out the most effective source of organic nutrients in comparison to chemical fertilizers during the rainy seasons of 2003 and 2004. The data indicated that among the manurial treatments, application of cattle dung manure (4 t/ha) recorded the highest seed yield, which was on par with that of chemical fertilizers. The post harvest soil data showed that the soil organic carbon, available N and K were higher in cattle dung manure treatment. Soil enzymes like dehydrogenase and phosphatase activity were significantly higher in organic manure treatments compared to chemical fertilizers and the control (Ramesh *et al*, 2006 a).

A 3-year (2004-07) field experiment was conducted to examine the relative effect of organic, chemical and integrated nutrient management practices on the productivity, crop quality, soil nutrient status and health in four cropping sequences viz. soybean-durum wheat (S-W), soybean-mustard (S-M), soybean-chickpea (S-C) and soybean-isabgol (S-I). The results indicated that in the first year (2004-05), the organic management practice (OMP) recorded 7.8, 5.6, 9.4, 3.0 and 2.5 % reduction in the productivity of soybean, durum wheat, mustard, chickpea and isabgol crops, respectively compared to the chemical management practice (CMP). However in the third year (2006-07), OMP recorded 10.6, 0.9 and 9.4% increase in the productivity of soybean, durum wheat and isabgol and 0.9 and 1.7% reduction in mustard and chickpea crops, respectively compared to the CMP. On an average, the total productivity of the system was 2.2 % less in OMP compared to the CMP while integrated management practice (IMP) recorded the highest total productivity (4.7 % higher). Among the four cropping systems, S-W recorded the highest and S-I, the lowest total productivity. The quality parameters assessed for the crops were not affected significantly among the three management practices. The nutrient status of soil in terms of available N, P and K were more favourable in OMP compared to CMP. A greater build up of nutrients in OMP was manifested especially in S-W and S-M compared to S-C and S-I cropping systems. Organic management practice resulted in the significant increase in the soil organic carbon and biological activity of soil as measured by dehydrogenase, alkaline phosphatase activity and microbial biomass carbon compared to CMP. Whereas, bulk density and mean weight diameter of soil were not affected due to management practice or cropping systems (Ramesh *et al*., 2007).

A field experiment was conducted for 3 years (2004-07) to study the effect of different organic manure combinations involving cattle dung manure (CDM), poultry manure (PM) and vermicompost (VC) *vis-a-vis* chemical fertilizers on the productivity of four soybean based cropping systems (soybean in rainy season followed by durum wheat/mustard/chickpea/isabgol in winter season) and soil quality parameters on deep Vertisols. Organic manures were applied based on the nitrogen equivalent basis and nutrient requirement of individual crop. The results indicated that application of CDM to soybean, combination of CDM + VC + PM to durum wheat and isabgol, CDM + PM to mustard, and CDM + VC to chickpea recorded grain yields, which were similar to the yields obtained in chemical fertilizers. Among the treatments, soybean-durum wheat cropping system and the manure combination of CDM + VC + PM recorded the highest total productivity of the system expressed in terms of soybean equivalent yield. In general, the grain quality of crops was not affected among the nutrient sources, but was found to be inferior in the un-manured control. At the end of the cropping cycle, combined application of different organic manures improved the soil quality parameters such as soil organic carbon (SOC), soil available nutrients (N, P and K), enzyme activity (dehydrogenase and alkaline phosphatase), microbial biomass carbon (MBC) and reduced the bulk density (BD) and improved the soil aggregate stability (MWD) compared to either chemical fertilizers or the control. Among the cropping systems, soybean-durum wheat recorded the highest SOC and accumulated higher soil available N, P and K compared to other cropping systems (Ramesh *et al*., 2007).

## Survey of organic farms in central Madhya Pradesh

A survey was conducted in selected districts of central Madhya Pradesh with an objective to study the productivity, economics and soil fertility evaluation in farmers' fields where organic farming is practiced in comparison to the chemical farming (Ramesh *et al*, 2006 b and 2007). The survey was conducted during April – June 2005 in 28 villages of 13 blocks spread in three districts of central Madhya Pradesh viz. Bhopal, Sehore and Raisan. The total number of farmers surveyed in the study was 98. The farmers were selected based on the criteria that they have been practicing organic farming for the last 2 to 3 years or more. The names of the farmers, villages and the blocks were selected from the list provided by the respective Joint Directors of Agriculture of the Department of Agriculture, Madhya Pradesh.

A questionnaire was prepared to collect the information on different aspects of crop management, productivity of crops and their economics and their perception and constraints in adopting organic farming from the individual farmers who are practicing organic farming. Soil samples were collected from conventional and organic farming area of the individual farmer's holdings. A total of 588 soil samples were collected for the detailed analysis. The soil analysis included the estimation of organic carbon, available macro (N, P and K) and micro nutrients (Zn, Cu, Fe and Mn), heavy metal load (Cd and Pb) and biological activity parameters (dehydrogenase, phosphatase activity of soil).

### Salient Findings of the survey:

- Majority of farmers (85.7 %) who have adopted organic farming have medium to large land holdings and at least 5 - 6 cattle per one hectare of land area under organic cultivation.
- Out of the total farmers surveyed, 50 % of farmers were adopting organic cultivation of crops from the last 2 years, 36 % from the last 2-5 years and only 14 %, for more than 5 years.
- Soybean, wheat, gram, lentil and safed musli were the major crops cultivated by the organic farmers.
- FYM, NADEP compost and vermicompost were the predominant source of manures for nutrient management in organic farming.

About 60 % of the organic farmers were using biofertilizers.

- In general, the quantity of organic manures being applied was lower than the nutrient requirement of the crops. On an average, farmers were applying 3.46 tonnes of FYM or 1.35 tonnes of vermicompost on fresh weight basis per hectare of soybean crop. For wheat crop, it was only 5.24 tonnes of FYM or 2.10 tonnes of vermicompost per hectare.
- About 45 % of farmers were not following any organic plant protection measures at all. Spraying of neem oil, cow urine and fermented butter milk were the most predominant methods of controlling pests and diseases by the organic farmers.
- Organic farming resulted in the reduction of yields to the tune of about 7.4 and 5.6 % in soybean and wheat crops, respectively.
- There was a reduction in the cost of cultivation (3.5 %) of soybean – wheat cropping system in organic farming compared to the conventional farming. However the gross income and net income of this system was lower in organic farming by 5.88 and 7.92 %, respectively.
- There was an overall improvement in the fertility and biological activity of soil in organic farming compared to the conventional farming.
- Nitrogen was the most critical factor in organic farming (as it found to be lower than that of the convention farming) and it limit the productivity of crops in the present survey due to the inadequate application of organic manures by the farmers.
- Support by the Government is the most predominant motivation factor for the adoption of organic farming by 68.7 % of farmers.
- Lack of marketing facilities and availability of premium prices were the two most important constraints for the adoption of organic farming.
- Control of pest and diseases and limited availability of organic manures were the most important technological constraints in adoption of organic farming.

## Conclusions

Only 30 % of India’s total cultivable area is covered with fertilizers where irrigation facilities are available and the remaining 70 % of the arable land, which is mainly rainfed, very negligible amount of fertilizers are being used. Farmers in these areas often use organic manures as a source of nutrients that are readily available either in their own farm or in their locality. The North- Eastern (NE) region of India provides considerable opportunity for organic farming due to least utilization of chemical inputs. It is estimated that 18 million hectare of such land is available in the NE that can be exploited for organic production. With the sizable acreage under naturally organic/default organic cultivation, India has tremendous potential to grow crops organically and emerge as a major supplier of organic products in world’s organic market.

The report of Task Force on Organic Farming appointed by the Government of India also observed that in vast areas of the country, where limited amount of chemicals are used and have low productivity could be exploited as potential areas to develop into organic agriculture. Arresting the decline of soil organic matter is the most potent weapon in fighting against unabated soil degradation and imperiled sustainability of agriculture in tropical regions of India, particularly those under the influence of arid, semiarid and sub-humid climate. Application of organic manures is the only option to improve the soil organic carbon for sustenance of soil quality and future agricultural productivity.

It is estimated that around 700 million tonnes of agricultural waste is available in the country every year but most of it is not properly used. This implies a theoretical availability of 5 tonnes of organic manure / hectare arable land /year, which is equivalent to about 100 kg NPK/ha/year . However, in reality, only a fraction of this is available for actual field application. Various projections place the tapable potential at around 30 % of the total availability. There are several alternatives for supply of soil nutrients from organic sources like vermicompost, biofertilizers, etc. Technologies have been developed to produce large quantities of nutrient-rich manure/composts. There are specific biofertilizers for cereal, millets, pulses and oilseeds that offer a great scope to further reduce the gap between nutrient demand and supply. There is no doubt organic agriculture is in many ways an eminently preferable pattern for developing agriculture and countries like India in particular.

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# Organic Farming Research in Karnataka – Outcome & Lessons Learnt

**M.N. Sreenivasa***

Increasing consciousness about conservation of environment as well as health hazards associated with agrochemicals and consumers preference to safe and hazard free food are the major factors for growing interest in organic agriculture.

Organic farming offers the possibility of sustaining crop yields and maintenance of soil health. It avoids or largely excludes the use of synthetic fertilizers, pesticides etc and solely depends on the use of crop residues, animal manures, biological inoculants, off-farm organic wastes, crop rotation etc., to maintain soil health and productivity. Use of organic manures enhance the bulk density of soil and there by reduces resistance to penetration by plant roots. Organic production methods are supportive of environment. Organic agriculture encourages a balanced host/ predator relationship through augmentation of beneficial insect population, biological and cultural pest control.

## Importance of Organic Agriculture

1. The demand for organic food is steadily increasing both in the developed and developing countries with an annual average growth of 20-25 per cent.
2. Decline in productivity of soil.
3. Indiscriminate use of pesticides affects human and animal health, biodiversity, wildlife etc. & cause environmental pollution.
4. High cost of inputs in conventional agriculture.
5. Declining factor productivity.
6. Deficiency of micronutrients.
7. Global warming due to rise in carbon-dioxide and temperatures.
8. Growth rate of agriculture production (1.5%) is much below the population growth rate (2.0%). Our country to be economically strong should improve on agriculture and allied enterprises.

## Principles of Organic Farming:

1. Enhancement of soil fertility by conservation and management of organic matter
2. Improvement in soil health by nourishing the living matter in soil.
3. On-farm development, conservation and efficient utilization of natural resources.
4. Crop rotation / intercropping/ multiple cropping to change the field ecology and disrupting the life cycle of insect pests, pathogens and weeds.
5. Prevention of pests and diseases through plant nutrient management, use of bio-pesticides, bio-fungicides, traps, barriers etc.
6. Use of bio-fertilizers, green manures etc in plant nutrient management and maintenance of ecological balance.

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## Important events on the development of organic farming

- The roots of organic farming can be traced in the European literature during 19th and 20th century.
- Australian philosopher Sir. Rudolf Steiner introduced Biodynamic Agriculture in 1924.
- In Switzerland, Biological agriculture was developed by Hans Multer and Peter Rush.
- In UK. Sir George stapledon, Lady Eve Balfour and Albert Howard gave the idea of organic farming and sustainable agriculture. In 1940, Albert Haward of UK wrote a book entitled “Organic growing methods in India”.
- In Japan, a farmer cum Writer Masanobu Fukuoka invented Zero till system for small scale gain production which he reported as natural farming.
- In USA, Rodale family started soil health foundation in 1947 which is called as Rodale Institute of Organic Farming.
- In 1960, the publication of “Silent spring” generated wide spread concern about use of pesticides and its ill effects.
- In 1972, the International Federation of Organic Agriculture Movement ((IFOAM) was started at Versailles, France with an aim of dissemination of information on the principles and practices of organic agriculture.
- During 1980’s and 1990’s conservation of bio-diversity, nature, animal welfare, rural development etc were treated as important aspects of organic agriculture.

## International recognition

- In November 1998, the IFOAM adopted basic standards for organic farming and processing.
- In June 1999, the Codex *Alimentarius* Commission adopted the Guidelines for production, processing, labeling and marketing of organically produced foods.
- They are intended to enable member countries to draw up their own rules, on the basis of the principles, while taking account of specific national requirements.
- In 1999 the FAO also embarked on an OF work programme, mainly concerned with promoting OF in developing countries.
- The IFOAM, has 600 organizational members from 120 countries including India. The main thrust of IFOAM is to Define concept of organic farming through their basic standards, harmonize certification programme through accreditation system, Participation in UN, FAO and WHO and Contact with international NGO’s and communication through seminar, magazines etc.

## Status of Organic Farming in India

- The task force of GOI under the chairmanship of Shri.Kunwarji Bhai Jadav of Rajkot and Commissioner of Agriculture GOI as member secretary suggested, need for alternative to modern conventional agriculture.
- The task force also, gave brief account of practices of organic farming and other systems *viz*. Bio-dynamic, Rishi Kheti etc., being practiced in India.
- Ministry of Commerce, GOI has launched National programme for organic production and National standards on organic production (NSOP) in March, 2000.
- National standards for organic products have been standardized during May 2001 and could be sold under the logo *India organic.*
- National Accreditation Policy and Programmes (NAPP) has been formulated

with accreditation regulations announced in May 2001.

- This makes it mandatory for all certification bodies engaged in inspection and certification of organic crops and products to be accredited by an accreditation agency.
- Foreign certification bodies operating in the country must also be accredited.
- Government of Karnataka also formulated a policy on organic farming during March, 2004 (8-3-2004). The status in Karnataka is given below:

## Karnataka – Inherent advantages

- Varied agro-climatic regions and diversified cropping situations *viz*., cereals, pulses, oilseeds, sugarcane, spices, coffee, fruits, inter/mixed cropping systems, plantations etc.
- Potential for on-farm input management *viz.*, crop residues, organic manures, green manures, bio-pesticides etc., which are the store house of nutrients
- Small holdings, prevailing farming systems which combine agriculture, livestock, horticulture, forestry, poultry, fisheries etc.
- Indigenous technical knowledge and skills and availability of trained man power
- Scientific thinking and approach and government policy support towards organic farming is increasing.
- Greater domestic market for organic food.

## Role of Microbes in Organic Farming

Microorganisms are playing a key role in organic farming in terms of organic matter decomposition, bio-fertilizers, bio-pesticide etc. At UAS, Dharwad, the results of several experiments conducted revealed *Phanerochaete chrysosporium* to be an efficient lignocellulolytic fungus for decomposing several agroresidues including sugarcane trash, redgram stalk, cotton stalk etc. This is known to produce lignin degrading enzymes like lignin peroxidase, manganese peroxidase, glyoxal oxidase and reduces C:N ratio. At the same time, scientists have worked out the possibility of enrichment of decomposed material by inoculating free living nitrogen fixers like *Azotobacter* and P-solubilizers. Such attempts have given fruitful results in enrichment of vermicompost with higher amount of N and P contents.

In continuation to decomposition and enrichment of agro residues, the results of several interaction studies clearly showed that coinoculation of *Trichoderma harzianum*, a cellulolytic fungus and P- solubilisers viz *Pseudomonas striata, Bacillus polymyxa* along with the application of rock phosphate resulted in better decomposition of cotton stalks and nutrient uptake by the test crop.

The cropping system influence soil microflora. The dynamics of soil microflora and soil enzymes was studied is a long-term integrated nutrient management experiment in a fixed site in two cropping systems at UAS, Dharwad. Both soil microflora and soil enzymes were highest in groundnut-sorghum cropping system as compared to sorghum-safflower cropping system. The organic C, available N, available P, soil microflora and enzyme activities increased significantly with the application of organic fertilizers along with inorganic. Positive correlation was observed in soil microflora, soil enzymes and nutrient availability. These results highlight the significance of application of organic matter in maintenance of soil fertility and bio-dynamics (Tables 1-4). Several efforts to enrich vermicompost with beneficial microflora gave fruitful results (Table-5).

Of late, lot of importance is given to protect the environment from pollution. Hence several scientists are exploiting microbial technologies for production of bioethanol from agro residues.

**Table 1. Population of microflora before sowing (I) and after harvest (AH)**

| Treatments | Total Bacteria (No. x $10^6$/ g soil) | | Fungi (No. x $10^3$/ g soil) | | Actinomycetes (No. x $10^2$/ g soil) | |
|---|---|---|---|---|---|---|
| | I | AH | I | AH | I | AH |
| T1: 100% org | 55.30* | 67.20 | 56.70 | 69.00 | 46.70 | 58.80 |
| T2: 75: 25 org: inorg | 55.30 | 64.60 | 56.70 | 64.00 | 46.70 | 58.20 |
| T3: 50:50 org: inorg | 62.70 | 71.60 | 57.00 | 74.00 | 42.70 | 63.60 |
| T4: 100% inorg | 57.30 | 74.00 | 58.30 | 81.40 | 42.00 | 61.20 |
| SEm± | – | 3.33 | – | 2.65 | – | 3.99 |
| CD at P=0.05 | – | NS | – | 8.17 | – | NS |
| CV (%) | – | 10.70 | – | 8.20 | – | 14.80 |

* Mean of three replications.

**Table 2. Population of FNF and PSB**

| Treatments | Free living N2-fixers (No. x $10^3$/g soil) | | PSB (No. x $10^3$/g soil) with zone | | PSB (No. x $10^3$/g soil) without zone | |
|---|---|---|---|---|---|---|
| | I | AH | I | AH | I | AH |
| T1: 100% org | 32.0 | 49.4 | 3 | 4 | 30.7 | 43.4 |
| T2: 75: 25 org: inorg | 32.0 | 45.2 | 4 | 4 | 30.7 | 59.2 |
| T3: 50:50 org: inorg | 32.3 | 56.0 | 6 | 8 | 31.0 | 55.0 |
| T4: 100% inorg | 31.3 | 43.4 | 5 | 8 | 31.3 | 51.0 |
| SEm± | – | 2.65 | – | – | – | 2.21 |
| CD at P=0.05 | – | 8.71 | – | – | – | 6.81 |
| CV (%) | – | 12.2 | – | – | – | 9.50 |

**Table 3. Dehydrogenase activity, soil respiratory activity and grain yield of sunflower**

| Treatments | Dehydrogenase activity ($\mu l$ of H2 released /g air dried soil) | | Soil respiratory activity (wt of CO2 (g)/100 g soil/ 2 hrs) | | Seed yield (q/ac) |
|---|---|---|---|---|---|
| | I | AH | I | AH | |
| T1: 100% org | 4.2 | 15.0 | 0.11 | 0.14 | 5.43 |
| T2: 75: 25 org: inorg | 4.2 | 16.1 | 0.11 | 0.22 | 5.68 |
| T3: 50:50 org: inorg | 4.3 | 16.4 | 0.11 | 0.21 | 5.75 |
| T4: 100% inorg | 4.3 | 16.1 | 0.11 | 0.19 | 5.81 |
| SEm± | – | 0.24 | – | 0.10 | |
| CD at P=0.05 | – | 0.73 | – | NS | |
| CV (%) | – | 3.30 | – | 12.6 | |

**Table 4 : Soil Biological properties ( Bengal gram ) RARS, Raichur for the year 2005-06**

| Treatments | Total Bacteria ($No x 10^6$/g soil) | | Total Fungi ($No x 10^3$/g soil) | | Total Acti-nomycetes ($No x 10^2$/g soil) | | Freeliving $N_2$ fixers ($No x 10^3$/g soil) | | PSM ($No x 10^3$/g soil) | | Dehydrogenase Activity (microliters of $H_2$ released/g of soil) | | Respiratory activity (wt. of $CO_2$ (g)/ 100 g soil/2 hrs.) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | AH | I | AH | I | AH | I | AH | I | AH | I | AH | I | AH |
| $T_1$ 75% OM | 63 | 84 | 56 | 78 | 44 | 56 | 31 | 43 | 28 (3) | 36 (6) | 3.98 | 4.36 | 0.11 | 0.16 |
| $T_2$ 100% OM | 63 | 96 | 58 | 89 | 47 | 61 | 31 | 48 | 32 (2) | 41 (6) | 4.25 | 4.96 | 0.11 | 0.18 |
| $T_3$ 50%+50% | 66 | 118 | 58 | 86 | 50 | 68 | 37 | 52 | 33 (3) | 42 (8) | 4.63 | 5.11 | 0.14 | 0.24 |
| $T_4$ 100% IOM | 49 | 94 | 46 | 68 | 29 | 54 | 22 | 31 | 25 (2) | 38 (5) | 2.93 | 3.73 | 0.08 | 0.16 |
| $T_5$ 100% IOM + OM | 53 | 112 | 52 | 92 | 41 | 71 | 33 | 43 | 31 (3) | 40 (6) | 3.90 | 4.30 | 0.10 | 0.18 |
| SEM ± | 4.10 | | 2.90 | | 2.40 | | 2.10 | | 2.60 | | 0.21 | | 0.01 | |
| CD at P = 0.05 | 12.40 | | 8.60 | | 7.60 | | 6.30 | | 7.80 | | 0.63 | | 0.03 | |

**Table 5 : Population of *Azospirillum* and P-Solubilizers and N & P contents in vermi compost**

| Treatments: | Population of *Azospirillum* (MPN No x 10 $^5$/g) Period in months | | | | Population of PSM (No x 10 $^7$/g) Period in months | | | | N-content (%) | P-content (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | Mean | I | II | III | Mean | | |
| AZO | 32 | 54 | 84 | 57.0 | 13 | 16 | 21 | 16.7 | 0.64 | 0.68 |
| PSB | 14 | 18 | 21 | 17.7 | 39 (3) | 54 (5) | 61 (9) | 51.3 | 0.56 | 0.98 |
| AZO+PSB | 33 | 70 | 95 | 66.0 | 41 (4) | 63 (8) | 69 (11) | 57.7 | 0.79 | 1.15 |
| Mean | | 26.3 | 47.3 | 66.3 | 46.9 | 31 | 44.3 | 50.3 | 42 | |
| SEM± | 0.91 | 1.62 | 1.74 | | 1.24 | 1.36 | 1.89 | | 0.03 | 0.04 |
| CD at P=0.05 | 2.70 | 4.80 | 5.30 | | 3.60 | 4.10 | 5.7 | | 0.09 | 0.13 |

Initial population of *Azospirillum* : 46 x 10 $^5$/g of Lignite & *Pseudomonas striata* 36 x 10 $^7$/g of lignite.
N - Content in UIC : 0.56% P-content in UIC : 0.68 %

Bioethanol can be blended with petrol up to 20%. At present, ethanol is blended up to 5% with diesel for transportation. Several microbial cultures viz., *Trichoderma reesei* and *Pachysolen tannophilus* NCIM-3445 showed their efficiency in terms of higher ethanol yield. Such studies certainly help to protect environment from pollution.

Another potential area which uses microbial technology in organic farming is biocontrol of pathogens and crop pests by which usage of chemical insecticides can be reduced and in turn environmental pollution can be avoided. Several microorganisms are known to improve plant growth directly through nutrient mobilization and production of plant growth hormones and indirectly through suppression of plant pathogens or by inducing systemic resistance in plants. The soil microorganisms having these multiple beneficial traits are referred to as plant growth promoting rhizobacteria (PGPR). Recently they are also referred to as plant health promoting rhizobacteria (PHPR). Fluorescent pseudomonad play a key role in biocontrol of plant pathogens as they have rapid growth, simple nutritional requirement and ability to utilize diverse organic substrates. They are known to produce highly potent broad spectrum antifungal molecules against various phytopathogens. They are reported to produce antibiotics, siderophores, HCN etc. They also compete for space and nutrients with soil borne plant pathogens. Fluorescent pseudomonads are promising bioinoculants for agricultural system to increase productivity as they are cost effective and ecofriendly. Anther fungus, *Trichoderma harzianum* is also being used extensively. Some of the microbial pesticides NPV, GV, *Bacillus thuringiensis, B popilleae, Metarrhizium anisopliae, Beavaria bassiana, Nomuraea rileyi, Verticillium lacanii etc.*, are being used under field conditions for biological control of crop pests. All these organisms can grow well and show activity at an optimum RH (Minimum 75%-85%) and temperature 28-30$^0$C. The moisture and temperature play a key role on the growth of micro organisms. The environmental conditions should also be favourable for their action after spraying these microbial pesticides on to the crops. Heavy rainfall/ higher temperature after spraying will result in loss of microbial pesticides due to washing or inactivation of enzymes. Hence it is better to spray these microbial pesticides during late evening or early hours of the day for efficient activity.

## Parasitoids and predators :

During the past 100 years, several parasitoids and predators have been identified. Until 1990, nearly 5500 natural enemies have been introduced to new areas, out of which, 340 parasitoids 74 predators were successful. The rapid evaluation and introduction of number of natural enemies in situations where chemical control was either insufficient or impossible, has taught crop protection specialists that biological control of pests is economical and profitable. During last decade GOI has spent 15,000 million rupees on bio-control of crop pests covering an area of 40 lakh hectares.

The major advantages of use of bio-pesticides are 1. Economical, 2. Selective & no side effect 3. Self propagating 4. Safe to non target organism 5. No resistance development.

Ex: *Epiricania, Aphelinus, Micromus, Dipha, Trichogramma*.

## Organic farming research in Karnataka

- The Govt. of Karnataka formulated organic farming policy on 8-3-2004.
- Each taluk will have one organic village with 100 ha of land under conversion which is managed by NGO's, KSDA, BAIF etc.
- ICAR, New Delhi has identified 12 centers for organic farming research out of which UAS, Dharwad is one.
- Organic farming under different cropping system is being researched. Two years results demonstrated the possibility of getting higher yield under organic farming in chilli, cotton, groundnut, sorghum, Bengal gram etc.
- Organic farming research is carried out on research station under fixed plot technique and development of Bio-farm is planned at UAS, Dharwad.
- DBT project on popularization of organic farming practices among weaker sections is under implementation.
- Nearly, 252 farmers are practicing organic farming in 12 districts of North Karnataka.
- Under UAS, Bangalore a similar type of work is being carried out at Shimoga.

Organic farming should be taken as means of enhancing soil fertility, soil health and productivity and to achieve sustainability. Of late, many farmers are distressed due to high cost of inputs in conventional agriculture. Organic farming will be the answer for some of these problems as soil fertility and productivity problems will be address on sustainable basis. Organic farming is based on locally available, renewable resources, hence easily affordable to even small and marginal farmers. We need to create awareness among farmers so as to reduce environmental pollution and poisoning of food while ensuring sustainable production.

## Future Thrusts

1. Testing the effect of organic inputs (*Panchgavyya, Beejamruth, Jeevamruth* etc.) on all crops in different agro climatic zones.
2. The principal compounds and microflora present in these organic inputs need to be identified.
3. More systematic studies are required to understand the role of organic inputs in imparting drought tolerance, prevention of diseases, pest control etc.
4. Importance of organic food on human health need to be highlighted.
5. There is a need to determine economic feasibility of organic practices.

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# Organic Farming : Building on Farmers' Knowledge with Modern Science

**O P Rupela***

## Summary

Most agricultural scientists are trained in crop production and protection that require fertilizers and synthetic pesticides. Scientists have largely evaluated components used by practitioners of organic farming (OF) in isolation, eg. evaluation of compost for replacing fertilizers. The OF system that integrates trees, annual crops and animals in a farming system perspective using locally available biological resource has not been studied in totality. This chapter therefore argues that unless studied in totality, its potential cannot be denied by research institutions.

The document discusses some common myths that render agricultural scientists averse to OF. The document also demonstrates that crop yields without agro-chemicals were indeed higher or similar to the treatments receiving agrochemicals, in seven out of nine years, in a large plot study on a rainfed Vertisol in semi-arid conditions at ICRISAT. Comparable or higher yields of cotton and tomato were also harvested in on-farm experiments (involving seven to 21 farmers in a season), in two villages, evaluating low-cost bio-options of crop protection against farmers practice using synthetic pesticides, for at least four years in a row (2004 to 2007/08). Farmers in these on-going studies paid partially for the cost of the materials and advice they received from researchers, suggesting strengths in the biological options of crop protection, without synthetic pesticides.

The paper provides data/citations to suggest that production of sufficient quantities of biomass as a source of crop nutrients can come close to the recommended levels of fertilizers in rainfed agriculture. Botanicals to protect crops and the biomass can be strategically produced on the very field where we grow crops without seriously affecting productivity of unit land area.

Overall, it argues in favor of developing agro-technologies that are low-cost, use/recycle locally available natural resource (land, water, plant biomass etc.) in order to empower small-holder farmers instead of increasing their dependence on purchased external inputs.

The author concedes that there will be situations where micro quantities of some elements would be needed as crop nutrients. Since mainstream system, even when working in a farming system perspective, has almost always involved agrochemicals there are few comparative situations to challenge/support this argument of the author. Therefore the author has liberally used experience of practitioners of OF to understand and assemble data/information in support of his opinion. Instances have been shared indicating that to sustain crop production and productivity per unit area, we need to build upon the foundations of traditional knowledge by articulating modern science. The author however is not a supporter of OF that requires certification by internationally accredited agencies.

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## Introduction

Green Revolution (GR) technologies, supported by policies, and fuelled by agro-chemicals, mechanization and irrigation, are well known to have enhanced agricultural production and productivity. While these technologies have greatly helped developing countries to address their food-security needs, farmers using these technologies, have to depend on external inputs which constitute the major cost of production, thereby eroding their profits. The manufacture of fertilizers and pesticides, the two major inputs of GR technologies, needs fossil fuels and/or expensive energy, and is associated with serious environmental and health issues. It is perhaps owing to these inputs and their negative impacts that the Intergovernmental Panel on Climate Change (IPCC) has noted that agriculture as practiced today (conventional, modern or GR agriculture) accounts for about one-fifth of the projected anthropogenic greenhouse gasses, producing about 50 per cent and 70 per cent, respectively, of anthropogenic methane ($CH_4$) and nitrous oxide ($N_2O$) emissions (www.gcrio.org/ipcc / techrepI/agriculture.html).

It is therefore time to identify and promote use of agro-technologies that are environmentally benign, empower farmers even while resulting in sustainable high yields. Low cost and biological approaches of crop production and protection based on traditional knowledge of farmers (see www.sristi.org for thousands of recipes relevant to farming) and locally available natural resources being researched at ICRISAT since June 1999, following organic farming principles (integrating crop plants, annual trees and animals) have been noted to have these features. Most of the inputs needed for this approach can be generated on the same field where food crops are grown and are therefore projected as alternatives to GR technologies.

The days are gone when we scientists educated/trained to grow crops with agrochemicals, were acknowledged as 'final authority' on a given subject. Today, lakhs of farmers across the globe grow crops without these inputs and are registered with accredited companies (including in India) as practitioners of organic farming (OF). They and several non-governmental organizations (NGO's) working on similar lines now differ from several aspects of mainstream agriculture. Some NGO's have demonstrated that crops can be protected without synthetic pesticides. Organic farming (OF) involves a holistic system of farming which optimizes productivity in a sustainable manner through creation of interdependent agri-eco systems where annual crop plants such as sorghum, perennial trees e.g. horticultural trees and animals (including fishes where relevant) are integrated and intricately linked on a given field or property.

Certified organic farming (COF) or labeled organic is a commercial quality control and marketing mechanism which entails third party certification or any other form of independent certification for individual commodities and the process of their cultivation (see www.ifoam.org for more information). Certification is done by agencies accredited by the competent authority in a given country. For instance, in 2007, India had 12 agencies accredited by Agricultural and Processed food products Export Development Authority (APEDA) under the Ministry of Commerce, Govt. of India.

Agricultural scientists, however, do not believe that crop yields without fertilizers can be high unless large quantities of compost that supplies nutrients (nitrogen, phosphorus and potash – NPK in particular), equivalent or close to the recommended levels are applied. It is then argued that large quantities of compost are not available to farmers particularly when farmers are shifting from cattle-based farming to mechanization. Use of composts, green manure etc. are considered as good practices and are widely recommended along with chemical fertilizers as "Integrated Nutrient Management" or INM.

Crops are potentially attacked by several different crop pests, both diseases and insect-pests. In the past, our emphasis has been mostly on synthetic pesticides that are nervous system or respiratory poisons to control such pests, and are potentially toxic to environment and operators. Most scientists are trained only in these options. Use of botanicals and entomopathogenic microorganisms for plant protection are regarded as good practices and came into prominence after it was becoming difficult to manage several insect-pests that had developed resistance to several different types of synthetic pesticide molecules (Kranthi *et al*. 2002). Most scientists (Entomologists in particular) appreciate the importance of soft options of crop protection but promote them along with chemicals as part of integrated pest management (IPM), because their belief is that the soft options on their own would fail to protect crops. In the whole scheme of crop protection from insect-pests in real world, natural enemies of insect pests do not find a place except the recognition in the form of lip service that they are important. And few may survive in the field with regular use of synthetic pesticides.

Some common myths addressed in this paper include (a) crop yields are low without fertilizers in OF, (b) large quantities of compost are required for organic farming, (c) OF cannot be practiced on large areas, (d) it is not possible to protect crops without synthetic pesticides. The myths are addressed based on experience gained from a large plot field experiment initiated in June 1999 on a Vertisol and comparing crop husbandry systems with and without fertilizers and synthetic pesticides at ICRISAT (see details in Rupela *et al*. 2006a). It argues that we need to have a re-look at the protocols of crop production and protection, if we are interested to make agriculture an environmentally benign process and at the same time not risking the food and nutritional security of a nation.

This document has drawn most examples and strengths from 'organic farming' because this was closest to the low-cost and biological options of crop production, the author works on. The intention of this document is not to make a case in favor of organic farming and more importantly not in favor of certified organic farming. Instead, its major intention is to plead in favor of the low-cost locally available natural resource that can be used for harvesting sustainable high yields by 'small-holder farmers' without dependence on market purchased inputs that the mainstream agriculture promotes.

## Addressing the Myths

### Are crop yields low in OF?

Reduced yields in the initial years when a field is converted from conventional agriculture (CA) to OF is a widely observed phenomenon, including in tropics, and OF cannot be quoted as a low-yielder on this basis. A few years are initially needed to build the agriculturally beneficial micro-organisms in soil that would have been adversely affected by long years of agro-chemical inputs used in CA. With scientific understanding of OF as a soil building process rich in microbial-activity, it will be possible to reduce this period to less than one year and the author has seen such farms. Overall, it can be argued that sustainable high yields are possible with OF (Rupela *et al*. 2005a), but scientists have not explored it enough in a farming system perspective where trees, crops and animals are intricately linked on a given farm.

For most scientists, it is indeed difficult to believe that high yields are possible without synthetic agro-chemicals. Therefore they would like to verify the claims of several OF practitioners. All the 31 million ha (including forest produce) in the world presently growing crops through OF practices are certified, implying that it is possible to obtain names and addresses of the producers/farmers from accredited certification agencies in a given country. It is the duty of the well meaning research institutes to access these names, visit these fields/crops and verify the claims by actual measurements. A book by Alvares (2005) published in 1996 and revised in 2005, has addresses and phone numbers of at least 400 farmers practicing OF in India. By the crop season 2006/07, a total of 485,000 farmers were registered in India [personal communication in Jan 2008, with Dr A.K. Yadav, Director, National Centre for Organic Farming (NCOF), Ministry of Agriculture, Govt. of India]. With regard to yields, several OF practitioners claim that their yields are comparable or higher than their neighbouring conventional farmers who use agro-chemicals. The author has visited/met/interacted with several farmers over the past five years and noted indicators that their claims may be correct. In addition, in an ongoing long term experiment at ICRISAT crop yields in seven out of nine years were similar or higher (Table 1) in the treatments involving low-cost and biological approaches (see Rupela *et al*. 2005b and Rupela *et al*. 2006a for more information) than the treatment 'conventional agriculture' on a rain-fed Vertisol (black soil rich in clay). In year one, crops in the organic farming treatments failed because the author was still learning how to raise crops with low-cost and biological inputs. Admittedly the evidences to indicate that high yields are possible with

**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.**

| Treatments | Year 1 | | Year 2 | | Year 4 | | Year 5 | |
|---|---|---|---|---|---|---|---|---|
| | Rainy (S) | Postrainy (P) | Rainy (C) | Postrainy (Co) | Rainy (M) | Postrainy (P) | Rainy (C) | Postrainy (Co) |
| 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) |
| 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) |
| 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) |
| 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) |
| Mean | 2.87 | 2.33 | 0.27 | 0.74 | 3.46 | 0.65 | 0.43 | 1.40 |

| Treatments | Year 6 | | Year 7 | Year 8 | Year 9 |
|---|---|---|---|---|---|
| | Rainy (M) | Postrainy (P) | Postrainy (Co)[1] | Postrainy (P)[2] | Postrainy (Co)[1] |
| LC 1 | 5.12 (0.158) | 0.95 (0.020) | 1.40 (0.028) | 0.78 (0.033) | 0.95 (0.032) |
| LC 2 | 4.89 (0.167) | 0.93 (0.014) | 1.00 (0.025) | 0.70 (0.028) | 0.90 (0.023) |
| MA | 5.27 (0.131) | 0.89 (0.014) | 0.91 (0.046) | 1.03 (0.025) | 0.93 (0.048) |
| MA+biomass | 6.06 (0.127) | 0.85 (0.016) | 1.28 (0.029) | 1.11 (0.032) | 1.24 (0.060) |
| Mean | 5.34 | 0.9 | 1.15 | 0.91 | 1.01 |

S= Sorghum, P= Pigeonpea, C= Cowpea, Co= Cotton, M= Maize, Data in parenthesis are ±SEs
*= extensive damage by aphids
1 = Cowpea grain in the rainy season was not collected, biomass was mulched in the same plots
2= Sweet sorghum was grown in the rainy season, only stover was collected.

OF are limited, but this is due to the fact that most agricultural research institutes have not worked on it. Therefore the onus is on these institutes to generate more data, including surveying the OF practitioners to verify their claims of high yields.

The proponents of OF in India state historical evidences (see website www.dharampal.net and www.cpsindia.org/tav.html) in support of high crop yields prior to 1835 when modern agro-chemicals were not on the scene. For example, the average yield of rice is quoted as around 3 t $ha^{-1}$. This mean yield of rice was based on a survey from over 1000 localities in two independent records/studies: the first, writings on palm-leaves in Tamil Nadu (still available) and the second, survey reports of Thomas Bernard of East India Company. Mean paddy yields of well performing localities were over 6 t $ha^{-1}$ in one and over 9 t $ha^{-1}$ in the other study. Mean yields of conventional rice these days in India (see www.dacnet.nic.in, 10 Aug 2007, a website of Government of India), ranges from $<1.0$ t $ha^{-1}$ (labeled as very low productivity states, e.g. Madhya Pradesh) to $>2.5$ t $ha^{-1}$ (labeled as high productivity states (e.g. Andhra Pradesh and Punjab). The average yield of Punjab in the recent past was about 4 t $ha^{-1}$. It is opined that these evidences should force agricultural scientists to think and explore how high yields were harvested in the past without agro-chemicals and develop those technologies for wider use.

Yield advantages due to application of both fertilizers and pesticides are not in doubt and have been researched and widely published. The major weakness of research on fertilizer recommendations is that these are crop focused and have generally been developed without considering the cropping system perspective of a given area and availability of natural resources of that area. Also, in the author's experience and understanding, when used along with biological resources such as plant biomass (particularly when used as mulch) much less quantities of fertilizers may be needed than those generally recommended by research institutes. The findings of ICRISAT (www.icrisat.org/Media/2006/media8.htm; www.icrisat.org/gt-aes/ResearchBreifs3.htm) through its research in Africa on "micro-dosing of fertilizers" [2 grams of Nitrogen (N), Phosphorus (P) and Potash (K) in ratio 15:15:15 per plant, total 20 kg per hectare] that resulted in substantial yield increases (between 44 and 120 per cent) for pearl millet and sorghum are perhaps indicators of this.

In the light of the historical evidences stated above, it is proposed that the agriculture of post 1900 without interventions of modern inputs of agrochemicals be termed as 'Traditional Agriculture or TA', the modern agriculture with agro-inputs as conventional agriculture or CA, and the interventions to TA by biological options as OF and the OF when certified be called COF.

OF is a knowledge intensive system and has been developed by practitioners themselves over the years. There are essentially no external inputs and therefore it is a low-cost system. This knowledge, expertise and experience is largely held with the practitioners of OF and yet to be documented professionally. Efforts have been made by some research institutes in India to document this knowledge as ITK (indigenous/traditional knowledge) but that largely remains in books (Acharya *et al* 2001) and needs to be applied. Available research data from the mainstream system in the area of biological options of crop nutrients and crop protection, without agro-chemicals, seem to explain some aspects. All the documented ITK and available research data need to be packaged into low-cost farmer-empowering agro-technologies.

Over the years, OF has not spread enough because the mainstream research institutes and Departments of Agriculture in different SAT countries do not support it. Additionally, some practices of OF remain laborious in the absence of research and development investments by the governments globally.

## Does OF needs application of large quantities of compost?

A crop does not differentiate whether nutrient elements are offered from fertilizers in a bag or from compost prepared by a farmer. Most scientists believe that large quantities of farm-yard manure (FYM) or compost are required for growing crops, if bagged fertilizers are not used. This belief is due to the fact that the value of FYM or compost is measured in terms of nutrients such as nitrogen or phosphorus that a crop needs. This perspective ignores the fact that there are different types of agriculturally beneficial microorganisms in compost and they have the ability to mobilise crop nutrients and even help in crop protection. To harness the value of these microorganisms, one needs to understand their food and other needs while they function on the root / rhizosphere of a given crop. Plant biomass, raw or processed (i.e. FYM) is a good food for microorganisms. Thus an OF practitioner does not need tens of cattle to make compost for each ha. Indeed, plant biomass can be strategically produced in large quantities on a given field. Rupela *et al*. (2006b) reported production of over 3 t ha$^{-1}$ dry mass (from year 5 onward) of *Gliricidia* lopings when grown (on rain fed Vertisol at Patancheru, ICRISAT with average rainfall of about 750 mm per annum) on 1.5m wide boundary strip of one ha field. Table 2 gives yield of loppings from the *Gliricidia* from year two to eight. Converted to N and P, this provided over 60kg N ha$^{-1}$ and about 4 kg P ha$^{-1}$ annually from year 5 onward (Table 2). While in high rainfall area 98.7 t ha$^{-1}$ (wet weight) was reported (implying availability of much more N and P than that obtained in the field at ICRISAT Patancheru) from farmers' fields in Thanh Haa watershed in Vietnam (ICRISAT 2005). At least one t ha$^{-1}$of weeds were uprooted and placed as surface mulch in the two 'low-cost' treatments (Rupela *et al*. 2006a). Together with the crop residues (Table 3), at least eight t ha$^{-1}$of biomass was generated in every year, from year 5. Quantity of biomass can be substantially more in well endowed rainfall and irrigated areas. The plant biomass serves as food for microorganisms, and small quantities of compost, cow-dung (applied strategically) or its ferments can serve as source of beneficial microorganisms that hasten degradation of the added biomass, when applied as surface mulch. Thus the biomass and microorganisms together can meet nutrient needs of crops grown on the same field, obviating the need for large quantities of compost for organic farming. Recycling of all locally available natural resources (plant biomass in particular) is extremely important, and most OF practitioners visited by the author were noted to observe such practices.

**Table 2. Yield of dry lopping and of N and P through the lopping of Gliricidia grown on 400 m long boundary of one ha field of an on-going long-term experiment (since June 1999), Vertisol, ICRISAT, Patancheru.**

| Year | Loppings, t ha$^{-1}$ | N from loppings kg ha$^{-1}$ | P from loppings kg ha$^{-1}$ |
|---|---|---|---|
| Year 2 | 0.06 | 1.4 | 0.09 |
| Year 3 | 1.43 | 32.8 | 2.14 |
| Year 4* | 0.98 | 22.5 | 1.47 |
| Year 5 | 2.62 | 60.3 | 3.93 |
| Year 6 | 3.31 | 76.1 | 4.97 |
| Year 7 | 3.36 | 77.3 | 5.04 |
| Year 8 | 3.62 | 83.2 | 5.44 |

* Aphids seem to have adversely affected plant growth

In addition, at least one t ha$^{-1}$ of weeds and 4.50 to 11.61 t ha$^{-1}$ crop residues were produced (Table 3). Together these can potentially add more than 100 kg N and more than 5 kg P per ha.

Table 3. 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 | |
|---|---|---|---|---|---|---|
| Treatments | Rainy (S) | 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) |
| 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) |
| 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) |
| 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) |
| Mean | 4.57 | 6.66 | 4.92 | 3.86 | 4.9 | 1.84 |

| | Year 5 | Year 6 | Year 7 | | | |
|---|---|---|---|---|---|---|
| Treatments | Rainy (C) | Postrainy(Co) | Rainy (M) | Postrainy(P) | Rainy (C) | Postrainy(Co) |
| LC 1 | 1.92(0.062) | 3.83(0.095) | 6.14 (0.150) | 1.65 (0.073) | 2.17(0.095) | 2.89(0.242) |
| LC 2 | 2.27(0.066) | 4.04(0.103) | 5.72 (0.190) | 1.67 (0.058) | 2.50(0.237) | 2.00(0.075) |
| MA | 1.76(0.053) | 4.32(0.134) | 5.75 (0.110) | 1.94 (0.066) | 2.17(0.140) | 2.84(0.128) |
| MA+biomass | 2.59(0.083) | 4.38(0.091) | 6.99 (0.229) | 2.00 (0.041) | 2.54(0.187) | 2.95(0.094) |
| Mean | 2.14 | 4.14 | 6.15 | 1.82 | 2.34 | 2.67 |

S= Sorghum, P= Pigeonpea, C= Cowpea, Co= Cotton, M= Maize
Data in parenthesis are ±SEs

In India, some cow dung ferments are widely used by OF practitioners for enhancing crop growth. In a preliminary study at ICRISAT Patancheru, one such ferment (locally called 'Amrit-Paani') was noted to have high bacterial population of cellulose degraders, nitrogen fixers, P-solubilizers, plant growth promoters and antagonists of disease-causing fungi. Data can be viewed at **Pages 366-367 of Archival Report, Global Theme Biotechnology and Crop Improvement 2005-06** (a file having this data has been posted at the FSN Forum Web site http://km.fao.org/fsn/fsn_home.html). As per this study, about 1000 to a million per ml or per g of each of the five different groups of beneficial microorganisms were noted in cow dung and in the ferment - Amrit Paani prepared using cow dung. It was calculated that to harness value of these microorganisms one cattle (with dung yield of about 8 kg per day) would be enough to meet the microbial needs of one ha. Thus we would not need large population of cattle for the science-based organic farming. It is also important to note that microbiologists can culture <10% diversity in a given niche due to technical limitations (Ward *et al*. 1990), implying that there may be many more and much diverse beneficial microorganisms in a given field which are yet to be studied. But it does not mean that they are not functioning in nature. It only means that scientists have yet to explore their value.

Occasionally, some published literature and websites (www.globalgap.org) indicate *Escherichia coli* or *E.coli*, a bacterium in animal excrements as potential health hazard and recommend separation of animals from cropped areas. This bacterium normally lives in large numbers in the intestines of animals, including humans. In fact, the presence of *E. coli* in intestines of humans is essential because they provide important nutritional factors (see web site www.micro.msb.le.ac.uk-video-Ecoli.html). Most strains of this bacterium are either friends of humans or are harmless except strain "O157:H7" which is a pathogen. A University of Minnesota study concerning faecal *E. coli* in freshly picked farm produce by Mukherjee *et al*. 2004 found that the percentage prevalence of *E. coli* in certified organic produce was similar to that in conventional samples. It is very important to integrate crops and cattle on the same field for sustainable high yield because the excrements are an important source of several beneficial microorganisms. Plausibly when there is a large population of beneficial microorganisms around, the scope of pathogens to take over is greatly reduced.

## How fertilizer need is met in OF

It may sound logical that fields not receiving fertilizers (urea, diammonium phosphate or DAP and single super phosphate or SSP) should have lower fertility than those receiving alternative inputs (FYM, biomass etc.), but that is not true. In fields where OF principles are being observed, it's fertility is highly unlikely to be low due to the fact that it is a more close system (i.e. it does not encourage removal of plant biomass from a given field) compared to conventional agriculture where most farmers remove all biomass from above the ground. Also, it is worth noting that the use of most fertilizers adversely affects the functions of the agriculturally beneficial microorganisms (e.g. biological nitrogen fixation – Streeter 1988). Thus the use of fertilizers beyond a level is counter productive and harms the microbial life of soil. Also, there is enough data available in the mainstream research suggesting that fields receiving organic inputs generally have healthy soils rich in microbial life (Parr *et al*. 1992).

Another important point is that most soils have all the 30 plus elements needed for crop production but these are in bound form. For example, theoretical estimates have suggested that the accumulated P in soil is sufficient to sustain crop yields worldwide for about 100 years (Goldstein *et al*., 1993). Plants cannot use these elements as food unless converted to soluble form or 'available form'. In OF, plants have to convert the unavailable bound forms to available form and that happens due to organic acids produced by beneficial microorganisms. These microorganisms are abundantly available on the surface of plant roots or in products such as in 'cow dung ferments', widely used by OF practitioners. Improved P-availability has been reported when some plants/crops secreting mineral-solubilizing factors from their roots (e.g. 'piscidic acid' from roots of Pigeon pea - Ae *et al*. 1990). Bagged fertilizers used in CA in soluble form, can be readily taken up by plants. But it is NPK that is widely available in market. Excessive and/or inappropriate use of NPK can cause imbalance in availability of the different other elements needed for plant growth, besides potentially suppressing functions of beneficial microorganisms (Streeter, 1988).

Of the approximately 30 different elements found in plant tissues and therefore needed for their growth are taken-up largely by roots of the plants during its growth. Four (nitrogen, carbon, hydrogen and oxygen) of the 30 elements constitute about 90% of the body weight of a plant (Bourguignon 1998). It is worth noticing that all the four are gases. Non-believers and/or unaware persons may note that ash content is generally less than 10% of crop biomass when burnt and it is suggestive of the fact that rest of the mass was due to gases or the elements that are volatiles. A plant can access the gases from air or soil (i.e. air in soil pores) and assimilate them in the presence of light through biochemical processes (eg. Photosynthesis) going on in its body during the normal growth process. Only rest of the <10% of its body weight is accessed exclusively from soil. It is hypothesized that in OF plants can access much of their need of the four major elements (N, C, H, O) from air (including the air in the soil pores) and water. Researchers need to verify and strengthen this hypothesis.

Results of a recent study at ICRISAT on soil samples from a field growing crops without agro-chemicals were revealing. These samples were from a field growing crops on a permanent heap concept developed by Dabholkar (2001) which had some similarity to the set-row concept described by Patel *et al*. (1983). Soil samples from heaps, below heaps and between heaps from a field brought to heap system only about three months before sampling were studied. Samples from fallow land of same farm were used as control/reference. The fallow land (labled as 'original' in Table 4) was noted to have low concentration of available form of micronutrients (at least for sulfur, boron and zinc) as per Sahrawat *et al*. 2007. Such fields should therefore be applied with micronutrient fertilizers for optimum yields. But in the heap method of growing crops used at this organic farm in village Bajwada, Dewas, Madhya Pradesh, the concentration of the same elements below the heap (having compost covered with grass mulch) was high enough (about twice to 8-times the critical limits suggested by Sahrawat *et al*. 2007) such that these quantities were no more deficient (see Table 4). It means due to the microbial activity in the biological approach (or organic farming) of heap method in this case, the non-available form of the nutrients was getting converted to available form and there was no need of external input. 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 form of an element in soil (including in the paper by Sahrawat *et al*. 2007) and not on the total quantity of that element present in soil which can be substantially higher than the critical limits in most soils (at least 12 times in the case of S, at least 45 times in the case of B and at least 103 times the critical limits in the case of Zn, in this field – Table 4). As would be apparent, most soils are likely to have all these elements in large quantities in non-soluble or total form. The job of solubilizing these elements is largely done by micro-organisms in nature, if they are given food in the form of plant biomass and enabling environment (eg. moisture and temperature). Also, when trees and annual crops are in the same field, trees can access such nutrients from below one meter soil depth, not explored by crop plants, and added on soil surface through the loppings of branches of trees stated above. Addition of at least eight t biomass per ha has been possible to a rainfed (mean around 750mm per annum) Vertisol when grown strategically through crop selection

**Table 4. Total boron (B), sulfur (S), iron (Fe), zinc (Zn), and available B, S, Fe and Zn, in the soil samples collected from Suchde Farm, village Bajwada (MP) on 19.09.07. All units are 'mg per kg soil'.**

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

Notes:

Mr Deepak Suchde (e-mail: deepaksuchde@gmail.com, mobile: 9329570960) grows crops on a small heap of specially prepared compost like soil (about 30cm diameter and 30cm high mulched with grass) which he calls Amrit Matti. Heaps were regularly watered with highly diluted (10-times) 'Amrit Pani' a ferment of 3 items (1kg fresh cow-dung, 1L cow urine and 50g Jaggary – all in 10L water and fermented for 3-days, found in studies at ICRISAT as very rich in agriculturally beneficial microorganisms, Archival Report GT-CI, 2005-2006, pages 366-367). Soil samples from the unplanted fallow area of same farm labeled here as 'Original soil' was used as reference.

Sahrawat *et al*. 2007, considered 0.58 mg per kg soil of B, 8-10 mg per kg soil of S and 0.75 mg per kg soil of Zn as critical limits.

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

NS (0.06) = Statistically non-significant at *P*=0.05 but the values are statistically significantly different at *P* =0.06.

plus *Gliricidia* on field bunds and weeds (Table 2 and 3). But this fact is not honored by most soil scientists and farmers are advised to spend on chemical fertilizers.

## Crop protection in OF

Only environment friendly options of crop protection are used in OF. These include plants and microorganisms with bio factors to kill or repel/suppress insect-pests, and cultural practices (poly crops, trap crops). Tropical countries are rich in tens or perhaps hundreds of plants (botanicals) with ability to help manage crop pests (both diseases and insect-pests). Also, microorganisms with the ability to kill/suppress crop pests occur in nature and some (e.g. *Bacillus thuringiensis*) are available commercially. In addition, each insect-pest has some natural enemies and a good number of them can be insects that are generally referred to as 'beneficial insects'. For example, as per a published report from ICRISAT, the most difficult insect-pest *Helicoverpa armigera* (also called legume pod-borer or cotton boll-worm) has about 300 natural enemies, including beneficial insects (Sharma 2001). Synthetic pesticides used in CA would highly likely kill all beneficial insects that occur in a field while the options used in OF either do not affect them adversely or affect them in a relatively small way.

In an ongoing farmer participatory evaluation of low-cost and biological options (indicated above) of crop protection in two villages, ICRISAT scientists along with partners from national agricultural research systems, have successfully protected cotton and vegetables since June 2003 (Rupela 2004; Rupela *et al*. 2006c; Rangarao *et al*. 2007). Each partner farmer divides a given field of crop of his/her choice into two parts, uses synthetic pesticides (called Farmers Practice or FP) in one and the suggested protocol (called 'Bio') in the other. Participant farmers in these villages have been paying the costs of materials used in 'Bio' plots at the rate of Rs. 1700/- per ha per crop, since June 2004. In all the four years so far, all participant farmers were generally benefited by harvesting more yield or by saving on costs of crop protection or both due to the suggested use of 'Bio' options compared to the farmers practice of using synthetic pesticides (Table 5). This suggests that the protocols of biological options were/are adequate enough to protect crops, even

**Table 5. On-farm evaluation of biological options of crop protection in two villages of Ranga Reddy district, Andhra Pradesh, India.**

| Village/ Season/ Crop | | Mean yield ($t\ ha^{-1}$) | | |
|---|---|---|---|---|
| | | BIO[!] | FP[!] | SE+ |
| Kothapally 2003/04(Cotton) | 17* | 2.43 | 1.87 | 0.08 |
| Kothapally 2004/05(Cotton) | 10* | 0.95 | 0.94 | 0.031 |
| Kothapally 2004/05 (Veg) | 7* | 1.54 | 0.97 | 0.198 |
| Kothapally 2005/06 (Cotton) | 6* | 1.74 | 1.38 | 0.096 |
| Kothapally 2006/07 (Cotton) | 9* | 1.99 | 1.68 | 0.061 |
| Kothapally 2007/08 (Cotton) | 11* | 2.52 | 2.30 | 0.057 |
| Yellakonda 2004/05(Cotton) | 21* | 1.15 | 1.21 | 0.043 |
| Yellakonda 2005/06(Cotton) | 7* | 1.48 | 1.29 | 0.055 |
| Yellakonda 2006/07(Cotton) | 9* | 1.95 | 1.56 | 0.058 |
| Yellakonda 2007/08(Cotton) | 11* | 2.53 | 2.21 | 0.047 |

* Number of farmers participating in the experiment in a given season

! = Data are means of number of farmers participating in the experiment in a given season. Only botanicals and entomopathogens were used in BIO (biological options) while synthetic pesticides were used in FP (farmers practice).

if only 7 to 21 farmers participated in a given season in a village.

Another example worth sharing is the successful management of pests without synthetic pesticides by Centre for Sustainable Agriculture (CSA), Andhra Pradesh, India. This NGO calls the method as non-pesticidal pest management (NPM) and is busy scaling up. In 2006, the NPM was used in 1050 villages, involving about 80,000 farm families and about 74,000 ha in 17 districts of Andhra Pradesh with the help of Government of Andhra Pradesh, India (see chapter by G. V. Ramanjneyulu *et al.* in this book). The area under this program substantially increased in 2007 (see www.csa-india.org).

The use of biological options for crop protection started attracting the attention of the mainstream system after the negative effects of the synthetic pesticides became known. While most scientists, particularly entomologists, believe that there is a role of biological options (indicated above) in plant protection, they generally state that the use of synthetic pesticides is a must to effectively manage insect-pests. This is perhaps due to lack of their experience with biological options and/or lack of trust in their efficacy. Government programs/policies on crop protection depend on the advice they receive from entomologists and pathologists. It is the rigid position of this group of scientists which is helping the status quo on synthetic pesticides. Farmers continue to use synthetic pesticides as their first choice and depend on input suppliers for advice on their use. Therefore a government concerned about the health and environmental costs of pesticide residues in the food chain, pollution of sub soil water and wellbeing of small-holder farmers, has to make enabling policies in this direction.

### OF is labour intensive

In the absence of mechanization (due to lack of research support from the mainstream system), several protocols of OF are indeed labour intensive. But this fact should go in favour of developing countries such as India where about 80% farmers are small-holder farmers having family labor and the government guarantees employment to its rural masses, for 100 days in a year. In due course with mechanization, it should be possible to reduce the requirement of labour for several OF practices.

### Practicing OF on large area

As per the 1991 census of India, 74 per cent farmers owned <1.4 to 2.4 ha and were called small and marginal farmers (Chadha *et al*. 2004). No doubt that the crop production based on low-cost and biological approaches are very relevant to small-holder farmers. But we have seen these approaches in practice with farmers owning over ten ha. Some such names and addresses can be sourced from the book by Alvares (2005). It would be worth visiting them to learn how are they managing such sizes using the biological approaches.

## Conclusion

Overall, what we need ideally is a high-yielding, income generating, science-based, farmer-empowering and eco-friendly agriculture system that provides nutritional and food security first to small-holder farmers and eventually to the nation. Organic farming principles have all these features. ***Appendix I*** has over 80 references where scientists have compared OF with conventional agriculture for different aspects eg. yield and nutritional value. Those interested could read them to convince themselves of the value of food grown using environmentally benign methods of crop production. Some of these publications would convince readers that protocols used by OF practitioners are scientifically sound but have not been explored adequately by agricultural scientists in its totality. Because millions of farmers are already using it globally, there is no need of its on-farm validation before Governments invest in scaling it up. However, there are several researchable topics indicated in this document and more are likely to emerge as scientists begin to explore it. Answers to all such researchable issues will be needed for a confident scale-up and its adaptation to big farms. As of now it is more relevant to small-holder farmers in developing countries. Scientists have a duty to give these farmers an opportunity to choose between “low-cost and biological options” based on organic farming principles and the modern agriculture which requires purchased-inputs.

No agricultural research institute can reject organic farming without evaluating/examining in a farming system approach, as it will be against the spirit of science. However, there are several unanswered questions from a scientific point of view and are indicated in this document.

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# Internalized Soil Productivity Management Systems and Smallholder Agriculture

**J. Venkateswarlu***

## Introduction

Over 80% of the farming community are smallholders. Their share in operational holdings is 36%. Between the marginal and small farmers, the former predominate in numbers (3.3 : 1) but the total area possessed by them is less (1 : 0.9). The average holding size is 0.40 and 1.42 ha respectively as in 1995-96. The scheduled casts are more (73%) amongst marginal farmers as compared to small farmers (8%). The tribal farmers are upto 8.6%. In any case the weaker sections dominate amongst the smallholders (Anonymous, 2004).

Considering all the important inputs in agriculture, the share of the smallholders is as follows (Sundaram *et al*, 2004).

| Input | % Share |
|---|---|
| Net sown area | 34.8 |
| Rice | 47.7 |
| Net irrigated area | 43.4 |
| Fertilizer | 41.7 |
| Fertilizer area | 39.4 |
| Electrical pumps | 53.9 |
| Diesel pumps | 58.9 |
| Power tiller | 50.4 |

The work force in agriculture and allied sectors in India is 59% as against 44% at the global level and 7% in developed countries (Anonymous, 2005). About 11% are landless (in 0 to 0.2 ha).

Thus smallholders are an important group that has to be attended to. In fact even in livestock sector, main income of these smallholders comes from livestock (MoA, GoI, 2004) as seen below.

| Land holding (ha) | Percent farmers whose main income comes from livestock |
|---|---|
| < 0.02 | 55.4 |
| 0.02 – 0.2 | 28.2 |
| 0.5 – 1.0 | 1.3 |
| 1.0 – 2.0 | 1.6 |

It is estimated that 83.6% of smallholders and landless involve more in livestock occupation. In fact the share of marginal holdings is on rise (NCF, 2007) over the last one decade.

| Livestock | Year | |
|---|---|---|
| | 1991-92 | 2002-03 |
| Milk bovines | 44 | 52 |
| Poultry | 55 | 63 |

There is a need to realize that the smallholders are both ecologically and economically disadvantaged.

Also, we have to realize that package approach has no relevance for rainfed farming, more so the smallholders. One can consider the criticality concept, meaning the most missing link be identified and addressed first. Most existing extension programmes and crop demonstrations operate through resource transfer (e.g. free seed, fertilizer, pesticide, small ruminants, fingerlings/cultures, saplings), instead of technology transfer. If there is strength in the technology it would be spreading

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on its own. Many a time creating awareness through training or field visits makes all the difference. And today there is a growing realization that knowledge and skill based rural economy leads to higher agricultural productivity (Bhattari and Narayanamoorthy, 2003). Even in the early sixties Shultz (1961) stressed on the importance of human capital in agricultural growth and development.

Coming to the future needs in R&D efforts in agricultural production, several authors discussed them in detail. Reddy, pointed out earlier that the future thrust in enhancing food production need be in rainfed areas. He pointed that ecological access for foodgrains in hinterlands could be achieved only with a concerted drive to enhance the productivity in rainfed areas. In fact he called for specific extension efforts so as to achieve this goal.

Brady (1982) focused on the need for evolving separate crop varieties for the ecologically disadvantaged areas. He argued that the Green Revolution (GR) approach is relevant only to better endowed areas (irrigation, high rainfall, better soils). For problem soils, there are solutions, but expensive and out of reach for a smallholder. So he suggested that by using the modern tools in breeding, crop varieties with better harvest index need be developed for the poorer environments. Kerr *et al* (1999) of IFPRI said that India has to depend on rainfed areas for future increased needs of food. They pointed out that the TFP is either static or declining in the GR areas. A sort of fatigue has come in the high input intensive agriculture, they opined.

Serageldin (1999) called for a separate effort to enhance productivity of crops and livestock at the level of small farmers. He felt that this could be feasible only by seeking positive synergism between crop and livestock production which was later endorsed by Kurien (2001). The other way to seek synergism is through tree-based cropping systems (agroforestry). Unfortunately alley cropping was promoted as the main approach of agroforestry in India in the earlier days. In the process, more damage was done to the concept of tree-based farming. Now it is realized that the system works well when the tree component is of economic value (e.g. fruit trees) that too not necessarily planted in alleys (Rao *et al*, 1998).

Dwarakinath (2000), while discussing the extension efforts, pointed out the need for specific attention to cater to the smallholders who largely adopt family farming. Similarly Jha (2001) said that modern tools must help the smallholders, be it information technology or biotechnology. Evans (2003) on the other hand said, till a major innovation in breaking yield barrier in crops comes through with the use of GM technology, improved agronomy alone could lead to improved productivity of crops. He cited the example of potatoes where 6-10 fold increase with a given variety became possible only with improved agronomy. To support this philosophy, the improved soil husbandry in the case of groundnut in North Carolina (USA) was cited. Similarly in the mid-west north America, zero-till or conservation tillage had become a sustainable system in not only improving cropping intensity, but also enhancing the crop yields. Among others, the major contribution of this practice is *in situ* capturing of the snow, thereby enhancing the soil moisture stored in the root profile.

As seen from the advocates on future needs, the thrust lies in rainfed farming, smallholders and improved soil, crop and livestock husbandry. Combining the best of traditional knowledge and modern technologies is called for.

## Systems of farming and the interventions in production systems

Different systems of farming currently followed when compared with those of traditional reveals interesting points.

**Table 1: Systems of farming and interventions in production systems**

| System | Present | Traditional |
|---|---|---|
| Input management | HEIA (External) | LEIA (Institutional, regenerative) |
| Commodity | Monoculture of either crops or livestock | Mixed cropping / farming |
| Biodiversity | Lost / Reduced | Maintained as part of the systems, more so with smallholders |
| Approach | Linear (Reductionistic) | Multifaceted (Dialectical) |

*HEIA = High External Input Agriculture; LEIA = Low External Input Agriculture*

*Result: Ecological niches for plants and varieties are not considered. With universalized recommendations costs in production are increasing. Peak labour demands are on rise. Productivity is declining. Resources are degrading. Ecological access to food is in jeopardy.*

Now, there is interest on Low External Input Agriculture (LEIA) from the existing High External Input Agriculture (HEIA) [Graves *et al*, 2004]. In India, this philosophy is widely adopted by Agriculture, Man and Ecology Foundation (AMEF) and its cooperating agencies for many years. It is enunciated as LEISA (Low External Input Sustainable Agriculture). LEIA / LEISA is more relevant to the smallholders who are the predominant part of the farmers in our country (~80%). Even during the early days of GR, the statisticians pointed out that instead of considering very high levels of external inputs (200-300 kg nutrients / ha), it would be more prudent to go for moderate levels (50-100 kg) as this would be in the linear response phase. They argued that it would benefit more area and even may not add to the divide between the rich and the poor. Internalized nutrient management systems are regenerative and in the reach of smallholders.

In this chapter, a brief attempt is made to highlight the internalized traditional soil productivity management systems in crop production. Some background of the system is also provided alongwith nutrient dynamics, with emphasis on N. Wherever available, some mention on soil physical condition is brought out. The external inputs like silt and sand and use of small ruminants for penning are excluded in this presentation.

## Mixed cropping

Earlier, diversity was the common feature in crop production system in rainfed areas. The crops are grown in irregular patterns either through broadcasting and/or mixing within row. This has been identified as mixed cropping (Freyman and Venkateswarlu, 1977). Largely, mixed cropping was practised by smallholders. And it is meant to meet the household food and nutritional security. In fact, as many as nine crops ("navadhanyalu") are used together in mixed cropping systems. Even vegetables, including leafy ones, are included. But all these systems are primarily to meet the household requirements of the tiller of the land.

In a detailed study Rao and Khan (2003) formed mixed cropping is largely the domain of the smallholders and is practised by in the disadvantaged areas. Of the farmers who practice mixed cropping 60%, 75% and 58% are smallholders in arid, semiarid and humid regions. And food crops are essentially the components in the mixed cropping with smallholders (100%, 71% and 93% in arid, semiarid and humid regions). Even with large holders the food crops dominated, the respective values being 100%, 72% and 94%.

| Region | Percent farmers practising mixed cropping only |
|---|---|
| Arid | 31 |
| Semiarid | 17 |
| Humid | 59 |

Mixed cropping has many benefits to the practising farmers (Parameswaran and Sivakumar, 2001)

- Different rooting systems of base and component crops
- One crop may provide a favorable micro-climate to another
- N-fixing plants fertilize non-N-fixing plants
- Pest management / control may be easy
- Labour demands are spread out
- Labour requirements are less, more so for weeding
- More moisture is retained in the soil
- Returns are higher per unit area
- Provides mixed diet over extended harvesting period
- Risk in crop failure less
- Extended labour employment

Mixed cropping provides a continuous vegetal cover to the soil during the rainy season, thus preventing the beating action of the rains. Further there would be considerable leaf litter which acts as a mulch and reduces evaporative loss of soil moisture. It also ultimately adds nutrients to the soil, thus enriching its productivity. Even the weeds are not considered as villains by the farmers. They form the green fodder for the livestock or even as uncultivated foods for human consumption (Sateesh, 2000).

Mixtures like sorghum, pearlmillet, pigeonpea, cowpea, hibiscus and horsegram are common to meet food, feed, vegetable, fuel (pigeonpea). Sometimes *Amaranthus* and sunhemp are mixed to meet the fibre requirements. Sunhemp is also grown in black soils as a green manure crop for about 6 weeks in the rainy season and incorporated into the soil to grow *rabi* sorghum. Cowpea and in a few instances cucumber for the vegetable while hibiscus and amaranthus provide green leaf vegetable.

## *Akkadi* system

It is a traditional system in southern Karnataka (red soils). This is mixed cropping of ragi with several other crops (Anonymous, 1999). Ragi is the staple crop. *Kharif* sorghum and field bean (*Avare*) are mixed to provide fodder. Pigeonpea enriches the soil and provides the much needed fuel besides the pulse. Niger is a nutritious oilseed with protein as well. Cowpeas and blackgram protect the soil from the splash action of raindrops. Mustard is a trap crop reducing pest incidence. Row planting is common using local seed drill. Also ragi seed is, sometimes, broadcast. Some enterprising farmers apply 2-3 tractor loads of FYM/ha (Rs. 1000 / tractor load) and apply one bag of DAP (50 kg). In high fertility soil, ragi is transplanted with every fourth row being cowpea, field bean or blackgram singly or in mixtures.

Niger is an interesting addition. It not only provides the oil and the protein, but through its root activity loosen the hard subsoil and the leaf litter acts as mulch-cum-manure. Such soils eventually got rejuvenated to better productivity. And this is what Sateesh (2000) also points in relation to the farmers of Medak district of Andhra Pradesh.

To sum up mixed cropping is a combination of cereals, pulses, oilseeds and vegetables meeting the daily needs of the smallholder, protecting the soil from erosion and enriching the soil with a great bio-diversity. It not only provides food, but also provides fuel, fibre, fodder and thatching/fencing material. Further some of the associate crops (mustard) act as trap / decoy crops. Finally it provides the storehouse for various commodities, as they come to maturity at different periods in the calendar year.

## Intercropping

The perceptions on intercropping depend on the researchers and the practitioner. The practitioner (farmer) aims at one or a combination of the following aspects:

i. Food security

ii. Income

iii. Trap crop

iv. Soil enrichment

The base crop which used to be the cereal was of the immediate concern of the farmer. Since his land holding is limited he tries to produce many other crops (e.g. legumes, oilseeds), vegetables and even fodder. Thus he likes to cover both food and nutritional security. This concept becomes more perceptible when women are the practising farmers.

The researcher considers, on the other hand, intercropping as a system for maximising productivity of the soils by efficient spatial and temporal use of resources (soil and rainfall). Evidently the researchers have no bias for a "base" crop. His urge would be how best to increase Productivity, Sustainability, and Monetary returns.

The increase in productivity comes through improved crop production technologies. Seed is the first in the chain through use of HYB/ HYV. Evidently the earlier systems and the growth rhythms are bound to change. For instance, the short duration sorghum/millets can provide more time and space for the pigeonpea. But if a *Phaseolus* / *Vigna* group of short pulse is taken up with these coarse cereals, the latter may be affected with a possible competition for water and nutrients at the critical physiological stages of these crops. By use of external inputs like N, we may affect the efficiency of the legume component. It could be easy for a researcher to place nitrogen exclusively for the cereal crop. But it means more labour for the farmer. So more cost/ha.

The most commonly researched intercropping is cereal-legume system. And the legume provides all the necessary ingredients for sustainable crop production. Associating legume in fibre crops like cotton and oilseed crops like castor are well researched upon. But the extensive plant protection measures for cotton/castor can lead to fair amounts of residues that might even affect human/animal health as these component crops are cleared earlier from the field.

Higher returns is one of the major thrusts of any researcher. But at what cost is the crucial question. With more than 75% farmers (in rainfed areas) being poorer, they cannot afford to take up high investment production system, more so in intercropping system. Through these systems many of the farmers seek food and nutritional security. How to reduce the costs of cultivation would, axiomatically, be the primary question that need be addressed by the researchers.

As mentioned earlier, mixed cropping provides enough leaf litter. In an excellent study Pratap Narain *et al* (1980) studied the leaf litter contribution in a sorghum + pigeonpea (1:1) intercropping in Kota (Rajasthan). Abstracted details are given in Table-2.

**Table 2: Contribution of leaf litter and N in sorghum + pigeonpea (1:1) intercropping**

| Treatment | Leaf litter (q/ha) | Total N (kg/ha) | Yield (q/ha) | |
|---|---|---|---|---|
| | | | Sorghum | Pigeonpea |
| NoPoKo | 22.6 | 30.9 | 10.83 | 8.91 |
| $N_{25}$PoKo | 10.5 | 14.6 | 15.43 | 4.78 |
| No$P_{40}$Ko | 27.1 | 37.3 | 10.94 | 7.834 |
| $N_{25}P_{40}$Ko | 18.33 | 24.5 | 15.43 | 4.98 |
| No$P_{40}K_{30}$ | 25.2 | 34.9 | 8.81 | 9.30 |
| $N_{25}P_{40}K_{30}$ | 7.9 | 11.0 | 14.98 | 5.10 |

The data suggest leaf litter could effectively enhance pigeonpea productivity. Chemical N additions did enhance yield of sorghum but could not compensate the loss in yield of pigeonpea. In another study Abdurahman *et al* (1998) found that the leaf litter in sorghum+pigeonpea system in a vertisol yielded 3.00 t/ha of leaves and left 2.40 t/ha of root mass, thus totally 5.4 t /ha of organic matter. The importance pigeonpea in the cropping systems is highlighted in such systems.

Coming to sustainability, intercropping experiences, reduced yield variations as compared to sole cropping as seen below (Rao and Willey, 1980; Walker and Subba Rao, 1982).

| Intercropping system | CV % |
|---|---|
| Sorghum + pigeonpea | 39 |
| - Sole sorghum | 50 |
| - Sole pigeonpea | 44 |
| Cotton + pigeonpea + sorghum | 44 |
| - Cotton + pigeonpea | 55 |
| - Sole sorghum | 68 |

## Traditional sequence cropping systems

The traditional double cropping systems in India are many. Two examples/case studies are given below.

## Case study-1: *Maghi* sorghum in deep black soils of Khammam, Andhra Pradesh

Khammam district in Andhra Pradesh receives more than 1000 mm annual rainfall with an assured moisture supply period of 180-210 days. The soils here are predominantly deep and black. They are universally poor in nitrogen and high in potassium, while available phosphorus is adequate only at a medium level of production.

In rainfed areas sorghum, maize, greengram and groundnut are the important crops. One of the important indigenous methods here is the greengram-sorghum sequence cropping system. It used to occupy around 60,000 ha in the district (Venkateswarlu, 1999).

### Features of sequence cropping

For the rainfed farmer of Khammam, sorghum, sown sometime in the second fortnight of August is the important staple crop. Rainfall analysis indicates that the highest probability of the onset of monsoon is in the fortnight beginning 11th June and recedes with a good assurance by end October. This means that the total length of monsoon rains is about 20 weeks. Since the soils are deep and with the rains ending in the cooler part of the year, the crop growing season would be about 180-210 days. Evidently, a two crop sequence with 65-70 days variety of grain legume followed by a coarse grain crop of about 100 days is a distinct possibility.

Thus the farmer has been taking up greengram as a grain legume when he is able to sow the crop by early June. He then incorporates the haulms as a green manure for the following sorghum crop which is neither a typically *kharif* nor *rabi* crop. This is known as *Maghi jowar* (sorghum), generally sown in the third week of August. In the process he not only capitalises on the nitrogen and other nutrients ploughed in through the greengram but also improves the physical environment of the soil. When greengram haulms are used as green manure about 35-40 kg N / ha would be incorporated into the soil prior to taking up *maghi* sorghum, besides the other nutrients added through the system.

Addition of such small quantities of organic residues is the only way to take advantage of organic matter additions in improving the soil physical condition. Such incorporations enhance soil aggregation in terms of mean weight diameter (mm) increasing from 0.11 to 0.38 in black soils. The infiltration also improved from 2.59 to 8.10 cm / ha. Such a practice would lead to better recharge of the root profile with subsequent showers, and consequently better root proliferation. The yield of *Maghi* sorghum in this area has been rising, unlike many other districts in the state. As of now the average grain yields of greengram and sorghum are 0.45 and 1.1 t/ha, respectively.

### Mid-season corrections

The rainfall, however, does not always follow the normal distribution pattern. On analysis, it is found that the duration of the rainy season could vary between a low of 14 weeks and a high of 28 weeks. Whenever the monsoon is delayed, the farmer applies mid-season corrections.

When he sows greengram by the last week of June, it may not mature fully for the timely sowing of *Maghi* sorghum. So he harvests greengram at physiological maturity and ploughs in the haulms as manure. In the event of a further delay in sowing, only the mature pods are picked and the haulms ploughed in. If, however, there is an even greater delay, the greengram is incorporated directly as green manure. In all cases, the farmer has two critical aims - firstly to sow his staple crop of sorghum on time, and secondly, to use greengram as a source of nutrition for the staple crop.

## Case Study - 2: Rice based double cropping in north east India

Largely, rice crop is the important staple for north east India. This is because of the good rainfall (more than 1000 mm) received in the region. Farmers take up rice crop in different physiographic situations in the sloppy lands that are common in the region (Venkateswarlu and Vittal 1999). In the high moisture regime zones they take a second crop of a legume. The legumes include lentil, lathyrus and sometimes blackgram and greengram. Mostly these legumes are cultivated through *paira/utera* cultivation. The seed of legumes is mostly broadcast when the standing rice crop about 7-10 days prior to harvest. The *piara / utera* crop, thus, is a bonus as there is no fertilizer application or land preparation. Incidentally the association of a legume in the cropping sequence provides space for N-economy and even better response to N on the following rice crop.

The farmers in many areas harvest about 1/3 of the rice plants from above and leave the crop residues in the field. They harvest the legumes by hand and leave the residues. The livestock is allowed to graze these fields which in the process leave their excretions (urine and dung) on the fields. When the next monsoon starts in the coming year, the farmers plough the residues into the soil and pond the rainwater in the fields. Since anaerobic conditions exist during the process, the residues quickly decompose as anaerobic decomposition is a low energy process.

In this system the nutrients recycled, with particular reference to N would be as in Table-3.

**Table 3 : Nitrogen additions in rainfed rice**

| Source | N (kg/ha) (upland to lowland) |
|---|---|
| Crop residue | 6 – 18 |
| Atmospheric N | 10 – 15 |
| Livestock | 10 – 15 |
| Soil non-symbiotic N | 4 – 5 |
| Soil available N | 20 – 30 |
| *Bueshening** (contribution of ploughed in weeds and excess rice seedlings) | 30 – 45 |
| Total | 80 - 128 |

* Applicable in bunded uplands, medium lands and lowlands

Of this we can assume 65% as usable by the standing rice crop from atmospheric N, soil N and non-symbiotic N. About ½ of total N may be available from other sources. The available N works out to 46-70 kg N / ha in areas practicing *bueshening* and 30 kg N / ha in unbunded uplands. It works out to 46 – 70 kg N / ha. Assuring a response of 20 kg grain / kg N the base yield with the recycling system varies from about 600 kg in unbunded uplands and 900 – 1400 kg in bunded uplands, medium lands and lowlands. And that is what the farmers obtain from their traditional farming.

Thus, farmers in the region have been practising a very sustainable low input technology to obtain respectable yields of about 800-1200 kg of rice per ha. In the above two examples the traditional wisdom of the farmer is clearly seen. As researchers we can only intervene to improve upon the system for enhanced productivity.

Even in medium rainfall areas, a short legume can be used as a cover crop. Venkateswarlu *et al* (2007) showed significant enhancement in soil organic matter as well as yield of sorghum and sunflower in a 10-year study with horse gram as a cover crop in the SAT red soils of Telangana

## Traditional tree-based systems in agriculture

Trees had been a common component in arable lands. However due to mechanization and overuse, many of them have vanished from the farmers' fields. Still a few examples are available where tree-based farming is in vogue. Two such examples are presented hereunder.

### a) Alder

Alder (*Alnus nepalensis*) is grown in Nagaland, Sikkim and other NE states for enhancing the soil productivity for growing various crops. Alder grows well in attitudes between 1000 – 3000 m msl and in high rainfall areas of Nagaland (>1500mm). It is a non-leguminous tree which, however, fixes atmospheric N through Frankia to the tune of 150 kg / ha (Sharma *et al*, 2002). Dhayni (1998) reported 2.2 times increase in yield of cardamom under Alder canopy.

Besides its role in improving soil fertility, alder is used for firewood, furniture and as poles in house construction. The foliage acts as a mulch. It provides shade to coffee plantations at lower altitudes and cardamom at higher elevation. The trunks of the roots are also laid across the slopes to slow down erosivity of the runoff water.

The alder trees vary in population in arable lands. These trees are pollarded at 2-2.5 m above ground level. The twigs and stems are used for fuel. The leaves are left on the field and burnt along with the stubbles of the earlier crop to add nutrients to the soil and also to oxidize $Fe^{2}$ to $Fe^{3+}$ (an irreversible reaction), thus reducing possible $Fe^{2+}$ toxicity in the oxisols of Nagaland. Then arable cropping is practised growing different crops (as mixture) needed by the farmer. The pollarded trees coppice well and by the time the crops come to maturity full canopy develops.

### b) Khejri

*Khejri* (*Prosopis cineraria*) is common in arid regions of NW India (west Rajasthan, Haryana, Gujarat, dry parts of Deccan). It is largely limited to rainfall below 500m. Khejri is a leguminous and is small to moderate sized evergreen thorny tree. It partly sheds leaves from mid-October to mid-February. Thus considerable leaf litter accumulates under the trees and light will be unlimiting for crops grow along with them. Agarwal *et al* (1975) have reported that *Khejri* fixes up to 250 kg N/ha/year.

In the farmer's fields under *khejri* canopy, the yield of barley was 999 kg/ha as against 537 kg/ha away from the canopy in Hisar district of Haryana under rainfed conditions (Kumar *et al* 1998). Such yield increases under *khejri* canopy were reported in the case of chickpea, pearlmillet, mungbean and clusterbean. Thus it is clear that *khejri* is the *kamadhenu* (well wisher) of the arid zone farmer providing sustainability in crop production.

### c) *Sesbanias*

*Sesbanias* as a plantation fixes upto 350 kg N / ha / year and the biomass could be upto 32 t/ha/year. The *S.rostrata* species nodulates on the stem also.

*S.sesban and S.grandiflora* find market as leaf fodder, edible flowers and leaves, fuel wood (calorific value of 4500 K cal/kg), charcoal, poles for house construction, small wood gums, medicine, pulp wood, etc. *S. bispinosa* is valued mainly as a source of green manure for *in situ* ploughing in crop fields. In addition to these direct benefits they confer several indirect benefits by improving the soil fertility status by way of N-fixation, providing shade, as wind breaks etc. Some *sesbanias* like *S.grandiflora* are preferred as shade plants in tea and coffee plantations.

### d) Gliricidia

Gliricidia received an interesting coverage recently from Joshi (2002). He recalled the great M.S. Sivaramani's effort in encouraging gliricidia (*Gliricidia sepium*) as a green manure for rice in the erstwhile Madras Presidency in the early 20th century. He also persuaded the nearby Bombay Presidency and the Princely states of Travancove and Cochin by planting gliricidia on rice field bunds and lopping it for use as green manure to the rice crop. Bumper crops were obtained by its use without application of any fertilizers.

Gliricidia, however, was not accepted as a panacea to substitute chemical fertilizers, more so for other crops than rice by the then government(s) at centre and state level. Thus Sivaramam and gliricidia went into oblivion. Fortunately, in the recent past there is rekindled interest in this wonderful tree. Its leaves (green manure) are not only used for rice, but used even for rainfed crops. The Jute Research Station, Barrackpore indicated that a 5t gliricidia green manure equals 40 kg N / ha effect. Sharma (1998) of CRIDA, Hyderabad also showed that the yield of sorghum with gliricidia at 40 kg N / ha level were 690 kg / ha as against 530 kg/ha with urea N.

## Green leaf manuring

a) Story of Pongamia

In Penugonda Mandal of Andhra Pradesh in one of the villages, the earlier generation of an irrigated farmer (large farm) was using the loppings of pongamia as green manure to his tankfed rice crop. The landless and / or the poor were lopping pongamia trees from the adjoining hillocks and CPRs and carting the same for a price. About 125 bundles / ha were being applied. It was costing Rs. 675/ha. Pongamia is an excellent green manure. It analyzes for 3.69 % N. 2.41 % $P_2O_5$ and 2.42 % $K_2O$. This process of green manuring came to a grinding halt when fertilizers (urea and DAP) appeared in the market. This was more so when farming came into the hands of the son. He found it economical and easy to handle to apply urea and DAP which was applied at 100 kg N and 50 kg $P_2O_5$ / ha. The costs were then Rs. 350/ha. Then came the grandson, a graduate in Agriculture. He was knowing the importance of organic manures and that too for a rice crop. And the costs of urea and DAP also increased by that time. 100 kg N + 50 kg $P_2O_5$ / ha cost him Rs. 1300/ ha. Not only that. The responses to added fertilizers declined from about 20-25 kg/kg nutrient to just 8-10 kg of nutrient. With his knowledge acquired during his studies, he moved to 50% pongamia loppings and 50% fertilizers. The rice crop yields started showing up again. The soils became healthy. The responses bounced back to 18-20 kg/kg nutrient.

Now he intends to use of 100% pongamia loppings as manure to his rice crop. It may cost him more (Rs. 1875/ha now). But still he prefers as the response would be at least 20 kg/kg nutrient as against 10 kg/ka with chemicals.

### b) *Bueshening* leads to green manuring

*Beushening* in rainfed lowland rice (Chandra 1999) is an age-old practice in the shallow submerged low land rice in most of the eastern states. *Beushening* is criss-cross ploughing in a standing rice crop of 30-45 days after seeding when 10-15 cm depth of water stands in the field. This is followed by laddering and seedling re-distribution. Sometimes weeding is also taken up.

The weed population decreased considerably with *beushening*.

| Treatment | Line | Deep weigh (g/m$^2$) | |
|---|---|---|---|
| | sowing | *Beush-ening* | No *Beush-ening* |
| Hand weeding | 90 | 62 | 92 |
| No hand weeding | 194 | 124 | 434 |

The grain yield under weed control was more than *beushening*. However hand weeding is a difficult proposition in these areas as labour is the constraint. The results suggest the merit of *beushening* was as much as 310 g / m$^2$ of weeds are buried as green manure. This is besides the additional rice seedlings ploughed in. The weeds and additional rice seedlings may add at least 45 kg N/ha taking 1.5% N as average content in the weed flora. With line sowing, *beushening* and no *beushening* the yields were 1870, 1680 and 790 kg / ha. Under same treatments when the weeding also was taken up the yields were 3040, 2910 and 2750 respectively. It, thereby, shows that weed control is needed for better yields. However, the additional yield with *beushening* even in hand weeded situations is due to root pruning of the rice seedlings. Thus in the absence of labour, at least *beushening* leads to higher productivity.

Finally, we may conclude that *beushening* suppresses weeds, leads to root pruning and incorporates weeds and excess rice seedlings as green manure for the standing rice crop. Such a 'green-manuring' effect is welcome in lowland rice as its decomposition does not need high energy (being anaerobic). Also *beushening* saves demand on labour, an increasingly felt constraint in these areas.

## Ley farming

Rao *et al* (1997) studied ley farming (with *Cenchrus ciliaris*) as an alternative farming system in the Indian arid zone. They found a six year lay in the arid zone would provide yields equivalent to 40 kg N/ha (Table - 4).

The increase in yield is attributed by Rao *et al* to the following

- Soil organic matter was more with ley farming (0.51 in control to 0.92 % in 6-year ley in 0-15 cm soil)
- VAM species (count/100 g soil) was more with ley farming (130 as against 390)

**Table 4 : Production of pearl millet as influenced by ley farming**

| Grass ley | Grain yield (kg ha$^{-1}$) | | Stover yield (kg ha$^{-1}$) | |
|---|---|---|---|---|
| | With stubble | No stubble | With stubble | No stubble |
| CCF[a] + no fertilizer | 850 | | 2200 | |
| CCF + fertilizer (20 kg N + 17.5 kg P/ha) | 1015 | | 2716 | |
| 4-year ley | 950 | 892 | 3090 | 2833 |
| 6-year ley | 1292 | 1050 | 3920 | 3350 |
| 8-year ley | 1450 | 1227 | 4467 | 3910 |
| Statistical significance [b] | | | | |
| Ley LSD | 156 | | 261 | |
| Stubble LSD | 117 | | 180 | |
| Ley X stubble LSD | N.S. | | N.S. | |

[a] CCF, conventionally cultivated field; [b] $p = 0.05$; N.S., non-significant
Note: Fertilizer N was applied through urea and P through single superphosphate

- Similar was the case with dehydrogenase, nitrogenase activity (1.7 and 3.9 times respectively over control)
- So was with nitrifying bacteria ($10^2$ / g soil) values being 4.2 for control and 7.9 for 6 year ley.
- The steady state infiltration rate (cm/min) was 0.14 and 0.16 with the control and 6-year ley while the saturated hydraulic conductivity in the field was 3.25 and 0.55 (Kfs x $10^{-2}$/sec). The data suggests retention of rainwater in the root profile.

Thus ley farming, practised, by a few farmers is allowing the soil to recoup and make it more living with improved organic matter and better microbial activity. Also the treatment retains rainwater in the root profile.

The ley farming was also tested in the red ley soils of the semiarid Telangana. Korwar (1992) reported that ley farming with *stylosanthus hamata* grown for 3 years followed by sorghum increased the organic carbon in the soil as also the yield of sorghum significantly. In a more recent field verification CEC and CRIDA have shown the significant increases in yield sorghum + pigeonpea intercropping system, and that too in a drought year (2004).

## Natural supply of nutrients

The natural resources (soil, rainfall, dust) provide several nutrients for crop plants. With reference to N. Barthalomew (1971) estimated these supplies as follows.

| Source | Amount (Kg/ha) |
|---|---|
| Soil organic nitrogen | 20 – 30 |
| Rainfall | 6 – 8 |
| Non symbiotic nitrogen fixation | 2-4 |
| Dust and organic particles through rainfall | 12-16 |
| Average | 30 – 35 |

Besides N, the rainwater provides several other nutrients. For instance, Krishanmoorthy (1955) estimated the average rainwater composition as follows, with reference to micronutrients.

| Micronutrient | Content (ppm) |
|---|---|
| Fe | 0.08 |
| Mn | 0.016 |
| Cu | 0.027 |
| Zn | 0.05 |
| B | 0.13 |
| Mo | 0.00075 |

*Note: The surface and groundwater would contain 1/3rd content of the cationic elements while it would be 6-10 times more in the case of anionic elements*

Thus the replenishment of nutrients from natural resources is one of the means for achieving some base level yield even without external inputs.

## End Note

From the above discussion, it is clear that there are ways and means to supply the needed plant nutrients without any ecological damage as is the case with the chemical agriculture/green revolution. These systems not only supply the nutrients but improve the soil physical conditions and provide the much needed energy to the various heterotrophic soil flora and fauna through the turnover of organics. We like to recall the statement of Charles E. Kellog, the famous soil scientist that "Essentially, all life depends upon the soil. There can be no life without soil and no soil without life; they have evolved together".

Such systems are not universal, but location and crop specific. They are doable. And a community managed development approach can be adopted in the improvement of soil productivity. Then the smallholders will be the beneficiaries by forming homogenous groups as SHGs. Even financiers will be assured. That upscaling doable/internalized production systems through SHGs is easy as indicated by Vijayakumar (2007). He succeeded in bringing considerable cotton area in Andhra Pradesh under NPM through the community developed management system.

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# Building Soil Organic Matter : A Challenge for Organic Farming in Rainfed Areas

**K.L. Sharma***

India is predominantly a rainfed country. Of the total geographical area of 329 m ha, 142 m ha is devoted to agriculture (FAI, 1990). The gross sown area is around 190 m ha. Out of an estimated net cultivated area of about 142.2 m ha, only about 55 m ha is under irrigation, while 87 m ha is unirrigated. The irrigated area produces about 56% of total food requirement of India. The remaining 44% of the total food production is supported by rainfed agriculture. Most of the essential commodities such as coarse cereals (90%), pulses (87%), and oil seeds (74%) are produced from the rainfed agriculture. These statistics emphasise that rainfed regions play a major role in ensuring food for the ever-growing population. The rainfed regions are predominantly marked by low cropping intensity, relatively low organic matter status, poor soil physical health and low fertility. Further, moisture stress accompanied by other soil related constraints also results in low productivity of crops (Sharma *et al.,* 1997).

## Soil-resources and related constraints

The yield curve in most of the crops such as rice, wheat and maize in irrigated areas has touched the plateau because of stagnated response to the added inputs. Therefore, it is anticipated that, if at all another green revolution is possible in Indian agriculture, it would come from grey (rainfed) areas only. Even with years of agricultural research, the gap between possible potential yield of rainfed crops and their actual realized yields could not be narrowed down. Apart from moisture limitations, rainfed areas are also at disadvantageous position because of low soil organic matter content and poor soil fertility. The predominant soil orders which represent rainfed agriculture are: Alfisols, Inceptisols, Entisols, Vertisols, Oxisols and Aridisols. Out of the total geographical area of 328.28 m ha, Entisols constitutes 24.4% (80.1 m ha), Inceptisols 29.1 % (95.8 m ha), Vertisols 8.02% (26.3 m ha), Aridisols 4.47% (14.6 m ha), Mollisols 2.43% (8 m ha), Ultisols 0.24% (0.8 m ha), Alfisols 24.3% (79.7 m ha), Oxisols 0.08% (0.3 m ha) and non-classified soils 7.01% (23.1 m ha). It has been estimated that about 187.7 m ha area, which constitutes of 57.1% of total geographical area is degraded. Of the total degraded area, water erosion constitutes 148.9 m ha (45.3%), wind erosion 13.5 m ha (4.1%), chemical deterioration 13.8 m ha (4.2%), physical deterioration 11.6 m ha (3.5%). Another 18.2 m ha (5.5%) land which is constrained by ice caps, salt flats, arid mountains, and rock out crops is not fit for agriculture at all (Sehgal and Abrol, 1994). The soils in rainfed areas have been severely affected due to (i) loss of finer fraction of top soils, organic matter and nutrients due to soil erosion and run-off processes, (ii) virtually no or low recycling back of crop residues to the soil due to competing demand for crop residues as animal fodder, (iii) temperature mediated oxidation of organic matter due to frequent

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tillage resulting into breaking of micro-aggregates and exposure of SOC entrapped in them. As lack of assured moisture does not support higher cropping intensity in these regions, contribution of root biomass towards organic matter in soil is also not very high.

Apart from these, low and imbalanced fertilizer use has also resulted in multi-nutrient deficiencies. In addition to the natural reasons, the man made reasons like inability of the resource poor farmers to feed their crops with external source of nutrients owing to risk involved, continuous mono-cropping etc., has resulted in poor soil fertility. Among the major nutrients, nitrogen is universally deficient (<280 kg $ha^{-1}$) in Indian soil whereas, phosphorus falls between low to medium (10-20 kg P $ha^{-1}$) category. Potassium, which was once considered to be adequate for meeting the crop requirements in rainfed areas, has also been documented to be deficient in many reports. Naidu *et al.*, (2002) have reported decline in the status of potassium in three soil series of Mahaboobnagar district of Andhra Pradesh based on the periodic monitoring.

As a whole in the country, about 75% of the 27,000 samples tested across the country were found to be deficient in available S (Biswas *et al*., (2004). In the states of Uttar Pradesh, Madhya Pradesh, Maharastra, Orissa, Jharkand, West Bengal, Andhra Pradesh and Karnataka, more than 70% of soil samples were either deficient or potentially deficient in available S. Tandon and Rego (1989) have reported that the Zn deficiency in semi-arid areas ranges from 26% (Gujarat) to 77% (Haryana). The analysis of more than 1,00,000 samples at eight centers of ICAR Coordinated Schemes on Micronutrients in Soil and Plants have shown that 47% of the soils were deficient in Zn. Zinc deficiency is more widespread in arid and semi-arid soils than in humid and sub-humid zones. The soils which are coarser in texture, high pH, high in $CaCO_3$ and low in organic carbon are generally prone to Zinc deficiency. Rego *et al* (2005) have concluded that more than 70% of the soils in states of Andhra Pradesh, Rajasthan, Gujarat, Haryana and Tamil Nadu are deficient in available boron based on the analysis of soil samples collected by them. Generally, Fe deficiency is noticed in calcareous Vertisols as there is a negative correlation between DTPA extractable Fe and $CaCO_3$ content (Murthy and Viswanath 1987). Venkatraju (1987) has reported the deficiency of Fe in red soils of Andhra Pradesh.

## Contribution of fertilizers in maintaining food security

Irrespective of role of other inputs, fertilizers have played a key role in enhancing the yields of various crops especially of those under assured irrigation. Increased use of chemical fertilizers has played a unique role in making the green revolution in India a success by virtually transforming Indian agriculture from subsistence to surplus generating enterprise. Fertilizer use has catapulted food grain economy to a position in which we are capable of producing substantially more than our requirements in normal monsoon years and even when the monsoon conditions were bad as in 1987-88, fall in production was minimal quite unlike the bad experiences of the mid-60s. In terms of Dr. Norman Borlaug, India and China would have needed about 2-3 times more land under cereals to meet the food needs of 1991, if these two countries would have continued to use the technologies of sixties and not enhanced the fertilizer input to sustain its present level of food production (Pratap Narayan and Uttam Gupta (1997). The comprehensive review on fertilizer use status (macro and micronutrients) in rainfed areas, related constraints and strategies have been discussed in detailed by Singh and Sharma (2002), Sharma *et al*, (2005) and Balloli *et al*. (2005). Although the fertilizer use has considerably increased from as low as 65 thousand tonnes during 1951 to 18145 thousand tonnes during 2004, still a net negative balance (removal-use gap) of 9701 thousand tonnes is reported (Tiwari, 2006; Tandon, 2004). The estimated fertilizer requirement during the year 2011 would be 28.08 million tonnes comprising of 16.17 m tonnes of N, 9.28 m tonnes of $P_2O_5$ and 2.63 m tonnes of $K_2O$ (Shriram, 2003). At present, the fertilizer nutrient ($N+P_2O_5+K_2O$) consumption in India is significantly low (99 kg $ha^{-1}$) as compared to our next door neighboring country, China (277 kg $ha^{-1}$) and other Asian countries such as Japan (290 kg $ha^{-1}$) and Republic of Korea (409 kg $ha^{-1}$). Surprisingly, in about 70 districts of India, still the fertilizer use is less than 25 kg $ha^{-1}$ (Tiwari 2006). If second Green Revolution is to be achieved, the present level of fertilizer consumption has to be increased considerably specially in rainfed areas. Considering the present level of native soil fertility, and organic matter status in rainfed semiarid tropics, complete substitution of inorganic sources of nutrients with organic sources is rather an indomitable task. Hence, there is a need to strategically plan for improving soil organic matter and nutrient pools by way of recycling of organics and by adopting integrated nutrient management practices. Build up of organic matter in tropics and semi-arid tropics, is a challenging task.

## Soil organic matter

Soil organic matter, a most precious component of soil, is also considered as store house of many nutrients. It consists of a mixture of plant and animal residues in various stages of decomposition, substances synthesized chemically and biologically from the breakdown products, and microorganisms and small animals and their decomposing remains. In simple terms, it can be classified into non-humic and humic substances. Non-humic substances include those with still recognizable physical and chemical characteristics such as carbohydrates, proteins, peptides, amino acids, fats, waxes, alkanes, and low molecular weight organic acids. Most of these compounds are attacked relatively readily by microorganisms in the soil and have a short survival period. The humic substances which form the major portion of organic matter in soil are characterized by amorphous, dark colored, hydrophilic, acidic, partly aromatic, chemically complex organic substances with molecular weight varying from few hundreds to several thousands. Humic substances are categorized into three parts: i) humic acid which is soluble in dilute alkali but is precipitated by acidification of the alkaline extract, ii) fulvic acid which is the humic fraction that remains in solution when the alkaline extract is acidified and iii) humin, which is the humic fraction that cannot be extracted from the soil or sediment by dilute base and acid (Schnitzer, 1982). When plant and animal remains are recycled in soil, they undergo the various stages of microbial decomposition and humification. Since agricultural soils contain little litter and decomposed litter layers, SOM generally refers to non-humic substances which constitute 10-15% of total organic materials, and the humic substances which comprise the largest fraction (85-90%).

Organic matter (OM) is what makes the soil a living, dynamic system that supports all life. The significance of soil organic matter (SOM) accrues from the following facts:

- Organic matter is considered as a food / energy source for soil microorganisms and soil fauna. Without OM, the soil would be almost sterile and consequently, extremely infertile.
- It is the storehouse of many plant nutrients such as N, P, S and micronutrients and contributes significantly to the supply of these nutrients to higher plants. There is very little inorganic nitrogen in soils and much of it is obtained by transformation of the organic forms. Plants are therefore, dependent either directly or indirectly, for their nutritional requirement of nitrogen on SOM.
- SOM also plays an important role in improving the majority of soil physical properties such as soil structure, water

holding capacity, porosity, infiltration, soil drainage, etc.

- Soil organic matter also helps in improving various chemical properties of soil. For example, the increased cation exchange capacity and enhanced ligancy help in trapping nutrient cations like potassium, calcium, magnesium, zinc, copper, iron, etc. Improved soil buffering is its another important contribution.
- Apart from the nutrients within the soil organics themselves, SOM contributes to nutrient release from soil minerals by weathering reactions, and thus helps in nutrient availability in soils.
- Plant growth and development are benefited by the physiological actions of some organic materials that are directly taken up by plants.
- The organic substances also influence various soil processes leading to soil formation.

## Organic matter as soil structure builder and store house of nutrients

It has been established that the organic matter content of agricultural soils is significantly correlated with their potential productivity, tilth and fertility. Although the amount of soil organic matter (SOM) in most semiarid dryland soils is relatively low ranging from 0.5 to 3% and typically less than 1%, its influence on soil properties is of major significance. Organic matter is the predominant material facilitating soil aggregation and structural stability even at low concentrations. Better soil structures helps in improved air and water relationships for root growth and in addition protect soils form wind and water erosion. The dark colour imparted by humic fraction of SOM increases the soils capacity to absorb heat and to warm rapidly in the spring. In semiarid regions with low or intermittent rainfall, organic matter is the major pool for some of the essential plant nutrients. The N, P, S contents of these soils average 0.12%, 0.05% and 0.03% respectively, with 95% of the N, 40% of the P and 90% of the S being associated with the organic matter component. Since the soil organic matter constitutes the predominant pool of plant nutrients, the decomposition and fluctuation within this pool are of major significance to nutrient storage and cycling. In many dryland cropping systems, depending on fertilizer additions and crop rotations, 50% or more of the nitrogen required by the crop comes from the mineralization of SOM. The microbial action that mediates this decomposition and nutrient release process is regulated by perturbations of the system such as wetting of dry soil, tillage, and addition and placement of residue. These types of perturbations affect the dynamics of SOM decomposition, the size of the microbial biomass pool and nutrient release (Smith and Elliott, 1990).

## Factors affecting organic matter in soil

According to Ghosh and Bhradwaj (2002), organic matter content in soils varies considerably and is largely dependent on the environmental conditions. Most of the cultivated soils in temperate regions contain high OM levels (5-10%) in their surface horizon, whereas similar soils in the tropics and semi-arid topics have only one-fifth or one-sixth as much (often less than 1%). These variations are attributed to certain 'factors of soil formation' as given below:

Organic matter = f (climate, time, vegetation, parent material, topography,……)

According to Jenny, the order of importance of different soil forming factors in determining the organic matter content of soils is as follows: climate> vegetation > topography>parent material> age. Further, Theng *et al.* (1989) expressed that the overall importance of the environmental factors determining soil C content is in the following order: rainfall>pH> clay content> temperature for tropical regions and rainfall> pH> temperature > clay content for temperate regions (Prasad and Power, 1997).

## How management effects SOM

There are several reports on the influence of soil management practices on SOM. It has been understood that management practices can modify soil organic matter levels by affecting organic matter inputs and influencing to some extent the degree or potential for turnover. Results of long-term rotational experiments indicate that increasing C inputs (e.g. manure) can cause a gradual organic matter accumulation over time, especially in arable farming systems (Jenkinson, 1990). Soil management strategies used to enhance organic matter storage, where organic C inputs remain stable, involve practices that provide for cool wet conditions at the soil surface (i.e. change in soil microclimate) such as mulches, surface residue application and minimum or reduced tillage (Follett, 1993; Kern and Johnson, 1993). However, major short-term improvements in soil organic matter storage are dependent upon changes in vegetation or cropping practices, crop rotations, etc.

## Soil capacity for organic matter storage

Carter (1996) has comprehensively reviewed the storage capacity of organic matter in soils. He has emphasised that the amount of organic matter stored by any particular soil is dependent upon climate, soil type and landscape, type of vegetation and soil management practices. The influence of climate on soil organic matter storage can be expressed by the relationship between mean annual temperature and annual precipitation. Tate (1992) and Cole *et al.* (1993) emphasised that the wet, cool climates tend to slow organic matter turnover and subsequently favour organic matter accumulation in soil while moist, warm or hot climates favour rapid decomposition. Generally, soil organic matter decomposition processes are strongly dependent upon the interaction between temperature and precipitation. The overall influence of climate, however, can be modified by soil type and landscape. Edaphic conditions, such as soil particle size, pH, quantity and type of clay minerals, and internal drainage can influence organic matter accumulation and storage. Such intrinsic properties can impact on organic matter storage and decomposition, either directly or indirectly, by modifying the soil chemical (Tate, 1992), physical and biological environment, and subsequently influencing the soil aggregation process (Oades and Waters, 1991; Robert and Chenu, 1992). Soil topography and drainage can also modify the macroclimate resulting in a range of microclimates across a landscape and subsequent differences in soil organic matter storage.

Within any one climatic zone, vegetation differences can have a major impact on soil organic matter accumulation. Differences in C fixing capacity and in C partitioning within plants resulting in concomitant differences in root biomass, shoot/root ratios, thickness of roots and amount of root exudates can influence organic matter mineralization and accumulation in soil (Juma, 1993). Shifts in use of vegetation can directly increase soil organic matter storage (Schlesinger, 1990). A combination of soil and vegetation factors can enhance organic C storage in some situations (e.g. Mollisols) (Scharpenseel *et al.*, 1992). In many cases, however, vegetation effects are related to the high ratio of C to N in roots and other plant residues (compared to soil), and thus constitutes a temporary (i.e. non-sequestered) accumulation of organic matter subject to relatively rapid turnover and dependent on continual C inputs.

## Progressive concepts, diverse views, scopes and experiences – towards organic farming

The various views and experiences related to organic farming and management practices are presented as follows:

- As envisaged in tenth five year plan of government of India under chapter 5.1

(5.1.72-74) on agriculture, a sizeable quantity of organic farm wastes is generated which could be utilized for providing nutrition to the crops after converting it into compost or manure. The report of the Task Force on Organic Farming, 2001 constituted by the Department of Agriculture and Cooperation (DARE) has estimated that about 356 mt crop residue is available annually. Out of this, about 170 mt is soil incorporated and about 136 mt is available for manuring. Besides the crop and crop residue, a sizeable quantity of municipal solid waste is also available, which could be utilized for generating energy and making manure. Technologies for pelletisation and bio-methanization are available for using the municipal solid waste to generate energy and manure. Alternatively, the entire municipal solid waste could be used for making compost, for which technologies are already available. Vermicompost, which is rich in nutrients, could also be made from the organic farm wastes. The conversion of farm waste and municipal solid waste into compost/manure can supplement the use of fertilizers in crop production. Use of such composts will also improve the health of soil by providing organic matter for the required biological activities in addition to improving the physical condition of the soil. As organic matter also contains micronutrients, the increasing deficiency of micronutrients in soil could also be corrected. Therefore, thrust will be given for using organics in agriculture by converting farm waste and municipal waste into good quality compost/ manures/ vermicompost.

- The realization of the importance of organically produced food is growing all over the world and the demand for such food items is increasing. Prices of such products are several times higher. Being a low chemical fertilizer consuming country, especially in the rainfed areas, northeastern and hill states, India has good opportunity to take up production of organic foods for exports and domestic use. Considering this, organic farming would be encouraged and facilities developed for testing and certification of organically produced foods (X Plan document, 2002-03).

- Organic farming took on a new lease of life during the 1980's, not just in Britain but also around the world. The problems of over production in developing countries and the environmental impact of agriculture have brought the growth of the organic movement and the market for organically produced food. Organic farming is increasingly being recognized as a potential solution to many of the policy problems facing agriculture in both developed and developing countries. Denmark, Sweden West Germany etc., have introduced schemes to support farmers financially during the critical conversion period (ITCOT, 2001).

- Organic farming prohibits the use of synthetic fertilizers, pesticides, growth regulators, and livestock feed additives. Organic farming definitely includes application of crop residues, animal manures, green manures, off-farm organic wastes, crop rotations involving legumes and biological pest control to maintain soil productivity. (Palaniappan and Annadurai, 1999). In other words, the basic idea behind organic farming is to feed the soil to maintain its health rather to feed the crop. In the language of Funtilana (1990), it is one of the ways to return some thing back to the nature, which has been taken from it. While practicing the concept of organic farming, we have to be alert about ecological fundamentalism that leads to the total exclusion of synthetic chemicals. (Hegde *et. al.,* 1995).

- There is a diversity of opinion, which has emerged across the world over about the myth, and the facts of organic farming. Some people believe these opinions as myths, whereas some believe that there may be a truth. Some of the diverse opinions are that (1) organic food tastes better and is of superior quality; (2) organic food is more nutritious and safer; (3) organic farming is eco-friendly; (4) organic farming improves soil fertility and chemical fertilizers deteriorate it; (5) organic farming sustains higher yield (6) enough organics are available to replace chemical fertilizers (Chhonkar, 2003).

- Chhonkar (2003) in a very comprehensive and explicit manner, reviewed that green revolution in India came due to introduction of high yielding varieties, extension of irrigated areas use of high analysis fertilisers and increase in cropping intensity which in turn made this country self sufficient in food. To achieve the food production targets, compared to chemical fertilizers, the contribution of organic manures to supply essential plant nutrients declined. At the same time indiscriminate and blind use of chemical pesticides to control various insect pests and diseases over the years has destroyed many naturally occurring effective biological control agents. Resistance of pests to chemical pesticides is also on the rise. The occurrence of multi-nutrient deficiencies and overall decline in the productive capacity of soil under intensive fertilizer use have been widely reported. Consequent to these problems, various new concepts of farming such as organic farming, natural farming, biodynamic agriculture, do-nothing agriculture eco-farming etc are being advocated.

- Lampkin and Padel (1994) expressed that organic farming is an approach to agriculture where the basic objective is to create integrated, humane, environmentally and economically sustainable agriculture production systems, which maximize reliance on farm-derived renewable resources, and the management of ecological and biological processes and interactions so as to provide acceptable levels of crop, livestock and human nutrition, protections from pests and diseases, and an appropriate return to the human and other resources employed. Many people interpret the meaning of organic farming differently. The term 'organic' is best thought of as referring not to the inputs used, but to the concept of the farm as an organism, in which all the component parts - the soil minerals, organic matter, microorganisms, insects, plants, animals, and humans interact to create a coherent whole. Alternatively, organic farming is termed as the ecological agriculture, stressing the reliance on eco -system management rather than the external inputs, chemical or otherwise. According to the American Society of Agronomy, an organic system is one, which is structured to minimize the need for off-farm soil, or plant focused inputs. Detailed description of organic farming has been given by Lampkin, (1990) and Neuerburg and Padel, (1992).

- Lampkin (1994) described the key features of organic farming as;

  1) Protection of long-term fertility of soils by maintaining organic matter levels, enhancing soil biological activity and careful mechanical intervention; (2) providing crop nutrients indirectly using relatively insoluble nutrient sources which are made available to the plant by the action of soil micro-organisms (3) making adequate N supply by means of biological N fixation, by incorporating legumes in crop rotations and by recycling of organic materials including crop residues and livestock wastes; (4) weed, disease and pest control relying primarily on crop rotations, natural predators, diversity, organic manuring, resistant varieties, and (preferably minimal) thermal, biological and chemical interventions; (5) the extensive management of livestock, paying full regard to their evolutionary adaptations, behavioral needs and animal welfare issues with respect to

nutrition, housing, health, breeding and rearing; and (6) careful attention to the impact of farming system on the wider environment and the conservation of wild life and natural habitats.

- According to Dahama, (1997), organic farming is a production system, which favours maximum use of organic material (crop residues, animal excreta, legumes, on and off farm organic wastes, growth regulators, bio-pesticides etc., and discourages the use of synthetically produced agro-inputs, for maintaining soil productivity and fertility and pest management under conditions of sustainable natural resources and healthy environment.

- Cultural practices and management are important determinants, which govern the organic matter status in soil. There are several factors which influence organic matter content of soils. Some of these factors include temperature, rainfall, type of vegetation, tillage practices, and susceptibility to erosion and moisture regime. In general, organic matter appears to be a function of climate and soil management (Sekhon and Meelu, 1994). Fall in content of organic matter has been reported as climate changed from humid to arid (Katyal, 1985).

- Sustainable crop production strategies are necessary to avert food shortages and to ensure uninterruptedly adequate level of soil fertility status. It also aims at preserving the inherent soil quality over time, in order not to compromise or reduce food growth opportunities for future generations. Equalizing nutrient harvests with additional inputs is a prerequisite in sustaining productivity goals (Katyal *et al.*, 1999). Hence, while practicing organic farming, one has to keep in mind the nutrient balance in soils.

- Sharma and Srinivas (1997) and Sharma *et al.* (2007) have reported that non conventional farm based materials such as castor stalks, sunflower stalks, loppings of gliricidia maculata and cowdung can be successfully converted with or without small quantity of rock phosphate and pyrite into a nutritive compost containing total N as high as 1.08 to 1.6%, mineral N, 108 to 208 ppm, C: N ratio: 15.58 to 21.52, and total hydrolysable N: 6870 to 9724 ppm. They have further emphasized that use of earthworms can substantially influence the manurial value of the compost thus produced. This strategy can be linked with organic farming.

- Sharma *et al*. (2004), reported that the two INM treatments, 2t gliricidia loppings + 20 kg N and 4 t compost + 20 kg N were found to be most effective in increasing the sorghum grain yield by 84.6 and 77.7 percent over control. However, the highest amount of organic carbon content (0.74%) was recorded in 100 % organic treatment (4 t compost + 2 t gliricidia loppings). Some of these options of managing nutrients by using farm based organics can form a potential component of organic farming.

- While conducting the long-term experiment, Sharma *et al.* (2002) reported that the conjunctive use of urea and organics such as loppings of leucaena and gliricidia (1:1 ratios on N equivalent) had considerable effects on raising the sorghum grain yield to the levels of 16.9 and 17.2 q $ha^{-1}$ respectively and thus revealed that a minimum of 50 % N requirement of sorghum can be easily met from farm based organic sources of nutrients. This information can be used to supplement fertilizer nitrogen upto 50% by using green loppings of *Gliricidia maculata* and *Leucaena leucocephala* and will be useful while planning for raising organic produce.

- Sharma *et al.* (2005) reported that organic carbon in the soil was significantly influenced by application of crop residues such as sorghum stover and gliricidia @2 t $ha^{-1}$ under minimum and conventional tillages in sorghum-castor rotation in rainfed Alfisols. Further, they reported that increase in nitrogen levels from 0 to 90 kg N $ha^{-1}$ also helped in significantly improving the organic carbon status in these soils over a period of 8 years. From these studies, they concluded that continuous application of organic residues is inevitable to see the significant effect on organic carbon status in soils. One has to think to improve organic carbon and nutrient pools in soil by way of recycling of sparable crop residues and other biomass available in the farm while going for organic farming.

- Further, the long term studies conducted on finger millet for 14 years in Alfisols of Bangalore dryland centre also revealed that continuous use of FYM @ 10 t $ha^{-1}$ in combination with recommended level of NPK helped in giving higher yields and improving organic carbon in soil considerably (Sharma *et al.,* 1999).

- Vandana Shiva (1991) has observed that in Punjab, where green revolution has made much headway, the once fertile soils are now diseased and dying under the influence of uncontrolled irrigation and indiscriminate use of inorganic fertilizers. For producing the same quantity of farm products, it has become necessary to enhance input use every year. This has increased the cost of production per unit of output resulting in the marginalization of resource poor farmers and weakening of the food security of the economically deprived people.

- Thampan (1995) opined that organic agriculture is comparatively free from the other complex problems identified with modern agriculture. It is basically a sustainable farming system and bestows many benefits to the practicing farmers. It is environmentally friendly as it conserves the ecological base of farming and does not cause pollution. It also augments the local availability of biomass for use as source of renewable energy to satisfy the increasing energy needs of rural households.

- Based on the research conducted by Dr. Franko weibel (2000) and reported in the Journal of Applied Nutrition, it has been found that on a per weight basis, over a two-year period, average levels of essential minerals were much higher in the organically grown apples, pears, potatoes, and corn as compared to conventionally produced products. The organically grown food averaged higher in Ca, Cr, Fe, Mg, Mo, P, K, and Zn and lower in Hg and Al. A more recent study in Australia showed a similar difference between Ca and Mg levels in organic and non-organic food. It was also stated that, plants naturally synthesize phenols for defence against pests and diseases. Possibly, the unsprayed organic plants were stimulated to make higher levels of these critical molecules in response to pests attack. These phenolic compounds that protect the plant also have been shown to be disease protectants in humans (http:// www.mvoai.org/24_appendix7.html).

- Soil organic matter is valuable because of both its beneficial effect on soil quality and crop productivity and its potential to sequester C. Long-term experiments provide an opportunity to identify crop management practices that enhance or degrade soil quality (Rasmussen and Parton, 1994).

- With the intense use of fertilizer and pesticides, soils in most part of the world have shown elevated levels of metal concentrations in the soil, which might be a potential source of their introduction into food chain. Microbial activities and processes like soil microbial respiration, microbial biomass C, biomass N, N mineralization have been used successfully for studying metal effect on soil quality (Khan, 2000). The use of no tillage without residue burning during eight years on an Ultisol located in South Chile has produced soil quality changes. Soil organic matter content in the 0-5 cm deep layer has increased from 6 to 8% (Rulfo-Vilchis *et al.,* 1997). The capacity of inorganic production practices to improve soil quality was mainly due to use of more diverse crop sequences, application of organic amendments, and less frequent tillage (Liebig and Doran, 1999). There were significant differences in the soil quality among farmer's field in terms of INS (Indigenous N supply). Heavy metal contamination can impact soil ecosystems sufficiently to result in significant losses in soil quality (Kelly and Tate, 1998). From soil conservation perspective, no-tillage has an additional advantage because surface cover is maintained throughout the year, thereby reducing the potential for soil erosion (Pikul and Aase, 1995).

- According to Rajendra Prasad (2005), continued use of organic manure on a farm improves its organic matter content, which supports the soil micro, meso and macro fauna and makes the soil a living body. Organic manure improves soil structure and increases water holding capacity, which is important under dry farming conditions. Continuous addition of organic manure assures a regular supply of micronutrients. Nevertheless, availability of macronutrients from organic manures is not as fast as from chemical fertilizers, because it depends upon the rate of their decomposition which is controlled by their C: N ratio. Myths such as better taste, improved quality and higher nutritive value generally attached with organically produced foods have been argued and found to lack a scientific basis. Nevertheless, market for organically produced foods is on the increase.

- Tandon (1997) has estimated that if we consider that 30% of dung, 80% of excreta and 33 % of crop residues of total production will be available for agricultural use, 5.05, 6.24 and 7.75 Mt of NPK may be supplied through these organic sources by the year 2000, 2010, and 2025, respectively. Another potential source of nutrient could be green manuring. Apart from these, sewage sludge and industrial effluents, which are quite rich in nutrients, can be another source of nutrients. Chhonkar *et al.,* (2000 a,b) has reported that 285 Indian distilleries in a year amount to nearly 40 billion liters which can provide 0.48 Mt of K, 0.052 Mt of N and 0.008 mt of P (0.54 mt NPK). Further, some more optimistic estimates reveal that by capitalizing all possible sources of nutrients, only 25-30 % of the nutrient need of Indian Agriculture can be met by utilizing various organic sources. It is also said that on per kg nutrient basis, organic manures and residues are more expensive than chemical fertilizers. (Rajendra Prasad, 2000).

- According to Badgley *et al*. (2007), based on 293 examples, the average yield ratio of organically to non-organically produced food was < 1.0 for developed world and > 1.0 for developing world. Further, they claimed that organic agriculture has the potential to contribute quite substantially to the global food supply, while reducing the detrimental environmental impacts of conventional agriculture. They also observed that leguminous cover crops could fix enough nitrogen to replace the amount of synthetic fertilizer currently in use.

Considering the whole spectrum of the above discussion on organic farming, it can be concluded that in semi-arid tropical rainfed regions, specific strategies need to be followed to improve the organic matter in soils and soil fertility levels. In view of the targets fixed for food production to feed the growing population, synthetic fertilizers cannot be replaced instantaneously in case of cereal crops where nutrient removal rates are very high. However, in case of some of the commercial cash crops such as fruits, vegetables, etc., where assured export market is available, organic farming can be practiced by following suitable soil – crop management practices.

The management practices must focus on improving the organic matter status in soil and organic pool of nutrients. Building the fertility status with special emphasis on hydrolysable nitrogen pools in rainfed soils will help in slowly moving towards organic farming. Some of the strategies for improving the organic matter and nutrient pools in soil and the overall strategies for improving the productivity of crops are suggested as follows.

## Strategies to enhance SOC

1. Controlling top soil erosion
2. Conservation tillage (specially reduced and zero tillage) and surface residue management, mulching, etc.
3. Balanced and adequate fertilization and integrated nutrient use
4. Inclusion of legumes in cropping systems
5. Green manuring and green leaf manuring
6. Carbon sequestration through agroforestry tree species and its recycling by leaf litter fall.
7. Use of soil amendments
8. Regular use of manures

## Strategies for enhancing the productivity of rainfed crops and cropping systems on sustainable basis

- Correction of limiting nutrient(s) including micronutrients, balanced fertilization through site-specific nutrient management approach in rainfed areas can help in augmenting the productivity
- Inclusion of short duration legumes in cropping systems
- Green leaf manuring with the help of nitrogen fixing trees like gliricidia and leucaena and off-season biomass generation and its incorporation
- Recycling and enhancing the quality of organic residues using effective composting methods
- Capitalization of the potential of microbes/ bio-fertilizers
- Linking agricultural practices with short and long-term climatic forecast
- Adoption of site-specific soil and water conservation measures,
- Appropriate crops and cropping systems for wider climatic and edaphic variability
- Enhancing the input use efficiency using the principle of precision agriculture
- Diversified farming systems for enhanced income and risk mitigation
- Ensuring credit, market access and crop insurance

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# Green Leaf Manuring and Organic Farming

**G. Subba Reddy***

## Introduction

Indian Agriculture has made tremendous progress during the last four decades. The success in agriculture production is attributed to wide spread adoption of high yielding varieties and realization of their full potential by enhancing the use of essential inputs along with improved management practices. However, these benefits are not accrued in rainfed regions to the same extent. Indian agriculture mostly depends on seasonal rains. Even after exploiting the existing irrigation potential, 60% of the agricultural land would still remain rain dependent. Water stress accompanied by poor soil fertility are main cause of the low productivity of these rainfed soils. Wide nutrient gap exists between removal and supply in farmers' fields under rainfed environment. This gap can be minimized by supplementation of organics with inorganics, tree based nutrient recycling through agro-forestry and green leaf manuring practices (Singh, *et al.*, 1998).

Rainfed soils are not only thirsty but also hungry as these soils are nearly exhaustive of organic matter and suffer heavily from several nutrient deficiencies (Katyal, *et al.*, 1991). Maintaining the balance between nutrient removal and addition is one of the pre-requisites for sustainable rainfed agriculture. Hence there is an urgent need to find out alternate sources of nutrients to supplement inorganic fertilizers.

## A) *In situ* biomass production

### 1. Green manuring vs green leaf manuring

The practice of green manuring is as old as that of the art of manuring crops. Crops grown for the purpose of restoring or increasing the organic matter content in soil are called green manure crops. Their use in cropping system is called green manuring, where the crop is grown *in situ* or brought from outside and is incorporated. Green leaf manuring consists of gathering green biomass from the nearby locations and adding to the soil. In both, the organic materials should be worked out into the soil for easy and rapid decomposition. Legumes are usually utilized as green manuring crops as they fix atmospheric N and leave part of it for utilization of companion and succeeding crops. Green/green leaf manuring in rainfed land helps to improve physical and chemical properties of the soil, maintenance of organic matter and serves as a source of food and energy for microbial population in the soil (Palaniappan, 1997). The criteria for selection of green leaf manuring crops in rainfed regions are: multipurpose use, high biomass production, fast initial growth, more leaf than wood, N fixing ability, good affinity with mycorrhiza, efficient water use, tolerant to pests and diseases, easy and abundant seed formation, high seed viability, high N content. Some cropping systems where green manuring is possible along with net income are given in Table 1 & 2.

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**Table 1. Potential areas for adoption of green manuring in rainfed cropping systems**

| Area | Soil type | Rainfall (mm) | Cropping System |
|---|---|---|---|
| Bangalore | Alfisol | 924 | Cowpea-fingermillet |
| Bhubaneswar | Alfisol | 1463 | Greengram-fingermillet |
| Ranchi | Alfisol | 1462 | Fingermillet-chickpea |
| Rewa | Vertisol | 1168 | Blackgram-wheat |
| Agra | Inceptisol | 765 | Greengram-mustard |
| Akola | Vertisol | 877 | Greengram-safflower |

**Table 2. Economics of innovative GLM based cropping systems in Vertisols of Madhubhavi village (Bijapur)**

| Cropping system | Net income (Rs/ha) | | |
|---|---|---|---|
| | 1999 | 2000 | Mean |
| Fallow-safflower/sorghum | - | 745 | 745 |
| Cucumber-sunflower | 32566 | 52026 | 42296 |
| Cucumber-*rabi* sorghum | 23159 | 8819 | 15989 |
| Mungbean-sunflower | 15275 | 7370 | 11323 |

### 2. Hedge row planting

Mulch cum manure is a practice adopted to improve the fertility and productivity of the soil under rainfed conditions. Growing of leguminous bushes, which have the capacity of fixing nitrogen can be grown on field boundaries. The biomass obtained from this plantation can be utilized as mulch in between crop rows raised during *kharif*. This practice facilitates in reducing the impact of rain on the soil, minimizing the nutrient and soil losses and controlling the weeds effectively. Besides improving the yields, this system improves soil quality (Table 3).

### 3. Agro forestry

Alley cropping is a system of growing crops in alleys formed by hedge rows and shrubs. Hedge rows are coppiced at sowing of crop and during the season to prevent shading. The biomass obtained from the hedge rows can be used as mulch to cut down the cost of nutrients (Tables 4 & 5). Suitable tree/ shrubs for GLM purposes were identified for varied environments in the National Agricultural Research System (Table 6).

## B) *Ex situ* biomass production

### 1. Block Plantation

Block plantation of leguminous trees/ bushes in non-arable lands helps to produce biomass. Some of the suitable species grown as block plantation include Neem (*Azadhirachta indica*), *Delonix elate*, *Pelophorum spp.*, *Ipomoea cornea*, *Calotropis gigantia* which have good potential as green leaf manures in rainfed

**Table 3. Mulch-cum-manure technology on productivity of sorghum + Pigeonpea-Castor system at Nallavelli village in Andhra Pradesh (1999-2000)**

| Treatments | Castor equivalent (kg/ha) | Net income (Rs/ha) | Annual run off (mm) | Total soil loss (t/ha) |
|---|---|---|---|---|
| T1: No FYM and no fertilizer | 328 | 2035 | 33.90 | 0.58 |
| T2: FYM@5 t/ha + 40:30:0 kg NPK/ha | 691 | 5493 | 24.70 | 0.22 |
| T3: T2 + glyricidia | 984 | 8307 | 14.90 | 0.16 |

**Table 4. Influence of *Leucaena* loppings on productivity and nutrient uptake in sorghum**

| Treatment | Grain yield* (kg/ha) | Uptake (kg/ha) | |
|---|---|---|---|
| | | N | P |
| Control | 1160 | 33.7 | 14.0 |
| Subabul loppings added | 1440 | 40.2 | 17.2 |
| Subabul was planted without adding lopping | 990 | | 11.3 |
| Subabul planted and lopping were added | 1350 | 38.7 | 17.9 |

**Table 5. Influence of *Leucaena* mulch on productivity of wheat in *leucaena* based agro forestry system**

| Treatment | Yield (kg/ha) | | % increase due to mulching |
|---|---|---|---|
| | Mulching | No mulching | |
| Leucaena + 8 rows of wheat | 2333 | 2035 | 15 |
| Leucaena + 12 rows of wheat | 2193 | 1862 | 18 |
| Leucaena + 16 rows of wheat | 2528 | 1942 | 23 |
| Leucaena + 20 rows of wheat | 2446 | 1883 | 23 |

*Leucaena paired row at 40 cm apart.

**Table 6. Tree species for green leaf manuring for different agro eco system**

| Agro Eco system | Suitable species |
|---|---|
| Humid zone | *Acacia auriculiformis*<br>*Calliandra calothyrus*<br>*Glyricidia sepium*<br>*Leucaena leucocephala* |
| Semi-arid zone | *Acacia albida*<br>*Prosopis cineraria*<br>*Pongamia glabra*<br>*Albizzia falcatoria*<br>*Cajanus cajan* |
| Arid zone | *Acacia nilotica*<br>*Cassia siamea*<br>*Prosopis alba*<br>*Azadirachata indica*<br>*Calotropis gigantia*<br>*Ipomea caruca*<br>*Zyzyphus mauritania* |

environment (Gajanan *et al.*, 2000). Climatic zone suitable species are listed in Table 6.

### 2. Plantation on highways and waterways

There is a need to augment biomass production and produce more and more biomass by extending the area. In short, about 60 lakh tons of green manure can be produced by planting trees on high ways and on sides of railway lines (Krishnappa *et al.*, 1996).

## Participatory technology development on GLM

GLM practices in different production systems were more confined to research stations. Hence there is a need to give highest priority to generate, assess and refine the technologies of GLM on participatory mode. The important areas that need attention for the wide spread use of this practice are: Selection of the species for different environments, establishment techniques of GLM trees and shrubs, agro-techniques for sustainable production of biomass, integration of indigenous green leaf manuring practices with modern technologies, time and method of incorporation of various materials for higher N-use efficiency and evaluation of low cost equipment for effective incorporation.

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# LEISA Approach in Soil Fertility Management - A Case Study with Use of Groundnut Shell Manure

**V. Maruthi***

Organic farming's basic tenet is the creation of a healthy, fertile soil. On this base, the rest of the production system is built. Organic farming is primarily a soil building process. Relevant to this is understanding soil as a living, dynamic entity to achieve self-sufficient agro-ecosystem. Non-recycling of biological wastes back into the soil deprives microbes of their food supply, which in turn affects the release of essential nutrients and affects the yields of the crops initially. Generally, organic farming systems should maintain or increase soil fertility on a long-term basis. This is achieved through management practices that create soils which can feed the plants and not through soluble fertilizers (chemical). Organic farming systems rely upon crop rotations, crop residues, animal manures, legumes, green manures, mechanical cultivation, application of approved mineral-bearing rocks to maintain soil structure and productivity and to supply plant nutrients.

Generally shift from chemical fertilizers to organics disturbs not only soil microbial activity but also the nutrient dynamics, therefore, the yields in the initial years of shifting, reduce and after a gestation period, yields similar to the inorganic fertilizers are possible. Organic matter content, microbial activity and general soil health are taken as measures of soil fertility. An analysis of organic farming systems has found that organic farming increased microbial activity by 30-100% and microbial biomass by 20-30%.

Plants grown in an organic system take up nutrients as they are released slowly from humus colloids by microbial activity as governed by temperature. In this type of system, the metabolism of the plant and its ability to assimilate nutrients cannot be stressed by excessive uptake of soluble salts.

Depending upon the material, organic wastes can supply macronutrients (N, P, and K) and micronutrients to the soil for use by crops. These materials can replace part or all synthetic fertilizers used in an operation. Adding organic matter to mineral soils can improve their physical properties (infiltration, water holding, structure, etc.) and chemical properties (Cation Exchange Capacity, fertility, etc.). Through agricultural utilization of organic wastes, producers can benefit (and possibly derive marketing potential) from materials that otherwise may be placed into landfills or present environmental pollution.

## Strategies of Soil Fertility Management

Soil Fertility Management for organic farming incorporates the use of animal manure, compost, cover crops, green manure, legumes rotation, phosphate rock, agroforestry and perennial grass-crop rotations for organic matter enhancement.

i. The use of animal manure completes nutrient cycle allowing for a return of

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energy and fertilizer nutrients to the soil. Manure from livestock feedlots, poultry operations and dairies could be utilized. The use of compost in commercial organic agriculture is promising. Compost is beneficial in a number of ways. It contains antibiotics and antagonists to soil pests; increases crop yields and builds up soil organic matter.

ii. The use of green manures and cover cropping is a standard practice in organic farming. Selection of green manure crops and aspects of management is dependant upon the intended function of the crop. A significant drawback in using green manures and cover crops is that they occupy land in *lieu* of a cash crop. Often times, a grower may not be able to afford this short-term reduction in income.

iii. Cropping systems

iv. Soil amendments

v. Crop residues

The negative impacts of the green revolution technologies prompted us to look back at the indigenous practices which disappeared over time. Some practices however survived through the green revolution phase, mainly due to their strength and local relevance (Thrupp, 1989). One such practice is the preparation and application of groundnut shell manure (GSM) using groundnut (*Arachis hypogaea* L.) shell, a crop residue that groundnut farmers of Anantapur district in India have practiced for generations and continue to practice even today. In the olden days, these farmers used to meet the nutrient requirements of crop through crop residue management as significant amount of nutrients are still present in the plant residues after harvest (Fraser and Francis, 1996). This practice used to improve the water holding capacity of the soils by enhancing the organic matter (Jenny, 1941; Perucci *et al*., 1997).

Short-term methods in achieving organic cultivation involve introducing the organics in the existing farmers' practices at possible levels, rejecting the opinion of " very difficult to adopt". The value addition of residues if flows in the daily routine of the farmers conserving all renewable resources can be sustainable. Over time, if the farmers, begin to utilize more organics in his/her farm, undoubtedly "improved soil resilience during droughts". This leads to the medium term goal of shifting to organics. Both these goals will achieve the long-term goal of organic farming. But before it is targeted, attention should be to identify value addition opportunities of such residues.

### a. Direct land application

Direct land application of raw or partially treated wastes is a well-known method of waste utilization. Animal wastes and sewage, sludges contain both plant-available nutrients and immobilized nutrients (which may become available as the organic material decomposes). Waste material characteristics, soil moisture, and temperature will affect the rate of decomposition in the field. Application rates should be based upon soil fertility, crop requirements, and chemical characteristics of the waste(s). Timing will depend upon crop needs and the weather. Application method will depend the physical characteristics of the waste and upon equipment availability.

No herbicides or pesticides may be used at any stage of the cultivation or processing of organic produce. The most common method employed for weed control is the use of mulches which have other advantages such as moisture retention and stabilizing soil temperatures while reducing erosion. Plants being grown organically are less susceptible to attack by pests and diseases since they are not being stressed by the uncontrolled uptake of soluble salts, however these plants are not totally immune to attack. Environmental controls such as provision of suitable habitats for predatory insects and insectivorous birds are encouraged in preference to the use of naturally occurring pesticides such as Pyrethrum, although it is permitted.

### b. Value addition/ conversion

Research to develop feasible and sustainable organic cultivation techniques, which are site-specific, is urgently required. This would include monitoring the environmental impact of organic production systems, such as leaching of nitrates, the volatilization of ammonia from livestock wastes, etc. The research should focus not only on chemical fertility, but also on the physical and biological fertility of soil, appropriate machinery for tillage and harvesting operations.

Groundnut shells constitute 30-40% by weight of harvested groundnut pods. While the weight of shells obtained from a single crop in a hectare of land is not much (typically 400 kg), the volume of shells is large. The farmers of Anantapur spread the groundnut shells to a height of two inches on the floor of the cattle shed where cattle are housed. The cattle urinate and defecate on the layer of shells and these wastes get mixed with the shell as the cattle trample and roll over the floor in the shed. Urine and dung laden shells are removed from the floor after 4 days and heaped outside. Another layer of shells is spread, removed and added to the heap. This process continues until all the available shells get exhausted. The material in the heap is allowed to decompose for 2-3 months after which it turns into fine organic manure.

At the beginning of the monsoon season, the shell manure is spread in the field and incorporated during preparatory tillage. Typically, a farmer with 2 ha of land gets about 800 kg of shell after removing the seed. In a cattle shed of 10 m long and 3 m wide designed to house 5 adult cattle, about 200 kg shell is required for each spreading. Thus, the shell available with the farmer is exhausted in 4-5 cycles of spreading and removal spanning 20-25 days. During rest of the year, the farmers prepare farmyard manure with the urine, dung and fodder waste from the cattle shed. After 2-3 months, 600-700 kg of shell manure (dry weight) is obtained. Since the quantity of shell manure generated is small, farmers can divide their field into two parts and apply the available shell manure to each of the two plots in alternate years.

In the earlier days, crop production in these areas was entirely based on organics. They adopted several nutrient and pest management techniques which is now generally known as Indigenous Technical Knowledge (ITK). Some ITKs have applicability for the recent times others were lost due to the advances in technology and degeneration depletion of local resources. However, there are some ITKs, which are still practiced with all interest and enthusiasm. One among them is Cattle shed bedding with crop residues. The author carried out a participatory research with farmers on this practice for 3 years. The experiences are summarized below:

**Preparation of Groundnut shell manure (GSM):** The process of putting the material (crop residues) as bed in the cattle shed and scraping the urine soaked shell and heaping it. The groundnut shell manure so heaped had to undergo decomposition for about two months. However, one of the farmers did not remove the soaked layer but went on putting another layer over the other. The reason he gave is that the layer existing below will not get dried and lose the nitrogen element.

### Perceptions of the farmers about experimenting

The farmers were very enthusiastic about the advantages of utilizing crop residues for recycling. Cattle urine for quicker decomposition is being saved which is a renewable energy source as water for composting is a great constraint in most of the villages. Provides dry environment for cattle besides acting as the absorbing material.

## Results

Significant difference was observed with regard to yield in groundnut shell manure applied fields over the farmers' practice. However, compost application resulted in equivalent yields to that of groundnut shell manure, but the treatment of regenerative practice, which is entirely organics, recorded better than the farmers' practice. However the difference was marginal.

The groundnut shell applied alone resulted in significant yield increase in irrigated *rabi* crop was involved.

During *kharif,* 10-15% increase in yield was recorded while it was 20-25% during *rabi*.

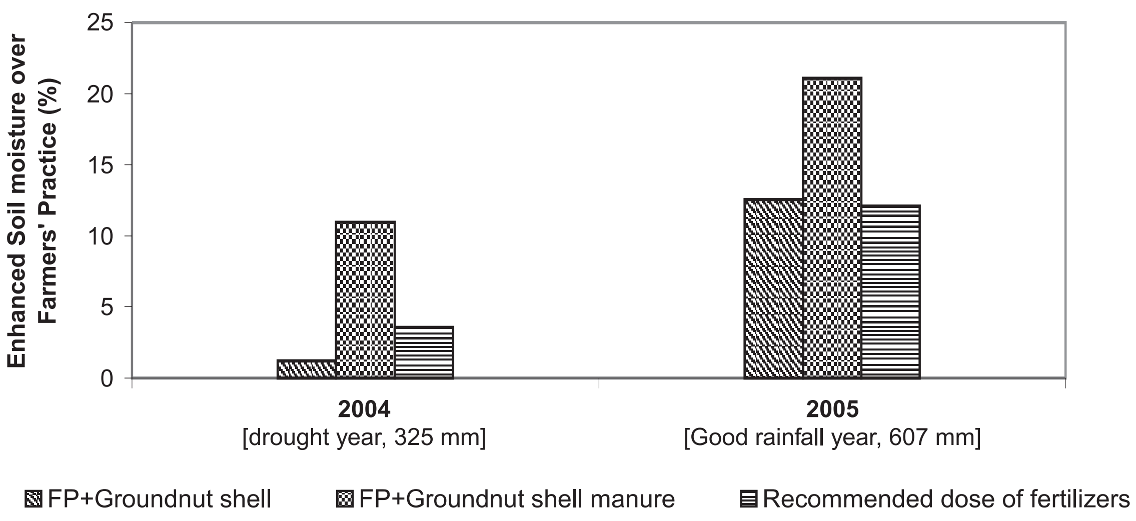
For a dryland crop, water holding capacity of soil gets improved through application of groundnut shell. If *kharif* crop, it helps in drought coping while in case of *rabi* irrigated crops, this reduced the irrigation frequency reducing the use of ground water.

Application of combinations of organics and inorganics had varied impact on the soil and crop in terms of enhanced soil moisture holding capacity and nutrient availability during cropping through reduced soil resistance for peg penetration. During a drought year (2004), at pegging stage (38DAS) when there was a dryspell of 24 days, application of FP+GSM improved soil moisture retention by 9% over FP while it was only 7% over groundnut shell application (Figure 1).

At the end of two years, it was found that two sequential applications of 1 tonne of either groundnut shell or GSM in addition to farmers' practice improved the soil chemical characteristics marginally while no significant improvement was observed with soil physical characteristics, though improved soil moisture retention could be observed during cropping period enhancing the growth and yields of groundnut and castor. Otherwise no particular trend was observed with regard to calcium.

## Yield attributes and Yield

Improved soil moisture retention, reduced soil resistance, nitrogen sufficiency and enhanced plant nutrient uptake resulted in concomitant increase in yield attributes of groundnut *viz.*, percent filled pods per plant and 100 seed weight. Percent filled pods per plant realized were 59-67% of the total pods




*Treatment details in Table 1*

Figure 1. Influence of different treatments on improved soil moisture retention during two years

produced per plant during a deficit rainfall year (2004) while it rose to 87-93% during 2005, a well distributed rainfall year. Dry spells at flowering and pod filling stages affected both percent filled pods per plant and 100 seed weight in groundnut while only filled pods per plant was influenced during a well distributed rainfall year. Crops with the GSM application recorded highest number of filled pods per plant (50 and 69 respectively) when compared to the crop applied with groundnut shell (41 and 67 respectively) and farmers' practice (42 and 64 respectively) in both drought year as well as during the well-distributed rainfall year. Besides this, number of pegs formed per plant was more (25%) in GSM as there was more moisture retention in soil. There is a chance of tapping this increased sink capacity by improving the filled pods per plant. The groundnut crop suffered from dryspells of 24 days and 30 days duration at flowering and pod filling stages in 2004. Rainfall during crop growth was 265 mm, which reduced soil moisture availability at critical stages, and affected the nutrient uptake resulting in low % filled pods per plant (59 to 72%). Hence low groundnut yields were lower during 2004, ranging from 465 kg $ha^{-1}$ to 546 kg $ha^{-1}$ (Table 1). However, the receipt of 503 mm rainfall during crop period of 2005 resulted in yields to the tune of 1817 kg $ha^{-1}$ to 2102 kg $ha^{-1}$. This emphasizes the importance of soil moisture availability to the crop in drylands. Further GSM applied crop recorded highest yields both during 2004 and 2005, over groundnut shell applied crop. Expression of low yields by applying groundnut shell as such could be due to high content of fibre (65%-70%), which is known to be a recalcitrant substance highly resistant to decomposition. This emphasizes the importance of application of more organics in improving soil moisture and maintaining soil health in drylands.

It is evident that application of value added crop residues has added advantage in improving the yield levels over farmers' practice irrespective of the quantity and distribution of rainfall and is a better alternative strategy in drought mitigation particularly in rainfed production systems.

## Epilogue

There are ITKs collected, documented and validated which can be integrated (the existing ITKs documented in several parts of India) into the practice of organic farming. Packages of practices have to be developed on land preparation, soil management, harvesting and storing. Demonstration farms need to be

**Table 1. Effect of different treatments with organics on yield and yield attributes of groundnut during *kharif***

| Treatment | Yield and yield attributes | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Seed yield (kg $ha^{-1}$) | | Haulm yield (kg $ha^{-1}$) | | % filled pods per plant | | 100 seed weight (g) | | Shelling % | |
| | 2004 | 2005 | 2004 | 2005 | 2004 | 2005 | 2004 | 2005 | 2004 | 2005 |
| Farmers' practice | 459 | 1817 | 818 | 2687 | 59 | 74 | 26.7 | 37.3 | 58 | 60.2 |
| FP +Groundnut shell | 500 | 2012 | 847 | 2882 | 68 | 77 | 31.0 | 38.1 | 62 | 60.7 |
| FP +G S M | 546 | 2102 | 902 | 3055 | 70 | 79 | 31.4 | 38.4 | 65 | 62.4 |
| Regenerative (only organics) | 469 | 1974 | 877 | 3004 | 72 | 76 | 29.1 | 37.7 | 62.9 | 61.8 |
| R D F | 465 | 1991 | 821 | 2934 | 65 | 76 | 30.7 | 38.6 | 60.9 | 63.6 |
| CD 5% | 35 | 157 | NS | 192 | - | - | 1.37 | 0.8 | - | — |

*FP: 18:36:18 N, $P_2O_5$, $K_2O$; FP + groundnut shell: FP+1 t of groundnut shell $ha^{-1}$; FP+GSM: FP + groundnut shell manure @ 1 tonne $ha^{-1}$; Regenerative: 1 t groundnut shell manure + 1 t FYM; RDF: 20:40:20 N, $P_2O_5$ & $K_2O$ respectively.*

established in different locations to illustrate successful organic practices. This helps in information dissemination and training.

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# Role of Biofertilizers in Organic Farming

**B.Venkateswarlu***

## Introduction

Poor soil fertility is one of the important factors limiting crop yields in rainfed regions. Fertilizer use in drylands has not been showing significant improvement over the years due to the risk factors and poor economic base of dryland farmers. In view of this and the growing concerns on sustainability and soil quality, reliance on Integrated Plant Nutrient Supply (IPNS) systems has become more critical now than ever before. Biofertilizers are an important component organic farming in drylands where farmers tend to rely either on 'no cost' or 'low cost' inputs. Alfisols and Vertisols, the two predominant soil types in drylands are low in many of the essential nutrients and any supplementation through biofertilizers helps the farmers in a significant way. This chapter reviews the scope of biofertilizers in organic farming; covering the types of biofertilizers, their field performance, interaction with the environment and future research needs.

## Significance of biofertilizers in rainfed farming

There are a number of biofertilizers with possible practical applications in dryland crops. The scope and importance of biofertilizers in drylands can be realized from the fact that nearly 35 million ha under coarse cereals, 23 M ha under pulses, 8 M ha under groundnut and 4 M ha under soybean can be benefited by using one or other types of biofertilizers. Biofertilizers help in increasing crop productivity by way of increased N fixation, enhanced availability of nutrients through solubilization or increased absorption, stimulation of plant growth through hormonal action or antibiosis, or by decomposition of organic residues. The role and importance of biofertilizers in sustainable crop production has been reviewed by several authors (Biswas *et al.,* 1985; Wani and Lee, 1992; 1995a; Katyal *et al.,* 1994).

## Biofertilizers relevant to rainfed agriculture

The biofertilizers relevant to dryland agriculture are; *Rhizobium/Bradyrhizobium* which fix nitrogen in a number of pulse crops, groundnut, soybean and N-fixing trees which form an important components of the agroforestry systems; *Azotobacter* and *Azospirillum* which are non-symbiotic and associative symbiotic organisms respectively and are useful in promoting plant growth in a number of cereal crops through N-fixation and growth promotion. Phosphate solubilising bacteria (PSB), VAM-fungi and plant growth promoting rhizobacteria (PGPR) are other groups of organisms which are relevant for increasing the availability of phosphorus and promoting plant growth through a variety of mechanisms like suppression of pathogens, siderophore production and growth hormone secretion in the soil.

### *Rhizobium/Bradyrhizobium*

*Rhizobium/Bradyrhizobium* is one of the widely studied organism relevant to a number of pulse crops, groundnut and soybean in the rainfed production systems. Contribution

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of the legume-*Rhyzobium* symbiosis to the production system varies depending on a number of physical, environmental, nutritional and biological factors. Therefore, in agronomically important legumes, it is essential to assess whether BNF is able to meet the crop demand for N or artificial inoculation is necessary. Most cultivated tropical soils in India are reported to have relatively large populations (>100 $g^{-1}$ dry soil) of rhizobia capable of nodulating the legumes (Nambiar *et al.,* 1988, Venkateswarlu, 1992, Khurana and Dudeja, 1997). Surveys of legume crops in farmers fields have shown poor to medium nodulation in large (65%) areas and good nodulation only in few pockets (36%) (IARI, 1980; Tauro and Khurana, 1986).

The need to inoculate the legumes to be grown on drylands must be assessed by considering three interacting factors viz. plant, bacterial strain and the environment. In most rainfed areas, legumes of the cowpea miscellany group have been grown for hundreds of years and the population of native rhizobia are generally adequate at planting time both in Alfisols and Vertisols, despite wide seasonal variation (Venkateswarlu, 1992; Hegde, 1994). Immediately preceding crop history has a significant influence on the number of native rhizobia and the inoculation response of legumes to follow (Venkateswarlu *et al.,* 1997). Nevertheless native rhizobial populations play critical role in the success of legume inoculation with the persistence of the inoculant strain generally decreasing with increase in the population density of native rhizobia (ICRISAT, 1981). However, some inoculant strains succeed in forming more nodules despite the presence of competing indigenous rhizobia, e.g., NC 92 on groundnut (Nambiar *et al.,* 1988).

At research stations, extensive data has been generated on inoculation benefits from rhizobial strains on a number of pulse crops, groundnut and soybean under the umbrella of the All India Coordinated Research Projects on pulses, groundnut, soybean and dry farming. However, data from on-farm trials is meagre. Multilocational trials conducted during 1970s on pigeon pea, chickpea and green gram gave variable results with the benefits from inoculation ranging from 9-70% (Rewari and Tilak, 1988). More recent data from 1991 to 1994 also indicated the high variability in response depending on the crop, location and the season (Khurana and Dudeja, 1997). In chickpea, the increase in grain yield over non-inoculated control varied from 6.5 to 30.9% during 1991-92, 1.2% to 40.9% during 1992-93 and 0 to 37% during 1993-94. Similarly in pigeon pea the yield increases ranged from 1.1 to 20.3, 1.9 to 47.8 and 26.4% respectively during 1992, 1993 and 1994.

Multi-locational trials were also conducted on a number of *kharif* and *rabi* legumes under the dryland agriculture project (AICRPDA). These trials represented the farmer's condition more realistically since these were conducted under complete unirrigated conditions, while trails under the crop-based projects were often provided protective irrigation. Compiled data on major pulses from 11 dryland centers, summarized by Katyal *et al*. (1994) indicated positive response only at 3 locations (Table 1). The yield increases varied from 0 to 47%. The positive response could not be explained in terms of crop, soil type or rainfall.

Coordinated trials on groundnut across different locations also presented variable response picture. Significant and positive response were obtained with *kharif* groundnut involving Robut-33-1 cultivar and NC-92 strain combination at 4 out of 8 locations, while with several other varieties, results were non-significant (Nambiar, 1985). With *rabi*/summer groundnut, *Rhizobium* strains IGR-6 and IGR-40 failed to increase the yield that could reach the level of statistical significance (Joshi, 1994). Early experiments on soybean showed positive effects of inoculation as the crop was introduced new into the country, but with continuous cultivation and the build-up of native populations of *Bradyrhizobium japonicum*, inconsistency in response, so characteristic

Table 1 : Summary of the trials conducted on *Rhizobium* at different dryland research centers during 1974-1985.

| Center | Climate and soil type | Crop | Response (% increase in yield over control |
|---|---|---|---|
| Agra | Semi-arid<br>Entisol | Clusterbean(2) | 11.2-16.6[1] |
| Bangalore | Semi-arid<br>Alfisol | Horsegram (1) | <1.0 |
| Dantiwada | Arid<br>Aridisol | Greengram (2) | 0-3.5 |
| Hissar | Arid<br>Aridisol | Greengram (1) | <1.0 |
| Hyderabad | Semi-arid<br>Alfisol | Cowpea (1)<br>Pigeonpea (1)<br>Dolichos (1)<br>Horsegram (1) | <1.0<br><1.0<br><1.0<br><1.0 |
| Jhansi | Semi-arid<br>Alfisol & Related soils | Clusterbean (2) | 8.6 to 3.7 |
| Jodhpur | Arid<br>Aridisol | Greengram (2)<br>Mothbean (2)<br>Clusterbean (3) | <1.0<br><1.0<br><1.0 |
| Kovilpatti | Semiarid<br>Vertisol | Redgram (2)<br>Greengram (1)<br>Chickpea (2)<br>Soybean (2) | 40-47.2<br>12.5<br>4.0-8.2<br>0/0-5.0 |
| Indore | Semi-arid<br>Vertisol | Chickpea (2)<br>Soybean (3) | 4-8.2<br>0-1.6 |
| Rewa | Semi-arid<br>Vertisol | Chickpea (2)<br>Soybean (2) | 2.9-22.0<br>0.0-5.0 |
| Varanasi | Semi-arid<br>Entisol | Blackgram (2)<br>Chickpea (2) | 0.135-2.32<br>0-13.5% |

1 significant increase over control
Source : Katyal *et al.*, 1994.
Figures in parentheses indicates no. of years trials conducted.

of other legumes, is noted in soybean too (Balasundaram *et al.*, 1994).

There have been some *on-farm* trials in India and other tropical countries on legume inoculation. In 228 inoculation conducted under the International Network of Legume inoculation Trials (INLIT) by cooperating scientists in 28 countries over the years, inoculation resulted in significant yield increases in approximately 52% of the trials (Davis *et al.*, 1985). The results of 1500 demonstrations on farmers' fields with pigeon pea conducted at Gulbarga district of Karnataka state in India showed 100% increase in yield (1035 vs. 516 kg $ha^{-1}$) due to balanced use of diammonium phosphate and *Rhizobium* inoculation (Chinmulgund and Hegde, 1987). However in organic farming phosphorus need to be supplied as rock phosphate. In 12 trials with chickpea, inoculated plots gave on an average 116 kg $ha^{-1}$ more grain than non-inoculated plots. In another set of field demonstrations, inoculation increased grain yield by 112-227 kg $ha^{-1}$(Chandra and Ali, 1986). The compiled results of farmers' field trials conducted during 1991-93 on five pulse crops are given in Table 2.

Table 2: Response of pulses to rhizobial inoculation at the farmers' fields (1991-93).

| Pulse crop | Location | Number of trials | Increase over uninoculated control | |
|---|---|---|---|---|
| | | | kg $ha^{-1}$ (Range) | Per cent (Average) |
| Chickpea | Badnapur | 5 | 140-160 | 10 |
| | Durgapura | 2 | 250-520 | 24 |
| | Sehore | 3 | 120-140 | 20 |
| Lentil | Dholi | 3 | 50-110 | 15 |
| | Ludhiana | 5 | 40-60 | 17 |
| Pigeonpea | Badnapur | 4 | 20-70 | 8 |
| | Gulbarga | 1 | 80 | 9 |
| | Vamban | 11 | - | 14 |
| Mungbean | Sehore | 5 | 140-180 | 17 |
| | Badnapur | 3 | 40-110 | 7 |
| | Durgapura | 2 | 30 | 4 |
| | Ludhiana | 5 | 40-110 | 15 |
| | Vamban | 6 | - | 12 |
| Urdbean | Badnapur | 2 | 50 | 13 |
| | Dholi | 5 | 70-80 | 17 |
| | Vamban | 7 | - | 12 |

Source : Khurana and Dudeja (1997).

## Residual effects of legumes

Legumes are known to leave considerable amount of residual N in the soil which benefits the subsequent cereal crop which is relevant for organic farming. These benefits however depend on the purpose for which the legume crop is taken, *i.e.*, grain, fodder or green manure. The amount of nitrogen added both through current transfer in the intercropping systems and residual amount added in the sequence cropping system is a subject of controversy and figures vary widely depending on the crop, location and phosphate application to the legume crops (Subba Rao and Chandrasekhara Rao, 1980). In a long-term crop rotation experiment that began in 1983 at ICRISAT, Patancheru, India, mean residual effects of legume-based crop rotations on yields of sorghum over the last ten years were greater than those from Sorghum + Safflower (S +SF-S +F) plots (Rego and Bufford, 1992).

Growing legumes in rotation improves the mineral-N content of the soil as compared to the non-legumes (Rao and Singh, 1991; Wani *et al.*, 1995); however it does not fully explain the beneficial effects of legumes to the following crops. Legumes based crop rotations have a number of non N-rotational effects like increased soil microbial biomass (Kucey *et al.*, 1988; Wani *et al.*, 1991), improved soil structure (Latif *et al.*, 1992) and increased water-holding capacity of the soil (Wani *et al.*, 1994). Inoculation of legumes also results in additional yield advantage to the succeeding cereal crops. Results from 13 multi-locational experiments indicated that the effect of *Rhizobium* inoculation on succeeding wheat and sorghum crops ranged from – 1.19 to 2.32 and 3.54 to 2.48 quintals respectively (Biswas *et al.*, 1985). However, further studies are required to critically elucidate the beneficial effects of legumes on subsequent crops and the additional advantage of inoculation, if any.

## Azotobacter and Azospirillum

Although a large number of non-symbiotic and associative symbiotic microorganisms capable of fixing atmospheric nitrogen have been reported (Wani, 1990), *Azotobacter* and *Azospirillum* are two organisms, which are extensively studied, and considerable data on agronomic significance has been generated (Pandey and Kumar, 1989; Wani, 1990). It is generally agreed that these organisms improve plant growth and yield not only through nitrogen fixation but also through production of phyto hormones (Venkateswarlu and Rao, 1983; Okon, 1985; Wani, 1990). The estimates on the amount of N-fixed by these organism and the crop response vary widely depending on the bacterial strains, soil fertility status, crops and annual rainfall (Wani and Lee, 1992). Multi-locational trials in India showed that seed inoculation with *Azospirillum brasilense* increased the mean grain yields of pearl millet significantly at 6 and with sorghum at 4 out of 9 locations tested. The yield increase with pearl millet varied from – 10 to 17% and with sorghum 7-31% (Subba Rao, 1986).

Inoculation trials with *Azospirillum* at selected dryland research centers showed highly inconsistent results (Venkateswarlu, 1992; Katyal *et al.,* 1994). Sorghum and pearl millet responded positively during 1981 at Hyderabad (Das, 1985) but during 1982 the response was not significant **(Table 3)**. At Kovilpatti *Azospirillum* failed to have a significant effect on the yields of pearl millet during 1984-86 and cotton during 1985-87. Method of inoculation (seed vs. soil) could not alter the response pattern. In sierozemic soils of Hisar, *Azospirillum* inoculation on the straw (20%) and grain (15%) yields of pearl millet was found in the arid soils of Jodhpur (Venkateswarlu, 1985). The bacterium promoted plant growth essentially by phytohormone production rather than via $N_2$ fixation.

**Table 3: Effect of Azopsirillum inculation on grain yield (q $ha^{-1}$) of sorghum and pearl millet at Hyderabad (1981).**

| Treatment | Sorghum (730 mm) | Pearl millet (590 mm) |
|---|---|---|
| Control | 26.7 | 13.5 |
| Inoculated | 31.5 | 16.6 |
| CD (P=0.05) | 4.07 | 1.38 |

Source : Das, (1985); Figures in the parentheses represent the annual rainfall.

A number of early experiments demonstrated the beneficial effects of *Azotobacter* inoculation to maize, sugarcane, rice, tomato, onion, mustard (Patil, 1985). However, very few trials have been conducted on dryland crops. Yield benefits in sorghum, pearl millet and rainfed cotton due to *Azotobactor* inoculation are summarized in **Table 4.** Crops grown in soils rich in organic matter generally tend to respond more positively to *Azotobactor* inoculation. Wani *et al.* (1988) summarized the data from inoculation trials of pearl millet at several locations in India with *A. lipoferum* and *A. Chroococcum* on a comparative basis **(Table 5).**

**Table 4: Benefits of *Azotobactor* inoculation in some dryland crops**

| Crop | Yield increase over control (%) |
|---|---|
| Sorghum | 15-20 |
| Pearl millet | 0-27 |
| Cotton | 11-16 |

Source : Venkatraman and Tilak (1990)

## Phosphate solubilizing microorganisms

A group of heterotrophic microorganisms are known to have the ability to solubilize inorganic P from insoluble sources (Gaur, 1990). This group covers bacteria, fungi and some actinomycetes. These organisms solubilize the unavailable forms of inorganic-P like tricalcium, iron, aluminum and rock phosphates into soluble forms by release of a variety of organic acids like succinic, citric, malic, fumaric, glyoxalic and gluconic acids (Gaur, 1990). In culture media, the P solubilising ability is generally related to the degree of acidifaction of the media as measured by fall in pH, but the same was not found true in soil (Venkateswarlu *et al.,* 1984). Although bacteria and fungi have been the major groups of organisms with phosphate solubilising ability (Gaur, 1990), some actinomycetes have also been reported to solubilise-P (Rao and

**Table 5: Summery of pearl millet inoculation experiments with two N-fixing organisms conducted at different locations in India.**

| Item | *A.lipoferum* (ICM 1001) | *A.chroococcum* (ICM 2001) |
|---|---|---|
| No. of field experiments conducted | 24 | 24 |
| No. of experiments which showed significant increase in grain yield | 11 | 8 |
| No. of experiments which showed non-significant increase in grain yield | 10 | 12 |
| No. of experiments which showed no response | 1 | 2 |
| No. of experiments which showed reduction in grain yield | 2 | 2 |
| Average increase in grain yield due to Inoculation | 11% | 8% |

Source : Wani *et al.* (1988)

Venkateswalru, 1982), both from tri-calcium and rock phosphates.

Responses of grain crops, vegetables and forages, to seed inoculation with P solubilizers along with organic amendments and rock phosphate, bone meal or single super phosphate (SSP) have been studied. During the 1970s, out of 37 field trials conducted in India, 10 trials showed significant increase in yields in the case of wheat, rice, maize, chickpea, pigeonpea, soybean, groundnut, and berseem (Sundara Rao, 1968). Significant increase in soybean yield was obtained due to inoculation with *B. polymyxa or P.striata* along with rock phosphate application over control, whereas application of 80 kg $P_20_5$ $ha^{-1}$ through SSP did not result in similar increase. In wheat and rice no significant increases were observed due to inoculation. In multilocational trials conducted with different crops, increased yields (0-15%) were obtained due to inoculation with 'Microphos' culture with or without rock phosphate addition. The beneficial effect of inoculation was also observed on the crops grown after the inoculated crop (Gaur, 19900. Little information is available on the performance of PSB under dryland conditions though these organisms have an important role to play in Vertisols where P availability is a major problem due to fixation. Limited trials conducted at Indore and Kovilpatti revealed significant benefits in terms of yields of soybean, maize, pulses and millets along with enhanced availability of P. Addition of FYM improved the performance of these organisms significantly.

So far only bacteria like *B.megatherium* and *P.striata* have been commercialized as phosphate solubilising biofertilizers because of the filed efficacy and the relative ease with which bacteria can be cultured and commercially produced. On the other hand fungi like *Aspergillus awamori* and *Pencillium digitatum* are not being produced on commercial scale due to constraints in handling large quantity of spores/mycelia and the low shelf-life of such inoculants as compared to bacteria. During 1990's commercial manufacture of PSB has picked up and farmers acceptability of products like 'Microphos' and 'Biophos' has increased particularly in crops like groundnut.

## Plant growth promoting rhizobacteria (PGPR)

A group of rhizosphere bacteria (rhizobacteria) that exerts a beneficial effect on plant growth is referred to as plant growth promoting rhizobacteria or PGPR (Schroth and Hancock, 1981). PGPR belong to several genera, e.g., *Actinoplanes, Agrobacterium, Alcaligenes, Amorphosporangium, Arthrobacter, Azotobacter, Bacillus, Bradyrhizobium, Cellulomonas, Enterbacter, Erwinla, lavobacterium, Pseudomonas, Rhizobium, Streptomyces*, and *Xanthomonas* (Weller, 1988). *Bacillius* sp. are appealing candidates as PGPR because their endospore producing ability which makes them ideal inoculants for dry areas. Currently *Pseudomonas sp.*are receiving much attention as PGPR, because of their multiple effects on plant growth promotion.

PGPR are believed to improve plant growth by colonizing the root system and pre-emptying the establishment of or suppressing deleterious rhizosphere micro organisms (DRMO) on the root (Schroth and Hancock, 1981). Inoculating planting material with PGPR presumably prevents or reduces the establishment of pathogens (Suslow, 1982). Production of siderophores is yet another mechanism through which high affinity $Fe^{+++}$ chelators that transport iron into bacterial cells and are responsible for increased plant growth by PGPR (Kloepper *et al.*, 1980). Under Fe-deficient conditions, fluorescent pseudomonads produce yellow-green fluorescent siderophore-iron complex (Hohnadel and Meyer, 1986) which creates an iron deficient environment deleterious to fungal growth.

Most of the field trials on PGPR are being conducted in USA and Europe with promising benefits in terms of yield improvements and disease protection. However, no data are available on the field performance of PGPRs under Indian conditions. Some limited work has been initiated on groundnut recently at the National Research Centre for Groundnut (Pal *et al*, 1999).

## Vesicular- arbuscular mycorrhizae (VAM)

The symbiotic association between plant roots and fungal mycelia is termed as mycorrhiza. These fungi are associated with majority of agricultural crops. They are ubiquitous in geographic distribution occurring with plants growing in artic, temperate and tropical regions alike. VAM occur over a broad ecological range from aquatic to desert environments (Mosse *et al.*, 1981). These fungi belonging to the genera *Endogone, Glomus, Entrophosphora, Gigaspora, Acaulospora, Scutellispora* are obligate symbionts and have not been cultured on nutrient media using standard microbiological techniques. They are multiplied in the roots of host plants and the inoculum is prepared using infected roots and soil.

Crop responses to VAM inoculation are governed by soil type, host variety, VAM strains, temperature, moisture, cropping practices and soil management practices. In general, field experiments with VAM inoculation are fewer than those reported for *Rhizobium, Azospirillum or Azotobacter*. The major constraint for field trials with VAM has been the inability to produce 'clean pure' inoculum on a large scale as with bacterial inoculants. The results of field trials conducted in India reviewed by Wani and Lee (1992) indicated that VAM inoculation increased yields significantly in around 50% trials and the response varied with soil type, soil fertility, and VAM culture. The scenario is similar to that for *Rhizobium* and *Azospirillum* with regard to consistency. In such a situation, until suitable methods are evolved to multiply VAM on large scale for field inoculation of crops directly sown in the field, the best strategy to utilize VAM fungi for dryland crop production is to concentrate on crop and soil management practices for optimally exploiting the native VAM (Wani and Lee, 1995c). This suits well for organic farming concept also. Experiments conducted at CRIDA, Hyderabad indicated that on marginal Alfisols, VAM inoculation in the planting pits improved the growth of *Leucaena leucocephala* (CRIDA, 1998).

## Applications methods

### Rhizobium

- Pulse legumes such as chickpea, pea, lentil, blackgram, greengram, cowpea and red gram
- Oilseed legumes like soybean and groundnut
- Fodder legumes like bersem and Lucerne

The treatment of seeds with the slurry of *Rhizobium* inoculants is the effective method of application for getting maximum response. The method of application is described below.

- Prepare the slurry of required quantity of inoculant in sufficient water (generally 400-500 mL of water is enough for 200g of inoculant). To prepare the slurry, boil 50g gur in one liter of water and cool it.
- Pour this slurry over the heap of seeds to be treatment. Mix the seeds thoroughly with hands. Now spread the treated seeds over clean floor or on plastic sheet or on gunny bag for drying under shade
- Sow the treated seed immediately

**Doses:** 10kg of normal size seeds such as moong, urad, arhar, cowpea, lentil and berseem may be treated with 200 g of *Rhizobium* inoculant by slurry method. Large size seeds such as groundnut, chickpea, soybean and pea etc. require 400 to 500g of inoculant for 10 to 12 kg of seeds.

### Azospirillum and Azotobacter

*Azosprillum* and *Azotobactor* are broad spectrum inoculants that can be used for many crops. The inoculant may be used in different ways depending upon the crop.

The methods of application are:

- Seed treatment
- Seedling dipping
- Soil application

Seed treatment: Same as described for *Rhizobium.*

Dosage: 10kg medium size seeds such as wheat, cotton, maize, etc., may be treated with 200g of inoculant whereas, 100g per acre inoculant is enough for treatment of very small size seeds such as mustard.

Seedling dipping: This method is useful where the transplantation of seedlings are required. It is ideal for vegetable crops. The method of application is:

- Prepare the suspension of required amount of inoculant in water in the ratio of 1:10.
- Dip the roots of seedlings in suspension and keep them immersed for about 5 minutes.
- Take out the seedlings from the suspension and transplant them.

Dosage: Suspension of one kg in 10 to 15 litre of water is sufficient for treating of seedlings for one acre.

Soil application: Mix 3-5 g inoculant thoroughly with 50 kg finely powdered FYM. Broadcast this mixture at the time of last ploughing.

### Phosphate Biofertilizers (PSB)

PSB can be used for all crops including paddy, millets, oil seeds and pulses. Methods recommended for application of PSB are:

- Seed treatment
- Seedling dipping
- Soil application

Seed treatment: Same as described for *Rhizobium.*

Dosage: 10kg medium size seeds such as groundnut, wheat, cotton, maize, etc., may be treated with 200g of inoculant whereas, 100g per acre inoculant is enough for treatment of very small size seeds.

Seedling dipping: This method is useful where the transplantation of seedlings are required. It is ideal for vegetable crops. The method of application is:

- Prepare the inoculant suspension in water in the ratio of 1:10.
- Dip the roots of seedlings in suspension and keep them immersed for about 5 minutes.
- Take out the seedlings from the suspension and transplant them.

Dosage: Suspension of one kg in 10 to 15 litre of water for treating of seedlings for one acre.

Soil application: Mix 3-5 g inoculant thoroughly with 50 kg finely powdered FYM. Broadcast this mixture at the time of last ploughing.

Note: In case of PSB, best results are obtained when applied with well decomposed organic manure.

### Biofertilizers in Organic Farming

All biofertilizers are permitted in organic farming except GMOs. They can be used for seed treatment, soil application or foliar sprays. They can be mixed with other organic amendments or in the process of production of composts such as phospho compost. Though biofertilizers are permitted inputs as per NPOP, they need to meet the statutory quality standards laid down by BIS. Since synthetic fertilizers are completely banned in organic farming, and their prices are only likely to go up with spiralling oil prices, we must make use of biofertilizers extensively in rainfed agriculture, particularly in organic cultivation.

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# Bio-intensive Integrated Pest Management in Organic Farming

**Y.G. Prasad***

Although pests, weeds and pathogens are thought to destroy 10-40% of the world's gross agricultural production, pesticides are not the perfect answer to controlling pests and pathogens. Over-reliance on the use of synthetic pesticides in crop protection programs around the world has resulted in disturbances to the environment, pest resurgence, pest resistance to pesticides, and lethal and sub-lethal effects on non-target organisms, including humans. These side effects have raised public concern about the routine use and safety of pesticides. One consequence of greater regulation is the development of a number of chemicals that are highly targeted in their effect. Though these newer pesticides are more selective, less damaging to natural enemies and less persistent in the environment, many of these are more expensive to farmers than broad-spectrum products. What farmers need is a wide range of possible technologies that can make use of the agro-ecological pressures of predators, competition and parasitism to control pests more effectively than pesticides alone. Most pest species are naturally regulated by a variety of ecological processes and if these regulations work in harmony, the crop damage caused is relatively insignificant in most cases.

Bio-intensive integrated pest management (BIPM) could be defined as: "a systems approach to pest management based on an understanding of pest ecology. It begins with steps to accurately diagnose the nature and source of pest problems, and then relies on a range of *preventive* tactics and biological controls to keep pest populations within acceptable limits" (Benbrook, 1996). BIPM goes hand in hand with the concept and practice of organic farming. The Codex Alimentarius Commission defines organic agriculture as a holistic food production management system, which promotes and enhances agro ecosystem health, including biodiversity, biological cycles and soil biological activity. It emphasizes the use of management practices in preference to the use of off-farm inputs, taking into account that regional conditions require locally adapted systems. This is accomplished by using, where possible, agronomic, biological and mechanical methods, as opposed to using synthetic materials, to fulfil any specific function within the system (Ramesh *et al*., 2005)

However, while in the context of pest management, reduced-risk pesticides are used as a last resort to minimize risks in BIPM, synthetic pesticides have no place in organic farming. Despite this contradiction, a striking similarity in the primary goals exists between the two. BIPM also provides guidelines and options for the effective management of pests and beneficial organisms *in an ecological context*. The flexibility and environmental compatibility of a BIPM strategy make it useful in all types of cropping systems (Dufour, 2001) including organic farming.

The role for BIPM approach vis-à-vis organic farming could be envisaged in several ways indicated below:

1. Organic farming aims for an optimum and sustainable use of local natural resources

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for production without the application of external inputs like synthetic pesticides, chemical fertilizers, herbicides, defoliants and chemically treated or genetically modified (GM) seed. However, external 'organic' inputs may be used. Agricultural production is considered 'organic' when it has been certified 'organic'. However, certified organic products may not be the only interest under the corporate social responsibility (CSR). Interest in other additional approaches such as 'Better Cotton', 'cotton from origin' (whether United States, Peru, Africa, or India), IPM or ICM cotton is expected to grow over the next few years (International Trade Centre, 2007, Organic cotton: an opportunity for trade, ITC, Geneva, 48p). BIPM strategy fits well with this type of approach.

2. Also, farmers wishing to convert to organic agriculture will have to go through a conversion period of one to three years, depending on their fields' history. The conversion period enables the soil and the environment to recover from previous cultivation, while applying organic methods of production. The 'in-conversion' produce cannot be sold as 'organic', and does not usually fetch a premium in the market. The risks and costs of conversion are a major barrier to the adoption of organic agriculture. This transition phase also provides a good window for application of bio-intensive IPM practices as this strategy is relatively better equipped to manage protection needs and production risks.

3. Conversion to organic agriculture is not easy. It takes knowledge, time, investment, and a lot of motivation and organization. Markets can drive conversion only in part through demand growth. Farmers and their organizations need support to build capacity to convert to organic agriculture, in particular in order to bridge the conversion period and related risks of production. Although, the infrastructure for organic cotton training and extension is expanding, much can be learned from training and extension approaches for integrated pest management (IPM) and integrated crop management (ICM).

## Bio-intensive pest management practices

An important difference between conventional IPM and biointensive IPM is that the emphasis of the latter is on proactive measures to *redesign* the agricultural ecosystem to the disadvantage of a pest and to the advantage of its parasite and predator complex. Bio-intensive pest management in organic farming begins by making sensible choices that include:

- Crop rotation to break the cycle of pest carry-over. Rotation with a non-host legume is ideal in terms of pest management and soil fertility
- Deep ploughing to expose hibernating stages of insects to hot summer temperatures
- Soil solarization technique for control of soil borne pathogens
- Growing crop varieties (non-GM) that are naturally resistant to diseases and pests.
- Seed treatment with permitted preparations and biopesticides
- Choosing sowing times that prevent pest and disease outbreaks. Careful management in both time and space of planting not only prevents pests, but also increases population of natural predators that can contribute to the control of insects, diseases and weeds
- Improving soil health to resist soil pathogens especially root diseases and promote plant growth through use of cover crops, green manures, animal manures to fertilize the soil, maximize biological activity and maintain long-term soil health
- Encouraging pollinators and natural biological agents for control of pests through

modification of habitat such as cultivation of intercrops and border crops; erection of resting structures for birds; providing food sources and application of food sprays for beneficial insects

- Augmentative releases of parasitoids and predators such as *Trichogramma*, *Chrysoperla* and Coccinellids.
- Application of permitted microbial biopesticides such as nuclear polyhedrosis virus (NPV), granulosis virus (GV), *Bacillus thuringiensis* (Bt) and plant origin biopesticides (Neem, Vitex etc).
- Using physical barriers for protection from insects, birds and animals and methods for collecting insects
- Using semi-chemicals such as pheromone attractants and trapping pests.

## Key bio-intensive IPM components and their usage in organic farming

**1. Selection of naturally resistant crop cultivars:**

A major unit of defense is to have crops that are resistant to pests and diseases. For low external input farmers, resistant crops represent an important alternative to pesticides. A list of important resistant cultivars of major rainfed crops grown in Andhra Pradesh are given below (Venkateswarlu and Prasad, 2004) (Table 1).

**2. Locally produced biopesticides**

Microbial biopesticides have an excellent scope for management of pests in organic farming when used intelligently. Biopesticides based on Bt, NPV and GV have now been brought under the ambit of the Central Insecticide Act, 1968. Commercialization of

**Table 1. Pest resistant cultivars recommended for cultivation in Andhra Pradesh**

| Sl. No. | Location | Crop | Resistance to | Cultivar |
|---|---|---|---|---|
| 1 | Anantapur<br>Kurnool<br>Cuddapah | Groundnut | Bud necrosis<br><br>Leaf spots<br><br>Kalahasty malady<br>Multiple resistance to pests and diseases | Vemana, K 134, TAG 24, Tirupathi 3, ICGS 10, 11, 86325<br>Vemana, Kadiri 3, Naveen, K 134, ICGS 10<br>Tirupathi 2<br>ICGV 86325 |
| 2 | Anantapur | Sunflower | *Helicoverpa* | KBSH-6, BRS-3 (line) |
| 3 | Mahabubnagar & Nalgonda | Castor | Fusarium wilt<br>Jassid<br>Whitefly<br>Capsule borer | GCH-4, 48-1, DCS-9<br>Tripple bloom cultivars<br>Zero bloom cultivars<br>JI-144 |
| 4 | Mahabubnagar, Nalgonda<br>Adilabad, Kurnool & Khammam | Sorghum | Shootfly<br>Stem borer<br>Midge<br>Grain mold<br>Charcoal rot | ICSV 705 and 717<br>IS-2205 and IS-2376<br>ICSV 197, 743, 745 and 88013<br>CSH-1, CSV-15<br>M 35-1, CRR 12 |
| 5 | Mahabubnagar<br>Rangareddy<br>Warangal<br>Khammam<br>Nalgonda | Redgram | *Helicoverpa* pod borer | ICPL 332 (Abhaya) |
| 6 | Warangal<br>Adilabad | Cotton | Jassids<br>Whitefly | L603, 604, Narsimha, NHH 390, LH4<br>Kanchana, LK 861 |

microbial pesticides is possible only after registration with the Central Insecticide Board (CIB). At present, the following NPVs have been registered with the CIB in India: NPVs of *Helicoverpa armigera* and *Spodoptera litura*. While regulation is good for quality control of commercial products, this has led to higher pricing making their field use expensive. Currently, commercial NPV price ranges between Rs 150-200 for 100 ml product (ca $1 \times 10^9$ viral bodies $ml^{-1}$) for NPVs infecting *H. armigera* and *S. litura*. Protection cost for one spray in cotton at 500 LE (larval equivalents) $ha^{-1}$ costs Rs 950 and in chickpea at 250 LE $ha^{-1}$ costs Rs 475. One spray with Bt at 0.25-0.3% concentration costs Rs 300-500. It is possible that communities or agencies engaged in organic farming can produce locally both NPV (Jayaraj *et al*., 1989, Ramakrishnan *et al*., 1976) and Bt (Vimala devi *et al*., 2005; Vimala devi and Rao, 2005). The local production can result in reduction of protection costs and leads to internalization of expenditure within the community which goes well with the organic farming principles of using local resources.

**i) Viral biopesticides (NPV and GV)**

Majority of insect viruses used as biological control agents belong to the baculovirus group. These viruses are characterized by the presence of rod shaped nucleocapsid (hence "baculovirus', from baculum, meaning rod) and the ability to form proteinaceous occlusion bodies within infected cells. Baculoviruses are of two types: Nucleopolyhedroviruses (NPVs) and Granuloviruses (GVs) based on the type of occlusion body formed. NPVs have the following advantages for consideration in BIPM initiatives: Species-specific action and hence safe to non-target organisms; non-pathogenic to most beneficial insects and hence fit admirably into BIPM initiatives especially in vegetable crops where pesticide residues are a major problem and fit well into organic farming. Successful use of NPVs is possible in several crops (Prasad and Prabhakar, 2005) (Table 2).

**ii) *Bacillus thuringiensis(Bt)* biopesticide**

Bt is a naturally occurring soil bacterium that produces crystal proteins toxic to several

**Table 2. Field use recommendations for NPV/GVs in food and commercial crops**

| Baculovirus type | Crop | Crop stage | Dosage (LE $ha^{-1}$) | Number of applications per crop season |
|---|---|---|---|---|
| *Helicoverpa armigera* (gram pod borer/American bollworm) NPV | Red gram | Flower initiation, 50% flowering and peak flowering | 250-500 | 2-3 at 10-14 days interval |
| | Chickpea | 30 DAS and flowering | 250 | 2-3 at 7-12 days interval |
| | Tomato | Fruiting stage | 250 | 3 at 7 days interval |
| | Cotton | Fruiting stage | 500-750 | 1-2 at 10 days interval |
| | Sunflower | Flower head | 250 | 1 |
| | Groundnut | Flowering onwards | 250-500 | 3-4 at 7-10 days interval |
| *Spodoptera litura* (tobacco caterpillar or leaf worm) NPV | Tobacco Vegetables Groundnut Cotton | Need based | 250-500 | 1-3 applications at 7-14 days interval |
| *Achaea janata* (semilooper) GV | Castor | 35-75 days after sowing | 500 | 2 sprays first applied between 35-50 days and second at 60-75 days crop age based on pest incidence |

insect species during the sporulation stage of its multiplication cycle. The crystalline protein inclusion constitutes 20-30% of the dry weight of sporulated cell allowing for commercial exploitation as a biopesticide. The potential of this bacterium in the management of several caterpillars causing serious damage to the cultivated crops world over is well documented over the last fifty years. There are currently more than a hundred products of Bt registered for the management of important lepidopteran insect pests such as *H. armigera* (bollworm), *Plutella xylostella* (diamond back moth), *Trichoplusia ni* (looper) and *A. janata* (Vimala devi *et al*., 1996). Bt occupies 95% share of the microbial bio-pesticide market. The principal reasons for the success of Bt include the high efficacy and insect specificity of its insecticidal crystal proteins (ICPs) and their bio-degradability. Bt has a good scope for use by organic farmers especially on fruits and vegetables. The commercial *Bt* products are powders containing a mixture of dried spores and toxin crystals. Bt is applied as a foliar spray best against young caterpillars at concentrations between 0.2-0.3% giving a good coverage on plant surfaces. As Bt is deactivated by sunlight, spraying in late afternoon or evening or on cloudy days is most effective. Alkaline water (pH of 7.8) or acid water will deactivate the crystals. Generally repeat applications may be required under high pest pressure.

**iii) Inundative releases of bio-agents**

Apart from conserving native natural enemy populations which are density dependent mortality factors regulating pest populations in a given agro-ecosystem, another bio-intensive IPM option available for organic farmers is augmentative release of natural enemies that multiply during the growing season. Augmentative release may be made with either short- or long-term expectations depending on the target pest, the species of natural enemy and the crop involved and can be cost-effective. The two most commonly released bioagents are: egg parasitoids, *Trichogramma* wasps and the predatory lacewing, *Chrysoperla carnea*. *Trichogramma chilonis* is the dominant species of wasps in India. It has been used for the biological control of several pests in sugarcane, paddy, cotton and maize (Jallali and Singh, 1993; Prabhakar and Prasad, 2005) (Table 3).

**Table 3. Field use recommendations for bio-agents**

| Crop | Stage | Pest | Natural enemy species | Dosage per hectare | Number of releases |
|---|---|---|---|---|---|
| Paddy | 30 days after transplanting | Stem borer | *T. japonicum* | 50000 eggs | 6 at weekly interval |
| Cotton | 45 days onwards | Bollworms | *T. chilonis* | 150000 | 6 at weekly interval |
| Tomato | 45 days after transplanting | Fruit borer | *T. brasiliensis* | 50000 | 6 at weekly interval |
| Sugarcane | 45-90 days after transplanting | Early shoot borer and stalk borer | *T. chilonis* | 50000 | 4-6 at 10 days interval |
| | | Top shoot borer | *T. japonicum* | 50000 | 4-6 at 10 days interval |
| Maize | 45 days onwards | Stem borer | *T. chilonis* | 75000 | 6 at 10 days interval |
| Vegetables | 30 days onwards | Aphids, Whitefly, Thrips, *Spodoptera* | *C. carnea* | 5000 grubs | 3-4 at 15 days interval |

## Conclusion

The principles of bio-intensive pest management are similar to those of organic farming with the exception of allowing careful use of selective pesticides as a last resort. BIPM is a systems approach to pest management and fits well into organic farming. Key components of BIPM strategy include microbial based biopesticides (NPVs and Bt) and conservation and augmentation of natural enemies (*Trichogramma* and *Chrysopa*). Local production and use of these components by the community or agencies involved in organic farming is feasible after some training and capacity building. Such a strategy of local production can off-set escalation of protection costs when purchased as externally produced 'organic' inputs.

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# Microbial Pesticides in Organic Farming

**P.S. Vimala Devi***

In the view of resurgence of interest in alternate agriculture in recent years, organic farming is emerging a viable option in many countries. Organic farming is a production system that avoids or largely excludes the use of synthetically produced agricultural inputs like fertilizers, pesticides, growth regulators, live stock feed additives etc. Approximately 31 million hectares (75 million acres) worldwide are now grown organically.

IFOAM (International Federation of Organic Agriculture Movements) is an international body that serves as a forum to exchange knowledge on organic agriculture. It sets and regularly revises organic standards. These standards distinguish organic from high-input farming based on their distinctively different agricultural practices. Organic systems use cultural, biological and mechanical methods instead of inputs such as chemical fertilizers or pesticides wherever possible. Any deviation from that method must be justified on the basis of need. For example, synthetic pheromone traps with substances to attract insects, have always been allowed in organic production since these traps are a sustainable tool in monitoring and controlling insect populations. According to the IFOAM principles, organic systems have demonstrated that production and processing has been possible without GMOs. Therefore, there can be no demonstrated need for GMOs in these systems. For instance, *Bacillus thuringiensis* (Bt) has for many years been used as a biopesticide in organic agriculture to control infestations by lepidopteran insects such as caterpillars. For IFOAM, organic agriculture has no need for transgenic crops, which express the same anti-lepidopteran protein.

## Pest Control

Organic farming is a process which prohibits the use of synthetic fertilizers, pesticides or chemicals in growing crops. Instead, it uses beneficial naturally-occurring materials, in conjunction with proper soil and crop management practices, to develop and protect optimal soil health and crop ecology. In fact, in order to be certified organic you must be free from these materials for a minimum of three years prior to your first harvest. Organic farming results in less damage to the environment and ecosystem. From the water we drink, to the soil we farm, to the air we breathe, less contamination means a safer planet for everyone. Simply put, organic farming results in safer products for you, your family and the environment. Spraying of *Bacillus thuringiensis*, a pathogen capable of attacking several lepidopteran insects has been successfully adopted in many countries to control pests on many crops. Such bio pesticides are developed by culturing the pathogens found in the insect species. With environmental restrictions on chemical pesticides, these alternatives are gaining popularity.

Pest control in organic farming begins by taking right decisions at right time such as growing crops that are naturally resistant to

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diseases and pests, or choosing sowing times that prevent pest and disease outbreaks. Careful management in both time and space of planting not only prevents pests, but also increases population of natural predators that have natural capability to control insects, diseases and weeds. Other methods generally employed for the management of pests and diseases are: clean cultivation, improving soil health to resist soil pathogens and promote plant; growth; rotating crops; encouraging natural biological agents for control of diseases, insects and weeds, using physical barriers for protection from insects, birds and animals; modifying habitat to encourage pollinators and natural enemies of pests, and using semi-chemicals such as pheromone attractants and trap pests. For reactive treatment of pest control, biological control agents are some times used in organic system. *Bacillus thuringiensis* is commonly used as a microbial insecticide against lepidopterous pests.

**a) Practices Allowed:**

1) Preventive management such as intercropping and crop rotations.
2) Biological controls, such as release of natural predators and parasites.
3) Sprays and dusts of low ecological profile, including insecticidal soaps, rock powders and diatomaceous earth.
4) Microbial preparations such as *Bacillus thuringiensis*, NPV, entomopathogenic fungi etc.
5) Pheromones used as traps and pheromones used as mating disruptive if not applied to a food crop.

**b) Practices Prohibited:**

1) Synthetically compounded insecticides, nematicides, acaricides, rodenticides, molluskicides, ovicides, or repellants.
2) Traps containing prohibited pesticides.
3) Natural poisons that are environmentally persistent and have long-term effects, such as arsenic and lead salts.

## Microbial Pesticides

With the ever-increasing awareness of the harmful effects of chemicals on man and his environment, the immediate need for sustainable, eco-friendly pest management has been felt very strongly providing an impetus to research and development of microbial pesticides. Microbial control includes all aspects of utilization of microorganisms or their by-products for the control of pest species. Among the different microbial agents developed and tested, bacteria, viruses and fungi are considered promising for the control of insect pests (Table 1). Microbial control agents are relatively host specific and do not upset other biotic systems. They are safe to humans, vertebrates, beneficial organisms and do not cause environmental pollution and are compatible with most other control methods. They are ideal for both short and long term pest suppression. Unlike chemical pesticides, they are harmless to humans and other non-target organisms, they do not leave chemical residues on crops, are easy and safe to dispose of and do not contaminate water systems. The microbial pesticides can be locally produced and used for pest management in Organic farming. Some of the promising microbial insecticides that can be employed in organic farming are discussed below.

### *Bacillus thuringiensis*

Many different types of bacteria are known to acutely or chronically infect insects. *Bacillus* is by far the most important microbial pesticide genus. *Bacillus thuringiensis* (Bt) has been the most widely used and successful microbial pesticide ever registered. *B. thuringiensis* is an insecticidal bacterium, marketed worldwide for control of many important plant pests - mainly caterpillars of the Lepidoptera (butterflies and moths) but also for control of mosquito larvae, and simuliid blackflies that vector river blindness in Africa. Bt products represent about 1% of the total 'agrochemical' market (fungicides, herbicides and insecticides) across the world. The commercial Bt products are powders containing a mixture of dried spores and toxin crystals. They are applied to leaves or other environments where the insect larvae feed. The toxin genes have also been genetically engineered into several crop plants. Today they are used mainly in viticulture, forestry, green spaces and in potato, fruit and vegetable cultivation. They are particularly important in organic farming; Bt preparations account for around 90% of all bio-insecticides. By contrast, they comprise only one percent of agro-chemicals.

When cultured under appropriate conditions, Bt sporulates (endospore) and forms a crystalline parasporal body which contains the insecticidal protein toxin called delta endotoxin. This body is usually referred to as the crystal. Bt can be produced in a liquid medium by deep fermentation. When sporulation is complete, the bacterial cell lyses and releases the spores and crystals into the surrounding medium. The crystal is a bipyramidal aggregate of protein molecules (about 130-140 kDa) that is actually a **protoxin** - it must be activated before it has any effect. The crystal protein is highly insoluble in normal conditions, so it is entirely safe to humans, higher animals and most insects. However, it is solubilised in reducing conditions of high pH (above pH 9.5) - the conditions commonly found in the mid-gut of lepidopteran larvae. For this reason, Bt is a highly specific insecticidal agent. When ingested by the lepidopterous caterpillars, the crystal is activated by alkali dissolution and digestion by gut proteases, releasing the smaller, potent endotoxin of about 60kDa which binds to the midgut epithelial cells, creating pores in the cell membranes and leading to equilibration of ions. As a result, the gut is rapidly immobilised, the epithelial cells lyse, the larva stops feeding, and the gut pH is lowered by equilibration with the blood pH. The length of time until death depends on the species of insect and the dosage but feeding stops rapidly. The lowered pH in the gut enables the bacterial spores to germinate, and the bacterium can then invade the host, causing a lethal septicaemia.

*B. thuringiensis* and its various subspecies, strains and geographic isolates have been studied in detail for their efficacy in the field and laboratory against major lepidopterous pests such as *Helicoverpa armigera, Spodoptera litura, Leucinodes orbonalis*, *Plutella xylostella*, *Pieris brassicae*, *Spoladea recurvalis*, *Phthorimaea operculella*, *Achaea janata*, *Prays citri*, *Earias vittella*, etc. Over 12 commercial formulations of *Bt* are available in the market (Table 2). In India bulk of Bt is sold through Govt. subsidy programmes. The trade is mainly on vegetables where *Plutella* on cole crops is the main target pest and *Helicoverpa* spp. on cotton, vegetables, pulses and oilseeds. Area wise segmentation of Bt products is 20% in North India, 30% in South India, 45% in Western India and 5% in Eastern India. Wockhardt has set up a hitech plant to manufacture Bt technical product and formulation based on a native strain near Aurangabad with a production capacity of 100 tonnes/annum.

Work under the Andhra Pradesh Netherlands Biotechnology Programme at the Directorate of Oilseeds Research, Hyderabad, on Bt with specific reference to cost-effective production, field testing, transfer of technology has met with success and received the acceptance of farmers in Mahbubnagar and Nalgonda districts. A simple, cost-effective protocol based on the principle of solid state fermentation for the multiplication of Bt has been developed for which a patent application has been filed by ICAR on 10/07/2002. One local isolate DOR Bt-1 isolated from a dead castor semilooper larva collected from farmers' fields at Kothakota has been identified for large scale field use. The formulation has been registered with the Central Insecticides Board. The technology is being offered on a non-exclusive basis for commercial exploitation. Three micro-enterprises have been established by the Directorate in A.P. in association with two NGOs.

## Entomopathogenic fungi

More than 700 species of fungi, mostly Deuteromycetes and Entomophthora from about 90 genera are pathogenic to insects. Genera that have been most intensively investigated for mycoinsecticides include *Beauveria, Metarhizium, Verticillium, Hirsutella, Erynia, Nomuraea, Aspergillus, Aschersonia, Paecilomyces, Tolypocladium, Leptolegnia, Coelomomyces* and *Lagenidium*. The first two genera have been used on a large scale over a number of years while others have been aimed mainly at glasshouse pests or disease vectors. There is a world wide resurgence of interest in the use of entomopathogenic fungi as biological control agents, and a significant advance in development and manufacturing of these agents in the future is expected with recent biotechnological innovations.

**Mode of Infection**: The fungus invades the host cuticle through the body wall and spiracles primarily and also through the mouth parts. The conidia germinate on the insect cuticle by producing germ tubes which penetrate the body wall. The penetration is both mechanical (pressure exerted by germ tube) and enzymatic through the action of proteinase, lipase and chitinase on the cuticle. Growth of the fungus after it reaches the haemocoel is by budding which produces hyphal bodies. These are transported through out the haemocoel and give rise to localised concentration of mycelia. A heavy growth of intertwining mycelia develops in the haemocoel 1-2 days later. The larval body is completely mummified and covered by a dense white mycelial mat from which conidiophores arise close together and produce conidia 1-2 days later. Under suitable environmental conditions (essentially high humidity), death is followed by external sporulation, which helps to spread the fungus and establish an epizootic which may result in very high levels of kill. Fungi, unlike bacteria or virus, do not require ingestion for infection, so sucking insects are also targets either by primary contact of a mycoinsecticide or by secondary uptake of the pathogen from sprayed vegetation.

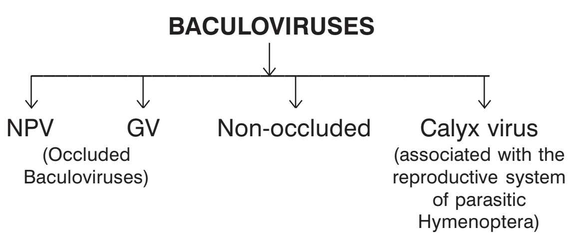
Toxin production is reported for *Metarhizium anisopliae, Beauveria bassiana, Verticillium lecanii, Paecilomyces* etc. Several studies have revealed positive correlations between RH/rainfall with rate of fungal infections thus indicating that fungal survival and spread are assured under higher rainfall and humidity conditions.

Entomofungal pathogens recorded from India include *Beauveria bas*siana, *Metarhizium anisopliae*, *Verticillium lecanii*, *V. aphidicola*, *Nomuraea rileyi* from *H. armigera*, *S. litura* and *Trichoplusia* spp., *Hirsutella* spp., *Erynia neo*aphidis, *Paecilomyces farinosus*, *Pandora delphacis*, *Entomophthora aulicae*. Several species of entomopathogenic fungi such as *Beauveria bassiana*, *Metarhizium an*isopliae, *Nomuraea rileyi*, *Hirsutella thompsonii* and *Verticillium lecanii* have been studied in detail for their efficacy in the laboratory and the field. Mass production techniques have been standardized. The entomopathogenic fungi have given promising results in humid and mild climate areas and seasons. In India, work with white halo fungus *V. lecanii* has brought down the coffee green bug *Coccus viridis* to almost negligible proportions in the Pulney hills. The green muscardine fungus *Metarhizium anisopliae* has also been useful for the control of rhinoceros beetle of coconut Oryctes rhinoceros. At the Directorate of Oilseeds Research (DOR), studies with the fungal pathogen *Nomuraea rileyi* have generated the basic data pertaining to effective field dose, field persistence, instar susceptibility, identification of virulent isolates, cost-effective mass multiplication and formulation. This fungal pathogen infects a majority of noctuids viz., *Helicoverpa armigera*, *Spodoptera litura*, *Plusia* spp. etc. UAS Dharwad has undertaken mass production of the fungus and is making it available to farmers. Commercial formulations of *B. bassiana* are currently available in India.

Protocol for low cost mass production of *B. bassiana* as well as its formulation in oil has been developed at DOR.

## Baculoviruses

Viruses of several types are known to infect insects but baculoviruses are found only in arthropods and have not been recorded from vertebrates/plants, safe to man and non-target organisms and hence have received priority consideration for development as insecticides. Insect baculoviruses are important natural regulating factors for insect populations particularly Lepidoptera. Their commercial development has been limited by the need to produce them *in vivo* and by their generally high specificity, which while desirable from an environmental point of view, limits markets. Although baculoviruses have not had the commercial successes of *Bt*, they have significant potential for use in organic farming because they do not affect non-target insects (parasites and predators), safe to humans and environment. In pest management, it is important to have a selection of control agents when designing strategies. Viruses are not likely to evoke cross resistance to chemicals or to each other, so more attention must be given to viral pesticides.




Epizootics of baculovirus diseases are frequent in lepidoptera and sawflies with very high larval mortalities resulting in strong population depression.

Epizootic development requires:

a) several host generations

b) high virus infecting capacity

c) persistence of the virus inside and outside the host.

Baculoviruses survive long periods in soil. Reservoirs of baculovirus in soil have long term importance and initiate epizootics when insect populations resurge following a phase of low density.

### *Symptoms of Viral infection*

- Dead larvae may be found hanging from or lying on leaf or plant surfaces.
- The cuticle may be very fragile, rupturing easily when touched, releasing the body contents which have become liquefied.
- Porcelain white masses of fat body may be visible through the cuticle.

**Baculoviridae** are characterised by the presence of proteinaceous inclusion bodies within which either a single virus particle (GV) or many virus particles (NPV) are embedded. The matrix protein within which the virus particles (Virions) are embedded are called **polyhedrin** for NPV and **granulin** for GV. The polyhedral inclusion bodies (PIB) of NPV are upto 5Fm in diameter and may contain several hundred virus particles. Each virus particle may contain one or more than one nucleocapsid. The inclusion bodies of GV are called capsules or granules and measure 400 - 500 nm x 200 - 300nm. Each capsule contains a single virus particle.

**Mode of Infection:** Infection occurs most commonly via the midgut following ingestion of inclusion bodies. When infected, and under the alkaline conditions of the lepidopterous and sawfly midgut, the inclusions breakdown releasing virus particles. In lepidoptera, the virus particles pass through the midgut cells, sometimes with a replicative phase and enter the haemocoel. Major sites of replication are the nuclei of fat body, haemocytes and hypodermis.

All viral insecticides are currently produced in susceptible host insect larvae, most of which are reared on artificial diet. This is usually labor intensive and expensive but does not require much capital investment. Therefore, cost of crop protection basically depends on the number of larvae which have to be reared, infected and harvested to treat one hectare typically 100 - 1000. Labor is usually cheap and plentiful in developing countries and hence virus can be easily produced at a reasonable cost. Long term benefits can be achieved through the use of NPV since most of the dead larvae remain on the plant with their integument ruptured resulting in release of NPV laden haemolymph to persist in the soil and result in epizootic spread of the disease in the next crop.

### Mass Multiplication of Baculovirus

Infected larvae
↓
Suspended in sterile distilled water (7 days)
↓
Decant supernatant
↓
Filter through double layered muslin cloth
↓
Suspend in distilled water
↓
Purify by centrifugation

Branch 1:
↓
Centrifugation at 200 RPM for 5 min to sediment impurities
↓
Centrifuge supernatant at 10,000 RPM

Branch 2:
↓
Low speed centrifugation at at 250-500 RPM for 5-10 min.
↓
High speed centrifugation of supernatant at 3000 RPM for 30-60 min.
↓
Resuspend pellet in distilled water and Repeat alternate cycles of centrifugation
↓
NPV

**Table 1: Candidate microbial pesticides available for pest control**

| Pathogen | Major Target Groups |
|---|---|
| *Bacillus thuringiensis* (Cry I A-G, Cry II A-C, Cry III A-D, Cry IV A-D, Cry II A) | Lepidoptera, Coleoptera, Diptera |
| *Bacillus sphaericus* | Diptera |
| Nuclear Polyhedrosis Viruses | Lepidoptera |
| Granulosis Viruses | Hymenoptera |
| *Beauveria bassiana* and *Metarhizium anisopliae* | Coleoptera, Lepidoptera, Hymenoptera, Orthoptera |
| *Beauveria brongniartii* | Coleoptera, Homoptera, Lepidoptera, Diptera |
| *Nomuraea rileyi* | Lepidoptera |
| *Verticillium lecanii* | Homoptera, Thysanoptera, Diptera |
| *Lagenidium giganteum* | Mosquito larvae |
| *Paecilomyces fumosoroseus* | Coleoptera, Homoptera, nematodes |

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# Use of Neem and Other Plant Products in Organic Farming

**M. Prabhakar and B. Venkateswarlu***

## Introduction

Agriculture during the last 3 decades relied heavily on externally produced inputs. Moving away from traditional practices of organic recycling and mixed cropping did improve the crop yields substantially, though the sustainability of these gains is being questioned now. Agrochemicals among others had a significant impact on the productivity, but the negative fall out of the indiscriminate use of pesticides is now being realised by all. However cost effective alternatives are to be provided to the farmers to minimise the use of such inputs. Due to the continuous extension efforts and awareness campaigns by scientists, development departments and NGOs, the concept of integrated pest management and non-chemical methods of pest suppression are gathering momentum across the country. Products derived from neem tree are one of the important components of non-pesticidal approach, which have proven their efficacy under field conditions and are now being routinely adopted by the farmers. Use of neem in pest management can be considered as one of the best examples of LEISA and if successfully adopted can be a role model for the so-called “alternate agriculture”.

Today neem-based products remain most potential and commercially viable biopesticides. Various results obtained globally have shown that neem and its allelochemicals have a variety of effects on pests. More than 140 active principles have been identified to date that occur in different parts of the tree. The most important components identified have been the tetranotriterpenoids, the azadirachtins. These occur at concentrations of 0.1 to 0.9 % in the seed core and it has been established that a dose of 30 to 60 g azadirachtin per hectare is sufficient to combat and repel the key pests of various crops (Kour, 2004).

Over 500 species of insects have been tested with neem products and 413 of these are reportedly susceptible at different concentrations (Schumutterer, 1995). Similarly, neem preparations also act as nematicides against endoparasitic species of *Meloidogyne* and *Globodera*, ectoparasitic species of *Hoplolaimus* and *Tylenchorhynchus* and semiendoparasitic species of *Rotylenchus* and *Pratylenchus* nematodes (Musabyimana and Saxena, 1999). The neem products also control many fungal and bacterial plant pathogens, mites, and animal and plant viruses (Manasur *et al*., 1987 and Schmutterer, 1995)

### Mode of action of Azadirachtin

All biologically active Neem compounds are suspected to be derived from one parent compound, the tetracyclic triterpenoid tirucallol. All other products formed are considered successive rearrangement and oxidation products of tirucallol. It is generally accepted that the tetranotriterpenoid (also called limonoid) compound azadirachtin is responsible for the majority of biological effects observed in organisms exposed to Neem

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compounds (Isman, 1990). However, 25 different biologically active compounds have been isolated from Neem seeds (Lee *et al*., 1991). Both primary and secondary antifeedant effects have been observed in the case of azadirachtin. Primary effects include the process of chemoreception by the organism (e.g. sensory organs on mouthparts which stimulate the organism to begin feeding) whereas secondary processes are effects such as gut motility disorders due to topical application only. Schmutterer (1990) suggested that azadirachtin modifies the programs of insects by influencing hormonal systems, especially that of ecdysone. The effects of azadirachtin are both dose and time dependent, prevent both ecdysis and apolysis, and can cause death before or during molting, possibly inducing "permanent" larvae. Azadirachtin appears to block the release of neurosecretory material from the corpora cardiaca resulting in a reduced turnover rate. This affects the rate of synthesis of PTTH by brain neurosecretory cells.

## Use of Neem Products in OF

Azadirachtin, a tri-terpenoid present in neem seed kernels, is the main compound responsible for the antifeedant and repellent action of neem products. However, in nature there is a large variation in the quality of neem seeds available with respect to the active ingredient. Secondly, neem products are not effective against all pests. They are most effective against beetle larvae, butterfly and moth caterpillars, reasonably effective against plant hoppers and leaf miners, exhibit satisfactory effect on aphids and white flies but poor control on mealy bugs, scale insects and mites. Therefore, farmers should be made aware of this limitation. Further one cannot see a knock down effect with neem products as with chemical pesticides, since they act essentially as antifeedant, repellent and growth retardants. It is only in the past decade that the pest control potential of neem, which does not kill pest like neurotoxins but affects their behaviour and physiology, has been recognised. Though subtle, neem's effects such as repellency, feeding and oviposition deterrence, growth inhibition, mating disruption, chemo-sterilization, etc. (Schmutterer, 1995) are now considered far more desirable than a quick knock-down in integrated pest management programs as they reduce the risk of exposing pest natural enemies to poisoned food or starvation. Their safety to mammals is an added advantage. Toxicological data shows that azadirachtin to be relatively low in mammalian toxicity, with an acute oral $LD_{50}$ to rats of >5000 mg/kg (Koul, 2004). The United States Environmental Protection Agency has exempted Azadirachtin from the requirement of a tolerence for residues at a usage rate of 20 gms a.i. per acre per application.

Use of neem products is the best example of an Indian ITK, which was forgotten with the advent of chemical pesticides but again revived during the last five years with new insights into the chemistry, mode of action and field efficacy of active ingredients from neem seed, largely due to extensive research done in India, UK and Germany. With increased awareness on its potential in IPM, a number of doable technologies have been developed which constitute both use of traditional extracts and the high-tech quality assured formulations produced in a modern factory. During the last two years, neem products have at last reached the farmers' fields from the research labs. With abundant resources of neem trees in India (estimated to be 15 million producing nearly 5 lakh tons of seed/annum), the priority has to be on a decentralised, low cost on-farm pest management strategy, which truly reflects the concept of LEISA. Following are some recommended uses of neem products at the farm level. These practices can be adopted by the farmers with least external inputs and are based on extensive research during the last one-decade in India and abroad.

## Aqueous Neem Seed Kernel Extracts (NSKE):

This is prepared by mixing 5% finely ground powder/paste of well-dried neem seeds in water. The seed powder is tied in a cloth, immersed in water over-night and stirred well to make a ready to spray suspension. The suspension needs to be filtered through a double-layered cloth while filling the sprayer. The main advantage of the suspension is its effectiveness since it is prepared freshly and the drawback is that it cannot be stored for long since it is a water extract. Farmers need to collect neem fruits well ahead of the cropping season, de-pulp and dry them under shade. Moisture control in the de-pulped seeds is critical in maintaining the quantity of the active ingredient. Drying seeds up to a moisture content of 8% is recommended for short-term storage.

### Use of Neem Oil

Neem oil is mixed in water at 0.5 to 2% concentration, emulsified well and sprayed on the crop. Adding soap solution (5 mL/L) or a commercial emulsifier is important as spraying of neem oil alone or oil not properly mixed with the water can damage the crop due to the phytotoxicity. The quality of neem oil is very important. The active ingredients in neem oil like azadirachtin and salanin remain stable only up to 65$^{o}$C. Therefore, oil expelled from cold expellers where the temperature is regulated during expelling is most effective. Farmers can also use hand-expelled oil without any loss of active ingredients. Because of the variation in the quality of neem oil used by the farmers, the effectiveness of the product differs from place to place.

### Use of Neem Cake

Neem cake is used for soil amendment @ 0.25 to 0.5 t/ha and it has variety of effects such as control of nematodes, soil borne fungi and as nitrification inhibitor. Unlike kernel extracts and neem oil, which can be used against specific crop pests more effectively, neem cake can be used for a variety of crops and fruit trees to achieve multiple benefits of increased nitrogen use efficiency and control of soil borne pests and diseases.

### Advantages of Neem Products

- The technology of preparation of extracts and application is fairly simple which the ordinary farmers can adopt easily.
- Biodegradable, easily obtained from renewable sources and is available locally every year on the farmer's fields
- Neem products do not leave residues in the environment, i.e. soil, groundwater and food products like grain, vegetables and fruits.
- Safe to non-target organisms including natural enemies.
- Low risk of pest resistance due to different mode-of-action.

### Using the seed resources locally

For the neem products to be widely used in pest management, adequate seed resources are to be available to the farmers. Neem trees generally grow in the households, on village common lands, avenues, farm boundaries and often scattered in the middle of the farms. Unaware of the usefulness of the tree in pest control, farmers often cut well grown good yielding trees for marketing as timber. The seed available from the trees growing on common lands and avenues is collected by landless labourers and children and marketed to the village merchants at a low price, which then goes to the organized neem extraction factories in the cities. While this provides some employment and income to the poor, the valuable resource is going out of the village. Under the concept of LEISA farmers need to be educated to use the neem seed resources available with in their households or farms for their own land. As a next step it should be ensured to use of entire seed resources generated in the village with in that village only. This is a critical aspect of popularizing neem in a decentralized mode of pest management. Used properly, locally prepared neem extracts are as effective as the commercial neem formulations, which are quite expensive to the farmers.

### Planting more neem trees

Besides discouraging cutting of existing neem trees, there is a need to promote planting of neem trees in villages to ensure availability of seed resources on a sustainable basis locally. Research at Central Research Institute for Dryland Agriculture, Hyderabad led to the identification of superior type neem trees which have higher quantity of active ingredients in the seed, besides having good silvi-cultural characters. Early flowering and fruiting in some of the selected trees helps in collecting much of the fruits before the starting of the monsoon season thus avoiding damage of fruits due to excess humidity and fungal infection. These seeds/saplings can be made available to the farmers and NGOs on a specific request. Even tissue culture plants of this elite clone can be made available in limited number for model plantations. These plants flower early and produce uniform yields. As a typical example of LEISA, 8-10 neem trees of selected variety planted around the farm boundary can provide sufficient seeds after 5 to 6 years to control important pests in one acre of land on a renewable basis. This practice of planting few trees around every farm is more sustainable than commercial block plantations in a concentrated manner. Neem planted in monoculture is prone to pests and diseases. Boundary plantation of neem trees therefore should be taken up as a campaign to produce enough seed for future use in IPM.

### Other plant products

Like neem, pongamia and custard apple are other plant species with good potential in IPM and organic farming. Pongamia seed powder extracts, oil and cake can be used in similar manner as that of neem. Combined use of neem and pongamia oil in 5:1 ratio was found to be more effective than neem oil alone. Custard apple leaf extracts and seed extracts are also quite effective. Leaf extracts are prepared by grinding 50g fresh leaves in one litre or boiling in water till dark colour is obtained. Cooled extract is filtered and sprayed. In case of seed extracts 500g powder can be suspended in 10 litres. After 12h soaking, it is ready for spray. In case of custard apple, oil extraction is not recommended at farm level as it causes irritation to eyes and skin. Even making seed powder results in fumes, which cause allergy and irritation. Farmers need to be trained properly in handling custard apple products.

The leaf extract of *Vitex negundo,* a common bush found on field bunds also contain pesticidal properties and is widely used as pesticide by many framers in Andhra Pradesh. Five kg of chopped fresh leaves of *Vitex* is grinded followed by boiling for 30 min in 5 l of water. After cooling, the contents are filtered using a muslin cloth and another 45 l water is added to make the final volume to 50 l. Surfactants like any detergent powder are added before spraying. The fungicidal properties of *V. negundo* also have been reported (Dev *et al*., 2002). Soil application of neem cake, foliar sprays of neem seed kernel extract and leaf extract *of V. negundo* significantly reduced the leafhopper incidence in rice, which is a vector of rice tungro disease (Rajappan *et al*. 2000).

## Conclusions

Azadirachtin together with other constituents of neem seeds such as salannin, nimbin, nimbidin, meliantriol and a number of other limonoids exhibit insect repellent, antifeedent and insect growth regulatory activities. In view of the multiple benefits of using neem based products in organic farming there is an urgent need to provide training on different aspects of neem products that include i) Scientific methods of fruit collection. ii) Control of fruit decay and fungal infection by regulation of moisture and temperature during the wet season. iii) De-pulping, decortication and storage methods with out loss of active ingredients. iv) Preparation and use of extracts based on kernels, oil and press cake. v) Raising of neem saplings in the nursery and cultivation of neem trees on boundaries as well as in agroforestry systems. Large pool of information on the above aspects is available with Khadi and village industries commission (KVIC) and a number of research institutes under ICAR and Agricultural Universities. NGO's can play an important part in training of progressive farmers and women, who then can play a catalytic role in popularizing the use of neem in IPM. Concerted efforts can make neem a true role model of LEISA technologies, which can be replicated, in number of other developing countries.

**It took 22 years** and the efforts of more than 40 chemists, but Steven V Ley's group from Cambridge University in UK has finally managed to complete a 64-step synthesis of azadirachtin, a naturally occurring insecticide in the year 2007 (Angew. Chem. Int. Ed., DOI: 10.1002/anie.200703027 and 10.1002/anie.200703028). This synthesis may yield the ability to create and test each chemical component of neem oil in an isolated environment. Experiments of this nature would allow researchers to continue to unravel the mystery surrounding the activity of neem compounds. Research of this type enhances the existing knowledge of how neem controls insects and mites, allowing better use of this product by consumers, growers, farmers, and researchers.

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# Biofungicides in Organic Farming

**Suseelendra Desai***

## Introduction

Agricultural, horticultural and ornamental crop plants are subjected to biotic stresses such as insect-pests, plant pathogens and nematodes inflicting severe crop losses. Currently, the most widely used control measure for suppressing these organisms is the use of pesticides. However development of resistance by organisms to pesticides, accumulation of residues in the food chain, and environmental pollution have led to a search for alternative pest and disease management strategies. In case of chemical disease control, increasing cost of soil fumigation, and lack of suitable replacements for methyl bromide etc. have particularly speeded up the search for alternatives.

These developments have led to renewed interest on the use of "biologically based pest management strategies". One approach to such biologically based strategies is the use of naturally occurring and environmentally safe biocontrol agents (BCAs) such as fungi used alone or as a component of integrated pest management (IPM) strategies. Biofungicides are the products containing beneficial living organisms, often selected from natural environments that are used for pest management. These products are subjected to Environmental Protection regulations and worker protection standards. These microbes have been formulated with prolonged shelf-life and enhanced field performance. Biofungicides are formulated as powders for seed treatments, as granulars for soil application, and as suspensions for root drenches and foliar sprays.

Plant pathogens and some BCAs have co-evolved over time, establishing specific modes of co-existence. Hence, biological control could be either to enrich the native BCAs by specific cultural practices such as the use of organic amendments or by using introduced BCAs to establish and balance biocontrol agents in the pathogen's environment. Introduction of BCAs for the control of plant diseases has been practiced in agricultural fields since 1927 (Millar and Taylor, 1927). Over the intervening years, from hundreds of biological control agents identified as potential candidates, only a few have been formulated for commercial use against various diseases. Of these, only hardly about 5% of BCAs have actually achieved their aim (Justum, 1988). Several factors contribute to this large gap between research and successful commercial exploitation (Templeton, 1986 and Gutterson *et al.*, 1990).

### Development of biofungicides

For successful development of biofungicides, several critical steps have to be followed such as collection of microorganisms from different agro-ecological conditions, preliminary evaluation of their potential in laboratory conditions, testing in greenhouse and field condition of the efficacy of short-listed potential candidate biofungicides, development of cost-effective mass multiplication methods, formulation with a prolonged shelf-life and arranging proper

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marketing strategies. Care should be taken to apply correct selection criteria as some experiences have shown that extrapolation of greenhouse results to a real-life field situation may not always be obtained (Lewis *et al*, 1990). All introductions also may be unsuccessful for the reason that the results obtained in a particular environment have been extrapolated to other totally different ecological niches (Lewis and Papavizas, 1991). Hence, while care should also be taken to build awareness about biofungicides among the stakeholders, demonstration of the usefulness of the technology in their fields and necessary refinement should be taken up. Arrangements for the supplies at the farmers' immediate reach should be made as often non-availability of the input when required was found to be one of the reasons for non-adoption of technology.

## Mode of action of biofungicides

Biological products reduce disease through different mechanisms, such as competition, antagonism, antibiosis, enhanced nutrient uptake, and/or by inducing host resistance. Products that utilize more than one mechanisms may have better acceptability at the field level due to their increased activity and/or may inhibit a wider range of target pests. These mechanisms are described below.

- Competition can be an effective mechanism used by biological control agents in reducing pest which normally occurs at phyllosphere or rhizosphere. Both beneficial and deleterious microbes compete for nutrients leaked by plant cells. Biological control agents that use competition to suppress diseases generally need to be applied in high densities before the pathogen is present to smudge pest populations.

- In antagonism, biocontrol agents attack and feed on the pathogen. For this mechanism to be operative, the biological control agents must be preferably present before the pest appears.

- Antibiosis involves the production of secondary metabolites such as enzymes and toxins that will inhibit growth and reproduction of the pest. The biocontrol agents possessing this property need not be present in high numbers, but should exert their antibiotic effect before infection/ infestation occurs. This mechanism has been successfully demonstrated in bacterial BCAs.

- Many biocontrol agents can improve growth and suppress pest by manipulating nutrient availability. By altering pH or by releasing enzymes that dissolve insoluble elements, these biological agents increase the availability of certain fertilizers. This mode of action has not received as much attention as other mechanisms, but may become important in nutrient deficient soil mixes.

- Lastly, some biocontrol agents can induce defense responses in plants that can help in offering the required protection against target pests. These defenses could be induced either in the form of systemically acquired resistance or induced systemic resistance. These mechanisms are more often demonstrated in plant-pathogen interactions.

However, normally biocontrol agents adopt more than one mode of action and hence it is required to characterize all the desirable traits of the bioagent and catalogue the traits so that they could be exploited for different crop production systems.

## Formulation of biofungicides

Formulation of a biofungicide is a crucial step as the live organisms have to be delivered to the farmers timely with appropriate viable counts for effective management of the target pest. For industries to commercialize these technologies, model studies for the large scale multiplication are needed, which include a suitable and cheap medium, method of fermentation (solid or liquid), type of formulation (wettable powder, liquid, granular), nature of filler material, delivery systems, optimum storage conditions of the product and information on shelf-life. Often, dusts contain about 5-10 per cent colony forming units (cfu) of BCA by weight, wettable powders might have 50-80 per cent cfu by weight, granular formulations might contain 5-20 per cent cfu by weight and liquid formulations contain about 10-40 per cent cfu by weight. Certain specific conditions might increase efficacy of a formulation. Addition of organic acids to *T. koningii* formulations and polysaccharides and polyhydroxyl alcohols to *T. harzianum* increased the activity of the BCAs (Nelson *et al*, 1988).

Gangadharan *et al*., (1990) found that tapioca rind, tapioca refuse and well decomposed farmyard manure formed good substrates for the mass production of *T. viride* and *T. harzianum*. Vermiculite-based fermenter biomass of formulation with an initial population of $205x10^6$ cfu/g stored in milky white bags showed an exponential phase up to 30 days ($309x10^6$ cfu/g). Further temperature of 20-30°C was optimum for the storage of the formulation at which even after 75 days, the product contained $206\text{-}271x10^6$ cfu/g (Nakkeran *et al*,1997). Sankar and Jeyarajan (1996) developed seed dressing formulations of *T. viride*, *T. harzianum*, and *Gliocladium virens* for management of *Macrophomina phaseolina,* in sesamum. To overcome the barriers of the commercial use of phenazine-producing pseudomonads, Slininger *et al*., (1996) have optimized the culture conditions, physiological state, and associated metabolites on the biocontrol ability of pseudomonads. A fermenter biomass containing 24-48 h old cells had longer drying survival rate, but shorter shelf-life. Similarly, methyl cellulose-water formulations retained better viability.

## Quality control and quality assessment of biofungicides

One of the major bottlenecks for the wide spread adaptation of biofungicdes in crop production systems is lack of reasonable quality control. Being live organisms, these products must have more stringent quality control systems in place and quality assessment at regular intervals. Unfortunately, unlike the chemical formulations, there have been no stringent guidelines for maintaining good quality standards. Biological control is a very complicated natural phenomenon that needs a thorough understanding of the process for maintaining required order of quality. A number of criteria have to be fulfilled to develop a high quality biofungicide product such as maintenance of a pure culture, good mass multiplication facilities, optimum formulation practices and appropriate storage conditions. Contaminated cultures, bad fermentation and improper formulation conditions would lead to growth of other microbes which could ultimately lead to disasters. For instance, solid-state fermentation, though simple and easy, is a potential source of cross contamination as it is often difficult to maintain sterile conditions. Products formulated using such biomass fail to give expected results and also show variations between batches. On the contrary, liquid fermentation though can offer production of pure biomass for formulation, is expensive. Hence, a combination of both these methods could help in developing pure and cost-effective formulations. Another concern to the maintenance of quality is the emergence of a lot of small time entrepreneurs who do not possess required facilities and so market spurious products in the name of biocontrol agents. Though, biological control helps in managing some pathogens, such practices will lead to loss of faith of farmers in biological control. These problems could be overcome when proper care is taken to establish good fermentation and formulation facilities and stringent regulatory systems are in place.

## Registration of Biofungicides

A range of biofungicides including bacteria and fungi as active ingredients are now commercially available in many countries for control of pests. The regulatory requirements have been generally favorable and less stringent to BCAs than chemicals. Registration of BCAs with a federal or central regulatory agency is mandatory before its release to end-users i.e., growers and a number of countries have developed legislations for registration of biopesticides. For instance, Europe follows the OECD definition of biopesticides, that includes pheromones, insect and plant growth regulators, plant extracts, transgenic plants, and microorganisms (OECD, 1996). In the United States, the US Environmental Protection Agency (EPA) regulates biological pesticides or biopesticides. The generic and product-specific data requirements for biological pesticides appear in Title 40, Part 158, of the Code of Federal Regulations (CFR). A complete description of all data requirements and study protocols for biological pesticides is presented in the Pesticide Assessment Guidelines, Subdivision M: Guidelines for Testing Biorational Pesticides (US EPA, 1989). In China, the Institute for the Control of Agrochemicals, Ministry of Agriculture (ICAMA), is the authority for biopesticides registration. The Government of India in its notification of 8-15/99-CIR, dated 02.08.1999 has empowered Central Insecticide Board to facilitate registration of biopesticides and allowed for the registration of two types of registrations for biopesticides under section 9(3) of the Insecticides Act of 1968, i.e., provisional and regular. The Canadian and United States regulatory agencies, recently have taken a common approach and interpretation of results, on the harmonization of guidelines in semio-chemicals and pheromones. This is a welcome approach, and extending this harmonization on a global scale would foster enhanced adoption of biocontrol agents. International harmonization and uniform set of rules would not only lower costs, but would also give encouragement to researchers and industrial partners to the rapid development of innovative new biocontrol approaches for development of sustainable agriculture.

## Conclusions

For organic agriculture pest and disease management without insecticides and fungicides is a challenge. Biofungicides are very critical in this regard as more and more effective products are being launched in the market. However, the efficacy of such products should be demonstrated to the farmers through on-farm trials and awareness training programs organized from time to time about the new products and their method of usage. Research also should be focused on development of cost-effective products, preferably with broad-spectrum activity so that farmers can use them successfully in organic cultivation. Future research should focus on the interaction of other permitted inputs in organic farming with BCAs, to enable integrating of BCAs for enhanced productivity and profitability.

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# Pest Management in Organic Farming using Crop-Crop Diversity

**M. Srinivasa Rao***

## Introduction

One of the primary objectives of organic farmers is the reduction of production inputs. Pesticides are high on their list of priorities in this regard. Aside from the need to reduce inputs, organic farmers have limited range of options available in terms of pesticides, with most chemical products not being allowed in their production systems. This creates a need for alternatives to pesticides or means that are effectively compatible with the requirements for organic production and eco-friendly.

Intercropping has been used in many production systems for various reasons, among this optimization of space, hedging with a range of crops and management of pests (Wright, 1999); intercropping is typically applied by subsistence farmers with limited resources, as well as by ancient agrarian cultures. These farmers tend to base their crop selections upon generations of experience with indigenous crops (Zhou *et al.,* 1992). Experience of this nature is generally lacking in modern agriculture, creating the need to conduct basic ecological studies to be able to manage agricultural ecosystems effectively.

Crop diversification and rotation are essential elements of organic vegetable cultivation. Diversification can enhance economic stability by allowing the risks of production agriculture to be spread over a greater number of crops. Ideally, the crop mix should be complementary in nature.

As many organic farmers grow a range of crops, it would be relevant to develop a means by which they could reliably select crops to combine, and simultaneously enjoy the benefits of reduced pest pressures. Pest pressures may be reduced in diversified systems for various reasons, most important being the encouragement of beneficial insect diversity and abundance and reduced ability of pests to locate their preferred feed. Providing already diversified growers with an additional benefit from combining certain crops should be a valuable contribution.

The cultural control is particularly important in case of pigeonpea as it is often grown as a component of inter or mixed cropping systems. Several studies indicated that diversification practices such as intercropping are beneficial because of lower damage by insect pests in these systems (Risch *et al.,* 1983).

### Significance of crop-crop diversity

The crop diversity is of several ways like crop-weed diversity, crop-border diversity and crop-crop diversity. By introduction of one crop in existing crop, crop-crop diversity can be created or enhanced. Intercropping is the most popular form of crop –crop diversity.

Biotic, structural, chemical and micro climatic factors apparently constitute associational resistance, which probably reduce the pest infestation. The general reduction of pest infestation was noted in early reviews on intercropping (Srinivasa Rao *et al* 2002). The

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factors that influenced pest; population in intercropping might be physical protection from wind, shading, prevention of dispersal, production of adverse stimuli, olfactory stimuli camouflaged by main crop, presence of natural enemies and availability of food. Research in diversified agro-ecosystem demonstrated that these systems tend to support less herbivores load than corresponding monoculture

However, the generalisation that diversity decreases the pest problems does not hold true for many types of situations and pests. Similarly the intercropped system may not necessarily reduce pest density nor do increases yield.

The growth behaviour of pigeonpea makes it less competitive for resources when grown with other short season crops. Availability of cultivars with different durations of maturity offers scope for manipulation of crop environment for low pest incidence (in terms of choice of appropriate duration and intercrop). Whereas, growing long duration pigeonpea with short season crops like sorghum is common and short and medium duration pigeonpea cultivars have a significant role in cultural and agronomic manipulation to minimise insect damage .In India calendar sprays are recommended and followed with first application at 50% flowering and second and third applications at fifteen days interval. Farmers in Southern India do apply insecticides 3 - 6 times in a crop season led to a major problem of increased levels of resistance to organophosphates and synthetic pyrethroids in polyphagous pest *H. armigera* in Indian sub continent. This resulted in control failures and lack of confidence in insecticides by farming community. It is therefore important to identify an effective combination of non-chemical measures, evaluation of their efficacy and development management strategy for organic farming. The significant effect of intercropping on various insect pests across different crops was mentioned in the Table 1a&b. A perusal of tables indicates that in majority of the systems reduction of pest and proliferation of natural enemies was noticed across different field crops. The impact of intercrops on both the insect pests and natural enemies was more evident.

**Table 1a: Examples of crop pest population management through Intercropping**

| Agro-ecosystem | Pest | Factor/Effect |
|---|---|---|
| Pigeonpea+paddy | Pod borer | Incidence reduced than sole crop of pigeonpea |
| Beans+maize | *Empoasca krameri* Ross and Moore | Reduction of pest incidence |
| Cowpea+maize | *M.testulalis*<br>*C.ptychora.*M and *M.sojostedti.*T. | Increased<br>Decreased |
| Pigeonpea+pearlmillet | *H.armigera* | More Damage |
| Cowpea+sorghum | *Ophiomyia phaseoli*. | Reduced and higher yields |
| Pigeonpea+sorghum, greengram and groundnut | *E. kerri* | Highest reduction |
| Cowpea+maize, pepper and cassava | *M. sjostedti, A.craccivora* K., *Mylabris sp.* | Reduction of pests |
| Pigeonpea+coriander | *H.armigera* | Low incidence |
| Short and medium duration pigeonpea +sorghum or castor | Many insect pests including pod borers except *C.gibbosa* | Lower incidence than sole crop of pigeonpea |

**Table 1b: Examples where natural enemies effected through Intercropping**

| Agroecosystem | Natural enemies | Factor/Effect |
|---|---|---|
| Maize+groundnut | Predating spiders and spiderlings | Activity more |
| Pigeonpea+sorghum | Predators and parasitoid complex | No increase nor movement |
| Blackgram+sorghum | Predatory spiders | Increased |
| Sorghum+cowpea | Ichneumonid parasitoid | High pupal mortality of pests |
| Chickpea+coriander parasites | Larval parasites | Reduced pest due to more no. |
| Pigeonpea +cotton | *Gryon* sp. On *Clavigralla* | Less than sole pigeonpea |
| Short duration pigeonpea + sorghum | *Trichogramma,* Coccinellids and anthocorids | More than sole crop |
| Pigeonpea+sorghum, cowpea and bajra | coccinellids | Less than sole crop of pigeonpea |
| Cotton+clusterbean Cotton+cowpea | Predators, Spiders, Coccinellids | More population |
| Short and medium duration pigeonpea+sorghum or castor | Coccinellids dominated by *Menochilus sexamaculatus* and spiders dominated by *Clubiona* sp. | Highest activity than sole crop of pigeonpea |

(Source: Srinivasa Rao *et al* 2002)

## Intercropping in organic production of vegetables

Wright (1999) evaluated a method for the selection of vegetable crops suitable for intercropping and organically compatible pest management. The method tested was based upon ecological principles that predict the diversified systems should be less prone to attack by pests, owing to reduced ability of pest insects to locate their preferred food plants and enhanced activity of beneficial insects. The results showed that intercropping *per se* increased beneficial insect diversity. Largely certain crops determined abundance of pest insects e.g., broccoli, which attracted large number of crucifer flea beetles. Diversifying plots resulted in improved natural enemy complexes. Litterick *et al.* (2002) opined that pest control strategies in organic farming systems are mainly preventive rather than curative. The balance and management of cropped and uncropped areas, crop species and variety choice and the temporal and spatial pattern of the crop rotations used all aim to maintain a diverse population of beneficial organisms including competitors, parasites and predators of pests. Caporali *et al*. (2003) showed that the integration of biodiversity at the farm level is more likely to be achieved in organic farms than in conventional ones. Wide range of indicators of cropping system, biodiversity to be able to document elements of both structural and functional diversity with a value of agro ecosystem sustainability was applied. Crop protection strategies in organic agriculture and horticulture aim to prevent pest, disease and weed problems through optimization of the cropping system as a whole Jones *et al.* (2006) reported that the addition of sunflower intercrops proved to be an effective habitat modification for augmenting avian insectivore numbers and insect foraging time in organic vegetables.

## Cover crops for diversification in organic production

Cover crops can be beneficial for intensive organic vegetable production in a number of ways. Water penetration and infiltration can be improved by root growth of a cover crop and by returning organic matter to soils. Increased organic matter may improve the soils ability to retain moisture. If leguminous cover crops are grown, soil nitrogen can be increased through nitrogen fixation (Venkateswarlu *et al* 2007). Grasses are particularly helpful in promoting soil structure and soil aggregating stability because of their fibrous root systems. Microbial activity, often stimulated by cover crop root exudates and organic matter additions to soils, has also been shown to promote aggregate stability. As microbes decompose organic matter, nutrients are released. Weed suppression for subsequent crops may be another benefit. Furthermore, cover crops can provide a favorable environment to attract and sustain beneficial arthropods.

Ngouajio and McGiffen (2004) evaluated the effect of cover crops and management systems on weed and insect populations in lettuce (*Lactuca sativa*). Cover crops treatments included cowpea (*Vigna unguiculata*), sudangrass (*Sorghum bicolor*), and the traditional summer dry fallow. Over the two years, cover crops had no effect on insect populations in lettuce, as neither cover crop is an alternate host for lettuce insect pests. However, the population of cabbage loopers {*Tricoplusia ni* (Hubner)} increased at the end of each growing season in cowpea mulch plots. The cowpea cover crop suppressed weeds and increased yield. The integrated system reduced production inputs. The number of insecticide applications was reduced from four to one without an increase in insect damage. Cowpea cover crop offered many advantages in vegetable based cropping systems. Jones *et al.* (2006) explained about many approaches and methods for growing and marketing organic vegetables and highlighted the number of different organic vegetable crops and two cover crops currently grown on the Central Coast. Barley (cover crop), cabbage, cauliflower, cucumbers, garlic, lettuce, onions, peas, peppers, sweet corn, vetch (cover crop), and winter squash were the major crops. Additional crops were often included in a grower's operation for greater diversification. It was suggested to maintain insectary plantings in or near fields to provide a habitat and food source for beneficial arthropods.

## Crop diversity in pigeon pea based production system

Crop-crop diversity is possible when crop plant species can be arranged in space by strip/inter cropping, inter-planting and mixed –row cropping. Studies were conducted on relative incidence of pests on various crops including pulses in sole and inter cropping systems. The monocultures or sole cropping, although highly productive and efficient, refers from genetic base resulting higher pest susceptibility. Intercropping as one of the important cultural practice in pest management is based on the principle of reducing pests by increasing the diversity of the agro-ecosystem (Baliddawa, 1985).

Experiments were conducted to study the impact of crop-crop diversity on incidence of pod borers of pigeonpea in light soils of Telangana region of A.P., wherein different intercrops were evaluated. The effect of intercrops was significant on other pests (*Mylabris*, *H.armigera*, *E.atomosa* and *M.vitrata*) also. Pigeonpea with sorghum and maize as intercrops recorded low incidence of *Mylabris* spp. population than the rest of systems except pigeonpea with blackgram. Significant low population (1.7 larva per plant) of *H.armigera* was observed in pigeonpea with sorghum system and was followed by pigeonpea with castor though it did not vary with pigeonpea with greengram or groundnut systems which recorded 1.9 larva per plant). The other pod borers *E. atomosa* and *M.vitrata* were also low in pigeonpea with sorghum intercropping system.

## Pod and Grain damage

Among pod borers, *H.armigera* damaged maximum number of pods followed by *M.obtusa*. Damage by *M.vitrata* was minimal. Pod damage by lepidopteran borers (*H. armigera*, *E. atomosa* and *M.vitrata*) and dipteran pod fly (*M.obtusa*) was least in pigeonpea intercropped with sorghum compared to sole pigeonpea and the other intercropping systems (Fig.1). Blackgram and groundnut as intercrops recorded significantly lower level of pod damage by *H.armigera* and *M.obtusa* and though these did not vary with pigeonpea+greengram and pigeonpea+castor intercropping systems. Higher pod damage was noticed in pigeonpea+ soybean, pigeonpea sole and pigeonpea +maize and pigeonpea +sunflower systems. The least number of pods were found in pigeonpea intercropped with sorghum. Significant differences in grain damage were noticed among cropping systems. Pigeonpea intercropped with sorghum had the lowest grain damage (15.2%) as against in sole pigeonpea. Blackgram (20.5%), castor (21.8%) and groundnut (22.3%) intercrops also reduced the grain damage in pigeonpea. Similar trend was observed with the grain damage by pod fly also and least damage was recorded in pigeonpea with sorghum system. Though the yields (17.2q/ha) were more in pigeonpea sole, yield loss due to insect pests was also higher (0.78 q/ha) in sole pigeonpea system. The yield loss was least in pigeonpea with sorghum (0.25 q/ha) with a 68% reduction of yield loss over sole pigeonpea.

## Predators

The most common predators observed in different intercropping systems included lady beetles, *Menochilus sexamaculatus* (F), *Brumoides suturalis* (F). *Illois indica* Timberlake, *Coccinella transversalis* (L) and *Coccinella septempunctata* (L), lacewings, *Chrysopa* spp., pirate or anthocorid bugs, *Orius* spp. and *Cotesia* spp. The largest component of predator guild in all intercropping systems was lady bird beetles which accounted for more than 80%.

The coccinellid population varied significantly among cropping systems throughout the crop growth period. The activity of coccinellids was recorded within a month after sowing and continued till the harvest of the pigeonpea (Fig.2). Coccinellids were significantly more abundant (0.73 per plant) in pigeonpea with sorghum followed by

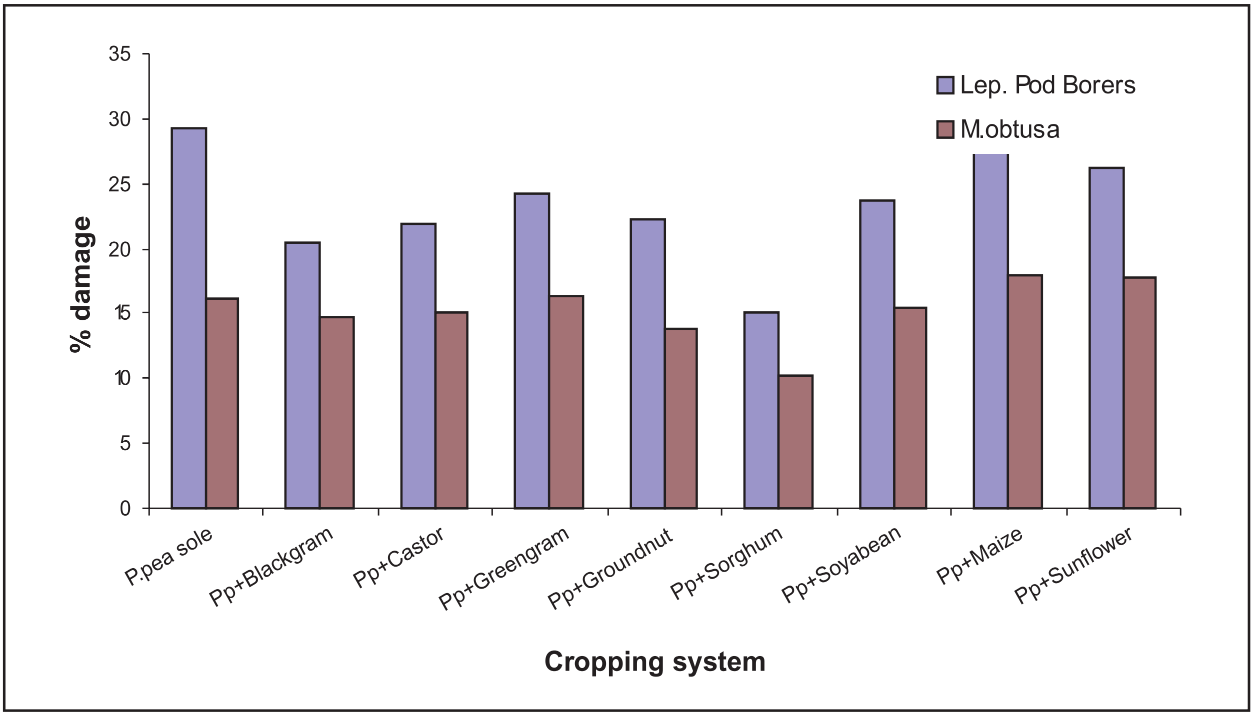


Fig 1 . Impact of crop-crop diversity on grain damage in Pigeonpea

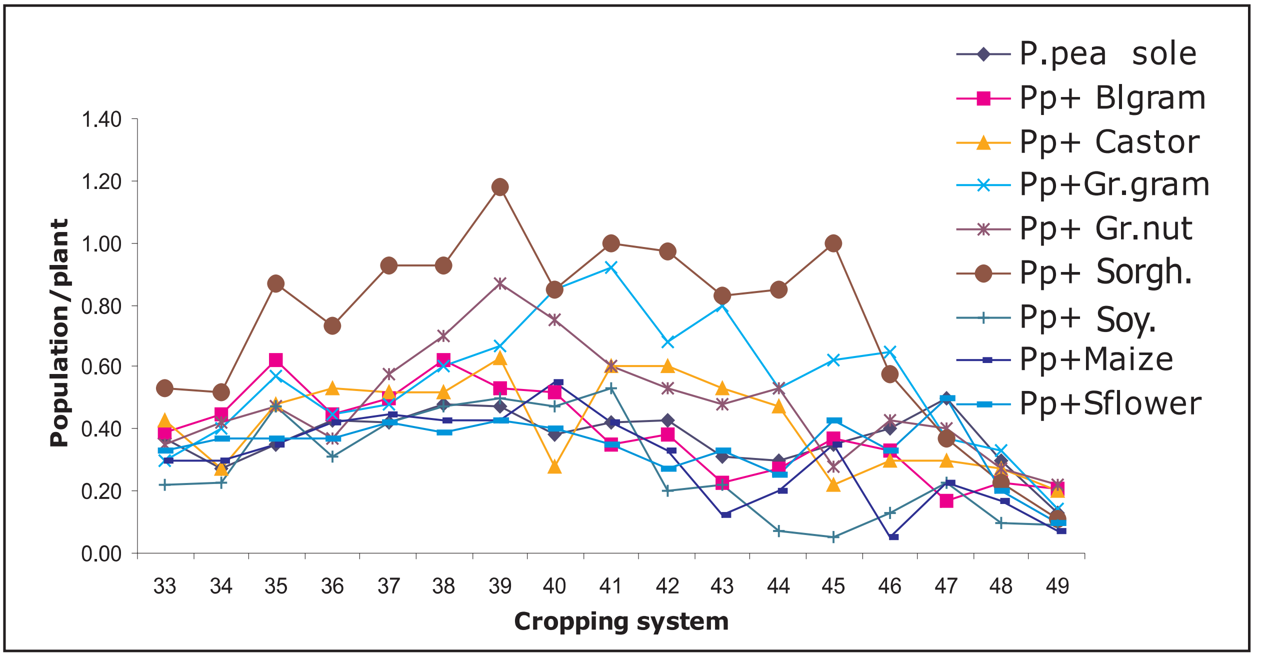


Fig 2. Impact of crop-crop diversity on Coccinellids in Pigeonpea

pigeonpea with greengram or groundnut as intercrops. The mean population of coccinellids (0.50-0.73per plant) was recorded in pigeonpea + sorghum, pigeonpea + greengram, and pigeonpea + groundnut intercropping systems. Pigeonpea with soybean, maize and sunflower had fewer coccinellids than sole pigeonpea.

Spiders of Clubionidae, Araneidae, Liny philidae and Thomisidae were observed in the cropping systems. Among them, *Clubiona* sp was most populous. Pigeonpea with sorghum and maize had higher population of spiders (0.44 and 0.39 per plant) than the rest of systems.

These systems were effective in reducing the population of insect pests and recorded more population of natural enemies. These recorded higher agronomical efficiencies both in terms of equivalent yields and LER also. The economics of the systems was also higher than sole pigeonpea. Thus the effective intercropping systems can serve as key component of pest management.

## Conclusions

Crop protection in organic agriculture is not a simple issue and an overall comprehension of system is required. It depends on a thorough knowledge of the crops grown and their likely pests, pathogens and weeds. Successful organic crop protection strategies also rely on an understanding of the effects which local climate, topography, soils and all aspects of the production system are likely to have on crop performance and the possible host/pest complexes. The real challenges may lie in the development of agronomically and economically successful system in a range of soil types and rotations including more novel organic crops.

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# Organic Farming in Fruit and Vegetable Crops

**R.S.Patil***

## Vegetables

Vegetables are rich and cheap source of vitamins and minerals which act as a protective food in daily diet. They are also consumed raw as a salad and are major source of fibre in diet. However, vegetable crops are vulnerable to diseases and pests, therefore they need chemical sprays to protect from them. Similarly, for getting optimal yield, they need chemical fertilizers. Thus, in commercial vegetable production with the increase in chemical inputs, the risk of degradation of environment and residue problems have increased. Therefore, todays need is to grow vegetables organically.

## Components for organic cultivation

### Fertilizers

**Farm Yard Manure**: This is the only easily available input to the farmers. It is well known that FYM improves soil physical properties by improving soil aggregation, aeration and water holding capacity. From the research conducted during past years, it is recommended to add 20 t of FYM/ha before planting for good crop growth and maintaining the soil health. To avoid bulky application of FYM, its combination with organic concentrates (e.g. neem cake, cotton cake etc.) were found promising.

**Vermicompost**: Vermicompost is a potential organic manure rich in NPK nutrients as compared to FYM or other organic manures. It also contains micronutrients, hormones and enzymes. The beneficial microorganisms also grow fast in vermicompost. It influences the physico chemical and biological properties of soil.

**Biofertilizers**: Biofertilizers are ecofriendly, low cost inputs playing a significant role in improving quality of agricultural produce and sustaining the productivity over a longer period of time. Among the biofertilizers for increasing nitrogen supply for vegetable crops, *Azotobactor* and *Azospirillum* are utilized @ 2.5 kg/ha, while for increasing the availability of phosphorus, Phosphorus Solubilising Bacteria (PSB) @ 2.5 kg/ha are used. Vesicular Arbuscular Mycorrhiza (VAM) are also used for mobilizing phosphorous and other immobile nutrients.

**Green manures**: Fast growing leguminous crops viz.Dhaincha, Sunhemp and Gliricidia are used as a green manure crops mainly to improve soil fertility and soil physical properties. It is one of the most effective and environmentally sound methods of organic farming which minimise the use of chemical fertilizers.

**Neem Cake**: It is utilized as a manure which supplies N:P:K in a considerable amount to the crop. It also acts as a medium for the growth of beneficial microorganism viz. *Trichoderma*. It acts as a nematicide for the control of phytophagous nematodes.

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**Other Organic Sources**: Groundnut cake, castor cake and fish meal also could be utilized for organic cultivation of crops.

**Poultry Manure**: It is also one of the important sources of nutrients to vegetable crops.

## Bio-pesticides and Bioagents:

**Neem seed Kernel Extract:** It is the only botanical pesticide widely used in organic cultivation of crops. Neem is made up of 40 different bioactive compounds called tetrano triterpenoids of limonoids. The main active principle of neem is azadirachtin. It exhibits antifeedants, insect repellent and insect sterilization properties. The research work on the efficacy of neem seed kernel extract against pests of vegetables was conducted at All India Coordinated Vegetable Improvement Project and NSKE 4% is recommended for the control of sucking pests and fruit borer of vegetable crops.

***Trichoderma viride*** : This microorganism is widely studied for its antagonistic activities towards soil borne soils pathogens. Different species of *Trichoderma* under field conditions were reported to control a large number of wilt pathogens. This is recommended as soil application with organic manures viz. FYM, vermicompost or neem cake @ 6.25 kg/ha. or drenching @ 5 g/L of water. This is also recommended as seed treatment @ 5 g/kg, seed and also mixed with *jeevamrut* or *beejamrut*.

***Paecilomyces liliacae*** : This microorganism is being utilized along with *Trichoderma* sp. as a mixed formulation for the control of phytophagous nematodes.

***Verticillilum lecanii***: This bioagent is recommended for the control of sucking pests viz. aphids, whitefly, thrips, leafhoppers and mites of vegetable crops. The recommended dose is 4 g/L.

***Beauveria bassiana*** : Many of the lepidopterous insect pests viz. brinjal shoot and fruit borer, okra shoot and fruit borer, tomato fruit borer are controlled by using this microorganism. The recommended dose is 4 g/L.

***Nuclear Polyhedrosis Virus***: This virus has been identified to infect *Helicoverpa armigera* which is polyphagous pest. The virus has been isolated from infected *Helicoverpa* larvae collected from field and being cultured in the laboratory. It is available in liquid formulation and recommended @ 1 mL/L. for the control of *Helicoverpa armigera* on tomato, pea, okra and cabbage.

**Bacillus thuringiensis**: The most widely used microbial pesticides are sub species and strains of *Bacillus thuringiensis* (B.t.). B.t. proteins are completely legitimate pesticides for use in organic farming. Powder and liquid formulations are available commercially. This biopesticide is recommended @ 1 g/L or 1 mL/L. for the control of various lepidopterous pests of vegetables.

***Pedators and Parasitoids***: *Trichogramma chilonis* an egg parasitoid of *Helicoverpa armigera* of tomato and okra, *Leucinodes orbonalis* of brinjal is recommended. *Chrysoperla carnae* is a predator used against sucking pests viz. aphids and whitefly. Other parasitoids and predators available naturally could be nourished, protected and made available by planting as refugia crops viz. maize and cow pea around the main crops.

**Trap crops/Barrier crops/ Refugia crops**: These crops viz. Maize, Marigold, Cowpea and Mustard are grown as the border of main crops. Maize is a trap or barrier crop in brinjal and okra. Marigold is a trap for *Helicoverpa armigera* in tomato while mustard is a trap crop for *Plutella xylostella* in cabbage. Cow pea also harbor some beneficial insects like lady bird beetle which is predator for aphids.

**Pheromone traps**: The concept of using pheromone trap is to monitor the pests for their appearance and the incidence e.g. tomato fruit borer (*Helicoverpa armigera)*, diamondback moth (*Plutella xylostella*), okra fruit borer (*Earias vittella*) and cucurbit fruit fly (*Bactrocera* *cucurbitae*). However, for brinjal shoot and fruit borer (*Leucinodes orbonalis*) it is being utilized for mass trapping.

## Research findings on organic vegetable production

The research work conducted on effect of each component of organic farming on production and protection of vegetables in Mahatma Phule Krishi Vidyapeeth, Rahuri is presented here.

### Tomato:

1. The experiment on organic cultivation in tomato was conducted on cv. *Dhanashree* during 2003. The data revealed that application of organic fertilizers containing F.Y.M. (20 t/ha.) + Neem cake (250 kg/ha) + Soil treatment with *Trichoderma* (6.25 kg/ha) + *Azospirillum* 2.5 kg/ha) + PSB (2.5 kg/ha with trap crop marigold and plant protection with NSKE 4 %, HaNPV 1 mL/L. and Bt 1 g/L has produced comparable yields to that of recommended dose of chemicals. The lowest incidence of fruit borer was observed in the treatment with trap crop. As far as diseases are concerned, no significant difference was observed in the treatments with trap and without trap crop. The B:C ratio was better in organic than inorganic treatment. (Table 1).

2. The experiment on organic cultivation in tomato conducted during 2005, on cv. *Phule Raja* revealed that application of organic fertilizers containing F.Y.M. (50% N i.e. 30 t/ha.) + Cotton seed cake 50% N i.e. 2.34 t/ha.) + Vermiphos (P) 0.5 t/ha. + Sulphate of potash (K) 0.1 t/ha. + Neem cake 200 kg/ha + *Trichoderma* 4g./kg + *Azospirillum* 200 g/10 l.+PSB 200g/kg and the plant protection with NSKE4%, HaNPV 1 ml/ l. and B.t. 1 g./l. recorded yields comparable to the recommended dose of fertilizers without FYM. In case of pest and disease incidence, no significant difference was observed in both the treatments (Table 2).

3. In another experiment on tomato conducted during 2006-2007, the treatment with RDF (20:100:100 NPK kg/ha) + FYM (20 t/ha), recorded maximum yield as compared to the organic treatments FYM (60 t/ ha)+Biofertilizers; Vermicompost (20 t/ ha) + BF and Neem cake (6 t/ha) + BF (Table 3).

**Table 1: Organic cultivation in tomato (cv. Dhanashree) during *rabi* season (Nov. 2003 - April 2004)**

| Treatments | Total Yield (q/ha) | B:C Ratio | Pest and disease incidence | | | |
|---|---|---|---|---|---|---|
| | | | Fruit borer (%) | Early blight (%) | Late blight (%) | TSWW (%) |
| **With trap crop** | | | | | | |
| Control RDF (200:100:100) + FYM 20 t/ha+Trap crop (marigold) | 465.39 | 1.20 | 4.43 | 15.82 | 22.76 | 7.22 |
| FYM (20 t/ha) + Neem cake 250 kg/ha.)+ Improved Package | 452.57 | 1.31 | 4.40 | 12.74 | 20.56 | 7.25 |
| **Without trap crop** | | | | | | |
| Control RDF (200:100:100) + FYM 20 t/ha + without trap crop | 457.76 | 1.18 | 6.50 | 14.88 | 19.34 | 8.10 |
| FYM (20 t/ha) + Neem cake 250 kg/ha.)+ Improved Package | 439.95 | 1.27 | 6.48 | 11.23 | 17.25 | 6.77 |

Package: Trichoderma 6.25 kg/ha+Azospirillum 2.5 kg/ha+PSB 2.5 kg/ha. Plant protection: NSKE 4%, HaNPV 1 mg/L., B.t. 1 g/L.

**Table 2: Organic cultivation in tomato ($F_1$cv. Phule Raja) during *rabi* season (Nov. 2005-April 2006)**

| | Treatments | Yield (q/ha) | | B:C | Pest and disease incidence | | |
|---|---|---|---|---|---|---|---|
| | | Total | Market-able | ratio | Fruit borer (%) | Late blight (%) | TSWW (%) |
| $T_1$ | FYM (50% N) + Cotton seed cake (50% N) + Package | 748.37 | 718.37 | 2.00 | 3.20 | 7.50 | 3.40 |
| $T_2$ | RDF (300:150:150) without FYM | 743.60 | 718.66 | 3.63 | 4.01 | 8.11 | 3.36 |

Treatment 1: FYM (50% N) (30 t/ha) _ Cotton seed cake (50% N) (2.34 t/ha) + Vermiphos (P) (0.5 t/ha) + SOP (K) (0-.1 t/ha)
Package: Neem cake 200 kg/ha + *Trichoderma* 6.25 kg/ha. + *Azospirillum* 2.5 kg/ha + PSB 2.5 kg/ha.+NSKE 4%, HaNPV 1 mg/L., B.t. 1 g./L. sprays

**Table 3: Organic farming in tomato for processing (cv. Dhanashree )**

| Treatment | *Kharif* 2006 | | *Rabi* 2006-07 | |
|---|---|---|---|---|
| | Fruit yield (t/ha) | Marketable yield (%) | Fruit yield (t/ha) | Marketable yield (%) |
| FYM (60 t/ha) + BF | 25.03 | 84.50 | 36.55 | 94.80 |
| Vermicompost (20 t/ha) + BF | 23.10 | 82.60 | 42.60 | 96.17 |
| Neem cake(6t/ha) + BF | 20.26 | 79.52 | 23.93 | 94.32 |
| RDF+FYM (20 t/ha) | 26.62 | 89.07 | 53.81 | 96.82 |
| RDF alone | 23.10 | 89.00 | 39.59 | 95.23 |

RDF: Recommended dose of fertilizer (200:2100:100)
BF: Biofertilizers i.e. *Azospirillum* _+PSB + *Azotobacter*
For organic plant protection NSKE 4 %, HaNPV, B.t., *Verticillium*, *Trichoderma* were used

## Cucumber :

The experiment on organic cultivation of cucumber conducted during 2004 for two seasons revealed that the maximum yield was produced with organic manure treatment consisting of cotton seed cake (25% N i.e. 0.64 t/ha) + Poultry manure (75% N i.e. 2.5 t/ha) + Vermiphos (0.500 t/ha) + Sulphate of potash (0.105 t/ha) + Neem cake @ 200 kg/ha + *Trichoderma viride* @ 4 g/kg + *Azotobacter* @ 200 g/ 10 kg + Neem cake @ 200 g/10 kg + PSB @ 200g/10 kg +NSKE 4% spray which was 23.4% higher during summer season and 30.01% higher during *kharif* than control (Table 4).

**Table 4: Organic cultivation of cucumber (var. *Himangi*) during *kharif* and summer, 2004**

| | Treatment | Yield (q/ha) | | B:C ratio | |
|---|---|---|---|---|---|
| | | Summer | *Kharif* | Summer | *Kharif* |
| $T_1$ | FYM (25% N) + Poultry manure (75%N) + Vermiphos + SOP+Package | 186.13 (+20.20%)* | 166.93 (+24.58%)* | 1.49 | 1.22 |
| $T_2$ | Cotton seed cake (25% N) + Poultry manure (755 N) + Vermiphos+SOP+Package | 191.00 (+23.44%)* | 173.53 (+30.01%)* | 1.56 | 1.32 |
| $T_3$ | Control (RDF+FYM 20 t/ha) | 154.73 | 134.40 | 1.54 | 1.19 |

*per cent increase over control; Note: Green manuring with dhaincha was done for all the treatments.

Treatment 1: FYM (25% N) (5 t/ha) + Poultry manure (75% N) (2.6 t/ha) + Cotton seed cake (50% N) (2.34 t/ha) + Vermiphos (P) (0.5 t/ha) + SOP (K) 90.1 t/ha); Treatment 2: Cotton seed cake (25% N) (0.64 t/ha) + Poultry manure (75% N) (2.6 t/ha) + Vermiphos (P) (0.5 t/ha) + SOP (K) (0.1 t/ha); Treatment 3: Control RDF (100:50:50) + FYM (20 t/ha)

Package: Neem cake 200 kg/ha + *Trichoderma* 4g/kg. + *Azospirillum* 200g/10 kg + *Azotobacter* 200g/10 kg + PSB 200 g/10 kg. Plant protection: NSKE 4%

## Bitter gourd

The experiment on organic cultivation of bitter gourd during 2005, revealed that maximum yield was produced with organic manure treatment consisting of Neem cake (25% N i.e. 0.7 t/ha) + Poultry Manure (75% N i.e. 2.47 t/ha) + Vermiphos (0.5 t/ha) + Sulphate of potash (0.2 t/ha) = Neem Cake @ 200 kg/ha + *Trichoderma viride* @ 4 g/kg + *Azotobactor* @ 200 g/ 10 kg + *Azospirillium* @ 200 g/ 10kg + PSB @ 200g/ 10 kg + FYM 20 t/ha.+NSKE 4% spray which was 13.40% higher than control. (Table 5).

## Cabbage

The experiment on organic cultivation of cabbage during 2003, revealed that maximum yield was produced with inorganic fertilizers as recommended by STCR but it was at par with that produced by organic package consisting of FYM @ 20 t/ha + Neem cake @ 250 kg/ha + soil treatment with *Trichoderma* @ 6.25 kg/ha + *Azospirillium* @ 250 g/ 10 L water + PSB @ 250 g/ 10 L water + NSKE 4% spraying + HaNPV @ 10 ml/ 10 L water + Bt.@ 10 ml/10 L water +*Trichoderma* @ 50 g/ 10 L water + trap crop of mustard in two rows in between every 25 rows of cabbage + Fenugreek in between plants of cabbage. The incidence of diamondback moth was less in this package (Table 6).

## Onion

1. The study on organic cultivation of onion during *rabi* 2005 revealed that the higher yield was obtained in FYM 30 t/ha + Neem cake 1 t/ha + Cotton seed cake 0.8 t/ha +

**Table 5: Organic cultivation of bitter gourd var. Phule Green Gold (August 2004-Feb 2005)**

| | Treatment | Yield (q/ha) | B:C ratio |
|---|---|---|---|
| $T_1$ | FYM (25% N) + Poultry manure (75% N) + Vermiphos (P) + SOP (K) + package | 250.20 (+7.75%)* | 1.83 |
| $T_2$ | Neem cake (25% N) + Poultry manure (75% N) + Vermiphos (P) + SOP (K) + package | 263.33 (+13.40%)* | 1.98 |
| $T_3$ | Control (RDF + FYM 20 t/ha) | 232.20 | 1.99 |

*per cent increase over control

Note: Green manuring with Dhaincha for all the treatments

$T_1$: FYM (25% N) (5 t/ha) + Poultry manure (75% N) (2.47 t/ha) + Vermiphos (P) (0.5 t/ha) + SOP (K) (0.1 t/ha)

$T_2$: Neem cake (25% N) (0.7 t/ha) + Poultry manure (75% N) (2.47 t/ha) + Vermiphos (P) (0.5 t/ha) + SOP (K) (0.1 t/ha)

$T_3$: Control RDF 9100 : 50 : 50) + FYM (20 t/ha)

Package: Neem cake 200 kg/ha + *Trichoderma* 4g/kg. + *Azospirillum* 200 g/10 kg + *Azotobactor* 200 g/10 kg + PSB 200 g/10 kg.

Plant protection: NSKE 4%

**Table 6: Organic cultivation of cabbage var. Golden acre (*Rabi* 2003)**

| | Treatment | Yield (q/ha) | No. of DBM larvae/plant |
|---|---|---|---|
| $T_1$ | Inorganic (without FYM) (160:80:80 NPK kg/ha) with trap crop mustard | 329.82 | 4.00 |
| $T_2$ | Organic package | 297.68 (-9.74%)* | 2.60 |
| $T_3$ | Recommended as STCR with trap cop | 346.42 (+5.03%)* | 4.13 |

*per cent increase or decrease over inorganic treatment

Organic Package: FYM @ 20 t/ha + Neem cake 250 kg/ha + *Trichoderma* 6.20 kg/ha. + *Azospirillum* 250g/10 kg + PSB 250 g/10kg. + NSKE 4% + HaNPV @ 10 ml/10 L + B.t. 10 g/10 L + *Trichoderma* @ 50 g/10 L.

NSKE 4% sprays + *Trichoderma* sprays 0.5%. However, the pests and disease incidence was the lowest in chemical sprays. (Table 7).

2. The study on organic cultivation of onion during *rabi* 2006 revealed that the treatment FYM 20 t/ha + 100% RDF + biofertilizers + chemical spray recorded maximum yield. Among the organic treatments FYM 20 t/ha + 75% N (Vermicompost) + 25% N (Cotton seed cake) + Neem cake + biofertilizers gave good results. Treatment with FYM 20 t/ha + *Beejamrut* + *Amrutpani* and FYM 20 t/ha. + *Beejamrut* + *Jeevamrut* also recorded good yield as compared with the recommended dose of fertilizer and other organic treatments (Table 8).

3. Studies conducted on effect of mulches on onion during *kharif*, 2005 revealed that maximum yield was obtained in the of sugarcane trash mulch with 40.70% increase over the control and maximum C:B ratio (Table 9).

**Table 7: Organic cultivation of onion (var. N-2-4-1) during *rabi*, 2005**

| Treatment | Yield (t/ha) | No. of thrips/ plant | Per cent disease intensity |
|---|---|---|---|
| GRDF (100:50:50 kg NPK + 20 t FYM/ha) + chemical spray | 30.25 | 6.14 | 22.09 |
| FYM 20 t/ha + Neem cake 1 t/ha + cotton seed cake 0.8 t/ha (201:162:211) + NSKE 4% + *Trichoderma* 0.5% | 29.82 | 29.92 | 53.15 |
| FYM 30 t/ha + Neem cake 1 t/ha + cotton seed cake 0.8 t/ha (251:227:299) + NSKE 4% + Trichoderma 0.5% | 31.88 | 30.04 | 36.29 |

**Table 8: Organic cultivation on onion (var. N-2-4-1) during *rabi*, 2006**

| Sl. No. Treatment | Yield (t/ha) | No. of thrips/ plant | Per cent disease intensity |
|---|---|---|---|
| FYM 20 t/ha + 100% RDF + Biofertilizers + Chemical spray | 35.96 | 17.05 | 11.48 |
| FYM 20 t/ha + 100% N through organic cakes + Biofertilizers + NSKE 4% | 28.00 | 60.32 | 57.53 |
| FYM 20 t/ha + 75% N through Vermicompost + 25% N through Cotton Seed Cake + Neem cake + Biofertilizers + NSKE 4% | 29.00 | 57.57 | 52.99 |
| FYM 20 t/ha + Beejamrut + Amrutpani + NSKE 4% | 28.02 | 77.57 | 57.62 |
| FYM 20 t/ha + Beejamrut + Jeevamrut + NSKE 4% | 26.25 | 77.57 | 59.14 |

**Table 9 : Effect of mulches on onion (Phule Samarth) during *Kharif*, 2005**

| Treatment | Yield of marketable bulbs (q/ha) | C:B Ratio |
|---|---|---|
| Black polyethylene mulch | 28.48 (+39.67)* | 1.57 |
| White polyethylene mulch | 23.96(+17.51)* | 1.66 |
| Wheat straw mulch | 26.65(+15.98)* | 5.09 |
| Sugarcane trash mulch | 28.69(+40.70)* | 6.63 |
| Control | 20.39 | 4.21 |

*per cent increase over control

## Fruit crops

From the limited research carried out, there is a definite promise for organic farming in fruit crops in Maharashtra. The shift from organic to inorganic farming is much easier, while the reverse is much more difficult which leads to short term problems viz. reduction in yield, increased disease and pest incidence, shortage of substitutes for inorganic fertilizers and pesticides etc,. In horticulture, it is easier to manage fruit crops organically than vegetable and flower crops due to perennial growth habit. The dryland fruit crops which are considered high valued health food and being easily grown organically for years are the best suited for organic cultivation e.g. custard apple, jamun, tamarind, anola and ber. Among the different irrigated fruit crops, banana, mango, sapota and guava can also be grown organically, but most challenging crops are grapes, pomegranate and citrus due to their vulnerability to many pests and diseases. Therefore, in future more efforts are needed to standardize organic techniques in these crops.

In addition to the common cultural practices, organic production of fruit entails proper nutrient management, intercropping, control of weeds, pests and diseases, soil and water conservation, etc.

The most important aspect in organic fruit production is supply of nutrients through organic source. The concentrate organics like oil cakes, bone/fish meal will be useful in supplying major nutrients. Biofertilizers like *Azotobacter*, *Azospirillum* and PSB are of immense use in supplying unavailable nutrients and has immense importance in fruit production. Green manuring not only helps to improve soil health but is also useful in reduction of weed intensity.

Studies conducted at Mahatma Phule Krishi Vidyapeeth, Rahuri showed increase in yield to the extent of 8.87 t/ha in acid lime and 7.7 t/ha in sweet orange with application of biofertilizers (VAM @ 500 g +PSB 100 g + *Azosprillium* 100 g + *T harjanium* 100 g per plant). Further more, the application of organic manures viz., FYM, vermicompost and neem cake resulted in to highest juice content (49%) with the highest TSS (15.50 Brix) in pomegranate. Similar results were obtained in aonla. Such quality improvement arising through organic cultivation is of utmost importance in processing industry. In banana, application of 25 kg compost + 1 kg vermicompost + 1 kg neem cake + 2.50 kg poultry manure per plant at 3$^{rd}$, 5$^{th}$ and 7$^{th}$ month after planting resulted in higher yields (5.5 kg bunch weight, 55.89 fingers per bunch and 6.8 hands per bunch).

Plant growth regulators have immense importance in quality improvement of fruit crops. However, use of these chemicals is not permitted in organic cultivation. Therefore, specific techniques should be evolved for quality improvement e.g. in grapes techniques like berry thinning, stem girdling, cane girdling, paper wrapping, spreading shade-net etc., Similarly, techniques need to be standardized in other fruit crops.

In pomegranate, sugarcane trash as a mulch, resulted in the highest marketable yield (17.65 kg/tree; total yield 19.35 t/ha). A few chemicals like vinegar, corn gluten, citric acid etc. recently emerged as weedicides in organic farming and can be evaluated particularly for dryland fruit crops.

Biological control of pests and disease has now been widely adopted in several fruit crops. Research outcome on orchard management showed high promise of some, e.g. *Verticillium lecanii* for control of mealybug, thrips, white fly and scales in pomegranate, grape, guava and custard apple (4-6 g/lit). Furthermore, NSE 5% spray also provide as an effective alternative. *Beauveria bassiana* 0.2% was also found effective against thrips. The nematodes and soil borne pathogens can be effectively controlled by means of *Trichoderma viridae* + *Paecilomyces* (*Trichoderma*$^{+}$), neem cake and black polyethylene mulch.

Control of diseases is the most limiting factor in organic fruit production and hence, selecting resistant varieties or rootstocks is of prime importance e.g. pomegranate decline by using acidic rootstock. Growers should practice sanitation by cleaning up debris, avoiding the incorporation of plant material of same crop carrying diseases into the soil, pruning of diseased plants and removing disease vectors. In organic farming a good defence against plant disease is to maintain the crop in good health and vigour but not with excessive nutrients and moisture.

## Weaknesses

Before starting organic cultivation of fruits, one shall consider following weaknesses of organic farming in fruit crops.

- Scanty research data.
- Availability of organic manure.
- Initial yield gap.
- Heavy load of pests and diseases.
- No concrete organic means to control disease once appeared.
- Only prevention is the way of controlling disease.
- No breakthrough for control of diseases.
- Climate plays havoc.

## Strengthening required

Organic cultivation in fruit crops is a difficult task. While implementation of organic cultivation, it is essential to study the crops in various aspects. For this purpose following points are important.

- Development of resistant varieties.
- Suitable rootstocks.
- Standardization of organic mulch.
- Organic weedicides.
- Effective combination of organic manures.
- Standardization of horticultural practices (e.g., girdling, berry thinning, wrapping with papers in grapes)
- Disease forecasting unit.

## Research Achievements

### Pomegranate

Experiment on effect against mealy bugs on pomegranate (2006-07) revealed that, *Verticillium lecanii* @ 6.0 g/L gave 83.97 per cent reduction of mealy bugs (nymphs) at 10 DAS as against control. The initial population of mealy bugs was 40 nymphs/ fruit.

### Banana

Experiment on organic cultivation of banana cv. *Rasthali* conducted at NRC, Banana, Trichi, revealed that the organic treatment comprising of Compost 2.5 kg + 1 kg Vermicompost + 1 kg Neem Cake + 2.5 kg Poultry Manure at 3$^{rd}$, 5$^{th}$ and 7$^{th}$ MAP (per plant) recorded 5.52 kg bunch weight, which was at par with the control treatment i.e., RDF. Thus with organic treatment the yield levels were maintained. Similar results were observed in the another experiment conducted at NRC, Banana, Trichi on cv. Karpuravalli.

Experiment on organic cultivation of banana conducted by Swamy *et al.* (2005) revealed that inoculation of suckers with VAM cultures (*Glomus fasciculatum*) @ 50 g/plant in pit before planting + 1 kg Vermicompost/plant found effective for increasing yield and recorded 25.44 t/ha yield of banana. Experiment on effect of *panchgavya* on bunch quality conducted at BRS, Marathwada Agricultural University, Parbhani revealed that the organoleptic score was increased by the application of *panchgavya*.

Experiment on control of red rust thrips on banana, conducted at BRS, Jalgaon, MPKV, Rahuri 2007, revealed that the bio-pesticides viz., NSKE 5% and *V.lecanii* were found effective. Per cent infestation on fruit/bunch in case of

NSKE 5% was 22.90 and *V.lecanii* 21.11 per cent as against 80.11 per cent in untreated control.

### Sweet orange

Experiment on organic farming in sweet orange conducted at AICRP on Citrus (2006) revealed that, with addition of vermicompost (20 kg/tree) + neem cake (8 kg/tree) with organic plant protection gave additional yield of 8.22 t/ha.

Experiment on use of biofertilizers in sweet orange and acid lime at Rahuri during 2006, showed that, in sweet orange, application of GRDF (15 kg neem cake + 20 kg FYM + 500:300:600 g NPK/tree along with biofertilizer VAM (500 g) + PSB (100 g) +*Azotobacter* (100 g) + *T.harzianum* (100 g) gave additional yield of 7.79 t/ha and with the same treatment, in acid lime, 8.87 t/ha additional yield was recorded.

### Grape

In grape, organic management for thrips was found effective. In two years trial, *Verticillium lecanii* at 0.05% found effective in reducing thrips population up to 53%, while NSKE @ 5% caused 54% reduction of thrip population and thereby increasing the yields.

In another experiment, for diseases management i.e., downy mildew and powdery mildew, initial spray of 1% Bordeaux mixture with *Azadiractin* 0.03% + *T.viride* and *T.harzianum* 0.5% each were effective in controlling the diseases. The following practices were also found effective for control of important pests and diseases of the grape. Cleaning and burning pruned material, removal of loose bark from stem & valanda, swabbing of stem and arms of vines with Geru 300 g in 10 L of water, spraying of 5% NSKE, two times starting from new flush stage, spraying of *Verticillium lecanii* 5 g + 5 mL whole milk/ L. at an interval of 10-12 days for three times, two releases of predatory beetles (*Cryptolaemus montrouzieri*) 155/ha two times at an interval of 21 days.

Arid zone fruit crops like custard apple, aonla, tamarind, jamun, ber can be grown easily by organically. However, crops like banana, grape, pomegranate, require special cultural practices along with organic cultivation practices for better yields.

## Conclusions

1. Conversion of recommended dose of fertilizers (RDF) in organic form resulted in maintaining high yield levels in vegetable crops.
2. Use of mulch, biofertilizers and biopesticides were found effective in organic vegetable cultivation.
3. Strong seasonal effect was observed in the performance of organic packages.

## References

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# Strategies for Organic Production of Tropical Tuber Crops

**Mrs. G. Suja***

## Call for organic farming

Four decades of "Green Revolution" based technologies of high yielding varieties, chemical fertilizers, pesticides, fungicides and herbicides and irrigation enabled rise in agricultural production in India and led to self sufficiency. There was sharp rise in food grain production from 50.8 million tones in 1950-51 to 208.6 million tones during 2005-06. However, the negative consequences of high input agriculture, which envisage large chemical inputs and few carbon additions, on long term profitability and resource sustainance, are now beginning to appear. These include: wide spread soil erosion, salinisation, decline in soil quality due to reduction in soil organic matter content, poor soil fertility, poor surface water quality, reduced water infiltration rates and unfavourable soil tilth, pesticide pollution, desertification, loss of biodiversity and adverse effects on human health. Besides, chemical based intensive agriculture resulted in prosperity of rich farmers in the irrigated tracts, neglecting the marginal and resource poor farmers in dry land areas.

Hence presently there is a growing interest to practice alternative agricultural systems that are less exploitative, less dependent on nonrenewable fossil fuels like fertilizers, pesticides etc., which can conserve the precious soil and water resources and protect the environment and human health. Organic farming is therefore an alternate farming strategy that focuses on soil health, environmental protection and human health by largely excluding the use of synthetic chemicals and with minimum use of off-farm inputs.

### Organic farming feasible in selected areas and selected crops in India

In India, about 62% of cropped area is rainfed, where there is little or no use of fertilizers and other agro-chemicals due to poor resources with small holder farmers. Thus promotion of organic farming in India is advocated initially in the rainfed areas particularly in the hilly areas of northern and north-eastern regions and dry land areas of the country. The Fertilizer Association of India has identified altogether about 50 districts in the states of Orissa, Jharkhand, Uttranchal, Himachal Pradesh, Jammu & Kashmir, Rajasthan, Gujarat, Madhya Pradesh and Chhattisgarh as low fertilizer consuming districts with fertilizer consumption ranging from 1.79 kg $ha^{-1}$ to 19.80 kg $ha^{-1}$ as against the national average of 90.2 kg $ha^{-1}$ (Das and Biswas, 2002). This means that there is immense scope for organic farming in these selected areas and for selected crops in India, like pulses, oilseeds, tuber crops etc., for which conventionally little or no fertilizers and agro-chemicals are used. On the other hand, some areas under tea, coffee, cashew, nuts and spices may be easily brought under organic

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farming with a thrust on export of organic produce. In other words, rather than promoting organic farming *en masse*, it would be appropriate to carefully delineate areas or crops where fertilizer use is nil or nominal or demarcate export oriented crops that can give reasonable yield of high quality produce without the use of chemicals. ***It is worthy to mention that tuber crops hold great promise in this regard.***

## Tuber crops: Underground crops with hidden treasures

Tropical tuber crops, including cassava, yams (greater yam, white yam and lesser yam), sweet potato and aroids like elephant foot yam, taro and tannia form the most important staple or subsidiary food to about 500 million population in the world. Tuber crops are the third most important food crops for man after cereals and grain legumes. These crops possess high photosynthetic ability, capacity to yield under poor and marginal soils and tolerate adverse weather conditions. They are also recognized as the most efficient converters of solar energy, cassava producing 250 x $10^3$ kcal/ha and sweet potato 240 x $10^3$ kcal/ha, as compared to 176 x $10^3$ kcal/ha for rice, 110 x $10^3$ kcal/ha for wheat and 200 x $10^3$ kcal/ha for maize; hence the tropical root crops are known to supply cheap source of energy. They can serve as substitute for cereals due to higher carbohydrate and calorie content. The higher biological efficiency and the highest rate of dry matter production per unit area per unit time make tuber crops ideal components of our food security system. Besides, they have potential as sources of alcohol, starch, sago, liquid glucose, vitamin C and as raw materials for many other industrial products and animal feed. In times of famine, tuber crops have come in handy to overcome catastrophes and provide relief from hunger.

Tuber crops are cultivated in India mainly as rainfed in the southern, eastern and north-eastern states. These crops form a source of livelihood to small and marginal farmers and tribal population in these areas. Cassava production is mainly concentrated in the states of Kerala, Tamil Nadu, Andhra Pradesh and NEH regions. Sweet potato is cultivated mainly in the states of Orissa, Bihar, Jharkhand, Eastern Uttar Pradesh, West Bengal, Madhya Pradesh, Maharashtra and Karnataka. Other tuber crops like yams (greater yam, white yam and lesser yam) and aroids (elephant foot yam, taro and tannia), popular as vegetables, are not yet commercially cultivated, being confined only to the home gardens in almost all the States (except elephant foot yam which is cultivated on a commercial scale in Andhra Pradesh).

## Prospects of organic farming in tropical tubers

Organic farming could be a viable strategy if it targets on sustainable production and focuses on environmental and human health. Conventional agriculture using chemical inputs results in higher yield, but it is ecologically degradative as it has several negative impacts on food, soil, water and environmental quality. Indiscriminate use of chemical fertilizers for decades has lowered the organic carbon status of our soils to less than one per cent. Moreover pesticide residues cause concern over the safety of food. In traditional agriculture, the use of chemicals (fertilizers and pesticides) though not practiced, adequate care is often not taken for the maintenance of soil health and fertility. Organic farming helps to promote biodiversity and soil biological activity and strongly advocates the use of on-farm generated resources. Reduced energy use and $CO_2$ emissions are the other benefits of organic farming. It offers opportunities for employment generation, waste recycling and export promotion. The clean and safe organic foods fetches a higher premium price in world markets.

Most of the tuber crops are grown by small and marginal farmers in rainfed and tribal areas and hence use of chemical fertilizers and insecticides are limited except in the case of cassava in the industrial production areas of Tamil Nadu (Salem, Dharmapuri, Namakkal, South Arcot districts) and Andhra Pradesh (Rajahmundry district). Tuber crops in general and aroids in particular, like elephant foot yam respond well to organic manures and there is considerable scope for organic production in these crops. Further tropical tuber crops are well adapted to low input agriculture. They are less prone to pest and disease infestations. Research work done in India and elsewhere had shown that the use of chemical fertilizers are beneficial in maximizing production of these group of crops. A perusal of data in Table 1 indicates the organic production potential of tropical tubers and experimental evidences clearly shows that satisfactory productivity can be obtained even in the absence of chemical fertilizers by proper supplementation of nutrients through organic sources. Presently there is a great demand for organically produced vegetables, particularly aroids and yams, among affluent Asians and Africans living in developed nations (Europe, United States of America and Middle East). The export of these tuberous vegetables will gain impetus through special government schemes like the Agri Export Zone (AEZ) Programme presently in operation in Kerala.

## Issues in organic tuber production

Practical application and operational methodologies in organic farming, especially in tuber crops are meagre due to lack of comprehensive research in this field. Absence of package of practices/recommendations for tuber crops hinders the implementation and promotion of this sustainable alternative

**Table 1. Production potential of tropical tubers with organic and inorganic inputs**

| Tuber crop | Tuber yield obtained due to application of organic manure (OM) alone | | Tuber yield under OM+ NPK | | | Reference |
|---|---|---|---|---|---|---|
| | OM used | Tuber yield ( t $ha^{-1}$) | OM+ NPK | Tuber yield ( t $ha^{-1}$) | % increase or decrease over OM alone | |
| Cassava | FYM | 10.45 | FYM+ NPK | 28.17 | +169.57 | Susan John *et al.* (1998) |
| | Ash | 12.25 | FYM+ NPK | 28.17 | +129.95 | Susan John *et al.* (1998) |
| | Ash+FYM | 13.29 | FYM+ NPK | 28.17 | +111.96 | Susan John *et al.* (1998) |
| Sweet potato | FYM | 15.57 | FYM+ NPK | 18.88 | +21.25 | Ravindran and Bala Nambisan (1987) |
| White yam (intercrop in coconut) | FYM | 7.55 | FYM+ NPK | 14.96 | +98.15 | Suja (2001) |
| | Coir pith compost | 9.03 | Coir pith compost + NPK | 24.61 | +172.53 | Suja (2001) |
| | Green manuring with sunhemp | 7.16 | Green manure+ NPK | 16.06 | +124.30 | Suja (2001) |

Source: Nayar and Suja (2004)

production system. Many methods and techniques of organic agriculture have originated from various traditional farming systems all over the world, where there is the non use of chemical inputs. To the maximum extent possible organic production systems rely on crop rotations, crop residues, animal manures, legumes, green manures, farm wastes, mineral bearing rocks and aspects of biological pest control to maintain soil productivity, to supply plant nutrients and to control pests, diseases and weeds. Being highly responsive to organic manures and having fewer pests and disease problems as compared to cereals and vegetables, the main issue in organic production of tuber crops is the proper scientific use of a wide variety of cheaper and easily available organic sources of plant nutrients.

## Strategies for organic tuber production

### 1. Building up of soil fertility

Before the establishment of an organic management system, the fertility status of the soil needs to improved by growing green manure crops like cow pea twice or thrice during a year and incorporation of the green matter at the appropriate stage. This helps to re-establish the balance of the eco-system and offset the yield decline, if any, during the initial period of organic conversion, as tuber crops are highly nutrient depleting crops. Virgin land or barren land, if available, also will be highly suitable for organic farming of tubers.

### 2. Use of organically produced planting materials

Varieties cultivated should be adapted to the soil and climatic conditions and as far as possible resistant to pests and diseases. Local market preference also should be taken into account. The planting materials should be produced by adopting organic management practices.

### 3. Meeting nutrient needs in organic tuber production

The potential organic sources of plant nutrients for tropical tuber crops are farmyard manure, poultry manure, composts like vermicompost, coir pith compost, mushroom spent compost, saw dust compost, press mud compost, green manures, crop residues, ash, oil cakes like neem cake etc. Table 2 indicates the average nutrient contents in these organic sources.

**Table 2. Average nutrient contents of some commonly used organic manures**

| Sl.No. | Organic manures | N (%) | $P_2O_5$ (%) | $K_2O$ (%) |
|---|---|---|---|---|
| 1. | Farm yard manure | 0.50 | 0.20 | 0.40 |
| 2. | Poultry manure | 1.2-1.5 | 1.4-1.8 | 0.8-0.9 |
| 3. | Vermi compost | 1.5 | 0.4 | 1.8 |
| 4. | Coir pith compost | 1.36 | 0.06 | 1.10 |
| 5. | Press mud compost | 1.30 | 2.20 | 0.50 |
| 6. | Mushroom spent compost | 1.84 | 0.69 | 1.19 |
| 7. | Sawdust compost | 1.00 | 0.50 | 0.50 |
| 8. | Biogas slurry | 1.41 | 0.92 | 0.84 |
| 9. | Neem cake | 5.0 | 1.0 | 1.5 |
| 10. | Bone meal | 3.5 | 21.0 | |

Vermicompost, produced by chemical disintegration of organic matter by earthworms, is an ideal blend of plant nutrients with the worm enzyme and probiotics boosting the crop performance. It contains higher amount of nutrients, hormones and enzymes and has stimulatory effect on plant growth. If farmers can produce vermicompost, utilizing on-farm wastes, organic farming of tuber crops becomes profitable.

Coir pith, a by product of the coir industry, an organic waste obtained during the process of separation of fibre from coconut husk, is normally resistant to bio-degradation and to acts as an environmental pollutant. Extraction of 1 kg of coconut fibre generates 2 kg of coir pith, and in India an estimated 5,00,000 MT of coir pith is produced per annum. Coir Board in collaboration with TNAU has developed the technology for converting coir pith into organic manure using PITHPLUS, a spawn of edible mushroom, *Pleurotus sajor caju*. Coir pith compost developed from coir waste is a good organic manure and soil conditioner applicable to tuber crops.

The practice of green manuring for improving soil fertility and supplying a part of N requirement of crops is age old. About 15-20 t $ha^{-1}$ of green matter can be obtained from green manure crops like cowpea when grown in systems involving tuber crops. Nitrogen contribution by green manure crops varies from 60-280 kg $ha^{-1}$.

Biofertilizers offer a cheap and easily available source of nutrients, especially N and P, besides enhancing the efficiency of native and applied nutrients in the soil. The commonly used N biofertilizer for tuber crops is the N fixing bacterium, *Azospirillum lipoferum*, which can partially meet the N demand of the crop. Powdered neem cakes also serve as an organic N source. These organic N supplements unlike the fertilizer N do not suffer much loss in the fields and enhances the N recovery. Phosphorus-solubilizing and mobilizing organisms such as phosphobacterium and mycorrhizae are helpful in augmenting P availability of the soil. Besides, natural reserves of rock phosphate are permitted for use as P fertilizer. Potassium for these crops can be supplied by using K rich organic amendments such as wood ash, rice straw and composted coir pith. Harnessing the above mentioned organic sources of plant nutrients conjointly to meet the nutrient needs of highly nutrient exhausting crops like tropical tubers will definitely help to maintain/promote productivity in organic farming in the absence of chemical inputs.

## 4. Pest, disease and weed management

When compared to cereals and vegetables, tuber crops have fewer pest and disease problems. Barring a few major ones, like cassava mosaic disease (CMD), cassava tuber rot, sweet potato weevil (SPW), *Phytophthora* leaf blight in taro, collar rot in elephant foot yam, the others are of minor significance. In general for the management of pests and diseases, non chemical measures or preventive cultural techniques can be resorted to. This includes use of tolerant/ resistant varieties, use of healthy and disease free planting materials, strict field sanitation, deep ploughing (eg. tuber rot), rogueing the field (eg. CMD), use of pheromone traps (eg. SPW), use of trap crops (eg. SPW, root knot nematodes), adapted crop rotations, use of neem cake (collar rot, tuber rot), use of bio-control agents like *Trichoderma, Pseudomonas* (collar rot, leaf blight) etc. Normally two hand weedings are advocated in tuber crops for efficient weed management. Since most of the tuber crops (except sweet potato) take about 75-90 days for sufficient canopy coverage, raising a short duration intercrop (like green manure/ vegetable/ grain cowpea, vegetables, groundnut etc in cassava, cowpea in yams and aroids) can also help to a great extent to reduce weed problem. Mulching the crop immediately after planting (in yams and aroids) will help to conserve moisture and regulate temperature, apart from weed control.

## Organic farming in aroids and yams is promising

Yams and aroids are important tuberous vegetables, rich in carbohydrates and containing appreciable amounts of protein, which can be grown with lesser chemical inputs, using organic wastes available in home gardens. These crops have several medicinal properties as well. In India, these are mainly cultivated in southern and north eastern states. The edible yams cultivated in India are greater yam *(Dioscorea alata*), white yam *(Dioscorea rotundata*) and lesser yam (*Dioscorea esculenta*). Important cultivated aroids are elephant foot yam (*Amorphophallus paeoniifolius*), taro (*Colocasia esculenta*) and tannia (*Xanthosoma sagittifolium*). Yams and aroids also form the staple food of the tribal communities, as in Wayanad and Idukki districts of Kerala, where these crops are grown strictly by organic management. Yams and aroids can be intercropped with perennial tree/fruit crops such as coconut, arecanut, rubber, robusta coffee and banana. This will help to augment the farm income and employment opportunities, enable better utilization of resources, serve as a precaution against crop loss due to climatic aberrations and market fluctuations as well as ensure food and nutritional security to resource poor farmers.

Presently comprehensive research on organic farming and published work on organic farming practices for tropical tuber crops is meagre. A research programme on "Organic farming of yams (greater yam, lesser yam and white yam) and aroids (elephant foot yam, taro and tannia)" is underway at Central Tuber Crops Research Institute. The Research Project envisages comparisons of yield, mineral and vitamin content and other nutritional attributes of tubers, soil quality and economics of aroids and yams grown under organic, traditional and conventional management. Formulation of package of practices prescriptions for conversion from conventional to economic organic production and promotion of scientific organic farming in tuber crops are the targets.

### 1. Aroids (Elephant foot yam and tannia)

Three years of experimentation indicated that organic farming is a viable proposition in elephant foot yam (EFY) (Suja and Nayar, 2006; Suja *et al*., 2006a; Suja *et al.,* 2006b, Suja *et al*., 2006c). Of the four production systems tested in elephant foot yam (conventional, traditional, organic farming and using biofertilizers) organic farming proved promising with high yield (64.48 t $ha^{-1}$) due to an overall improvement in soil physico-chemical properties (Table 3). Though the incidence of collar rot was not profoundly influenced by the various practices, organic and traditional plots showed lower incidence. Biochemical constituents such as dry matter, starch, oxalates, total sugar, reducing sugar and total phenols were not significantly influenced by different production systems. However, organically produced corms had slightly higher dry matter, crude protein and starch contents and lower oxalate content (Table 3).

There was not much variation in the mineral composition of corms from the various practices. However, corms produced by conventional practice had higher Mn content. After 2 years of cropping, pH, organic C, available P and K status of the soil were seen significantly higher in the organic plots. Physical properties of the soil viz., bulk density, particle density, water holding capacity and porosity remained unaltered under the influence of various production systems after 3 years. However, bulk density was slightly lower and water holding capacity and porosity slightly higher in the organic plots. The increased organic matter content of soil as evidenced from higher organic C status in organic plots might have resulted in the formation of stable soil aggregates with the resultant slight decrease in bulk density and increase in water holding capacity. There was no significant variation in the population of bacteria, fungi and actinomycetes among the various production systems. However the bacterial population and the total count of bacteria, fungi and

Table 3. Comparative advantages of organic farming over conventional and other production systems in elephant foot yam

| Production system | Corm yield ($t\ ha^{-1}$) | Dry matter (%) | Starch (% FW basis) | Oxalate (% DW basis) | Crude protein (% FW basis) |
|---|---|---|---|---|---|
| Conventional | 54.622 | 19.23 | 13.63 | 0.204 | 1.740 |
| Traditional | 51.715 | 20.49 | 16.62 | 0.189 | 1.876 |
| Organic | 64.480 | 21.37 | 16.57 | 0.172 | 2.160 |
| Using biofertilizers | 49.210 | 20.86 | 15.56 | 0.181 | 2.026 |

Source: Suja *et al*. (2006c)

actinomycetes were slightly higher in the organic plots due to higher availability of essential nutrients.

Organic farming proved superior producing significantly higher cormel yield (11.252 $t\ ha^{-1}$) and mother corm yield (22.962 $t\ ha^{-1}$) in tannia.

## 2. Yams

Three species of *Dioscorea* (D. *rotundata* (var. Sree Priya), *D. alata* (var. Sree Keerthi and *D. esculenta* (var. Sree Latha)) were tested under three production systems viz., conventional, traditional and organic farming. During the first year, the 3 species responded differently to the different production systems. *Dioscorea rotundata* produced higher yield in conventional practice (19.206 $t\ ha^{-1}$), which was on a par with organic farming (17.807 $t\ ha^{-1}$). In the case of *D. alata* all the production systems were on par; traditional practice (20.645 $t\ ha^{-1}$) resulted in slightly higher yield than organic (19.466 $t\ ha^{-1}$) and conventional practices (19.044 $t\ ha^{-1}$). In *Dioscorea esculenta*, organic farming proved superior (8.586 $t\ ha^{-1}$).

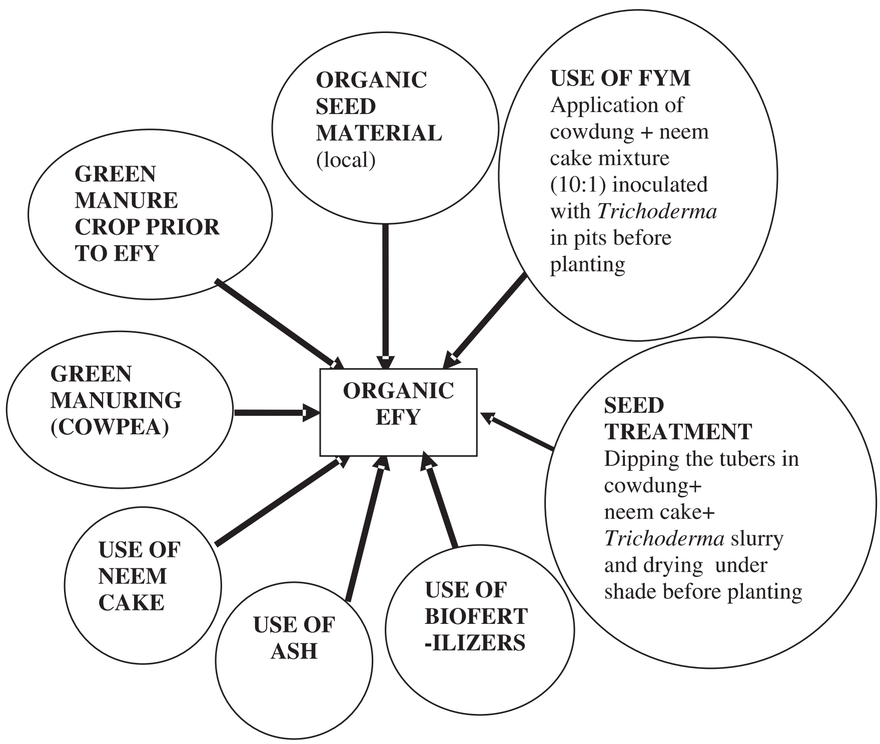


Fig 1. Essential components of organic elephant foot yam production

## Constraints in promotion of organic farming in tuber crops

In India the availability of organic manures is a major constraint. The total availability of NPK per annum through all the potential organic sources is estimated to be at 6.24 million tonnes by 2010, as against an estimated total NPK requirement of 26 million tonnes by 2011-12 to meet the targeted food grain production of 245-248 million tonnes (Tandon, 1997; Chhonkar and Dwivedi, 2004). Thus, most optimistic estimates show that only about 25-30% nutrient needs of Indian agriculture can be met by utilizing organic sources (Chhonkar and Dwivedi, 2004). Organic sources are bulky (high cost of handling and transportation), low analysis, slowly available and variable in composition. Being a major source of fuel in rural households, the availability of cattle dung for organic farming will be further limited. Apart from these, green manuring and recycling of farm wastes as manures has not become popular. Presently certification procedures are cumbersome and expensive.

## Future thrust

Proper delineation and identification of prospective areas and crops (like tuber crops) may be helpful for effective promotion of organic farming. There is a need to undertake systematic research on the comparative values/ advantages of organic farming over conventional farming on a long term basis for promotion of organic farming in tuber crops. Package of practices/recommendations for organic farming in tropical tubers have to be formulated. The extent of availability of potential organic sources needs to be ascertained along with measures that may be helpful in improving the convenience of their use in tropical tubers. Agronomic efficiency of various potential organic sources that may be suitable for organic farming needs to be assessed. The benefits accruing through organic farming on crop yield, quality, market preference and price advantage may be properly understood and promoted among farmers and consumers.

## Conclusion

Organic agriculture system is an alternative and appropriate management system intended to guarantee sustainable production of safe food with minimum environmental impact. Tuber crops can be considered to be highly prospective for organic farming. Organic production of tuber crops will be successful if sufficient biomass can be generated in and around the farms. Development of biogas plants/ biogas technology and agro-forestry for providing alternate sources of fuel, addition of crop residues, green manuring, recycling of on-farm and off-farm wastes and enhancing nutrient value of manures through proper composting, adoption of crop rotations involving legumes etc., are some of the strategies that will definitely help to promote organic farming of tuber crops in tribal and rain fed areas. These policies and practices will go a long way in supplementing inorganic fertilizers, whose use cannot be totally eliminated. The benefits accrued through organic farming like yield security, premium price for organic produce, safe food, better soil quality, reduced energy consumption and pollution will further help to promote this alternative farming strategy.

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# Organic Dairy Farming : Issues and Strategies

**D. Nagalakshmi***

Healthy and safe hood is basic for supporting a growing population and achieving minimum health standards. Any nation can boast of its development only if its population is fully fed and is in a state of good health. An adequate quantity of balanced and nutritious food is a primary indicator of quality of life, human welfare and development. Food from animal source (milk, meat and eggs) provide high quality protein, minerals, vitamins and micronutrients. Quality foods derived from animal sources have major importance for growth and well being of population. Further, all developed nations and some developing countries achieved food security by enhancing the productivity per unit of input. After achieving food security, now importance of food quality gained attention for further enhancing health status of mankind, minimize environmental pollution and to promote animal welfare as well.

Production of quality food is a serious challenge to consumers, farmers, processors, retailers and governments alike due to a shift in food consumption pattern and intensified food production techniques. As consumer awareness about the potential threats to health posed by food borne hazards has increased, consumer confidence in the effectiveness and integrity of food safety system has fallen. In Europe, the 'mad cow' disease emergency and recent alarms over dioxin contamination in meat have exposed the vulnerability in primary food production. Presence of pesticides and insecticide residues, mycotoxins, heavy metal contaminants of food grains, horticultural commodities and livestock products also pose threat to food safety. Good agricultural practices like integrated pest management, organic farming etc should be used in a pragmatic and sustainable mode to produce healthy food. Focus should be on improving quality of all types of foods, especially foods derived from animals.

To boost the agricultural and animal production, chemical fertilizers, pesticides and veterinary drugs have been used extensively during the past 3-4 decades. The substances, which affect the quality of food of animal origin, are contaminants and residues. Contaminants enter the food chain unintentionally due to environmental conditions in which the animals are surrounded or due to intake of contaminated feeds and water. This is true for heavy metals and mycotoxins. In case to veterinary drugs used for the treatment of animals and pesticides for the protection of plants or animals, the drug or the pesticide as such or their metabolites when appear in meat, milk and egg, are called residues. Appropriate sanitary and phytosanitary measures are to be taken not only to safeguard the health of domestic consumers but also keeping in view the export potential and regulations of World Trade Organization. Therefore there is a need to develop sustainable way of animal production systems, which allow for preservation of the environment and with a high standard of animal welfare without compromising food security and safety. Many consumers are

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seeking alternatives to conventionally produced animal products. Organically produced milk, meat and eggs are an alternative to conventionally produced animal products and the demand for this 'organic product' is sharply increasing day by day in the developed countries.

Lampkin (1990) defined organic agriculture as 'a production system which avoids or largely excludes the use of synthetic fertilizers, pesticides, growth regulators and livestock feed additives. To the maximum extent feasible, organic farming systems rely on crop rotations, crop residues, animal manures, legume green manures, off-farm organic wastes and aspects of biological pest control to maintain soil productivity and tilth, to supply plant nutrients, and to control insects, weeds and other pests. Organic crops are grown without the use of synthetic fertilizers or pesticides for at least three years prior to harvest. Cover crops, compost and other natural fertilizers are used for maintaining soil fertility and are necessary for sustaining certification; biological control and natural pesticides are used for pest control. Sustainability is the end goal of organic agriculture and as sustainability includes social, economical and ecological components so social justice and social rights are integral part of organic agriculture (IFOAM, 2000). Organic food is derived from crops or animals produced in farming system that avoids the use of man-made fertilizers, pesticides, growth regulators and livestock feed additives.

## Organic livestock production

Organic livestock production requires that animals are fed organic feed, have access to pasture or the outside and restricts the use of antibiotics and hormones. The organic milk is the resultant of the organic dairy farming system, wherein the milk is produced from disease free, healthy milch animals reared under nature's system. Organic livestock standards require that the animals be raised on certified organic feed. Organic feed is produced using feed ingredients from agri-farming without use of synthetic fertilizers or pesticides for at least three years prior to harvest. Organic feed can have some feed additives such as vitamins, minerals and probiotics, which are approved by the certifying authority and listed in the organic livestock standards. A proper herd health programme should include strategies for disease prevention, parasite control and disease treatment. Producers of organic animal products should use only healthy animals and follow approved managemental practices. Organic producers of livestock products must not withhold disease treatment in order to represent the livestock product as organic. All vaccinations for endemic disease are approved. Herbal, naturopathic and homeopathic treatments are approved for use on organic animals.

## Characteristics and advantages of organic milk

Organic milk has all the nutritional goodness of non-organic milk with additional health benefits.

1. Organic milk naturally contains more Omega 3 fatty acid than non-organic milk. Research at University of Aberdeen in 2004 showed that organic milk contained up to 71% more Omega 3 than non-organic milk and has a better ratio of Omega 3 to Omega 6 than non-organic milk. Similarly, Ellis's (2006) found that the organic farming system produces milk that is on average 68% higher in total Omega 3 fatty acids than non-organic milk. Omega 3 fatty acids are essential for maintaining a healthy heart, supple and flexible joints, healthy growth and strong bones and teeth.
2. Organic milk has higher concentrations of vitamin E, A and antioxidants. Organic reared cows, eat high levels of fresh grass, pastures and silage and thus on an average has 50% higher vitamin E, 75% higher ß-carotene and 2-3 times higher antioxidants like lutein and zeaxanthine than non-organic milk.

**Specifications of feeding and management for dairy cows raised organic farming (BCMAF, 2000)**

| Conditions | Requirements |
|---|---|
| Feed | Certified organic feed should be fed for 12 months prior to milk production |
| Antibiotics | Restricted- 30 day withdrawal or twice the labeled withdrawal time, which ever is greater |
| Hormones | Not allowed |
| Sanitation practices | Teat dips, milking sanitation chemicals allowed. However, equipment must be rinsed twice with clear (tested) water prior to milking |
| Vaccinations | All vaccinations for endemic disease are approved |
| Living conditions | ***Breeding and milking herd:*** Requires free access (weather permitting) to organic pasture for a minimum of 120 days /year<br>***Calves:***<br>Age: 24h to 3 mon<br>Outdoor system- 64sq ft/animal (5.95sqm/ani), eg. hutches<br>Indoor system- 40sq ft/animal (3.72 sq.m/ani)<br>3 mon to 181.4kg- 80sq ft/animal (7.43 sq.m/ani)<br>181.4 to breedable age- 100 sq ft/animal (9.29sq.m/ani) |
| Animals | Herd must undergo 12 month transition period on organic feed & management<br>Replacements-from non-certified sources must undergo a 12 month transition period<br>10% of herd can be replaced in this manner<br>Bulls- no requirements<br>Embryo transplanted animals prohibited. |

3. Organic milk contains conjugated linoleic acid (CLA) which is believed to boost immune function and reduce the growth of tumours.
4. Drinking organic milk minimizes the risk of consuming chemical residues.
5. Organic cows are not fed GM cattle feed and their feed is also free from solvent extracts and urea. This means that there is no possibility of GM or solvent residues being found in organic milk.
6. Organic cows are never given any animal-derivatives in their feed, which was the source of BSE (Bovine spongioform encephalopathy). No case of BSE has ever been found in a organically born and raised dairy cow.
7. On organic dairy farms, the use of fertility hormones and growth hormones are rare. Hormones are not used for stimulating the cow's milk production. Therefore the traces of these hormones in milk are negligible.

Organic livestock production undoubtedly reduces the risk of potential public health problems occurring by prohibiting the use of antibiotics, hormones and pesticides, which are suspected to have endocrine disrupting, carcinogenic, tertogenic, immunosuppressive and neurotoxic effects. The organic farming applies more stringent safety margins (i.e., withdrawal period) to acceptable practices such as use of antibiotics on individual sick animals. Organically produced animal products have lower levels of veterinary drugs and pesticides. As regular use of antibiotics is prohibited, organic meat potentially reduces the risk of contamination by antibiotic resistant bacteria. The 'organic' label provides the assurance that no food ingredient is subject to irradiation and that genetically modified organisms have been excluded. However, it seems that organic farming leads to higher risk for the contamination of products by parasites of livestock and by microbes present in the manure.

Organic farming is better for the environment. The production of livestock involves less intensive farming practices than in conventional one. Synthetic fertilizers and pesticides sprays are prohibited in animal feed and fodder production, and animals are kept at lower stocking rates. This lowers the pollution risk (Younie and Watson, 1992) and it also minimizes the nutrient losses at the farm level (Sundrum, 2001). A study in Netherlands showed the contribution of organic dairy farming towards ecological sustainability. The study showed that emission of green house gases ($gCO_2$- equivalents) and acidification potential ($gSO_2$-equivalents) per liter of milk were 14 and 40% less for organic than conventional dairy herds (Oosting and DeBoer, 2001).

Organic livestock farming is also better for animal welfare. There is no simple definition of animal welfare. Hodges (1999) defined animal welfare as, 'the care of animals kept in the service of mankind, so that their well-being is provided for, their natural needs are not restricted and their worth and dignity as individuals are recognized'. The studies of Bennedsgaard and Thamsborg (2000) indicated the welfare of animals was better in Danish organic dairy herds as compared to conventional herds in terms of general health (i.e., production, body condition, hock lesion, chronic infection) and udder health (mastitis occurrence, somatic cell count). The incidences of laminitis also reduced in organic raised dairy animals.

The question sometimes raised on individual welfare of animals with respect to health care, as there is a prohibition on conventionally used veterinary medicines (except in emergencies) on organic farms. The most common health problems on organic farms are mastitis and parasitism. The studies revealed that the incidence of mastitis was of the same or even more for organic farms in comparison to conventional farms (Weller and Cooper, 1996). However, a lower incidence of mastitis and reported by Hovi and Roderic (2000) among organic dairy herds in England and Wales.

## Organic movement around the world

There has been tremendous growth in the number of organic farms around the world in the past decade. As a result of changed consumer preferences, organic market growth in developed countries has rejuvenated the agricultural sector in developing countries too. World wide about 130 countries produce certified organic products in commercial quantities, which include 30 countries in Africa, 30 in Asia, 20 in Central America, 5 in Australia and the Pacific and most countries in Europe as well as the United States of America and Canada (ITC, 1999). The total market of organic food and beverages in 2001 was US $21 billion, and is expected to be $80 billion by 2008 with a growth rate of 20% per annum (ITC, 2002). The most recent estimates indicate that there should be at present more than 250,000 organic farms all over the world, covering a surface of about 26.3 million hectares (Willer and Yussefi, 2004). In relative terms, this is almost nil but the recent growth has been impressive and all experts forecast a continuous expansion.

## Organic dairy farming in India

The problems of developing countries like India are different from those of developed countries. In most of the developed countries, the problem is over production and highly intense farming practices. Whereas, in developing countries the problems are poverty, malnutrition and unemployment, so here food security is the prime goal rather than food safety. In this situation, development of organic sector itself is very difficult and development of organic dairy/meat sector is more difficult. Whatever developments have taken place in developing countries are mainly restricted to crop sector. In India, organic farming has made a humble beginning and about 35 organic products are exported that include tea, spices, basmathi rice, pineapple, honey, seasame cashewnut etc, However, organic livestock sector is yet to make a beginning. Domestic market has not carved out in India. Though organic product stores have come up in few cities, campaign in its favour has to gear up. Also, there is potential for boosting organic production to earn foreign exchange, besides ensuring the wholesome food to domestic consumers. Considering the rapidly increasing global demand for organic products, the Government of India approved a National Programme for Organic Production (NPOP) on 2nd May 2001 to boost organic production. The Non Government Organizations, private sector and certain public sector agencies like Agricultural and Processed food products Export Development Authority (APEDA) under Ministry of Commerce and Industry, are making concreted efforts to boost organic production in India. These agencies have taken up several steps to augment supply of organic food products mainly to meet export demands form developed nations. Some sporadic attempts have been made in India to produce milk as per the prescribed standards. For instance, Institute for Integrated Rural Development (IIRD) – Aurangabad based NGO established an Organic dairy with indigenous cow breeds and imparts training on organic management for organic agriculture school (Daniel, 1999). Besides some Gaushalas/Ashrams also claim to produce milk in organic ways. But such attempts are very limited.

## Present Livestock scenario in India

Livestock sector is an important component of India's economy in terms of income, employment, equity and foreign exchange. India possesses 20 per cent of worlds bovine population and 14 per cent of cattle population (Livestock census 2003) with 185 million cattle 98 million buffaloes holding No 1 position in the world, 61.5 million sheep possessing 5 per cent of worlds population ranking as No 2 position, 114.5 million goat possessing 20 percent of world population ranking No 1 position and 428.9 million poultry ranking 5th position, and 13.5 million pigs. India has also the distinction of having the largest number of breeds of all species of farm animals with immense genetic diversity. It has around 40 cattle breeds 9 buffalo breeds best in the world, 20 goat breeds 40 sheep breeds.

The significance of livestock contribution may be ascertained by the level of production of milk, meat, eggs and other related by-products. In India, milk production has increased by more than four folds from 17 million tones in 1951 to 78 million tones in 1999 assuming first position in the world (Rai and Sirohi, 1999). Similarly, India produced 4.2 million tones of meat (Beef 1.276, Buffen, 1.20, Mutton 0.179, Chevon 0.500, pork 0.386 and broiler meat 0.416 million tones) from 192 million cattle, 82 million buffaloes, 47 million sheep, 117 million goats and 11 million pigs (Ranjhan, 1999). India has 3.3% of cultivated area under fodder production, producing 150 million tones of green fodder. Seventy per cent of the livestock in India are owned by 67 per cent of small marginal and landless laborers, 76 per cent of milk is produced by this group, while over 90 per cent of small ruminants and almost the entire piggery sector is maintained and managed by the weaker sections of the society. Twenty four per cent of the eggs are produced by the rural back yard poultry farming.

## Role of indigenous cattle and buffaloes

Livestock production, and especially ruminant livestock, forms an integral part of many organic farms due to its role in nutrient recycling in livestock agriculture farming. The animals in our country most suited to organic farming are those that are well adapted to local situations and resources besides having pronounced ability to utilize fibre and non protein nitrogen (Chander and Kumar, 2002). Herein lies the significance of indigenous cows and buffaloes, which perfectly fit into organic farming practices. Milk production in India is predominantly the domain of small hold farmers in a holistic mixed farming system. Indigenous cattle and buffaloes render economic stability to farmers in confronting uncertainties associated with agriculture production in dry land or rain fed areas which constitute 66% of India's arable land. In fact, the indigenous cattle play a significant role in sustaining the economy of majority of the small hold and marginal farmers.

Rainfed areas confront great instability in crop production primarily due to erratic and inadequate rainfall. In the face of these uncertainties in crop production, livestock production has been a virtue to the farmers, ensuring economic stability. The bovine population provide draught power, milk, meat, hides, bones and much needed organic manure for sustainability of the soil fertility as well as to meet the requirements of house hold kitchen fuel in rural India. The chemical fertilizers consumption along with the other agrochemicals like pesticides and herbicides are very low in rainfed areas not touched by green evolution. Such areas are heavily dependent on farmyard manure, which is supplied by the indigenous cattle and buffaloes at negligible maintenance cost of their own unlike more demanding crossbred counterparts usually common in green revolution areas are well endowed in terms of external inputs.

It appears as though the exotic cattle is more productive than the local breeds but deeper evaluation reveals that this is more apparent than real. The exotic breeds require higher inputs than the indigenous breeds. The average milk production of 500 organic herds in Denmark was 10% less than that of conventional farms as organic milk production is based in high yielding dairy cows of the same genetic make up (Kristensen and Mongensen, 2000). On the other hand indigenous breeds thrive on crop residues like straw of rice and wheat, sugarcane leaves, etc., that would not be utilized in any other way, there by maintain their productivity efficiently. The qualitative traits of Indian cattle make them unquestionably suitable for organic practices. Hence these animals are most suited for organic farming. Also the health care requirement of Indian cattle and buffaloes is one of the lowest in world, owing to high disease resistance. Health signifies the most important sign of successful organic animal husbandry and all other aspects such as profit, fertility, growth rate, milk yield and feed conversion are related to the animal health (Boehncke, 1995). Since health is directly related to contribution of animals to the environmental soundness of the farming system, indigenous cows and buffaloes are perfectly suited to organic farming.

Animals in organic farming are often viewed to be necessary for crop production, as creature that keep the weed burden down and that produce manure to improve nutrient status of the soil. So the focus in the first instance should be on livestock in their own right as organic livestock husbandry, besides being an essential contributor to the organic crop husbandry. The indigenous cattle and buffaloes in India deserve attention in a sense that these are ideal for organic system if we evaluate in terms of principles, practices and standard of organic agriculture as developed by IFOAM, FAO/Codex Alimentarious and other bodies.

## Standards for organic milk/meat

Organic standards are the detailed rules defining a) the production and processing practices that are permitted in the growing and manufacturing of organic food and b) the precautions that must be taken to protect the integrity of an organic product or process (Michaud *et al*., 1994). Standards whether international or regional, are linked to a specific philosophy and they are not simply a collection of prohibitions describing what is not allowed in organic farming and what has to be done in order to farm organically. Implementing organic standards require inspection and the end product of the inspection is certification.

Certification ensures that organic products are produced, processed and packaged according to organic standards. Certification also ensures that consumers, producers and traders against fraudulent labeling of non-organic products. The accreditation process, which is conducted by an independent accreditation body, evaluates a certifier's inspection and certification procedures, as well as that organization's ability to remain free from vested interests (USDA, 2001).

There are a few standards for organic production like the IFOAM Basic Standards, EU Regulation No-1804/1999 and Codex Alimentarius ALINORM 99/22A. Apart from these international, standards most of the leading countries in organic production have their own national or local standards, like UKROFS in UK, JAS in Japan, California Organic Standards in state of California, USA. India too has developed National Standards for Organic Production (NPOP, 2000).

Though the development of organic sector in our country is not on par with the European countries, some development has already taken place in the organic crop sector and now that we are exporting a substantial quantity of organic tea, fresh and dried fruits, vegetables, nuts, rice, dried legumes, coffee, sugar, herbs and spices, but the export as well as production of organic dairy/meat is still small, though there are some excellent breeds of livestock, which are well suited in these climatic conditions, are more resistant to disease, and thrive well on crop residues. Most of the animal husbandry practices are traditional with a close resemblance to prescribed organic practices but we failed significantly to convert our advantages into fruitful gains. Small land holding, low level of literacy, lack of information, high stocking density, inadequate production of feed and fodder, high cost of certification, absence of marketing facilities are some hindrances in the way of conversion from traditional to organic.

### Important areas where the policy initiatives need to be taken are:

a) **Improvisation of Organic standards:** The present standards for organic production, which are based on IFOAM-Basic Standards, should be modified according to regional agro-climatic conditions.

b) **Development of Regional Standards:** To bridge the gap between the National and International standards. Regional standards should be developed to promote the marketing of organic products within the region.

c) Establishment of a low cost certification agency that the farmers can afford.

d) **Development of strong domestic market:** Without a developed domestic market, the benefits of producer's cannot be protected as international markets are always fluctuating. As such, the urban meat consumers pay 70-80 per cent more price for free-range poultry meat and eggs, which is a fair indicator of their willingness to pay more for quality products.

e) **Establishment of a 'Growth Centres' for organic production:** Some potential areas of the countries (hilly areas, forest areas, rain fed areas), where agriculture is not so well developed and animal rearing is not intensified, should be identified and some nodal agencies should be established. These agencies will provide the technical support to the farmers, will make arrangement for certification and will help in marketing. The success of these areas will be a model to the rest of the country.

f) **Research and development:** Organic farming needs research and development in order to apply the most modern knowledge and improve its performance. Universities and research centers should start research programme together with farmers.

# National standards of organic livestock production

| General Principles | Recommendations | Standards |
|---|---|---|
| **Animal Husbandry Management**<br>Management techniques in animal husbandry should be governed by the physiological and ethological needs of the farm animals in question<br>-Animal should be allowed to live by their basic behavioral habits<br>All the management techniques including those when production levels and speed of growth are concerned should be directed for the good health and welfare of the animals | For welfare reasons the herd or flock size should not adversely affect the behavioral pattern of the animals | The accredited certification programme shall ensure that the management of the animal environment takes into account the behavioral needs of the animals and provides for:<br>-Sufficient free movement<br>-Sufficient fresh air and natural day light according to the needs of the animals<br>-Protection against excessive sunlight, temperatures, rain and wind according to the withstanding capacity of the animals.<br>-Enough lying and/or resting area according to the needs of the animal. For all animals requiring bedding, natural materials shall be provided<br>-Ample access to fresh water and feed according to the needs of the animals.<br>-Adequate facilities for expressing behavior in accordance with the biological and ethological needs of the species.<br>No compounds used for construction materials or production equipment shall be used which might detrimentally affect human or animal health.<br>All animals shall have access to open air and/or grazing appropriate to the type of animal and season taking into account the age and condition, to be specified by the accredited certification programme.<br>The accredited certification programme shall allow exceptions in cases where:<br>-The specific farm or settlement structure prevents such access provided animal welfare can be guaranteed.<br>-Areas where feeding of animals with carried fresh fodder.<br>-Is more sustainable way to use land resources than grazing providing animals welfare is not compromised.<br>Restrictions shall always in include a time limit that shall be set for each exception.<br>Poultry and rabbits shall not be kept in cages.<br>Landless animal husbandry systems shall not be allowed.<br>When the natural day length is prolonged by artificial lightly, the accredited certification, programme shall prescribe maximum hours respective to species, geographical considerations and general health of animals.<br>Herd animals shall not be kept individually.<br>The accredited certification programme may allow exceptions e.g. male animals, smallholdings, sick animals and those about to give birth. |

| General Principles | Recommendations | Standards |
|---|---|---|
| **Length of conversion period**<br>The establishment of organic animal husbandry requires an interim period, termed the conversion period | The whole farm, including livestock, should be converted according to the standards set down. Conversion may be accomplished over a period of time | Animal products may be sold as 'product of organic agriculture' only after the farm or relevant part of it has been under conversion for at least twelve months and providing the organic animal production standards have been met for the appropriate time.<br>The accredited certification programme shall specify the length of time of which the animal production standards shall have been met. With regard to dairy and egg production this period shall not be less than 30 days.<br>Animals present of the farm at the time of conversion may be sold for organic meat when the organic standards have been met for 12 months |
| **Brought –in-animal**<br>All organic animals should be born and raised on the organic holding | Organic animal husbandry should not be kept on conventional raising systems. When trading or exchanging animals, it should be preferably between organic farms or as part of a long term cooperation between specific items | When organic livestock is not available, the accredited certification programme shall allow brought- in conventional animals i.e., calves up to 4 weeks old that have received colostrums and are fed a diet consisting mainly of full milk.<br>Accredited certification programmes shall set time limits (not exceeding 5 years) for implementation of certified organic animals from conception for each type of animal.<br>Breeding stock may be brought in from conventional farms. A yearly maximum of 10% of the adult animals of the same species on the farm.<br>For brought-in breeding stock the accredited certification programme shall allow maximum 10% in the following cases and with specific time limit.<br>- Unforeseen severe natural or man-made events.<br>- Considerable enlargement of the farm.<br>- Establishment of a new type of animal production on the farm, smallholdings. |
| **Breeds and Breeding**<br>Breeds should be chosen which are adapted to local conditions. Breeding goals should no be in opposition to animals natural behavior and should be directed towards good health. | Breeding shall not include method that make the farming system dependent on high technological and capital intensive methods. Reproduction techniques should be natural. | The accredited certification programme shall ensure that breeding system are based on breeds that can both copulate and give birth naturally<br>Artificial insemination is allowed only upon veterinary necessity<br>Embryo transfer techniques are not allowed.<br>Hormonal treatments for induced heat/birth are not allowed unless applied to individual animals for medical reasons and under veterinary advice.<br>The use of genetically engineered species of breeds is not allowed. |

| General Principles | Recommendations | Standards |
|---|---|---|
| **Mutilations**<br>The animals distinction characteristics should be respected | Species shall be chosen which do not require mutilations.<br>Exceptions for mutilations shall only be given so that suffering can be kept to the minimum | Mutilations are not allowed.<br>The accredited certification programme shall allow the following exceptions:<br>- Castrations<br>- Tail docking of lambs<br>- Dehorning<br>- Ringing<br>Suffering shall be minimized and anesthetics used where appropriate. |
| **Animal Nutrition**<br>The livestock should be fed 100% organically grown feed or good quality. All feed shall be offered to the animals in a form allowing them to execute their natural feeding behaviour and digestive needs. | The diet should be balanced according to the nutritional needs of the animals.<br>Products from organic food processing industry shall be used.<br>Colouring agents shall not be used in organic livestock production. | The accredited certification programme shall draw no standards for feed and feed ingredients.<br>The prevailing part (at least more than 50%) of feed shall come from the farm unit itself or shall be produced in co-operation with other organic farms in the region.<br>The accredited certification programmes shall allow exceptions with regard to local conditions under a set time limit for implementation.<br>The feed produced on the farm unit during the first year of organic management be classed as organic. Where it proves impossible to obtain certain feeds from organic farming sources, the accredited certification programme shall allow a percentage of feed consumed by farm animals to be sourced from conventional farm and should be a maximum of 15% of dry matter intake (DMI) for ruminants and 20% of DMI for non-ruminants and these percentages should be reduced to 10 and 15% of DMI for ruminants and non-ruminants, respectively within 5 years. The accredited certification programme shall allow exceptions to these percentages with specific time limits and conditions in the following cases.<br>- Unforeseen severe natural or man-made events<br>- Extreme climatic or weather conditions<br>Areas where organic agriculture is in early stages of development.<br>The following products shall not be included not added to the feed<br>- Synthetic growth promoters or stimulants and synthetic appetizers<br>- Preservatives, except when used as a processing aid<br>- Artificial colouring agents<br>- Urea, abattoir waste, all types of excreta and droppings even if technologically processed<br>- Feed subjected to solvent extraction or the addition of chemical agents<br>Genetically engineered organisms or products thereof<br>Vitamins, trace elements and supplements from natural origin<br>Young stock from mammals shall be raised using systems that rely on organic milk, preferable from their own species.<br>In emergencies the accredited certification programme shall allow the use of milk from non-organic farming systems of dairy based milk substitutes as long as they do not contain antibiotics or synthetic additives. |

| General Principles | Recommendations | Standards |
|---|---|---|
| **Veterinary Medicine**<br>Management practices should be directed to the well being of animals. Achieving maximum resistance against disease and prevention infections.<br>Sick and injured animals shall be given prompt and adequate treatment | Natural medicines and methods including homeopathy, ayurvedic medicine and acupuncture, shall be emphasized. When illness does occur, the aim should be to find the cause and prevent future outbreaks by changing management practices | The well-being of the animals is the primary consideration, in the choice of illness treatment. The use of conventional veterinary medicines is allowed when no other justifiable alternative is available. Where conventional veterinary medicines are used, the with holding period shall be twice the legal period. Use of synthetic growth promoters, synthetic substances for production, stimulation or suppression of natural growth are prohibited. Hormones for heat induction and heat synchronization are prohibited unless used for individual animal treatment, justified by veterinary indications<br>Legally required vaccinations and for those prevalent and expected diseases, vaccinations are allowed. Genetically engineered vaccines are prohibited. |
| **Transport and slaughter**<br>Minimise stress during transport and slaughter. Transport distance and frequency should be minimized. The transport medium should be appropriate for each animal | Animals should be inspected regularly during transported.<br>Animals should be watered and fed during transport depending on weather conditions and duration of transport.<br>Stress to the animal shall be minimized. Each animal shall be stunned before being bled to death. Where animals are bled without prior stunning this should take place in a calm environment. | Throughout the different steps of the process, there shall be a person responsible for the well-being of the animal. Handling during transport and slaughter shall be calm and gentle. The use of electric sticks and such instruments are prohibited. |

g) Training and extension should be provided to all categories of stakeholders of organic farming starting from producer to consumers.

h) Governments have to make legislation in order to ensure the much-needed regulatory framework, where all stakeholders can play on a fair-leveled ground.

## Conclusion

India has some excellent breeds of indigenous cattle and buffaloes possessing natural resistance against many diseases. These breeds are well adapted to Indian climate and food availability situations. The Indian livestock owners posses a wealth of indigenous practices to treat their animals locally. Therefore, a little bit of training and some incentives for organic management may help them to qualify for organic production. Converting to organic production may be far easier for Indian farmers in comparison to their European counterparts where conventional production has reached to very high level of input dependence, overuse of antibiotics, pesticides, feed additives etc. The low external inputs based Indian diary sector has better opportunities to convert to organic production since majority of Indian farmers are organic farmers not by choice but by tradition. The government policy support, incentives, creating awareness, training, development of strong markets for domestic and exports may turn the constraints into a big opportunity.

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# Non Pesticidal Management: Learning from Field Experiences

**Ramanjaneyulu GV, Chari MS, Raghunath TAVS, Zakir Hussain and Kavitha Kuruganti***

## Abstract

Pests and pesticides contribute to major economic and ecological problems affecting the farmers, crops and their environment. Two decades of experience in Andhra Pradesh on Non Pesticidal Management shows that pest is a symptom of ecological disturbance rather than a cause and can be effectively managed by using local resources and timely action. The emerging new paradigm of sustainable agriculture shows that the new knowledge synthesized from traditional practices supplemented with modern science can bring in ecological and economic benefits to the farmers. The small success from few villages could be scaled up into more than 1.5 million ha in three years. The costs of cultivations could be brought down significantly without reduction in yield. The institutional base of Community Based Organizations like Federations of Women Self Help Groups provides a good platform for scaling up such ecological farming practices. This experience also shows how the grass root extension system when managed by the community can bring in change and help the farming community to come out of the crisis.

**Key words:** Non Pesticidal Management, Pesticides, Natural Enemies, Community Based Organizations, Sustainable Agriculture

## Introduction

Farming in India evolved over centuries of farmers' innovations in identifying locally suitable cropping patterns and production practices. The crisis of food production and geo-political considerations during 1960s created conditions in many developing countries particularly in India to strive for food self-reliance. The country has chosen the path of using high yielding varieties (more appropriately high input responsive varieties) and chemicals which brought about what is popularly known as green revolution. This continued as a quest for modernization of agriculture which promoted the use of more and more of high yielding varieties/hybrids, chemical pesticides and fertilizers across crops and situations displacing farmers' knowledge, own seeds and practices. The country could become self reliant, but farmers became dependent on external inputs and credit and are caught in serious ecological and economic crisis. This crisis is manifesting itself in the form of migration, indebtedness and in extreme cases as suicides.

In midst of the deep crisis in agriculture farmers and various organizations associated with farmers are trying innovative approaches to sustain agriculture. One such initiative is the 'Non Pesticide Management' of crops to reduce the costs of cultivation by adopting a set of practices based on farmers' knowledge supplemented by modern science which makes best use of local resources and natural processes by the farmers and women self help groups in Andhra Pradesh. During *Kharif* 2007, more than 200 thousand farmers from 1500 villages in eighteen districts of the state have practiced

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this approach in more than 150 thousand ha in various crops. Sixteen of these districts are part of the 32 districts with serious agrarian crisis identified by the Government of India. The savings in costs of cultivation ranged from Rs. 600 to 6000 ($ 15 to 150 US) per ha without affecting the yields. This is part of the 'Community Managed Sustainable Agriculture' program with technical support from Centre for Sustainable Agriculture and its partner NGOs and financial and administrative support from the Society for Elimination of Rural Poverty, Government of Andhra Pradesh.

## Pests, Pesticides and the distress

The problems of pests and pesticides in farming are well documented. Among the production inputs in agriculture chemicals especially pesticides occupy major share of costs in crops like cotton, chillies, paddy etc. The pest resistance and resurgence due to abuse of pesticides propelled mainly by a lack of regulation of pesticide marketing extended on credit with high interests by "all-in-one dealers" (money lenders cum dealers of seeds/fertilizers/pesticides) and lack of market support ended up pushing hapless farmers into a vicious debt trap from which suicides were sought as a way out. The same pesticides which were promoted to solve the farmers' problems were consumed by these farmers to kill themselves.

**The dominant paradigm:** The dominant paradigm of pest management largely depends on use of chemical pesticides. The recommended schedules of the chemical pesticides are based on the studies conducted by the Pesticide Companies and Agriculture Research Institutes. The pesticides and the pesticide recommendations need to be registered with the Central Insecticides Board (CIB). Most of the chemical pesticides are used to kill the pest when it is in the most damaging stage of its life cycle (mostly the larvae stage). Farmers are suggested to spray their fields when the insects are in damaging proportions (Economic Threshold Level). Pesticides seriously disrupt the ecological balance among different pests and between pests and predators are disturbed which results in pest resistance, pest shifts, and pest resurgence. The regular use of pesticides creates pressure and result in the development of genetic resistance in the insects and makes the sprays more and more ineffective. All these make the farmer to increase the pesticide doses or go for newer pesticides frequently pushing the farmers into a vicious cycle of pesticides, increasing costs, ill health and debt.

**Pesticide induced pest problems:** Nearly from the beginning of the Green Revolution increases in insect populations following insecticide applications were detected. Insecticide induced increases in populations of sucking insects are among the first reliable symptoms of an intensification syndrome that destabilizes production (Kenmore, 1997). The pesticides often induce pest outbreaks by killing beneficial insects, reducing natural pest control, and resulting in sometimes explosive outbreaks of pest species which are either a) resistant to, or b) physically invulnerable to, pesticides. E.g. Brown Plant hopper eggs are laid within the rice stalk and shielded from spray; after spraying, they hatch into a field free of their natural enemies and reproduce explosively without predation (Kenmore, 1980). Systemic pesticides can kill the early "neutral" insects which lure the first generation of beneficials, and kill the beneficials as well (Mangan 1998). Similarly mealy bug and other sucking pests are increasingly becoming a problem in the cotton growing areas of Gujarat and Punjab. This ecological disturbance results in pest shifts as is seen widely today.

**Pesticide resistance:** Pesticide resistance which is heritable and results in significant decrease in the sensitivity of a pest population to a pesticide reduces the field performance of pesticides. Genetics and intensive application of pesticides are responsible for the quick build up of resistance in most insects. Natural selection by an insecticide allows some insects with resistance genes to survive and pass the resistance trait on to their offspring. The percentage of resistant insects in a population continues to multiply while susceptible ones are eliminated by the insecticide (IRAC, 2007). Eventually, resistant insects outnumber susceptible ones and the pesticide is no longer effective. How quickly resistance develops depends on several factors, including how quickly the insects reproduce, the migration and host range of the pest, the crop protection product's persistence and specificity, and the rate, timing and number of applications made. Resistance increases due to monoculture of crops, where insects reproduce quickly, there is little or no immigration of susceptible individuals and the grower may spray frequently. Based on their observations about resistance, farmers use either more concentration of the chemical (higher dose) or more sprays of the same or different chemicals mixed or with short intervals which is often termed as 'indiscriminate' use. But what is interesting is even after the resistance is reported; the recommendations are not changed or withdrawn. For example, *Helicoverpa* is reported to have developed 946 folds resistance against Cypermethrin, followed by 491 folds against Fenvelrate in different locations (http://whalonlab.msu.edu/rpmnews/vol.15_no.1/globe/PrasadaRao_etal.htm) in Andhra Pradesh. These resistance levels vary with region and reported differently by different authors. For example, Ramasubramanyam (2004) reported that *Helicoverpa* of Raichur strain developed 2489 folds resistance against Cypermethrin while Guntur strain developed next high level at 1213 folds resistance. Still Cypermethrin and Fenvelrate find place in pesticide recommendations in cotton and other crops for managing *Helicoverpa* at the same doses.

**Pesticide poisoning:** Pesticide poisoning is a significant problem in India. Pesticide poisoning to human beings through exposure to the toxic fumes while spraying is a lesser known and lesser acknowledged aspect of pesticide abuse in places like Warangal in Andhra Pradesh, Tanjavur in Tamil Nadu or Batinda in Punjab (Francesca 2005, Kavitha 2005, Chitra *et.al* 2006). There is no systematic documentation of such cases during hospitalization, often they are combined with the ingestion cases. The numbers of deaths that happen prior to hospitalization and not reported are substantially high. The socio economic and environmental conditions in which the

**Pest resistance:** Major pest management strategies are designed to prolong the life of pest control measures, by ensuring that insects do not rapidly develop resistance to pest control chemicals. There are two key mechanisms through which insect populations develop resistance to toxins:

- *Selection for resistance*. A number of individuals within an insect population are likely to be naturally resistant to a given chemical, even if the majorities are susceptible. When chemical pesticides are sprayed, susceptible insects will die, while resistant and escaped insects survive. Successive sprays amplify this effect. The resistant individuals are more likely to reproduce, and their offspring are more likely to share their parents' resistance to the chemical in question. In this way, chemical sprays and plant-produced toxins select insects for genetic resistance.
- *Selection pressure.* Even if the insect population doesn't contain any naturally resistant insects, high doses of a particular are likely to encourage genetic mutation in order to acquire

agriculture workers and small and marginal farmers work do not permit them to adopt the so called 'Safe use practices' often promoted by industry or agriculture scientists.

There are also several reports on the chronic effects of the chemical pesticides on the farmers (Mathur, H. B *et. al* 2005), growth and development of children (Kavitha, 2005, Kropp 2005) and women's reproductive health.

**Pesticides and ecological impacts:** The chemical pesticides leave larger ecological foot prints in manufacturing (e.g. Bhopal gas tragedy), storage and transport and usage polluting the soils, water and air. Some amounts of pesticides used in crop production appear as residues in the produce. These residues in food, soil and water enter into the food chain and cause serious health problems to human beings and other living beings (Karanth, 2002, Kavitha, 2007). The pesticide residues are even noticed in human milk (Down to Earth 1997). Studies show that the pesticide residues in soil can kill the soil microbes there by effect the soil fertility. Recent report by Jennifer Fox and colleagues at Tulane University shows that common pesticides block the chemical signals that allow nitrogen-fixing bacteria to function. Over time, soils surrounding treated plants can become low in nitrogen compounds, so more fertilizer is needed to produce the same yield (Fox, 2007).

**Pesticide regulation:** In India, the production and use of pesticides are regulated by a few laws which mainly lay down the institutional mechanisms by which such regulation would take place – in addition to procedures for registration, licensing, quality regulation etc., these laws also try to lay down standards in the form of Maximum Residue Limits, Average Daily Intake levels etc. Through these mechanisms, chemicals are sought to be introduced into farmers' fields and agricultural crop production without jeopardizing the environment or consumer health. In spite of these regulatory systems many pesticides which banned across the world for their toxicity and residual problem are still produced and used in India.

The pesticides and pesticide recommendations to control specific pests on crops are to be registered with Central Insecticide Board and Registration Committee (CIBRC). Pesticides are usually registered for one or two crops and one or two pests but sold, recommended and used for other crops and pests as well. (Kavitha, 2007).

## The Shifting Paradigms

The attempts to overcome the serious economical and ecological problems of the chemical pesticides have given rise to several paradigms of pest management.

## Integrated Pest Management

In an attempt to slow the development of pest resistance, improve the financial basis for agricultural production, and improve the health of the farming population, systems of Integrated Pesticide Management have been introduced around the world. IPM is an ecological approach to plant protection, which encourages the use of fewer pesticide applications. In 1968, FAO defined IPM as " Integrated Pest Management (IPM) means a pest management system that, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible manner as possible and maintains the pest populations at levels below those causing economically unacceptable damage or loss".

In IPM the dominant pests are counted by a method called scouting. The 'Economic Threshold Level' (ETL) is a formula for determining when economic loss of a crop's value exceeds the cost of a pesticide application. When the number of pests per hundred plants (or some representative number) goes above a certain predetermined quantity, economic loss will occur. This Economic Threshold Level based IPM does not take account of the whole agro-ecosystem, but only looks at the pest-plant relationship (Mangan, 1998).

The field experiences gave rise to several paradigms of IPM which agriculturists presently adhere to. The most up-to-date paradigm of IPM is ecology based approach which is promoted by FAO world wide in the form of Farmers Field Schools (FFS). Through interactive learning and field-experimentation, FFS programs teach farmers how to experiment and problem-solve independently, with the expectation that they will thus require fewer extension services and will be able to adapt the technologies to their own specific environmental and cultural needs (Vasquez-Caicedo *et al.,* 2000). Extension agents, who are viewed as facilitators rather than instructors, conduct learning activities in the field on relevant agricultural practices. In the FFS, a method called "agro-ecosystem analysis" is used to assess all beneficials, pests, neutral insects and disease, and then determine if any intervention like a pesticide spray is needed. Economic Threshold Levels are discussed in the FFS, but crop protection decisions are based on conserving beneficial insects/spiders.

The Indonesian tropical wet rice ecosystem the IPM field school experience (Kenmore, 1980, Way and Heong, 1994 and Settle, *et.al.,* 1996) shows that

- Beneficial insects/spiders comprise the majority of species in healthy ecosystems. 64% of all species identified were predators (306 species) and parasitoids (187 species); neutrals (insect detritivores, plankton feeders) comprise 19% (Settle *et.al.,* 1996) and Rice pests constitute only 17% of species.
- Beneficials are extremely effective in controlling major rice pests; very substantial reduction of pesticide applications does not threaten rice yield.
- Contrary to previous understanding, beneficials typically enter the tropical wet rice ecosystem before pests, and feed on detritivores and other "neutral" insects, e.g., Springtails (*Collembola*) and Midge larvae (*Chironomidae*) already present in the rice paddy. Beneficials are therefore present from the start of the crop season and effective in pest control from an earlier stage than had previously been assumed (Settle, *et. al.,* 1996; *Wu et. al.,* 1994)

These learnings should have led to research to understand the complex interaction between ecology, agronomy, biology, and climatology to develop ecologically-based disease and insect control strategies. But FFS mostly remained as a paradigm shift in agricultural extension: the training program that utilizes participatory methods "to help farmers develop their analytical skills, critical thinking, and creativity, and help them learn to make better decisions". The agriculture research and extension system world wide still believes that pesticides are inevitable in agriculture.

The effectiveness of the IPM FFS could have been enhanced by broadening the focus from a single crop to a broader systems approach, to address other matters, such as water management, crop rotation, crop diversification and marketing (Mancini, 2006).

Though FFS is seen as a knowledge intensive process, main focus was on taking external institutional knowledge to farmers. Proper space was not provided for traditional knowledge and practices or grass root innovations by farmers. In a study by Mancini (2006) evaluating the cotton IPM FFS in Andhra Pradesh, farmers reported that their confidence in implementing the new management practices was not strong enough to translate into a change in behaviour. This supports the argument that an effective, empowering learning process is based on experience, rather than on simple information and technology transfer (Lightfoot *et al*., 2001).

Pesticide industry is aware of the growing pest resistance towards their pesticides. Many of the pesticides become ineffective as the pests develop resistance and loose their market before they can recover the costs involved in developing the product leaving aside profits. This situation has forced the pesticide industry to come up with their paradigm of IPM called 'Insecticide Resistance Management' (IRM) which is a proactive pesticide resistance-management strategy to avoid the repeated use of a particular pesticide, or pesticides, that have a similar site of action, in the same field, by rotating pesticides with different sites of action. This approach will slow the development of one important type of resistance, target-site resistance, without resorting to increased rates and frequency of application and will prolong the useful life of pesticides. This resistance-management strategy considers cross-resistance between pesticides with different modes of action resulting from the development of other types of resistance (e.g., enhanced metabolism, reduced penetration, or behavior changes) (PMRA, 1999).

Though pesticide industry states that it fully supports a policy of restricted pesticide use within an IPM programme, the industry's view of IPM differs from that of many workers in the field in that it perceives a clear need for pesticides in most situations. Furthermore, its practice of paying pesticide sales' people on a commission basis, with increased sales being rewarded with increased earnings, is unlikely in practice to encourage a limited use of pesticides (Konradsen, 2003).

Right from the time of the Rio Earth conference, India has been highlighting this IPM policy in all its official documents. The ICAR had also established a National Centre for Integrated Pest Management in 1998. In India a total of 9,111 Farmers' Field Schools (FFSs) have been conducted by the Central Integrated Pest Management Centres under the Directorate of Plant Protection, Quarantine & Storage from 1994-95 to 2004-05 wherein 37,281 Agricultural Extension Officers and 275,056 farmers have been trained in IPM. Similar trainings have also been provided under various crop production programmes of the Government of India and the State Governments.

IPM is sought to be made an inherent component of various schemes *viz*., Technology Mission on Cotton (TMC), Technology Mission on Oilseeds and Pulses (TMOP), Technology Mission on Integrated Horticultural Development for NE, J & K, Himachal Pradesh, Uttaranchal, Technology Mission on Coconut Development etc. besides the scheme "Strengthening and Modernization of Pest Management" approach in India being implemented by the Directorate of PPQ&S [Plant Protection, Quarantine & Storage].

The problems with chemical pesticides also prompted the research systems industry to look for alternatives. Several schemes and projects have been initiated to research, produce and market biopesticides and biocontrol agents which are recommended as non chemical approaches to pest management.

Today, there is much data generated by the agriculture research establishment in India to show that non-chemical IPM practices across crops have yielded better results in terms of pest control and economics for farmers. However, the field level use of pesticides has not changed much. Though the pesticide consumption in the country has come down the actual progress of IPM on the ground has been quite limited. Further, even if pesticide consumption has decreased in terms of quantities due to a shift to consumption of low-volume, high-concentration, high-value pesticides, the real picture in terms of number of sprays and costs involved is still the same for the farmers.

The Integrated Pest Management (IPM) initiatives which have come up as an alternative though largely debates about the effects of pesticide on human health and on environment still believe that pesticides are inevitable, at least as a last resort and suggests safe and 'intelligent use'. On the other hand, replacing chemical products by biological products by itself may not solve the problem of pest management with restoration of ecological balance. While the inevitability of pesticides in agriculture is promoted by the industry as well as the public research and extension bodies, there are successful experiences emerging from farmers' innovations call for a complete paradigm shift in pest management.

## Non Pesticidal Management

The ecological and economical problems of pests and pesticides in agriculture gave rise to several eco-friendly innovative approaches which do not rely on the use of chemical pesticides. These initiatives involved rediscovering traditional practices and contemporary grass root innovations supplemented by strong scientific analysis mainly supported by non-formal institutions like NGOs. Such innovations have begun to play an important role in development sector. This trend has important implications both for policy and practice. One such initiative by Centre for World Solidarity and Centre for Sustainable Agriculture, Hyderabad was Non Pesticidal Management.

The 'Non Pesticidal Management' which emanates from collaborative work of public institutions, civil society organizations and Farmers in Andhra Pradesh shows how diverse players when come together to work in generating new knowledge and practice, can evolve more sustainable models of development.

Pest is not a problem but a symptom. Disturbance in the ecological balance among different components of crop ecosystem makes certain insects reach pest status. Therefore any rational approach to pest management should focus on preventing insects from reaching damaging proportions by restoring ecological balance. From this perspective evolved the Non Pesticidal Management which is an 'ecological approach to pest management using knowledge and skill based practices to prevent insects from reaching damaging stages and damaging proportions by making best use of local resources, natural processes and community action'.

### Non Pesticidal Management is mainly based on

- Understanding insect biology and behavior and managing them before they reach damaging stage and proportions. These preventive measures will reduce the pest numbers.
- Understanding crop ecosystem and suitably modifying by adopting suitable cropping systems and crop production practices. The type of pests and their behavior differs with crop ecosystem. Similarly the natural enemies' composition also varies with the cropping systems.
- Building Farmers knowledge and skills in making best use of local resources and natural processes.
- Natural ecological balance which ensures that pests do not reach a critical number in the field that endangers the yield. Nature can restore such a balance if it is not meddled with too much. Hence no chemical pesticides/pesticide incorporated crops at all.

For an effective communication to farmers about the concept effectively and to differentiate from Integrated Pest Management which believes that chemical pesticides can be safely used and are essential as lost resort it is termed as 'Non Pesticidal Management'.

### It is a paradigm shift

- From understanding and acting based on plant-pest relationship to pest-ecosystem relationship
- From adopting input centric to knowledge and skill centric practices
- From using external inputs to local natural resources
- From linear learning to an interactive learning

**Red Hairy Caterpillar *(Amsacta albistriga)* Management (1989-93):** During late eighties, Red Hairy Caterpillar (RHC) was a major pest in the dryland areas of Telangana region of Andhra Pradesh. The pest attacks crops like castor, groundnut, sesame, sorghum and pigeon pea in the early stages and causes extensive damage in dry land areas. This forces farmers to go for 2-3 resowings or late sowing which affect the yield. The problem of crop failure due to delayed and uncertain rainfall was compounded by this pest damage. Resowings were happening in more than 30 % area.

Discussions with several voluntary agencies, farmers from different regions and few concerned scientists established that

1. this pest infests crops only on light red soils
2. there is only one generation of moths that lay the eggs producing the caterpillars and these moths appear in waves at the onset of the monsoon
3. there are only a few peak emergences of these moths, controlling the pest necessitated the destruction of the early emergence of the moths
4. the foraging caterpillars are also attracted to some wild non-economical plants such as calatropis, wild castor, yellow cucumber
5. the later instars of larvae had dense red hairs all over the body, which prevents pesticides from reaching the body of the insects as a result any pesticide sprayed will not reach the body of the insect.

Dr. N. K. Sanghi, Zonal Coordinator, Zonal Coordinating Unit of ICAR, Hyderabad and Dr Abdul Qyaoom, Retd. Joint Director Agriculture, working with ASW (later on Centre for World Solidarity-CWS), a Hyderabad based NGO organised these extensive field visits. Based on these observations initial management plan based on cultural practices and technologies based on indigenous knowledge were designed to manage the pest attacks.

The literature showed that the adults of RHC are attracted to light which was confirmed by the observations of the farmers. Community bonfires were taken up to attract the insects and kill them. Later on based on the experiences of Tamil Nadu farmers and ICRISAT light traps (electric bulbs) were used to attract the insects. Other alternative options like solar light traps were also used. It was also realized that community action is a prerequisite for any such activity. Similarly, deep summer ploughing to expose the pupae and neem sprays over the early instar larvae were recommended. Dr. M. S. Chari, the then Director, Central Tobacco Research Institute and a famous Entomologist helped to conceptualize a complete package for RHC management. CWS, ICAR zonal coordinating unit, Directorate of Oilseeds Research in Collaboration with Department of Agriculture initiated a Red Hairy Caterpillar Management program with financial support from ASW, Germany and OXFAM.

**Phase I:** 1989-91 covering 8700 ha in 95 villages across 12 districts of AP involving 21 Voluntary Organizations (mainly using community bonfires, trenches around the field, calotropis and jatropha cuttings etc)

**Phase II:** 1992-93 covering 9561 ha in 57 villages across 8 districts involving 16 Voluntary Organizations (mainly using community bonfires, light traps, trenches around the field, calotropis and jatropha cuttings etc)

RHC could be effectively managed in dryland crops like castor, groundnut, Sesame, Sorghum and pigeonpea. Farmers could avoid late sowing and only 4% of farmers went for re-sowing in areas where RHC management was followed. The practices are still recommended by the Agriculture University, Department of Agriculture and NGOs. Farmers continue to practice community bonfires, trenches, light traps etc.

Source: Qayum. M. A. and Sanghi. N. K. (1993) Red Hairy Caterpillar Management through Group Action and NPM Methods published by ASW and Oxfam (India) Trust.

## Basic set of practices followed

Growing healthy plants is the first step in Non Pesticidal Management. This involves

**Good Quality Seed:** Selection and use of good quality seed from traditional farmers' varieties or improved varieties released by the public sector institutions is important. Farmers develop a seed matrix regarding suitability of the different varieties into the cropping patterns, based on the soil types, reaction to pest and diseases and their consumption preference. They maintain the seed in their seed banks. This ensures farmers to go for timely sowing with the seeds of their choice. In rainfed areas timely sowing is one critical factor which affects the health and productivity of the crop. The seed is treated with concoctions depending on the problem for example cow urine, ash and asafetida concoction provides protection against several seed borne diseases like rice blast, or *beejamrut* to induce microbial activity in the soil and kill any seed borne pathogens. Similarly in crops like brinjal where there is a practices of dipping of seedlings in milk and dipping fingers in milk before transplanting each seedling was observed to prevent viral infections. Several such practices are documented and tested by the farmers.

**Reduce stress:** The pest and disease susceptibility increases with abiotic stress. Practices like mulching will improve the soil moisture availability.

**Build healthy soils:** Healthy soils give healthy crop. Chemical fertilizers especially nitrogenous fertilizer makes the plants succulent and increases the sucking pests like Brown Plant Hopper in rice. Building soil organic matter and improving the soil health in terms of positive soil microbes will improve the inherent resistance in the plants and reduce the pest and disease incidence.

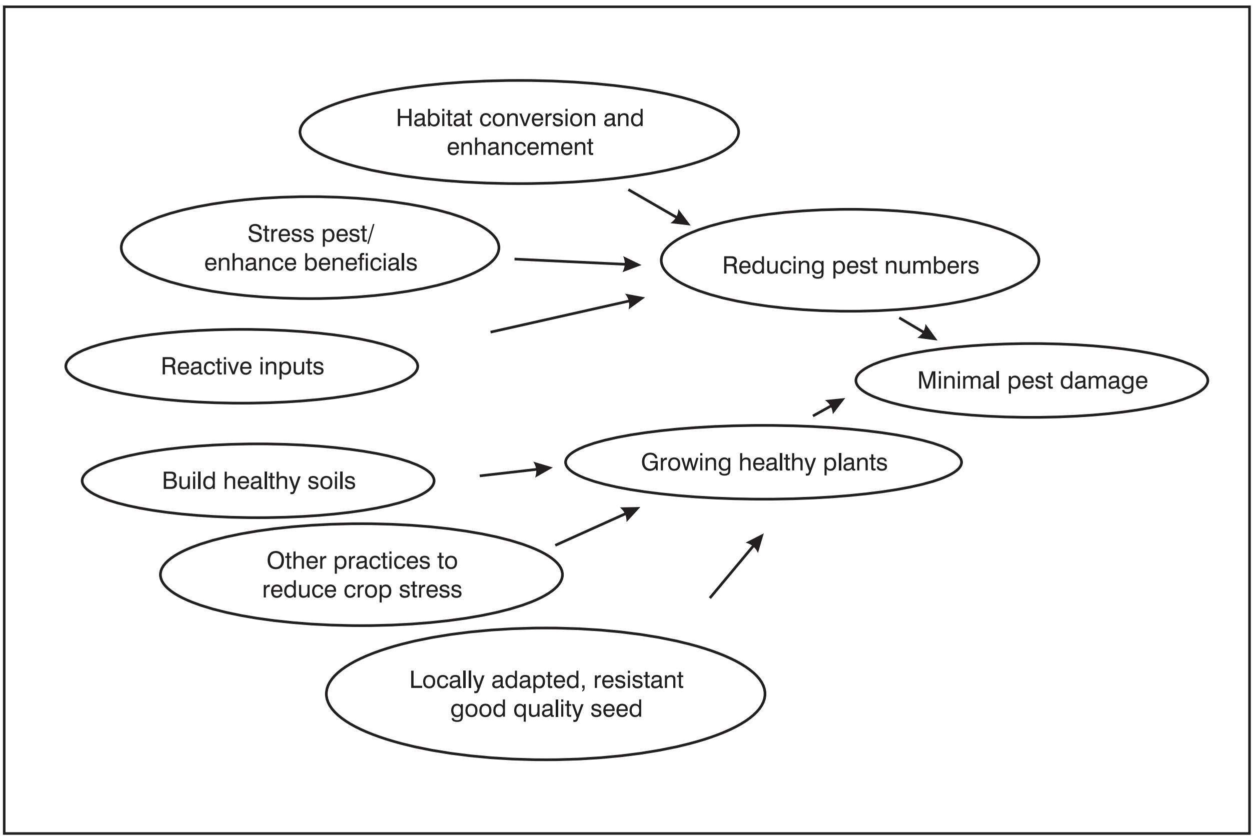


**Fig.1 Schematic Representation of Non Pesticidal Management**

## Enhancing the habitat

**Crop diversity:** Crop diversity is another critical factor which reduces the pest problems. Traditionally farmers have evolved mixed cropping systems, intercropping and crop rotation systems. These systems will create a better environment for nutrient recycling and healthy ecosystems. On the contrary the monoculture of crops and varieties lead to nutrient mining and pest and disease buildup. Under NPM farmers adopt mixed and intercropping systems with proper crop rotations.

**Border crops:** Many sucking pests fly from neighboring farmers' fields. In crops like chillies, groundnut, cotton, sunflower where thrips are a major problem, sowing thick border rows of tall growing plants like sorghum or maize will prevent insects from reaching the crop.

**Other agronomic practices:** Several crop specific agronomic practices like alley ways in rice to allow enough light to reach the bottom of the plant are documented by the farmers and suggested by the scientists.

## Understanding insect biology and behavior

**Life cycle:** In most of the insects which completely undergo complete metamorphosis, in the four stages of the life cycle, insects damage the crop only in one stage [larval stage in most of the cases] – at least two of the stages are immobile [egg and pupa]. The adult stage will not be on the crop. The different stages in the insect life cycle are morphologically different and relating between one stage and other is difficult unless one studies/observes the life cycle. Every insect has different behavior and different weaknesses in each of the stage. There are several options available to control them at each of these stages mostly using local resources. Similarly in insects with incomplete metamorphosis also understanding insects helps in managing them.

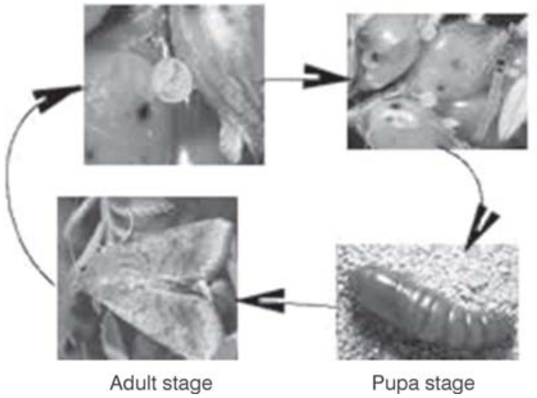


Fig.2 Typical Insect life cycle

**Biology:** The larva of Red Hairy Caterpillar (*Amsacta albistriga*) has a dense body hair over the body hence no pesticide reaches it when sprayed. There fore it needs to be controlled in other stages of its life cycle (see box). For any safe and economic method of pest management one must understand how the pest live and die, where does it come from and when, where and how does it damage the crop. Knowledge of these biological attributes of pest will help farmers to use NPM methods successfully on a sustainable basis (GAU 2003).

**Insect behavior:** Some insects like Spodoptera lay eggs in masses which can be identified and removed before hatching. Insects also have preference for ovi-position. Spotoptera prefers to lay eggs on castor leaves if available. Hence growing castor plants as trap crop is practiced. By observing the castor leaves farmers can easily estimate the Spodoptera incidence. Helicoverpa lays eggs singly, but has a preference towards Okra, Marygold (mostly towards plants with yellow flowers). Hence

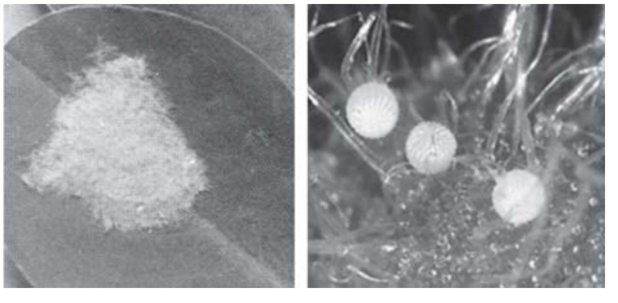

Fig.3 Egg laying behaviour of Spodoptera and Helicoverpa

marigold is used as a trap crop where ever helicoverpa is a major problem. The adult of red hairy caterpillar is known to get attracted to light. Hence organizing bonfires, using light traps etc will help in managing red hairy caterpillar. Rice Stem borer lays eggs on the tip of the leaves in nurseries; farmers remove these tips before transplanting.

Pheromone traps are used for mass trapping brinjal fruit and shoot borer (GAU 2003). Similarly, every insect in every stage of its life cycle has a different form and behavior. Monophagous pests have a different behavior compared to polyphagous pests. Understanding those helps in better management.

**Understanding crop ecosystem:** The pest complex and the natural enemy complex are based on the crop ecosystem. The pest complex of cotton is completely different from that of Sorghum. The pest complex in wet rice ecosystem differs from the pest complex in dry rice. Decision about any pest management intervention should take into account the crop ecosystem which includes cropping pattern, pest-predator population, stage of the crop etc. Similarly the management practices followed in one crop cannot be practiced certain other crop. For example in to manage *Helicoverpa* in pigeonpea, the farmers in Andhra Pradesh and Gulbarga use shake the plants and falling insects are collected over a sheet and killed (see box). This method cannot be adopted in cotton for managing helicoverpa because of the plant nature.

**Traditional Technology with a Modern Twist http://www.icrisat.org**

Farmers in south India used indigenous methods like shaking the plants manage the pod borer (*Helicoverpa armigera*) in pigeonpea until chemical insecticides were introduced in the early 1970s. After crop pollination and pod set, when 1-2 larvae per plant are noticed, three farmers/agriculture workers enter the field, one to hold/drag a polyethylene sheet on the ground, while the other two shake the plants. This gentle shaking can dislodge most of the caterpillars from the plants. These dislodged larvae are collected in a sack and destroyed.

During 1998-99 season, this technology was evaluated in a research watershed (15 ha) at ICRISAT-Patancheru with support from IFAD and in collaboration with ICAR, ANGRAU, MAU, and NGOs under the coordination of CWS.

The results showed 85% reduction in insect population, while the larval population in the adjacent, chemically sprayed plots remained high throughout the cropping period. This cost of this practice is just Rs 280 (US $ 6) per hectare to have 7 people to shake pigeonpea plants, and collect larvae; while each chemical spray costs Rs 500-700 (US $ 11-16) per hectare. This technology, initiated at a few locations during 1997, rapidly spread to more than 100 villages involving several thousand farmers in three states of southern India within two years.

Later, the larvae collected by shaking the plants were used for the multiplication of the Nuclear Polyhedrosis Virus (NPV), a biopesticide that kills *Helicoverpa.* The technology for NPV production involves collecting the larvae and feeding them with an NPV-infected diet till they die due to infection. NPV biopesticide is extracted from the dead larvae, and can be sprayed on crops to manage Helicoverpa attack.

This project proposal by ICRISAT and CWS had won the World Bank's Development Marketplace Award for 2005.

## Reactive sprays

Insect population may reach pest status if the preventive steps were not taken in time, changes in weather conditions and insects coming from neighboring farmers fields. Based on the field observations farmers can take up spraying botanical extracts and natural preparations (Green sprays). There are wide ranges of these preparations which are evolved by the farmers.

These preparations are mainly four kinds

**Aqueous or solvent extracts:** for example, Neem Seed Kernal Extract is very effective against many pests. There is a wide variation in the way these extraction is prepared. For extracting 'Allenin' from garlic kerosene is used as a solvent. After extraction this solution is mixed with chilli extract and used against sucking pests.

**Decoctions:** for example, plants like tobacco, *Nux Vomica* etc contain volatile compounds which can be extracted by boiling them in water to get the decoction. Several decoctions are used in pest management.

**Concoctions:** concoctions are mixtures. For example, five leave mixture which is a aqueous extract of any five latex producing leaves is used to control pests in Tamil Nadu and other parts of south India.

**Fermented products:** products made by fermenting the different botanicals with animal dung and urine. These products have rich microbial cultures which help in providing plant nutrients in addition to acting as pest repellents and pest control sprays. For example cow dung urine-asafetida solution is used to manage Rice blast.

### The Evolution of Dialogue on Non Pesticidal Management

In 1988, ASW (the parent organization of Centre for World Solidarity) organized People's Science Conference at Bangalore supported by EZE and ASW to promote concept of substituting synthetic chemical pesticides by a non-pesticide approach based on locally available resources. This led to a collaborative programme for non-pesticidal approach for controlling RHC in 1989 with Zonal Coordinator, Transfer of Technology (ToT) Unit, ICAR, Hyderabad; Department of Agriculture, ASW/CWS; OXFAM; and village based voluntary organizations as partners.

In 1994, CWS organized a workshop in collaboration with National Academy of Agriculture Research Management (NAARM), Hyderabad to bring together initiatives working in NPM across country. Several scientists and Civil Society Organizations have participated in the workshop. This workshop evolved a joint strategy paper on NPM.

In 1998, CWS organized second National Workshop on Non Pesticidal Management in collaboration with MANAGE in Hyderabad. The workshop which was participated by eminent scientists and civil society organizations called for expansion and popularizing the concept and practices.

In 2004, the sustainable agriculture desk in CWS was registered as an independent organization 'Centre for Sustainable Agriculture' (CSA) based in Hyderabad to address the larger issues in agriculture.

In 2004, Punukula, a small village in Khammam district of Andhra Pradesh which used to spend about Rs. 4 million annually on chemical pesticides to grow crops like cotton, chillies declared itself as a pesticide free after five years of NPM work.

In 2005, in the context of serious crisis in agriculture and farmers suicides, NPM got the attention of the Society for Elimination of Rural Poverty, Government of Andhra Pradesh which works with Federations of Women Self Help Groups and began scaling up by adopting an institutional approach across the state.

In *Kharif* 2007, NPM program reached 1500 villages with more than 200 thousand farmers participating covering 150 thousand ha. The success of the program in reducing the costs of cultivation and increasing the net incomes of the farmers has received Prime Minister's attention and was selected for a support from 11th Five Year Plan under National Agriculture Development Project to cover one million farmers cultivating one million ha in over 5000 villages.

In September 2007, CSA and WASSAN (sister organizations of CWS engaged in promotion of NPM) have organized a National Workshop on 'Redesigning support systems for rainfed farming' in collaboration with Rainfed Farming Authority and ICAR in New Delhi. The nationwide experiences of public sector and civil society organizations on local resource based, sustainable models in agriculture were discussed and urged the government to redesign the support systems to help promotion of such practices.

(Based on the internal documents, proceedings of workshops organized by CWS in 1994 and 1998, Ramanjaneyulu (2004))

## Successful case studies

### Punukula and Pullaigudem: The Pesticide Free Village

This is the story of how two villages in Khammam district of Andhra Pradesh put in efforts over a five year period (1999 to 2003) to rid themselves completely of pesticides. Today, the villagers do not use chemical pesticides at all - they are inspiring other farmers in their district and elsewhere to go the same way and improve their livelihoods. The Panchayat has passed a resolution that they would remain pesticides-free.

### The Punukula

For quite some time cotton has been the major crop in Punukula. It was cultivated as a monoculture and large amounts of pesticides were used to protect the crops. This caused a number of problems: there were cases of acute poisoning, which left people disabled for the rest of their life and caused enormous health service bills or ended fatal. The records of local hospital show that there used to be at least 50 to 60 poisoning cases per season earlier to 2000.

Another problem was caused by the credits that people took out to finance the pesticides. These credits caused the economics of farming to go out of control. The money seemed to have gone straight into the hands of the "single window" or "all-in-one" dealer. The dealer was indeed dealing a death blow to the farmers' dreams. He would be the one who would sell them seeds, fertilisers and pesticides – he would give these on credit to the farmers and even supply other credit. However, all of this was at high interest rates of 3-5% per month. Since the farmers were in no position to repay these loans, the agreement would be to sell their produce to this "all-in-one" dealer. The dealer in turn would inevitably fix the price at rates lower than the market value. The farmers had no choice but to accept the rate, in the hope that next year's investments would once again be supported by the dealer. The cycle became extremely vicious with no way out. The farmers were now truly on the Pesticides Treadmill.

Most people in the village recall with horror the strong clutches of the all-in-one dealer. The social stigma of indebtedness, especially at those times when the money lender put pressure for repayment is unbearable for many.

### The beginnings of the transformation:

In 1999, the local Non-Governmental Organisation, SECURE (Socio-Economic and Cultural Upliftment in Rural Environment), analyses with the villagers about their livelihoods revealed several problems related to their agriculture including lack of support for investment, higher expenditure each year, lack of marketing support, indebtedness etc. Realising that pesticides in cotton caused many of these problems, the organisation decided to work on the Non-Pesticidal Management (NPM).

After an initial hesitancy, the farmers gradually started realizing the difference. At the end of the first year, the positive results were already apparent with the NPM approach: In 2001-02, Non-Pesticidal Management work was taken up on 6.4 ha, with eight farmers in Punukula on cotton, and 7 ha with 3 farmers of pigeon pea.

Once again, in the conventional chemical plots, farmers experienced a negative income while the NPM farmers experienced a great economic improvement leaving them with positive net incomes.

**Table 1: Economics of NPM in Cotton Punukula village (*Kharif*, 2001-02) (on 6.4 ha, with 8 farmers in Punukula)**

| Particulars | NPM | Conventional |
|---|---|---|
| Avg. Yield (kg/ha) | 1575 | 1450 |
| Cost of plant protection ($ US/ha) | 107.50 | 214.88 |
| Net income ($ US/ha) | 85.50 | -130 |

By the second year, more farmers joined the effort as they had witnessed the good results first hand in the fields of the first year's participants. Farmers were also taken on exposure visits to other districts. There were more training-workshops held in the village. Slowly, word spread, and along with it, a serious conviction that getting rid of chemical pesticides is the only way out.

By 2002-03, the NPM was tried out in crops like Paddy, pigeonpea, cotton and chilli. The number of participating farmers went up to 59, with an area of 58 ha. The increased net incomes were to the satisfaction of the farmers.

In 2003-04, the acreage under NPM cotton went up to 480 ha in Punukula and Pullaigudem villages, covering all the cotton area of Punukula. The average yields remained around 3000 kg/ha. In Chilli, the discontinuation of pesticides also meant a great improvement in the quality of chilli and therefore, the produce fetched higher prices in the market.

## Impacts

In 2004-05, for a second year in a row, nobody in the village has gone anywhere near a pesticide dealer or dabba (pesticide storage). The Village Panchayat passed a resolution to announce that it is pesticides-free and would continue to be so. From the Panchayat's side, they requested pesticides dealers not to come into their village and market their products.

Farmers of the village were able to get rid of past debts in a couple of years' time. With the debt burden off, the farmers are willing to try out more and more ecological approaches, as well as try it on more crops. Farmers incomes have increased and started cultivating their fallow lands or leasing in from big farmers.

The ecological balance in the fields got restored. There are many more insects present in the fields, without any of them reaching

For the agricultural labourers also, things have improved on many fronts. There was a wage increase from 75 cents to one dollar during the corresponding period [when NPM was practiced]. They do not have to be exposed to deadly pesticides now, nor incur medical care expenses for treatment of pesticides-related illnesses. Some point out that there is even more work for the labourers – in the collection of neem seed, in making powders and pastes of various materials and so on. Farmers are even leasing in land and putting all lands under crop cultivation these days – this implies greater employment potential for the agricultural workers in the village.

a “pest” stage of threat. Birds are returning to the village, the villagers report. The health of the farmers improved – there are no more any cases of acute intoxication from the village.

The women’s groups bought a neem seed crushing unit in Punukula in 2004. This was done through the Panchayat with the help of Centre for World Solidarity, which gave a grant for the investment. Two women find full-time employment running this machine.

**The rapid spread of the approach:**

In Punukula, 174 farmers along with 120 farmers from Pullaigudem soon became capable of explaining to others the principles behind the new pest management approach and about how they were benefiting. Word spread both in sporadic ways and in a structured manner. Punukula farmers themselves decided to pro-actively spread the NPM message to nearby villages. Every relative that visits the village gets to hear about the transformation. Similarly, when Punukula farmers go to other places for other social purposes, they make it a point to bring up their story of NPM.

(Extracts from ‘Redefining Pest Management: a case study of Punukula’, Ramanjaneyulu and Zakir Hussain (2007))

## Enabavi: A Whole Village Shows the Way

Enabavi is probably the first modern-day organic farming village in Andhra Pradesh. The entire village, in each acre of its land, on every crop grown here, has shunned the use of chemicals in agriculture. They neither use chemical fertilizers nor chemical pesticides in their farming. This in itself meant a tremendous saving for the village in monetary terms. This small village in Lingala Ghanpur of Warangal district shows the way out of agricultural distress that almost all farmers find themselves in today.

Warangal district presents a classic paradox of an agriculturally developed district [with most area occupied by commercial crops] showing the worst manifestation of the distress of farmers – that of the highest number of suicides in the state in the past decade or so. It is a district where farmers’ frustration with lack of support systems manifests its self in almost-spontaneous and seemingly-well-planned agitations of unorganized farmers. Farmers in this district are known to have resorted to violence to end their problems, including resorting to a violent end to their own lives.

It is in this district that Enabavi stands out as a beacon of hope. Situated off the Hyderabad-Warangal highway near Jangaon town, Enabavi is today an inspiration to many other villages and farmers, thanks to the efforts of the local organization called CROPS, supported by other agencies like Centre for World Solidarity [CWS] and Centre for Sustainable Agriculture [CSA].

It is a small village which showed the resolve of a strong community which decided to take control of its agriculture into its own hands. With just 45 households in the village belonging mostly to the backward castes, the village started shifting to non-chemical farming about five years ago. Then in 2005-06, the entire land of 113 ha was converted to organic farming. This is not the organic farming as generally understood. No expensive external certification here. It is a model of “declared organic farming”. Though there are no formal participatory guarantee systems established in the village in this alternative model of organic farming, there is strong social regulation within the community to ensure that there are no ‘erring farmers’. The elders in the village take the youth along with them. They also have started investing in teaching their school-going children the knowledge and skills of non-chemical farming. Special training sessions have been organized by CROPS to rope in children into this new system of cultivation in the village.

The farmers here grow their food crops of paddy, pulses, millets etc., mostly for household consumption. In addition, they also grow crops like cotton, chilli, tobacco and vegetables for the market. Their average spending on chemical fertilizers and pesticides across crops used to be around $ 220 US per ha, while it was around Rs. $ 31.25 US/- per ha for seeds and this more often than meant credit from the input dealers, who would also double up as traders for the produce. These traders would dictate the price for the produce in addition to charging interest for the inputs supplied. Now, all of this has changed.

The process of change began with a programme that CWS had initiated to control the dreaded Red Hairy Caterpillar, in the late 90s. This was followed by converting all crops to the NPM. Later, some farmers came forward to shift from chemical fertilizers to other methods of soil productivity management. They started looking for other options like tank silt application, poultry manure application, vermi-compost, farm yard manure etc. CROPS stepped in at this point of time and subsidized the costs up to 50% for tank silt application and setting up vermin-compost units. The farmers set up their units at their fields and started following various ecological practices being recommended to them. They also started to depend on their own seed for many crops, except for crops like cotton. They set up farmers' self help groups for men and women separately and started thrift activities too.

Today, Enabavi has many valuable lessons to teach other farmers, not just on how to take up sustainable farming. They also have lessons to share on social regulation, learning from each other, the benefits of conviction born out of experience and most importantly, the way out of agricultural distress by taking control over one's own farming.

## NPM scaling up with SERP

Society for Elimination of Rural Poverty (SERP) is a registered society under Department of Rural Development implementing the largest poverty alleviation project in the state of Andhra Pradesh. The project understands that sustainable poverty eradication requires the recognition of the poor as active partners in the processes of social change; therefore all project interventions are demand based and are in response to the proposals conceived and planned by the poor.

SERP works towards empowering the poor to overcome all social, economic, cultural and psychological barriers thru self managed institutions of the poor. The project reaches the rural poor families thru social mobilization processes and formation of SHGs, federation of these into Village Organizations at village level and Mandal Samakhyas at the mandal level. The project envisages that with proper capacity building the poor women's federations would begin to function as self managed and self reliant people's organizations. The poor have started to demonstrate that they can shape their own destinies when adequate knowledge, skills and resource support is accessible to them.

In this context SERP initiated to work on agriculture based livelihoods supporting them to adopt sustainable agriculture practices to reduce the costs of cultivations. Learning from the experiences of villages like Punukula SERP initiated scaling up of NPM in collaboration with a consortium of Non Governmental Organizations and technical support provided by Centre for Sustainable Agriculture (CSA).

## Critical issues in scaling up

While the sustainable models in agriculture like NPM are established on smaller scale scaling up these experiences poses a real challenge in terms of

- Relevance of small experiences for a wider application
- Availability of resources locally
- Farmers willingness to adopt these practices

- Lack of institutional and support systems
- Supplementing farmers' Knowledge and enhancing the skills
- Reducing the time of transformation
- Reaching to larger areas with minimal expenditure
- Establishing extension system which give community a central stage

### Piloting in 2004-05

During December, 2005 a small pilot was launched in Kosigi Mandal (Blocks in Andhra Pradesh) as a livelihood intervention with the help of WASSAN. Farmers were trained systematically and technical support provided in the form of coordinators who were accountable to the Women SHGs. In 90 ha, average savings of $ 75 US/ha on pigeon pea the total savings were $ 6875 US (WASSAN, 2006).

### Grounding the work 2005-06

Based on the experiences drawn from the pilot, program for 2005-06 initiated by establishing clear institutional system and a community managed extension system in nine districts of AP. Five villages were grouped into a cluster and are provided with a cluster activist. Each village had a practicing farmer selected as village activist who coordinates the village level capacity building programs in the form of Farmer Field Schools. All over nine districts 12,000 farmers with 10,000 ha in both *Kharif* and *Rabi* adopted Non Pesticidal Management. Sixty two Federations of Women SHGs (Mandal Mahila Samakyas or MMS), 150 Cluster activists and 450 village activists are involved in managing the program. Each MMS entered into an agreement with This clearly established that a paradigm shift in understanding pest management both at farmers level and extension system level can effectively tackle the pest problem and also give ample benefits to farmers in terms of savings on input costs, health costs etc. Better quality products from such production systems also fetch a better price to farmers and are highly preferred by discerning consumers (refer http://www.downtoearth.org.in/default20060531.htm). Also, the NPM intervention for the first time shifted the control in terms of production back to the farmer (Sopan 2006).

Awareness created through state level campaign about the ill effects of pesticides and the potential alternatives – communication material created and distributed for use. Each participating farmer saved up to $ 160 US to $ 310 US per ha on an average (average across crops and across districts) on pest management expenses. With more area and more farmers coming into the program the saving will be higher. The ecological and other benefits would be enormous.

Nearly 30 neem seed powder units were established with SHGs along with 15 NPV units as village enterprises.

**Table 2: Economics of NPM across crops (2005-06)**

| Crop | Cost of Plant protection ($ US/ha) | | Saving |
|---|---|---|---|
| | Conventional | NPM | ($ US/ha) |
| Cotton | 315 | 63 | 252 |
| Chillies | 940 | 125 | 815 |
| Pigeon pea | 94 | 20 | 74 |
| Groundnut | 94 | 20 | 74 |
| Castor | 125 | 25 | 100 |
| Paddy | 125 | 15 | 110 |

The experiences during 2005-06 clearly showed the benefit of moving towards non chemical approaches in agriculture and farmers were enthused by these approaches. SERP has organized a state level mela at Krishi Vigyan Kendra, Banaganpalli, Kurnool district along with scientists from Agriculture University, ICAR institutions and KVKs.

## Moving to Community Managed Sustainable Agriculture

The successful grounding of NPM during 2005-06 has given important learning on how any ecologically sound and economically benefiting technology can be scaled up by providing proper institutional support. During 2006-07 more farmers in the same villages and more villages in the same districts and few newer districts joined the program. The program covered 1250 villages in 17 districts covering wide variety of crops from groundnut, paddy to chillies and cotton. Program expanded to districts like Guntur where the pesticide problem is serious and north coastal Andhra Pradesh where the productivities are in general low. The program is implemented in Adilabad, Ananthapur, Chittor, Guntur, Kadapa, Karimnagar, Khammam, Kurnool, Mahaboobnagar, Medak, Nalgonda, Nellore, Ranga Reddy, Srikakulam, Visakhapatnam, Vijayanagaram and Warangal. More than 80,000 farmers cultivating about 80 thousand ha. In addition to pest management initiations on soil productivity management and seed management have begun on a small scale. Agriculture credit from formal banks was mobilised in 3 districts to the tune of $ 150 million US.

In addition to NPM, efforts were initiated to establish seed networks so that farmers produce and share their seed. The pilot in Ananthapur has shown good results. In addition efforts are also began to have non chemical soil productivity improvement practices based on the experiences of the villages like 'Yenabavi' in Warangal which became the first organic village in the state. The benefits are not only seen in areas of high pesticide use but in areas of low pesticide use. The crop could be saved from the pests and diseases and managed well instilling new interest in the farmers.

During 2006-07 while the institutional systems are further strengthened focus was also given to specific commodities like paddy in Kurnool dist, Groundnut in Kurnool, Pigeon pea in Mahaboobnagar, cotton in Warangal and Khammam and Chillies in Guntur. The marketing links were explored. The NPM products were in demand and could command premium in the market. The local processing and marketing of the commodities have also brought in additional benefits to the farmers.

**Table 3: Reduction in pesticide usage in Ananthapur, 2005-06**

| Village | No. of Farmers | NPM area (in ha) (2005-06) | 2003-04 Pesticide usage(in lit) | Value of pesticides ($ US) | Value of NPM extracts ($ US) | Total saving ($ US) |
|---|---|---|---|---|---|---|
| Chinnajalalapuram | 39 | 73 | 7,000 | 13,500 | 1365 | 12,135 |
| Madirepalli | 36 | 56 | 5,000 | 10,000 | 1112 | 8,888 |
| Guruguntla | 36 | 42 | 4,687 | 16,400 | 910 | 15,490 |
| **Total** | **111** | **171** | **16,687** | **39900** | **3387** | **36513** |

Source: RIDS, Ananthapur

Table 4: Savings on pesticides during 2006-07

| Crop | Area (ha) | Avg.Savings/ha ($ US/ha) | Total Savings (Million $ US) |
|---|---|---|---|
| Cotton | 16,170 | 312 | 5.05 |
| Paddy | 20,112 | 63 | 1.27 |
| Pigeon pea | 9,732 | 75 | 0.73 |
| Groundnut | 9,200 | 50 | 0.46 |
| Chillies | 1500 | 937 | 1.41 |
| Others | 10,400 | 63 | 0.66 |
| **TOTAL** | **67,114** | | **9.56** |

This scaling up experience in AP has broken the myth that pesticides are inevitable in agriculture and also given important lessons on the paradigm shift in technology, institutional systems and support systems required for sustaining agriculture especially of small and marginal farmers.

## Restoration of ecological balance 2006-07

During *Kharif* 2007-08 the program is further expanded to cover 1,500 villages in 18 districts. There are more than 200 thousand participating farmers cultivating 150 thousand ha. In the villages which are in second year, works on soil productivity management with local resources and local seed management have been planned.

- Special focus on certain commodities to deal with post harvest management to increase the value of the commodities. This year village level quality control centers are initiated in chilli producing villages.
- The marketing Community Resource Persons working with women SHGs were also trained in NPM and in 50 clusters (250 villages) they started motivating farmers to adopt NPM practices.
- Best performing villages are identified as resource villages and best practicing farmers are identified as community resource

Table 5: Harmful vs. beneficial insects in cotton in Nalgonda district (*Kharif*, 2006-07)

| Sl. No. | Date of observation | Number of beneficial insects (10 plants) | Number of harmful insects (10 plants) | Number of bolls/plant |
|---|---|---|---|---|
| 1 | 11.08.06 | 7 | 3 | 18 |
| 2 | 25.08.06 | 11 | 8 | 22 |
| 3 | 01.09.06 | 9 | 11 | 26 |
| 4 | 08.09.06 | 13 | 12 | 28 |
| 5 | 15.09.06 | 13 | 14 | 32 |
| 6 | 22.09.06 | 14 | 13 | 40 |
| 7 | 29.09.06 | 16 | 14 | 50 |
| 8 | 06.10.06 | 9 | 9 | 54 |
| 9 | 13.10.06 | 10 | 8 | 60 |
| 10 | 20.10.06 | 17 | 5 | 65 |

Source: Kamadhenu RMG, Nalgonda dist.

persons who will help in further scaling up of the program.

- Community Seed Banks where farmers produce, save, share and use their own quality seed would be established in 70 villages.
- Program will also be integrated with other ongoing programs like National Rural Employment Guarantee Program (NREGP) to provide further employment opportunities to the agriculture workers.
- Total program expenditure is coming to about $ 11 US/ha

The State government proposed to scale up NPM into organic farming in 5000 villages over next five years covering 10 million ha with an outlay of $ 45.5 million US. The proposal has been accepted under Additional Central Assistance from Prime Minister's package for distress states.

## Conclusions

The pests and pesticides have seriously affected the farm based livelihoods in rural areas. The last three years experience in Andhra Pradesh shows that moving towards local resource based sustainable agriculture as the only way to sustain the livelihoods of small and marginal farmers and Community Based Organizations like Federations of women self help groups form an excellent institutional platform for scaling up such models. To sustain agriculture and agriculture based livelihoods, this calls for a complete paradigm shift in the way agricultural practices are understood, developed, promoted and supported. The new paradigm is based on the local resource based technologies and a community managed extension systems.

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# Community Managed Sustainable Agriculture

**D.V. Raidu and G.V.Ramanjaneyulu***

## Abstract

The Non Pesticidal Management initiative by the Society for Elimination of Rural Poverty (SERP) through Mandal Mahila Samakhya (MMS) in collaboration with NGOs in the last three years shows that moving towards local resource based sustainable agriculture is the only way to sustain the livelihoods of small and marginal farmers. The women self help groups form an excellent institutional platform for scalingup such models. During *kharif,* 2007 the program covered 5 lakh acres across 18 districts of Andhra Pradesh covering all the farmers in about 1600 villages benefiting 2 lakh farmers. The program is also integrated with ongoing programs like NREGA on pilot scale to provide further employment opportunities to the agriculture workers.

The last three years experiences have brought in big learnings in terms of sustaining agriculture based livelihoods. The costs of cultivation could be brought down ranging from Rs. 2000/acre in crops like redgram, groundnut, to Rs. 10,000/acre in chillies. The savings on other ecological and health costs is an added bonus. In Ramachandrapuram, a small village in Khammam District of Andhra Pradesh, all the 400 odd farmers could get back all their mortgaged lands back from the savings made in the last three years. There are more than 50 villages which have gone pesticide free during *kharif,* 2007. This program will be further strengthened with Additional Central Assistance under Rastriya Krishi Vikas Yojana to reach 5000 villages in next five years covering 25 lakh acres (10 % of state area) with an outlay of Rs. 182 crore.

## Introduction

Small and marginal farmers in several parts of India are in distress. Farmers in the States like Andhra Pradesh (A.P.), Maharashtra, Karnataka and Punjab are resorting to suicides due to high-levels of indebtedness and helplessness. The ever increasing costs of cultivation due to excessive dependency on external inputs and stagnation in market prices have made agriculture more and more non-remunerative. This can be analyzed through a simple equation: Input (costs far exceeds) > Output (price).

In the current situation, all "*factors of agriculture production*" are external to the farmer or farming community except for land and labor. This is more acute in the case of small and marginal farmers. The agricultural situation is characterized by:

- *The ever increasing costs of cultivation* due to high usage of inputs particularly pesticides and other chemicals, and heavy dependence on ground water extraction.
- *Non-remunerative market prices for the output* – growing globalization of trade resulting in decline in prices of commodities.
- *Increasing awareness and sophistication on the consumers' part* who are shying away from food products with high levels of pesticides and other chemicals.

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The spiraling costs of inputs specially seeds, fertilizers and chemicals have increased the cost of cultivation enormously. The result is serious indebtedness in the rural areas, farmers' suicides and large scale migration to urban centers. At this juncture, we need to deepen our understanding of how the agricultural value-chain affects small and marginal farmers and rural incomes. The crisis needs to be understood and several long-term interventions have to be initiated to address it.

## Moving towards sustainability

Agriculture is primary occupation of the rural masses. Unless agriculture becomes profitable by increasing the net profits and more realizable income, the impacts of other initiatives will not be seen. Therefore the focus needs to be on making agriculture and agriculture based livelihoods more sustainable.

Sustainable Agriculture is the one which is self reliant, situation specific, environmentally safe, knowledge intensive, resource-conserving and economically profitable [fair price obtained and net incomes increased] with a special focus on women, dalits, small and marginal farmers and tribal communities. The approach is that of Integrated Farming Systems. Such agriculture is expected to provide livelihood and food security to the communities that we engage with. Such agriculture also requires us to closely involve farmers and agricultural workers at all stages of the value chain to improve the village economy.

## Existing efforts

In the last 15-years, Centre for World Solidarity, Centre for Sustainable Agriculture (CSA), Deccan Development Society, MARI, WASSAN and several other grassroots NGOs in Andhra Pradesh have established strong evidence that regenerative and resource-conserving technologies and practices can bring both environmental and economic benefits for farmers and communities. Similar successes were established by various initiatives across the world by various grassroots organizations both in voluntary and public sector domain. All successes have had three elements in common and there is much to be learnt from these.

- **First**, of locally adapted, resource conserving, knowledge-centric, farmer-led technologies.
- **Second**, coordinated action by communities and community based institutions
- **Third**, supportive external government and/or non-governmental institutions working in partnership with farmers.

The crisis in agriculture which surfaced in the form of farmers suicides during 2004-05 forced the development organizations and state government to look for alternative models of agriculture which can sustain the livelihoods of the people depending on agriculture. The success of 'Punukula' village in Khammam District with support from Centre for Sustainable Agriculture which sustained the farming by switching over to Non Pesticidal Management (NPM) has attracted the attention of the state and centre. Hon'ble Minister for Agriculture, Government of Andhra Pradesh, Sri. Raghuveera Reddy visited the village along with Agriculture Scientists and Department Officials and appreciated the effort done by the farmers. Prof. Jayati Gosh, Chairperson of the Commission appointed by Government of Andhra Pradesh also visited the village and suggested to take up on a larger scale. Learning from these experiences SERP has taken up NPM on a pilot basis in Kosigi Mandal of Mahaboobnagar District with support of WASSAN and CSA during December'04 –April '05, covering 350 farmers growing red gram in 400 acres in 12 villages. The farmers could save more than Rs. 1500/acre on pest management.

## Grounding the work, 2005-06

During 2005-06, NPM was initiated in 450 villages with 23000 acres in 9 districts. All over 9 districts 11766 farmers with 22581 acres in both *kharif* and *rabi* implemented the program. Sixty two MMS, 150 Mandal

### Rolling out

**Mass campaign:** A state level campaign on the impacts of pesticides was initiated by CSA and network of NGOs through Media, through Kalajatha (folk) in almost all the districts.

**Establishing field experience:** Mandal has been taken as a unit with 3-5 villages, in each mandal with around 30-35 farmers in each village in the first year gradually covering the entire village in two years time. Farmers were identified after an initial campaign on the alternatives is carried out. Villages were selected so that all are more or less in close vicinity. Districts were selected based on ongoing work, existing experience and areas where pesticide-related problems are high. In each district upto 5 mandals where pesticide usage is high were selected for implementation of the program.

**Farmers' Field Schools:** Farmers are grouped into Farmers' Field Schools (Sasyamitra Sangha). These are learning groups which meet regularly in the fields and learn by doing. Village Activist will coordinate the conduct of the field schools. Gradually they would be federated to form 'Rythusanghas' at the village level. Resource material in the form of manuals, flip charts, films are produced and placed with every group.

In these districts, experienced NGOs from the Sustainable Agriculture Network (SANET) coordinated by Centre for Sustainable Agriculture (CSA) were identified and are associated with the programme. Initially two or three mandals were selected for facilitation by these NGOs. In each village a practicing farmer is selected as village activist to coordinate the work. At the cluster level (of five villages) Cluster Coordinator helps in coordinating the work. The Cluster Coordinators are trained regularly by the supporting NGOs.

**Program Management with MMS:** Continuing the spirit of SERP, the entire program is anchored with the Mandal Mahila Samakhyas' and their Village Organisations. The Funds are released to the MMS and the Samakhya appoints Cluster Activists and enter into agreement with NGOs. The program is regularly reviewed by the NPM sub committee at the VO, MMS and Zilla Samakyas.

Support is only in the form of technical support or any infrastructure like neem seed powder making units. Committees with DRDA officials are also formed at the district level. At the state level State Executive Committee Coordinates the work. An Annual General Body Meeting will review the implementation, discuss and finalize the program and guidelines every year in February.

level coordinators and 450 village activists are involved in the program. This clearly established that a paradigm shift in understanding pest management both at farmers level and extension system level can tackle the pest problem and also give ample benefits to farmers in terms of savings on input costs, health costs etc. Better quality products from such production systems also fetch a better price to farmers and are highly preferred by discerning consumers (refer http://www.downtoearth.org. in/ default20060531.htm). Also, the NPM intervention for the first time shifted the control in terms of production back to the farmer.

## Community Managed Sustainable Agriculture 2006-07

The successful grounding of NPM during 2005-06 has given important learning on how any ecologically sound and economically benefiting technology can be scaled up by providing proper institutional support. During 2006-07 more farmers in the same villages and more villages in the same districts and few newer districts joined the program. The program covered 1250 villages in 17 districts covering wide variety of crops from groundnut, paddy to chillies and cotton. Program expanded to districts like Guntur where the pesticide problem is serious and north coastal Andhra Pradesh where the productivity is in general low. The program is implemented in Adilabad, Ananthapur, Chittor, Guntur, Kadapa, Karimnagar, Khammam, Kurnool, Mahaboobnagar, Medak, Nalgonda, Nellore, Ranga Reddy, Srikakulam, Visakhapatnam, Vizianagaram and Warangal. More than 80,000 farmers cultivating about 1.8 lakh acres. In addition to pest management, initiatives on soil productivity and seed management have begun on a small scale. Agriculture credit from formal banks was mobilised in 3 districts to the tune of 15 crores.

In addition to NPM, efforts were initiated to establish seed networks so that farmers produce and share their own seed. The pilot in Ananthapur has shown good results. In addition, efforts also began to have non chemical soil productivity improvement practices based on the experiences of the villages like 'Yenabavi' in Warangal which became the first organic village in the state.

The benefits are not only seen in areas of high pesticide use but in areas of low pesticide use. The crop could be saved from the pests and diseases and managed well instilling new interest in the farmers. The Community Seed Banks were piloted in 12 villages of Ananthapur which showed very encouraging results. The farmers could produce and share seed with fellow farmers at the village level in crops like groundnut, paddy and pulses.

During 2006-07, while the institutional systems are further strengthened focus, was also given to specific commodities like paddy in Kurnool dist, Groundnut in Kurnool, Red gram in Mahaboobnagar, cotton in Warangal and Khammam and Chillies in Guntur. The marketing links were explored. The NPM products were in demand and could command premium in the market. The local processing and marketing of the commodities have also brought in additional benefits to the farmers. This scaling up experience in AP has broken the myth that pesticides are inevitable in agriculture and also given important lessons on the paradigm shift in technology, institutional and support systems required for sustaining agriculture especially of small and marginal farmers.

## Consolidating experiences and converging efforts 2007-08

During *kharif* 2007-08 the program was further consolidated in the existing villages and Star procument centres of SERP. In the villages which are in second year, works on soil productivity management with local resources and local seed management have been initiated.

This year Spices Board came forward to support the NPM program in Chillies. Sixty percent of India's chillies exports are from Andhra Pradesh and often the export consignments (included the processed products like pickles) are rejected due to pesticide residues. This year all the star procurement centres of SERP are also brought under NPM so that the production and market linkages can be easily established. The marketing Community Resource Persons are also trained in NPM and would be used in the program. Similarly best performing villages are identified as resource villages and best practicing farmers are identified as community resource persons who will help in further scaling up of the program.

*Kharif* (2007-08) program covered 5 lakh acres across 18 districts (Nizamabad is added) covering all the farmers in about 1600 villages benefiting 2 lakh farmers. This year the program is also integrated with ongoing programs like NREGA on pilot to provide further employment opportunities to the agriculture workers. The last three years experience shows that moving towards local resource based sustainable agriculture as the only way to sustain the livelihoods of small and marginal farmers and women self help groups form an excellent institutional platform for scaling up such models.

## Moving Forward

**Natural Resource Management:** A strong Natural Resource base is a prerequisite for promoting ecological farming. This includes improving soil health and productivity by using organic manures, improving the biomass and bio diversity at the village level in both private and common lands, restoring the tanks and evolving social regulation processes on to share and optimize water usage and adopt cropping patterns based on water budgeting. The opportunities provided by the NREGA will be fully utilized at the village level to benefit both agriculture workers and farming community.

**Community Seed Banks:** Today seed is unavailable both in quantity and quality. All the public sector institutions, seed corporations and private companies put together do not supply more than 18 % of the total seed. In this background, it is proposed to initiate and promote community based seed networks which select locally suitable seed, use, multiply and share with communities. These banks focus on selection and reuse of quality seed by the farmers with a focus to maintain crop and varietal diversity. These seed banks will plan and manage the seed requirements in the village. The would be procured from the fellow farmers, Agriculture University, ICAR institutions and international institutions like ICRISAT. Self sufficiency is achieved at the community/village level. Several such seed banks will be federated with an effective decentralized production, procurement, storage, distribution and marketing network in which 'Community Based Organizations' at village level plays the key role.

**Integrating livestock and dairying:** The livestock population in villages is dwindling due to mechanization and fodder crisis. Livestock on one hand acts as bio recycling units which convert the biomass-fodder, crop residues etc into valuable dung which improve the soil health and productivity and on the other hand help farmers to diversity their income source by selling the milk. The village milk procurement centres initiated by SERP has a very positive result. This initiative would be taken up to all the villages under CMSA.

**Credit Support:** a soft credit is a necessary requirement for farmers. By adopting sustainable agriculture, the farmers not only reduce their input costs but could make their investments productive. The experience of 2007-08 season in four districts shows that the farmers can easily repay the loans. Provision of a Community Investment Fund as a revolving fund at the village level which can be borrowed by the farmers through VOs at a low interest rate, will help the farmers to come out of the dependency on traders for inputs and credit which make them vulnerable to the exploitation. The high interest rates also increase the debt burden.

## Post Harvest Management

The post harvest management at the village level is an important issue to be addressed in every crop. This generates additional income in the village and improves the quality of produce and help farmers in getting better price.

- The experiences on processing and marketing of Red gram dal shows the benefits.

- Village Quality Assurance centres to handle crops like chillies which has aflatoxin problems will be initiated this year with support from Spices Board.
- Clean picking of Cotton will improve the quality of cotton
- Micro spinning of cotton is piloted in Khammam District with support from Ministry of Rural Development and Dastakar Andhra.
- Similar efforts in processing would be initiated in paddy, millets etc

### Integrating with Food Security program

SERP is running a large Food Security Program where members are advanced Food and essential commodities. Currently the communities are procuring from the open market. From this year, pilots would be initiated at the village level to integrate the sustainable agriculture production and marketing initiatives and the food security program. This decentralized production and consumption systems will reduce the 'long food miles' and reduce the costs handling and storage to greater extent.

### Marketing Strategy

The successful experiences of market procurement operations of SERP through VOs in Maize, Red gram and Paddy will be extended to all the villages where the sustainable agriculture program is implemented. The present farmer field school groups will gradually emerge into farmers organizations and will federate at village and mandal levels as 'Producer Collectives'. Strategies would be evolved to integrate with the ongoing food security program and marketing by inviting buyers.

**The marketing strategy is not premium and external market driven but to ensure a 'Fair price' to the farmers and healthy food to the communities.**

Additional price incentives for organic produce and export markets are a bonus to the farmers.

**Rainfed Agriculture:** special focus would be on promoting appropriate cropping patterns and production practices suitable to rainfed areas. The millets production and post harvest processing and demand generation for easily acceptance would be taken up.

**Infrastructure support:** At the village level we may need to provide certain infrastructure support

- Custom hiring centres of all agriculture implements
- Small enterprises which provide input support and processing
- Ware houses to store the produce before marketing
- Village Resource Centre (Rythu Vigyan Kendra) a place where farmers regularly meet, trainings are organized and provide information.

**Special Incentives:** Adoption of Sustainable Agriculture will increase the efficiency of water use and energy use. The chemical pollution of water, soil, air and food would be reduced. Provision of special incentives like Energy Bonus, Water Bonus etc could really help many more farmers to switch over to sustainable agriculture.

The proposal has been accepted for support under Additional Central Assistance to reach 5000 villages in next five years covering 25 lakh acres (10 % of state area) with an outlay of Rs. 182 crore. The MoU has been signed by the Prime Minister Dr. Manmohan Singh and Chief Minister of Andhra Pradesh Dr. Y. S. Rajshekar Reddy on 31$^{st}$ of July, 2007 in Hyderabad.

## Profile of organizations who took part in the project

**1. Society for Elimination of Rural Poverty (SERP)** is an autonomous society of the Department of Rural Development, Government of Andhra Pradesh. The Chief Minister of Andhra Pradesh is the Chairperson of the SERP. **Indira Kranthi Patham (IKP)** is a statewide community driven rural poverty reduction project implemented by SERP to enable the poor to improve their livelihoods and quality of life through their own organizations. IKP is a $260 million project implemented since 2000 with World Bank support. IKP consists of Andhra Pradesh District Poverty Initiatives Project (APDPIP) and Andhra Pradesh Rural Poverty Reduction Project (APRPRP) and works in all 22 districts of Andhra Pradesh. It builds on the Andhra Pradesh Governments investment in self help groups of women over the last fifteen years.

IKP is the single largest project in South Asia having supported in the last five years 620,000 self help groups (membership of 7.80 million) and their federations at village level and Mandal level throughout the state of Andhra Pradesh. This constitutes coverage of over 80% of all rural poor households The project facilitates the formation of groups of women, which are built into federations, and strong institutions of poor at various levels like the village (Village Organisation), mandal (Mandal Samakhya) and the district (Zilla Samakhya). These federations become the building blocks of any intervention, social or economic. On one hand, dissemination of best practices becomes easier since one addresses leaders who represent the groups. On the other hand, this strong network enables the women to be a pressure group, fighting for their rights and entitlements. IKP builds on the strengths of previous poverty projects in Andhra Pradesh, which facilitated formation of self-help groups. To strengthen the groups and continuously train them, Mandal Learning Centres have been set up with a computer, television where training classes are held and their skills enhanced.

In 2004-05, 289,000 groups assisted with Rs. 1240 crores (US$ 275 million) bank credit (as against Rs.755 crores (US$ 167 million) in 03-04). The highest in the country (40% of all India lending). In 2005 – 06, it is 288,000 groups with Rs.2010 crores (US$ 446 million), Rs. 20 million per mandal.

**Centre for Sustainable Agriculture (CSA)** registered as a trust on 4$^{th}$ March, 2004 is working with 130+ grass root level NGOs, involving more than one lakh small and marginal farmers on Sustainable agriculture programme. CSA is working in the state of Andhra Pradesh, Maharashtra and Punjab. CSA is having rich experience and expertise in preparation of resource/training material on various aspects especially sustainable agriculture. CSA provides technical support to groups that are promoting sustainable agriculture by way of training programmes and consultancies. CSA also takes up research studies/consultancies to generate data and information for action planning and policy advocacy.

**SANET: Sustainable Agriculture Network –** SANET is a network of NGOs and smaller networks of NGOs across the state which are involved in promoting sustainable agriculture. Currently there are 100 NGOs in the Network. The program is implemented through the partner organizations.