ORGANIC FARMING
IN LOW RAINFALL AREAS

A.K. Sharma • N. Patel • D.K. Painuli • D. Mishra

ICAR-Central Arid Zone Research Institute
(ISO 9001 : 2008)
Jodhpur - 342 003 (Rajasthan)

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Foreword

Multi-component farming systems are prevalent in low rainfall areas which include annuals, perennials and livestock. These systems rely heavily on recycling of local resources and have very low inputs in order to cope up with the risk of rainfall uncertainty. Under the prevailing climatic uncertainties, these system sustained yield to a reasonable level however, their productivity may be improved with the modern ecofriendly technologies.

Efforts has been done during last 50 years to improve productivity of such traditional systems by use of synthetic external inputs e.g. fertilizers, pesticides, weedicides, etc. However, the success was limited to good rainfall years. Thus, in such conditions use of synthetic inputs is risky and uneconomic in most of the years. Even negative results have been observed during below average rainfall years. In such a scenario use of organic manure for sustainable production is an effective alternative in this set of conditions. This practice provides at least some produce even under prolonged dry spell. Nutrition to plants through organic source mitigates the effect of climate related uncertainty as well. In this region, farmers practice organic farming since ages by default. On account of highly efficient nature in recycling of nutrients, it results towards better food and economic sustainability.

On account of high livestock population and available alternatives other than dung as cooking fuels there are ample opportunities to promote efficiently managed organic production system in this region. Such opportunities should be harnessed from the angle of economy and ecology. This holistic approach will help in improving productivity of natural resources and soil health besides quality food.

I compliment the contributors for compiling available information in the area of organic agriculture in arid region. It is hoped that the publication will be useful to the researchers, extension personnel and other stakeholders concerned with sustainable farm management in the region.

(R.K. Bhatt)

Date : 17,8.2015

Preface

Low rainfall regions (rainfall below 500 mm $year^{-1}$) mainly in the north western part of the country cover about 45 million hectares area in Rajasthan, Gujarat and Haryana, and small parts in Tamil Nadu and Telangana. About 82% of this area is rainfed. In this region climate is harsh with high temperature during major part of the year and rainfall is not only low but highly unpredictable in both distribution and amount Low rainfall and its erratic distribution are the major causes of uncertainty of agricultural production. This condition is further getting aggravated due to climate change.

Under such conditions use of synthetic inputs i.e. fertilizers, pesticides etc. is risk prone and uneconomic. Organic farming which utilizes local resources in an optimum way maintaining the sustainability of the system and health of the environment is a good choice for these areas. Farmers are practicing organic agriculture since ages by design or default according to soil and climatic conditions. A Model Organic Farm (MOF) has been established in 2008, at the Central Research Farm of the Institute at Jodhpur. The farm was registered for certification and got its status of "Certified Organic Farm" in year 2011.

In this bulletin, an overview of organic farming status and possibilities in low rainfall regions, and results of inter-disciplinary studies on soil properties, crop production and plant protection done at MOF have been given. Some policy measures have also been suggested.

Contribution of Mr A. Samad and Mr S.K. Sankla, Technical Officers, in establishing the organic farm, doing timely operations and recording observations is gratefully recognized. Support of the Ex-Head of Division Dr. S. Kumar for providing all possible facilities is thankfully acknowledged. We wish to express our sincere thanks and gratitude to Ex-Director CAZRI, Dr. M.M. Roy for his guidance, and for providing facilities and support for research work that made possible to develop and getting the status of Certified Organic Farm.

Authors

CONTENTS

INTRODUCTION

In the last few decades, awareness about health, social and environmental issues has increased. As a result it is now well appreciated that organic farming is one of the agriculture production systems that not only is supportive to the clean environment, but also is sensitive to the social issues like employment, health, migration etc. Definitions given by two international organizations verify this concept. The definitions are:

1. Organic agriculture is a holistic management system, which enhances agro-ecosystem health, utilizing both traditional and scientific knowledge. Organic agriculture systems rely on ecosystem management rather than external agricultural inputs (IFOAM, 2006).

2. Organic agriculture is an environmentally and socially sensitive food supply system. The primary goal of organic agriculture is to optimize the health and productivity of independent communities of soil life, plants, animals and people (FAO, 2002).

In simple words "Organic farming is the production system that utilizes local resources in an optimum way so that sustainability of production and wellness of the society and environment are maintained for a fairly long time".

Organic farming versus conventional (chemical) farming

Organic farming is commonly understood the exclusion of synthetic external inputs which is true but more important are the ideological differences with conventional farming that makes organic farming more suitable for society and the environment. Key differences are given below:

Organic farming	**Conventional farming**
Holistic approach	Reductionist approach
Decentralize production	Centralize production
Harmony with NATURE (harness the benefits)	Domination on NATURE (exploit for profit)
Diversity	Monoculture
Input optimization (save more)	Output maximization (spend more)

Conventional farming is also known as chemical intensive farming.

Objectives of organic farming

According to the International Federation of Organic Agriculture Movement (IFOAM) the objectives of organic farming are follows:

- To produce food of high nutritional quality in sufficient quantities
- To work in harmony with natural systems rather than seeking to dominate them
- To encourage and enhance the biological cycles within farming system involving microorganisms, soil flora and fauna, plants and animals
- To maintain and increase the long term fertility of soils
- To use, as far as possible, renewable resources in locally organized agricultural systems
- To work, as much as possible, within a closed system with regard to organic matter and nutrient elements
- To give all livestock, conditions of life that allow them to perform all aspects of their innate behavior
- To avoid all forms of pollution that may result from agricultural techniques
- To maintain the generic diversity of the agricultural system and its surroundings, including the protection of plants and wild life habitat
- To allow agricultural producers an adequate return and satisfaction from their work including a safe working environment
- To consider the wider social and ecological impact of the farming system

Essential characters of organic farming

The most important essential characters of organic farming are as follows:

- Maximal but sustainable use of local resources
- Use of purchased inputs, only as complementary to local resources
- Increasing crop and animal diversity in the form of poly-cultures, agroforestry, integrated crop/livestock systems, etc. to minimize risk and improve ecological balance and economic stability

- Ensuring the basic biological functions of soil-water-nutrient-humus continuum
- Creating an attractive overall landscape which gives satisfaction to the local people

Thus, to sum up, mixed farming, crop rotation and organic cycle optimization are the three key principles of organic agriculture.

Advantages of organic farming

Some important advantages of organic farming experienced worldwide are:

- It creates optimal conditions in soil for improved growth and physiological activities of plants and the higher crop yield
- It improves soil physical, chemical and biological conditions
- It improves soil carbon content (carbon sequestration)
- It utilizes organic wastes as inputs and thus minimizes pollution
- It mitigates environmental degradation
- It is more resistant to diseases, insects and pests
- Organically grown produce are believed to be nutritionally superior and good for health
- Higher demand of organically produced food coupled with its premium price may improve economy of the farmer and the region

Essential components of the organic farming

The three major components that create core environment for organic production system are:

1. Maintaining agro-diversity through cropping system, integration of animals and other beneficial flora and fauna.
2. Conservation and efficient utilization of local resources with least dependency on external inputs, and
3. Fairness in production and utilization so that every stakeholder of the system gets his due share.

In the above major components, some location specific minor components can be included/excluded as per the resources available with the farmer.

POTENTIAL OF ORGANIC FARMING IN LOW RAINFALL AREAS

Low rainfall areas (rainfall below 500 mm $year^{-1}$) of the country cover about 45 million hectares major part is in Rajasthan (12 districts) and a small part in Gujarat, Andhra Pradesh and Tamil Nadu. In these areas rains have erratic distribution and frequent droughts also cause uncertainty in agriculture production. This condition is getting further aggravated due to climate change. It has been projected that impact of climate change by the end of 21st century is more likely to be felt in low rainfall areas than in higher rainfall regions of India (Rao *et al.*, 2009).

Traditionally, in low rainfall areas multi-component farming systems are prevalent which include annuals, perennials and animal components. These systems have minimal or no external inputs and are based on recycling of local resources and help in spreading the risk of rainfall uncertainty. Although these systems have sustained production reasonably under the prevailing climatic uncertainties, their productivities are very low which can be attributed to inefficient use of local resources.

Under such conditions use of synthetic inputs i.e. fertilizers, pesticides etc. is risk prone and uneconomic. In the last 4-5 decades several attempts have been made to improve productivity of the traditional systems by use of synthetic external inputs e.g. fertilizers, pesticides, weedicides; however, the success was limited to the good rainfall years only. During below average rainfall years negative results were also observed. In view of high cost of chemical fertilizers but uncertain yield gains by their use, Agrawal and Venkateshwrlu (1989) suggested increasing the use of organic manure for sustainable production in low rainfall condition. This practice provides at least some produce even under prolonged dry spell. Balanced nutrition to plants through organic source may be a feasible option to mitigate the effect of climate related uncertainty. In low rainfall areas due to high risk associated with crop production, the use of agro chemicals is very less. Thus, farmers are practicing organic farming since ages by default. The system despite its low productivity compared to conventional system has established itself as highly efficient in terms of resource recycling and providing better food and economic sustainability in the arid region (Sharma and Tewari, 2009). Some promising crops for production under organic system are cumin (spice), psyllium (medicine), sesame (oilseed), clusterbean (gum), moth bean (traditional snacks e.g. papad, bhujia), etc. Enhanced quality of the products made from these organically grown crops in the existing production system with better utilization of local resources could make a considerable contribution in strengthening the economic sustainability of the low rainfall region (Sharma and Tewari, 2009). The improvement in the existing production system is possible by intervention in nutrient management and plant protection aspects. For nutrient management various practices such as ley farming, inclusion of legumes in crop rotations and efficient recycling of biomass are important. For effective non-chemical plant protection some measures e.g. crop rotation (Lodha, 2008), use of compost as soil application along with foliar spray of compost extract (Lodha and Burman, 2000), application of oil cakes or residues of mustard with one summer irrigation (Lodha, 2008) and application of neem based pesticides (Satyavir and Yadav, 2005) have been found promising. Thus, organic cultivation of selective crops having higher export potential provides an opportunity to strengthen the economy of the region.

The low rainfall areas that were fairly untouched from green revolution due to shortage of water are most suitable for organic farming which promises to be the future evergreen revolution (self sustainable system) as these areas have the following components which are integral to organic farming:

1. **Efficient use of limited water:** Water is a scarce resource in the low rainfall regions. However, at many places in the region water along with fertilizers is being used indiscriminately for production of water demanding crops viz. rice, wheat, cotton, sugarcane and vegetables. As a result danger of desertification due to various reasons including water logging and salinization is emerging in the region. The use of synthetic fertilizers increases water demand of crop. Contrary to chemical intensive farming, organic farming has been found to improve soil quality and water retention. The water demand can further be reduced by growing low water requiring but high value crops like spices and legumes.

2. **Low fertilizer use-early conversion:** In this area due to erratic pattern of rainfall, the rate of fertilizer application is very low (36.4 kg ha^{-1}) as compared to national average of 76.8 kg ha^{-1}. This can be a good opportunity for early and easy conversion into organic farming. According to the priority areas of National Organic Farming Policy this part of the country comes under the priority I and II, which can facilitate obtaining financial help from government agencies.

3. **Diversified farming system:** Farming systems in the low rainfall regions are highly diversified in nature. They incorporate crops, trees, animals, grasses, etc.

and have been scientifically found efficient in nutrient recycling and restoration of soil fertility. In these systems 10-30 trees ha^{-1} are available and 2-5 animals are reared by a farm family. This integrated farming system provides manure, minimizes pest incidence as well as favors organic farming.

4. **Rich traditional wisdom:** Rich traditional wisdom pertaining to restoration of soil fertility and pest control existing in these regions further strengthens and provides strong basis for organic farming (Sharma and Goyal, 2000).

5. **Natural availability of inputs:** Plants like neem, pongamia, calotropis, etc. are the best sources of biopesticides and are abundantly available in these areas. Neem plants are available in various densities and use of neem based biopesticides has been found effective in pest control in crops of low rainfall areas (Verma and Vir, 1997) under IPM mode. Minerals like rock phosphate, gypsum and lime are available in large quantities. These are good soil ameliorators as well as good nutrients suppliers. Further the farming systems in low rainfall regions are strongly animal based and subsequently large amount of materials namely urine, dung and bones are available for enhancing agricultural production.

6. **Employment opportunities:** Due to erratic rainfall and limited irrigation facilities, farming community of the regions remains underutilized during a major part of the year as cropping is possible in rainy season only. Migration of human resources during drought imbalances the development of agriculture as these areas remain no man's land during about half of the year. Since, organic farming is labor intensive and the required inputs are prepared at local level, ample opportunity is offered by the organic farming for employment and proper utilization of human resource.

7. **Soil improvement:** Soils in the region have low water holding capacity and are deficient in most of the essential nutrients. Addition of organic matter not only improves the water holding capacity but also enhances supply of nutrients to plants in a balanced manner.

8. **Mitigating effect of climate change:** Worldwide 90 million tons of mineral oil or natural gas is processed to get nitrogenous fertilizers every year. This generates 250 million tons of CO_2 emission. On the contrary, organic farms sequesters 575 to 700 kg ha^{-1} CO_2 to the soil. Organic farming thus reduces CO_2 emission by eliminating

synthetic fertilizers and at the same time reduces atmospheric concentration of the gas by storing in the soil, a win-win system (Niggli, 2008). Further, it is estimated that soils with higher humus content could adapt to the adverse effect of climate change.

9. **High value crops:** These areas have four major export oriented crops namely clusterbean (as guar gum), sesame, cumin and psyllium (isabgol). Total combined export of these crops is about ₹ 2000 crores year^{-1}. In view of the present trends and competitive market, enhancing export of mainly organic produce is a promising possibility for these regions.

Quality of organic produce *vis-a-vis* markets

Production of food in organic farming and maintaining quality is becoming a necessity both for international and domestic markets, because:

1. Demand of organically produced foods is increasing.
2. With the scientific advancement, many of our monopoly crops are being grown by several other countries and quoting lower rates in international market. For example, cumin was a monopoly crop of India but now it is being grown by China, Iran, Turkey and Egypt.
3. In this era of global open economy, domestic consumers are free to buy a quality with low priced produce from international market.

Therefore for maintaining our monopoly or rather competitiveness for international as well as domestic market, economic as well as quality production is becoming imperative.

Low cost quality produce

1. In organic production system, no external synthetic chemical is used, and moreover emphasis is given on recycling of locally available resources. With this approach cost of production can be reduced up to 60% as compared to conventional chemical farming.
2. There are several examples of experiments and farmers' experiences which show that due to balanced nutrient supply through organic sources, the quality of organic produce increases many fold in terms of aroma, essential oil content, texture, taste and shelf life. Such products fetch better market price.

Other issues for opting organic farming

1. **Low and reduced supply of fertilizers:** To some extent nitrogenous fertilizers and most part of the other fertilizers are imported from various countries. Not only these imported fertilizers but also supply of nitrogenous fertilizers is decreasing due to changing international scenario. Moreover, most of the fertilizers companies give priority to irrigated areas Punjab, U.P., Haryana, Maharashtra etc. for supply and rainfed areas are remained short supplied. Therefore, to reduce dependency on imported fertilizers and recurring problem of short supply in rainfed areas, opting organic farming is the only solution.

2. **Most suitable for spices and medicinal plants:** Most of the spices like cumin, fennel, ajwain, fenugreek etc are important ingredients of ayurvedic, allopathic and homeopathic preparations. These medicines are supposed to give to patients and if these ingredients have residues of pesticides it may be poisonous instead of curing the patients. Therefore, growing spices and medicinal plants organically is suitable as well as social option.

IMPORTANCE OF SOIL ORGANIC CARBON IN ORGANIC FARMING

Role of organic matter in soil

A healthy fertile soil is the basis of organic farming that affects the quality and health of plants. Use of organic matter over time invariably leads to increase in organic carbon level in soil, which favorably impacts the physical, chemical and biological properties of the soil and enhances the buffering capacity of the soil (Table 1). These changes have been universally observed in all arable soils and climatic conditions. Consequent to improved soil health, sustainable higher crop production is achieved. Therefore, soil organic carbon is accepted "the basis of good sustainable agriculture".

Factors affecting soil carbon level

In a natural ecosystem level of soil organic carbon at a given location is a function of:

1. Climate - primarily temperature and rainfall,
2. Soil - mainly texture and topography,
3. Vegetation, and
4. Time

Table 1. Importance of soil organic carbon to soil health

Component of soil health and significance	Effect of soil organic matter (soil carbon)
Chemical fertility: Relates to nutrients supply	Microbial decomposition of soil organic matter releases nitrogen, phosphorus and a range of other nutrients essential for plant growth. Also, CEC increase; this improves retention of nutrients and prevents strong fluctuations in pH.
Physical fertility: Relates to water, air, temperature and mechanical behaviors moderated primarily by structure	In the process of decomposition of organic matter by microbes resins and gums are produced. These bind soil particles together into stable aggregates. The improved soil structure holds more plant available water, allows water and air to move easily through the soil, offers less mechanical impedance to seedlings and roots, cultivates with more ease, reduces runoff and erosion, and moderates soil temperature.
Biological fertility: Relates to activities of the organisms	Organic matter plays important role in the soil food web by providing food and energy for soil organisms and micro-organisms. Thus, availability of organic matter controls the number and types of soil inhabitants and their activities. Important functions performed by these inhabitants include recycling and making nutrients available for other organisms, assisting root growth, assisting plant nutrient uptake, improving soil structure and even suppressing crop diseases.
Buffer for toxic and harmful substances	Soil organic matter act as a buffer for toxic and harmful substances by bonding them very tightly through sorption process and not to let release, thus lessening their harmful effects.

It tends to establish equilibrium with the ecosystem, but since all the factors except texture are dynamic hence soil organic carbon stock is also dynamic.

Climate: Wind is an important climatic parameter and causes soil erosion under arid condition. Soil organic carbon (SOC) content in wind eroded sandy soils is reported 50% less than that in non-eroded sandy loam soils. Temperature and rainfall are known to have significant influence on organic carbon level in soil. This is due to their controlling effect on plant growth and microbial activities. Better plant growth provides higher input of carbon to soil, while higher microbial activities cause greater depletion of soil carbon due to more decomposition of soil organic carbon including the residues. The difference between magnitude of their individual effect on addition and depletion of carbon determines the net balance of carbon in soil. This concept is universally evident. As an example, in hot and wet areas of the tropics despite high plant productivity and thus higher input of soil organic matter soil organic carbon levels are low. This low soil carbon status is attributed to high decomposition rates that decompose almost all organic carbon. However, as is broadly acknowledged high rainfall and low temperature conditions are in general conducive to accumulation of organic carbon in soils, while high temperature and low rainfall conditions are not conducive for the build-up of carbon stock in soil (Table 2).

Table 2. Effect of temperature on soil organic carbon within selected moisture belts in India

Area	Rainfall (cm)	Mean annual temperature (^oC)	Organic carbon (%)
Dry region	35-75	23-24	0.50±0.028
Semi-humid region	75-100	27-29	0.54±0.075
Humid region	125-225	12	1.26±0.18
Per humid region	250-500	14	2.06±0.49

Modified from Jeenny and Rychaudhuri (1960)

Kar *et al.* (2007) and Singh *et al.* (2007) have estimated that oxidation of soil organic carbon is approximately 200-850 $gm^{-2}yr^{-1}$ under the prevailing temperature and management viz. tillage in western arid part of Rajasthan. It is reported that in the central part of western Rajasthan the soil organic carbon has depleted between 1975 and 2002 by 10.4%. In the western Rajasthan as a whole the SOC in one meter deep soil has declined from ~825 Tg in 1975 to ~ 747 Tg by 2002 (Kar *et al.*, 2009).

Soil type: Soil type affects the carbon stock of the soil. In a fertile soil plant productivity and thus carbon input is high resulting in higher level of soil carbon content. Researchers have established that increase in clay content, in general has a positive impact on soil carbon stock. Accordingly, Alfisols in arid region, which are rich in clay content (36%) than Entisols and Aridisols, have higher organic carbon content (3.7 g kg^{-1}) than Entisols (1.5 g kg^{-1}) and Aridisols (1.0 g kg^{-1}). Organic carbon content in soils below 300 mm rainfall zones ranges from 0.05-0.2% in coarse textured soils, 0.2-0.3% in medium textured soils and 0.3-0.4% in fine textured soils (Praveen Kumar *et al.*, 2009). Dhir (1977) has shown that even in low range of organic carbon (<0.5%) increase in clay content is associated with increase in organic carbon. One prime reason for the positive relationship between clay content and soil organic carbon content is that clay surface and clay micro-aggregate protect organic materials from decomposition by either holding them tightly as complexes or by physically trapping them; thus, rendering them unavailable to the microorganisms.

Vegetation: Although climate and soil are the two important factors governing the choice and growth of a plant in an area, however, the plant itself makes a strong contribution to the status of soil carbon level also. Bhati and Joshi (2007) reported that in an agroforestry system at CAZRI Jodhpur SOC (%) was more under leguminous trees namely Acacia albida (0.179) and *Prosopis cineraria* (0.165) compared to non-leguminous trees namely *Tecomella undulata* (0.138) and *Ziziphus mauritiana* (0.138). Also less biomass input and more soil disturbance were among the other factors that resulted in buildup of less carbon in soil under the legume crop mung bean (0.125). Considering the carbon input in soil, components of plant both above the ground namely leaf and stem and below the ground namely root are critical. In low rainfall zones large volume of carbon gets sequestered through roots specially the tree roots. Planting of trees and grasses in the degraded lands of arid zone can increase soil carbon stock from 24.3 Pg to 34.9 Pg (Narain, 2008). Pearl millet crop grown under scarce rainfall condition at Jodhpur contributes on an average 700 kg ha^{-1} dry root biomass in surface 15 cm. The quantity must obviously be much higher under irrigated condition and varies with the crops and management.

Time: Soil organic carbon stock is dynamic. It has clearly been established that both carbon depletion and build up processes are strongly influenced by time, thus soil carbon status is a time dependent soil quality parameter. It has also been established that while the rate of depletion is a fast process the restoration is relatively a very slow process; and depending on the maximum carbon storage capacity of a soil in a given location and condition including the status of carbon depletion it may sometime take hundred to thousand years to attain equilibrium i.e. when soil is saturated with organic carbon and is left with no capacity to store any more amount of soil organic carbon. All the processes related to depletion and restoration of soil carbon is management dependent. Studies at CAZRI, Jodhpur showed the time dependence of carbon stock build up in 0-5 cm layer of an undisturbed Pal loamy sand soil. The amount of carbon increased exponentially with the age of plantation. Figer 1 depicts the three phases; A: Carbon saturated virgin soil under rich vegetation, equilibrium is reached (Input > Loss); B: soil "A" is put to cultivation. Initial fast rate of carbon depletion tends to slow down and attain equilibrium (Input < Loss); C soil "B" is under restoration measures. Initial rate of restoration is fast and tends to slow down with time.

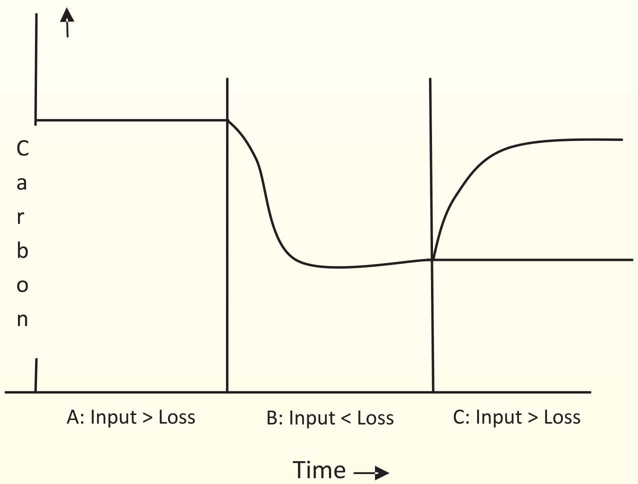


Fig. 1. Schematic representation of soil carbon change with time under different management.

Management practices

Some management practices such as cultivation, residue burning or removal, and fallowing that involves repeated cultivation to control weed reduce soil organic carbon by increasing decomposition by oxidation or reducing inputs of organic materials to soil or the both.

Management practices that do not favor higher carbon stock:

- **Tillage:** It exposes organic materials to increased oxidation and thus higher loss. Increase in soil erosion also occurs and thus accelerated loss of SOC.
- **Stubble burning/removal:** Both practices reduce input of organic matter and thus buildup of carbon stock. Exposure of unprotected soil surface to rain favors more erosion and thus loss of carbon from top soil. Burning also causes carbon loss due to heat/high temperature.
- **Low cropping intensity/fallowing:** In low intensity cropping/fallowing smaller inputs of organic matter does not favor buildup of carbon stock. During fallow period repeated cultivation to control weed accelerates loss of soil organic carbon by processes described above under tillage.

Approaches to enhance organic matter in soil

As discussed earlier, climate, soil type, vegetation, time and management practices govern the status of organic carbon in soil. While we don't have control over climate and soil type, we could however adopt appropriate vegetation, time and management practices to create a positive balance of organic inputs over the losses. This will enhance carbon level in soil.

In theory any management practice viz. manure, crop rotation, cultivars and irrigation which leads to large increase in yield should increase soil organic carbon due to increased carbon input resulting from higher biomass production. Also, the productivity increase achieved by crop intensification practices such as double cropping, opportunity cropping and multiple cropping enhance soil carbon. Conservation agriculture which emphasizes on reduced disturbance to soil to reduce carbon loss, and retention of stubble to increase carbon input is reported to build carbon stock in soil over the time. Various organic materials like manure, compost, bio-solids from sewage etc. are rich in organic carbon. Their use in agriculture especially the organic farming is being encouraged to enhance soil organic level in soil. The practices that help in build up of soil organic carbon are:

Reduced tillage: It reduces exposure of organic matter to oxidation and thus less loss.

- **Stubble retention:** Stubble retention favors higher input of organic matter and thus buildup of carbon stock. Increased protection of soil surface from rains favors less erosion and thus less loss of carbon from top soil. Stubble mulch can enhance biomass production resulting from higher yield and thus more input of organic matter.

- **Higher cropping intensity/less fallowing:** In higher cropping intensity/reduced fallowing input of organic matter is higher, this favors buildup of carbon stock.

- **Input of organic amendments:** Input of organic amendments viz. compost, worm castings, manure and recycled organic materials enhance carbon stock through direct effect as well as through enhanced production.

- **Increase crop yield:** Use of manures, irrigation, high yielding variety, optimized rotations including inclusion of legumes in crop rotation all increase crop yield per unit land area and thus higher input of organic matter.

AVAILABILITY OF ORGANIC INPUTS

Four districts: Jodhpur, Nagaur, Pali and Barmer were surveyed during 2006-08 to assess the availability of organic inputs in the low rainfall areas where biomass production is low, and to know the possibilities for further enhancement of quantity as well as quality.

The results of the survey indicated that:

- Availability at farm level was influenced by several factors like rainfall, cropping pattern, size of holding, availability of labor etc. In general at most of the places farmers used raw cow dung, kept under sunlight for months and this caused great loss in nutrient availability especially that of nitrogen. On an average 1.5-4.5 t ha^{-1} organic manure was available at farm level in the form of crop residues and animal dung.

- Availability increased at village level by 1.5-2.0 folds mainly because some farmers kept animals for dairy purpose. Large numbers of unproductive and old animals are also available in villages. These animals may not give milk but provide manure in substantial quantity. Cattle provides 4.6 to 11 kg ha^{-1} $year^{-1}$ nitrogen through urine (total agriculture land/total number of animals in the village). Trees which are the integral part of farming system of arid zone contribute equivalent to 0.04 t $manure^{-1}$ $tree^{-1}$ $year^{-1}$. Trees available in common land, protected areas, waste land, etc. also contribute to organic input availability at village level. Availability further increased at district level as intensive dairy farming was observed in peri-urban areas. After addition of organic input availability from all the sources the figure reached to 4.5-5.0 t ha^{-1}. This amount of organic input is sufficient for rainfed farming in low rainfall areas.

- The availability of nutrients can be further increased by adopting following management practices:

1. Crop rotation with leguminous crops like clusterbean, moth bean, mung bean, etc.
2. Avoiding heaping of dung under sun and use of improved methods of composting. In arid zone due to shortage of water and high temperature pit composting method has been found most suitable.

3. Tree leaf litter, animal urine, bones of dead animals, non-palatable weed biomass are some of the other rich and underutilized sources of nutrients.

Therefore, organic inputs are available in sufficient quantity in low rainfall areas; the only need is their efficient utilization.

Application of manure: Since manure is a bulky input, and therefore its method of application is very important specially to reduce cost of application and effective use in arid zone where losses may be high due to low soil moisture and high temperature. Therefore, subsurface placement may be the better option. However, very limited studies have been done on placement of manure. Reiman *et al.* (2009) found higher corn yield with the placement of manure. In placement operation, the placement device is very important for getting required results that need further studies.

PEST MANAGEMENT IN ORGANIC FARMING

In recent years organic farming has gained a lot of importance as the understanding regarding the ill effects of so called conventional farming in the general public has increased. People now want to use products which are healthy and free from chemicals and pesticides and they are ready to pay a little extra for these kinds of products. All this has to be done without affecting the productivity of the crop or the system. In organic systems, the goal is to alter the production system so that pests do not find plants, controlled by natural enemies (biological control), and their damage is kept to a minimum. Vigorous, healthy plants are more able to withstand damage caused by arthropods and diseases. Therefore, healthy soil and healthy plants are the foundation of organic production. Organic farming production systems adopt agricultural practices which rely on beneficial flora and fauna together with proper soil and crop management to protect and enhance optimal soil health and crop ecology. Practices adopted under organic farming are sustainable and gradually build a system where majority of insect pests are managed by their natural enemies i.e. the beneficial insects, predators and parasitoids of insect pests.

The general principles of insect pest management in organic production are: use of natural enemies (biological control), cultural practices like crop rotation, intercropping, sanitation, resistant varieties, maintenance of biological diversity or farmscaping (creation of habitat to enhance the chances for survival and reproduction of beneficial organisms), appropriate planting dates, and plant spacing, good soil management practices and use of organic pesticides like botanicals (neem oil, neem cake) and microbial (*Bacillus thuringiensis* (Bt), pyrethrum, and insect-parasitic fungi (Metarhizium, Beauveria, etc).

Beneficial insects

Contrary to popular perception that all insects are harmful and cause damage to plants, animals and human beings, many of the insects are beneficial and aid in food production by way of pollination and controlling insects which are pests.

Pollination: Pollination is one of the most important process in food production by plants. It is critical for food production and human livelihoods, and many flowering plant species only produce seeds if pollinators move pollen from the anthers to the stigmas of their flowers. Approximately 80% of all flowering plant species are specialized for pollination by animals which are mostly insects. Pollinators are essential for fruit and seed production in many vegetables, fruits, oilseeds and other crops. Pollinators such as bees, birds and bats affect 35% of the world's crop production, increasing outputs of 87 of the leading food crops. For human nutrition, the benefits of pollination include not just abundance of fruits, nuts and seeds, but also their variety and quality.

Among insects, bees (Hymenoptera: Apidae) are the most important and effective pollinators, but other insects such as wasps, flies, moths, butterflies and beetles also have a major contribution as pollinating species. Vertebrate such as bats, birds, hummingbirds and rodents, squirrels are also important pollinators. In an agro-ecosystem like organic farms, with diversity of flowering plants, there is abundance and diversity of pollinators too (Fig. 2).

Fig. 2. Honey bees on pearl millet and sesame.

Natural enemies: The use of natural enemies to maintain pest populations below damaging levels is known as 'Biological Control'. Natural enemies of insects fall into three major categories: predators, parasitoids and pathogens. Predators catch and eat their prey. Some common predatory arthropods include ladybird beetles, lacewings, syrphid flies, carabid (ground) beetles, big-eyed bugs and spiders. Parasitoids (sometimes called parasites) do not usually eat their hosts directly. Pathogens are organisms that cause diseases in insects. The main groups of insect disease-causing organisms are insect-parasitic bacteria, fungi, protozoa, viruses and nematodes. The bacterium Bacillus thuringiensis (Bt) is a well known microbial control agent that is available commercially. Several insect-pathogenic fungi are used as microbial control agents, including Beauveria, Metarhizium, and Paecilomyces.

Predators

The predators search out, attack and eat prey insects. The following predators are common in the arid ecosystem and are abundant at the organic farm.

Ladybird beetles - Coccinellidae (Coleoptera): Coccinellid beetles are the best friends of farmer. They are also called ladybugs. These beetles are conspicuous insects on farms due to their colorful and spotted appearance. They are oval-shaped, about 0.6-0.8 cm long with bright yellow, orange or red wing covers with dark spots or stripes. Most ladybugs voraciously feed on soft-bodied insects such as aphids, white flies, mites and scale insects, and in doing so they help to protect crops. They go through four stages of development: egg, larva, pupa and adult. Eggs are laid singly but in large numbers on leaves or near insect colonies. The tiny yellow egg hatches in about a week. Ladybug larvae resemble tiny alligators, with long, pointed abdomens, spiny bodies, and legs that protrude from their sides. After hatching, the ladybug larvae immediately begin to feed. The larvae feed and grow for about a month, and consume hundreds of aphids or other insects during this stage. A hungry ladybug larva can devour 50 aphids per day (Fig. 3).

Fig. 3. Different stages of Ladybird beetles.

Lacewings - Chrysopidae (Neuroptera): Green lacewings are generalist predators and are commonly found in agricultural habitats. Adult green lacewings are delicate soft-bodied insects with four pale green membranous wings, bright golden eyes, and green bodies. Adults are active fliers, particularly during the evening and night and are seen near lights. Adults feed only on nectar, pollen, and aphid honeydew, but their larvae are active predators. Chrysoperla carnea is a common green lacewing. Females lay their tiny, oblong eggs on silken stalks attached to plant tissues. Eggs are green when laid, and then darken before hatching. Eggs hatch in 4 days, and larvae develop through three instars before pupating. Larvae, which are pale with dark markings, look like tiny alligators. Larvae are flattened, tapered at the tail, measure 3-20 mm long, have distinct legs, and possess prominent mandibles with which they attack their prey. Larvae prey upon a wide variety of small insects including mealybugs, thrips, mites, whiteflies, aphids, small caterpillars, leafhoppers and insect eggs. Pupation occurs in loosely woven, spherical, silken cocoons attached to plants or under loose bark. Lacewings pass the unfavorable season as adults, usually in farm waste (Fig. 4).

Fig. 4. Egg, larva and adult of Chrysoperla.

Syrphids - Syrphidae (Diptera): Syrphid flies are also known as hover flies as they have a unique ability to hover, suspended in mid air like helicopters. They quickly fly or dart a short distance, only to hover again, and they can fly backwards also. Adults of many syrphid species resemble honey bees and wasps and have yellow and black stripes on their abdomen. Syrphid flies are important pollinators and can be found feeding on different types of flowers in the field. The larvae of these are important predators of aphids, scales, thrips and caterpillars. These insects are common in arid zone, especially during the winter season. When syrphid larvae populations are high, they may control 70-100% of an aphid population.

The life cycle of hover flies varies from three weeks to nine weeks. The eggs are creamy white, elongated oval and laid singly on leaves, usually in or near an aphid colony. These eggs hatch in two to eight days. Larva is yellowish, legless and blind. It has a typical maggot shape, tapering to a point at the head end and broadly rounded at the rear, with two narrow whitish long stripes on the body (Fig. 5). The larva fastens itself to a leaf or twig when it is ready to pupate. The color of the pupa changes from green to the color of the adult hover fly. Most pupa pass unfavorable season in soil or under fallen leaves.

Fig. 5. Syrphid fly on Fennel.

Ground beetles - Carabidae (Coleptera): These predaceous beetles are medium to large, soil-dwelling, often about 8-16 mm long, black or dark red, although some species are metallic blue, brown or green. Most species have a prominent thorax that is narrower than their abdomen. They have long antennae, long legs, are fast runners, and rarely fly and are attracted to lights at night. Carabid adults and larvae feed on soil dwelling insect larvae and pupae, other invertebrates such as snails and slugs, and sometimes on seeds and organic litter. The female lays eggs singly on the moist soil surface, and the egg hatches into an elongated larva. Larvae live in farm waste or in soil. Larvae are elongate and their heads are relatively large with distinct mandibles. Most species complete their life cycle from egg to adult in one year. Beetles can hide such as leaf piles, old boards, rotting logs. The beetles secrete a strong bad smelling substance for defense and this can cause a burning sensation on human skin when the beetles are handled (Fig. 6).

Fig. 6. Ground beetle larva and adult.

Wasps (Hymenoptera): A large number of wasps from several families prey on insect pests. Many take their prey, whole or in pieces, back to their mud, soil or paper nests to feed to the immature wasps. These hunting wasps can be important in controlling crop insect pests. For example, the common Polistes paper wasps, when hunting, may thoroughly search plants and feed on caterpillars, often providing substantial control of these insects. Many types of wasps are common in arid zone especially yellow wasps which are good pollinators of fruits like ber (Fig. 7).

Fig. 7. Wasp pollinating *ber*.

Spiders (Arachnida): All spiders are predaceous; they eat mainly insects, other spiders, and related arthropods. Some species capture prey in webs, others hunt for insects across the ground or on vegetation and devour them (Fig. 8). Spiders are classified in the arachnid group along with mites. Unlike insects, which have six legs and three main body parts, spiders have eight legs and two main body parts. Most of the spiders are harmless to humans.

Fig. 8. Spider on *ber*.

Parasitoids

Adult parasitoids lay their eggs in, on or near their host insect. When the eggs hatch, the immature parasitoids use the host as food. Many parasitoids are very small wasps and are not easily noticed.

Tachinid flies: Tachinid flies are important group of parasitoids. They look like house flies and are grey or brown covered with dark bristles. Adult tachinid flies lay eggs on various caterpillars, beetles and bugs, usually near the head. The eggs hatch almost immediately, and the young maggots tunnel into their host. After feeding internally for a week or more, the tachinid fly larvae eventually kill the host insect.

Braconid and ichneumonid wasps: These are a large and diverse group of insect parasites. Some are small and attack small insects such as aphids. Others live in the eggs of various pest insects. Larger parasite wasps attack caterpillars or wood-boring beetles. External evidence of these parasites' activity is often more obvious than with the tachinid flies. For example, aphids that are parasitized by these wasps are typically small and discolored and called "aphid mummies." Other braconid wasp species spin conspicuous pupal cocoons after emerging from a host. Small hymenopteran parasitoids are often seen on ber flowers, henna flowers and also on weeds like Pulicularia sp.

Enhancing biodiversity

As discussed earlier, the larval or young stages of many beneficial insects feed on other insects but the adults of most of the predators and parasitoids of pest insects require nectar and pollen at certain stages of their life for growth and reproduction. A diversified ecosystem with many types of trees, shrubs and small plants provides microhabitats, food sources (prey, nectar, pollen), alternative hosts and shelter for natural enemies and thus encourages their colonization and population build up. Creation of habitat on farms to enhance the chances for survival and reproduction of beneficial organisms is known as 'Farmscaping'. The plant species chosen for this purpose should be such that they themselves do not attract insect pests of the crops chosen for the farm and also the flowering should be in succession so that food is available for beneficial insects round the year.

Plants that have flowers with a good amount of nectar/pollen, like umbelliferae, compositae, and brassicaceae are especially attractive for insects. Flowers which are attractive in color, have small shallow flowers and plants with extra floral nectaries encourage beneficial insects on the farm.

Trees/Shrubs

Ber and henna in the organic farm provide pollen and nectar to variety of pollinators, predators and parasitoids besides providing shelter for insects like lacewing. Many lacewing eggs are seen on henna and ber plants. Predatory wasps are observed in good numbers on ber flowers. Calotropis shrubs encourage beneficial insects like coccinellids (Fig. 10) and syrphids. Moreover Calotropis and henna also support populations of prey insects viz., aphids and whiteflies which provide food to predators when the crops are not in field. Prosopis cineraria and Acacia senegal trees are also a good source of pollen and nectar and attract many types of pollinators and parasites on the farm (Fig. 9).

Fig. 9. Honeybees on *P. cineraria* inflorescence.

Fig. 10. Adult and pupa of Ladybird beetles on Calotropis.

Botanicals

Many plants have insecticidal properties i.e. they are toxic to insects. Botanical insecticides are naturally occurring chemicals (insect toxins) extracted or derived from such plants. They are also called 'natural insecticides'. Organic gardeners opt for these insecticides, instead of conventional chemical pesticides. In general, they act quickly, degrade rapidly and have, with a few exceptions, low mammalian toxicity. Neem is a very well-known example of botanical pesticide.

Neem: The well-known tree is common in most agro climatic zones in India and can be easily grown. Its leaves and seed kernels both have pesticidal properties. Leaf extract in water, spray of neem seed kernel extract, neem oil and use of oilseed cake in soil are common ways of using neem in organic systems. Neem extracts are a complex mixture of biologically active materials. Neem is not only active as a feeding deterrent for insects, but it also serves as a repellent, growth regulator, oviposition (egg deposition) suppressant or toxin.

Neem oil: Neem oil acts as powerful as an anti-feedant and insect repellent, oviposition deterrent and ovicidal effect. If eggs are produced they do not hatch, or the insect larvae are unable to moult properly. Only chewing and sucking insects are affected. Disruption of feeding and breeding gradually results in decline in insect population. Neem oil breaks down very quickly and is especially susceptible to UV light. But neem oil also acts as a systemic insecticide. Although neem oil is not harmful to beneficial, but its spray should be done in early in the morning or late afternoon or evening so that it does not affect bees, ladybugs, lacewings, predatory mites and wasps etc.

Neem leaf extract: Take one kilogram fresh green neem leaves, chop them and soak in five liters of water for overnight. Filter and add five liters more water to the filtrate.

Neem Seed Kernel Extract (NSKE): Collect ripe neem fruits during the season. Take care that the fruits are not soiled or contaminated with fungi as this may damage the quality of the final products prepared. Dry the fruits and store in jute bags. Remove seed coat and pulp from the neem seeds by hand. After depulping and cleaning, dry the neem seeds in the shade on a clean surface with good aeration. Do not make heap of the seeds. After drying the neem seed up to 11% moisture, store in jute bags, not in plastic bags, in a cool and dry place. If processed properly these neem seeds can be stored for 6-12 months. For the best results of the extract or for oil extraction use within after 3 months and before 8 months of storage. Remove seed coat (decorticate) with the help of mortar and pestle or any mechanical decorticator. Clean the neem kernel and seed coat mixture by winnowing seed coat. Take one kg of clean neem kernel, powder it in such a way that no oil comes out, soak in about 10 liters of water, add 10 ml of pH neutral adjuvant (mixture of emulsifier, spreader etc.) and stir the mixture. Keep the mixture overnight and filter it on the next day with clean muslin cloth. Put water in the residue and repeat the extraction 2-3 times. Use residue as manure for plants.

Spraying of NSKE: Spray of 1.25% to 5.0% (neem kernel w/v) of NSKE is recommended on the crops, lower concentration as a preventive and higher concentration as protective. Use the spray solution on the same day. Spraying should be done covering all plants foliage in the low intensity of sunlight preferably in the afternoon. Its effect remains for 7-10 days.

Calotropis leaves: Calotropis has been traditionally used for its insecticidal effect by farmers especially for controlling termites. In the organic farm extracts of several plants viz., neem, calotropis and leaves of non-palatable weeds are used as pesticide for controlling insect pests.

Preparation of extracts: Chop one kilogram fresh leaves of calotropis into small pieces; soak in five liters of water for overnight. Filter and mix one liter filtrate with nine liters of water, and spray on the crop in the evening as spraying in the evening gives better results.

Oilseed cakes: Application of nutrients only through organic source of fertilizers such as farm yard manure and oilseed cakes has long-term benefits in terms of building up of soil organic matter which favors multiplication of microorganisms besides improving the physical properties of soil. Oilseed cakes are a source of valuable major and micro-nutrients essential for optimal crop growth and yield and enrich the arid zone soils which are highly deficient in micronutrients. The utility of neem oil seed cake as a fertilizer as well as a pesticide on many economically important crop species is well known. Use of farmyard manure and neem seed cakes provide balanced nutrition to plants as compared to urea and other nitrogenous fertilizers, which sometimes make plants more prone to insect pests especially sucking insects, aphids, jassids, whiteflies. The balanced soil conditions and absence of chemical pesticides provides a favorable environment for the development of healthy microflora and fauna in the soil which in turn provides resistance to plants.

Tumba seed cake: Soil amendment with neem seed cake and tumba (*Citrullus colocynths*) seed cake @ 500 kg per hectare before transplanting reduced infestation of termites and thrips and increased the yield of chilli (Patel and Bhati, 2005). Treated plots had very less damage due to termites which was at par with endosulfan (4% dust 25 kg ha^{-1}) as compared to untreated plots. The incidence of sucking insect pests and apical leaf curl (matha bandhana) was significantly lesser than endosulfan treated and control plots. Significant increase in number of fruits was in the organic soil amendments, and during third picking it was maximum with the application of neem seed cake (46.7 fruits $plant^{-1}$) which was double than the number of fruits in plants of control plot (23.1 fruits $plant^{-1}$). Soil amendment with mustard/castor oil cakes 1000 kg ha^{-1} was effective in reducing the number of root galls and population of Meloidogyne incognita (Poonam *et al*., 2008) in chillies.

Crop rotation: Crop rotation is one of the most effective tools for managing pests and maintaining soil health. The life cycle of pest insects can be discontinued or disrupted by growing crops which are not hosts to the insect pests.

Intercropping: Intercropping encourages biodiversity and increases the effects of natural enemies by providing a nectar source for natural enemies and serves as a habitat for a variety of insects and soil organisms that would not be present in a single-crop environment. It also improves conditions (e.g. moisture, shelter) for ground-dwelling predators.

Crop residues: Some amount of crop residues should be left on the farm. During temperature and moisture fluctuations these provide hiding places for soil predators such as carabid beetles, spiders, and centipedes. The adults of many beneficial insect pass the unfavorable weather conditions in crop residue or farm waste.

Bird perches: Bamboo or wooden poles in the crop serve as bird perches where insectivorous birds like mynas, red-vented bulbuls, crows and green bee-eater can rest and look for prey insects (Fig. 11).

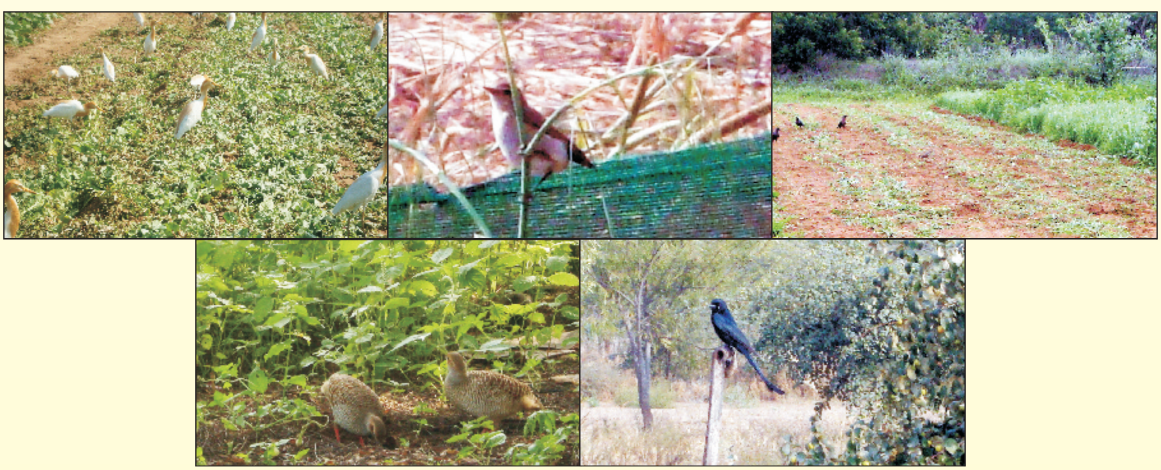
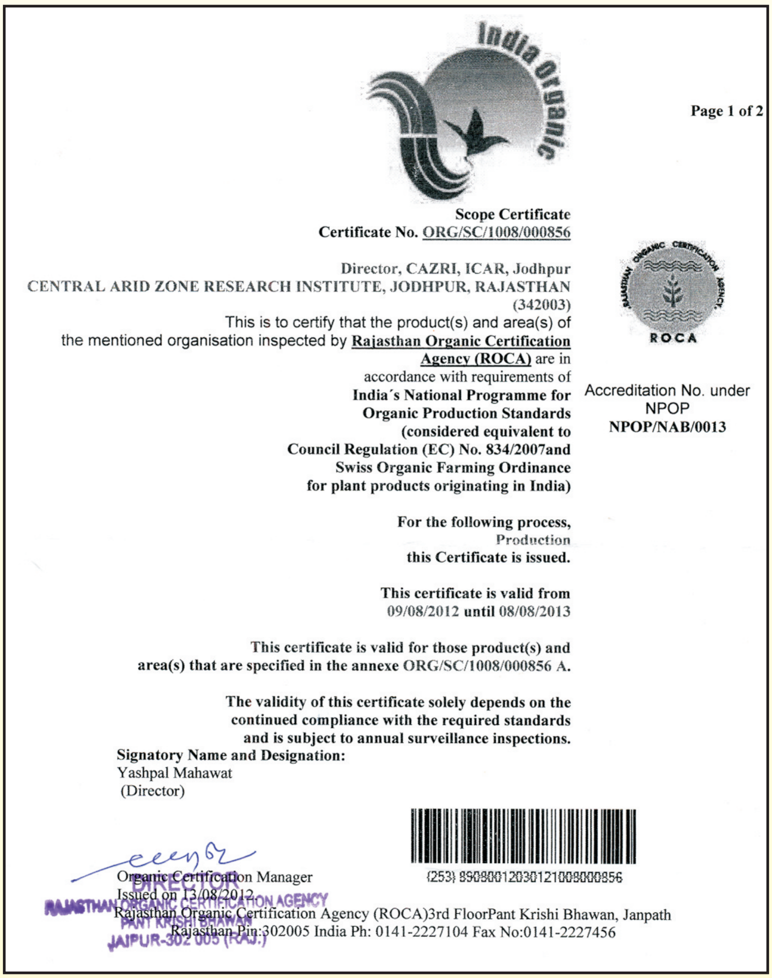


Fig. 11. Predatory birds at the organic farm.

MODEL ORGANIC FARM – CAZRI

Two hectare Model Organic Farm was established in 2008, at Central Research Farm of the institute for experimentation and developing a organic production system for low rainfall areas. The farm was registered with Rajasthan Organic Certification Agency (ROCA), Jaipur for organic certification in August 2008. For this purpose, records were maintained for input use, farming practices, produce storage etc., and auditors of ROCA visited several times to verify the records and testing of soil and produce. The model organic farm was declared “Certified” in August 2011 after completion of three years of registration (Fig. 12).



India Organic

Page 1 of 2

Scope Certificate
Certificate No. ORG/SC/1008/000856

Director, CAZRI, ICAR, Jodhpur
CENTRAL ARID ZONE RESEARCH INSTITUTE, JODHPUR, RAJASTHAN (342003)

This is to certify that the product(s) and area(s) of the mentioned organisation inspected by **Rajasthan Organic Certification Agency (ROCA)** are in accordance with requirements of **India´s National Programme for Organic Production Standards (considered equivalent to Council Regulation (EC) No. 834/2007and Swiss Organic Farming Ordinance for plant products originating in India)**

ROCA

Accreditation No. under NPOP
NPOP/NAB/0013

For the following process,
Production
this Certificate is issued.

This certificate is valid from 09/08/2012 until 08/08/2013

This certificate is valid for those product(s) and area(s) that are specified in the annexe ORG/SC/1008/000856 A.

The validity of this certificate solely depends on the continued compliance with the required standards and is subject to annual surveillance inspections.

Signatory Name and Designation:
Yashpal Mahawat
(Director)

(253) 8908001203012100800856

Organic Certification Manager
Issued on 13/08/2012

DIRECTOR
RAJASTHAN ORGANIC CERTIFICATION AGENCY
PANT KRISHI BHAWAN
JAIPUR-302 005 (RAJ.)

Rajasthan Organic Certification Agency (ROCA)3rd FloorPant Krishi Bhawan, Janpath
Rajasthan Pin:302005 India Ph: 0141-2227104 Fax No:0141-2227456

Fig. 12. Certificate by Organic Certification Agency.

Organic Certification

An organic producer or farmer knows that he used best and recommended practices and the produce is organic. However, a buyer or a consumer does not know this fact and he needs some type of third party verification for genuineness of organic produce. This is called organic certification. To do this certification of organic produce or process there are many agencies who are working at international level and following the standards of USA (USDA), Europe (EU) or Japan (JAS) or India (NPOP). Government of India has designated the APEDA (Agriculture Processed food and Export Development Authority) for accreditation of all the certification agencies. At present more than 15 agencies are doing the work of certification in India. Their fee structure varies as per the compliance of one or more than one standards. Being a complex and costly process of this third party certification, recently Govt. of India approved another type of certification that works well for the indigenous market. This system is called Participatory Guarantee System (PGS) and in this system farmers' groups certified each other and a regional body monitor their functioning. Details of both the systems are available at www.apeda.org or http://ncof.dacnet.nic.in/.

Facilities at organic farm

Following supporting facilities were created for research and demonstration of organic system:

Fig. 13. Model Organic Farm.

1. A trench cum mound was made around the farm for in situ conservation of rainwater and to avoid drift of contamination through water. *Cassia angustifola*, a medicinal shrub was planted on the mound for round the year availability of flowers for predators and further filtration of contamination (Fig. 14).

2. Two tanks each of 5000 liters capacity were constructed to harvest rainwater. Cemented catchment area was made around the ponds for maximum collection of rainwater. This water is utilized for raising low volume-high value crops e.g. cumin, psyllium etc. and this catchment area is also utilized for drying and thrashing of crops during the lean period (Fig. 15).

Fig. 14. Senna plantation on farm bund.

Fig. 15. Rainwater harvesting tank with passive drip system.

3. Manual weeding was done regularly, uprooted weeds were spread as mulch that later on decomposed and contributed organic matter up to 2.0 t ha^{-1} (Fig. 16).

Fig. 16. Manual weeding and mulching.

4. Different plant species including fruit trees namely *Ziziphus mauritiana*, *Phylanthus emblica*, *Cordia mixa*, shrub *Lawsonia inermis*, and plants for biopesticides *Adhatoda vasica*, *Vitex nigundo*, *Aloe vera* and *Cassia angustifolia* were planted on the farm. Besides, about 30 plants of *Prosopis cineraria* and 2 plants of *Azadirachta indica* (for biopesticide) growing earlier were also protected. This ensures nectar supply and shelter to the beneficial insects. Neem plantation was also done around the field for ready supply of material for biopestides.

Fig. 17. Senna plants Attract beneficial insects like bumble bees.

Fig. 18 Neem plantation on the farm boundary.

5. Six compost pits were made at one corner of the farm for making good quality of compost with the crop waste (Fig. 19).

6. Biopesticides were prepared with neem, Calotropis, Adhatoda etc. and other plants leaves and neem cake in the storage tanks in the field (Fig. 20). Pheromone traps were installed in crop field (Fig. 21) for trapping the pests like white grubs, Heliothis etc. and they worked effectively.

Fig. 19. Pit composting.

Fig. 20. Preperating biopesticides at the farm.

Fig. 21. Pheromone traps for monitoring and control of insects.

7. All the implements and produce of the organic farm were kept in the store, inside the field boundary to avoid any contamination.
8. Useful information was displayed at various places on the farm so that the visitors can learn and understand the system (Fig. 22).
9. **Three pronged strategy of sustainability:** Field water, field waste and field education (for the users) should be managed efficiently in the field itself (Figs. 23, 24, 25)

Fig. 22. Information display at farm.

Fig. 23. Field level rainwater harvesting with bunding and ponding.

Fig. 24. Mulching of crop residues at farm.

Fig. 25. Farmers' training at organic farm.

OUTCOME OF RESEARCH

Selection of crops and rotation

In the development of organic production system crop rotation of leguminous and non-leguminous crops was followed. During rainy season two crops, clusterbean (industrial gum) and sesame (oilseed) were grown, whereas in winters, two crops of the region namely cumin (spice) and psyllium (medicinal use) were taken to study their performance in organic system. On the basis of experiments conducted at the organic farm and other places at CR farm CAZRI the findings are:

Soil properties improvement

Soil moisture: Increase in soil moisture retention with the use of organic manure was observed, which helped in better growth and yield of crops (Fig. 26). Similarly increase in soil organic carbon from 0.23% to 0.29% was recorded after six-year-application of compost @ 5.0 t ha^{-1} (Fig. 27).

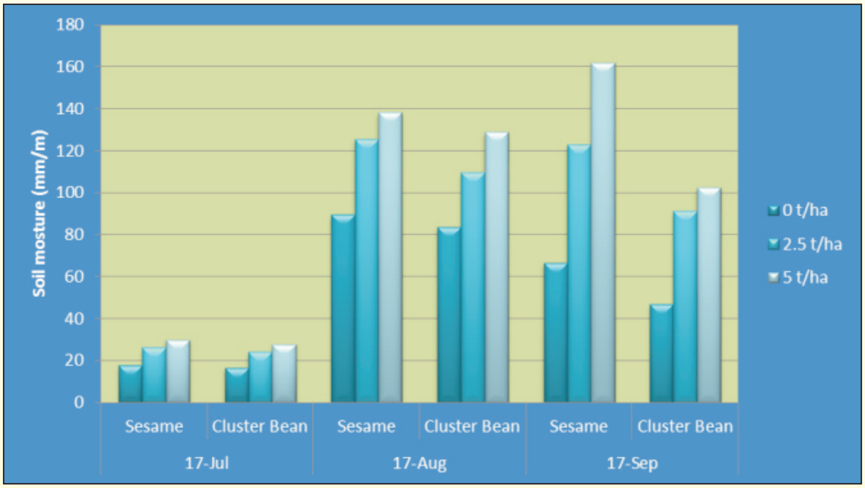


Fig. 26. Effect of level of manuring on soil moisture status.

Soil fertility: Long term field experiment on Pal sandy loam soil was initiated in 2005 in a strict organic farming mode making no use of any synthetic chemical for any purpose. Mono cropping of pearl millet and clusterbean but in two different set of rotations namely: i) pearl millet - clusterbean, and ii) clusterbean - pearl millet was studied. Growing these two crops in rotation is a common practice in arid western Rajasthan; while pearl millet is the main traditional food/fodder crop, clusterbean (a legume crop), is

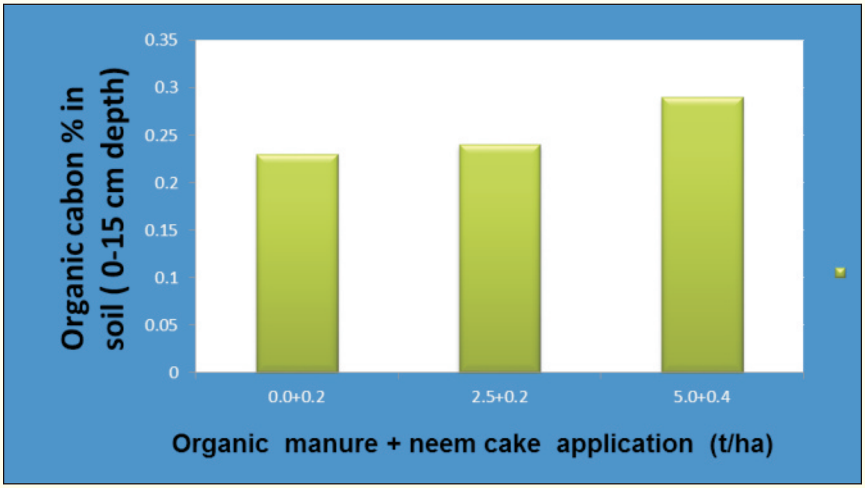


Fig. 27. Change in soil organic carbon with compost application for six years.

a relatively new introduction to restore fertility of the soil. In the rotations every year compost + neem cake @ 0 + 0.2 t ha^{-1} (C0), 2.5 t ha^{-1} + 0.2 t ha^{-1} (C1) and 5.0 t ha^{-1} + 0.4 t ha^{-1} (C2) were added as treatments in three replications with RBD. The neem cake was primarily added to control termite which is a serious problem in the arid region. At the end of sixth crop season after the crop harvest, soil samples from the surface and subsurface were collected. Besides change in organic carbon, samples were analyzed by standard procedures for various soil physical, chemical and microbial properties also, including in situ observations on infiltration, field capacity moisture, penetration resistance etc. (Table 3 and 4). These observations were taken to have a comprehensive understanding of the impact of manure application on soil health. Such holistic information for organic farming is almost absent in general and specifically for the arid region of India.

Since no discernible differences between the crop rotations were observed hence data for the two rotations have been pooled together. Although, the trends for surface and 15-30 cm depth soil were similar, the magnitude of change was small at 15-30 cm depth compared to surface layer. The results presented here are for surface layer only. Application of compost enhanced organic carbon by 1.13 and 1.4 times in C1 and C2 over C0, respectively. As a result of increase in carbon, improvement in other soil properties was also observed as shown in the following tables.

Table 3. Influence of organic inputs on physical properties of Pal series soil at 0-10 cm

Compost + Neem cake ($t\ ha^{-1}\ yr^{-1}$)	Cone index ($kg\ cm^{-2}$)	Field capacity moisture (% by weight)	Infiltration rate ($cm\ hr^{-1}$)
0.0 + 0.2	5.10	7.87	7.8
2.5 + 0.2	4.76	8.18	9.8
5.0 + 0.4	3.91	8.31	11.5
$S\ E_d$	ns	0.40	1.2

Table 4. Influence of organic inputs on physico-chemical and microbial properties of Pal series soil at 0-15cm

Compost + Neem cake ($t\ ha^{-1}\ yr^{-1}$)	pH	EC ($dS\ m^{-1}$)	Available K ($kg\ ha^{-1}$)	Available P ($kg\ ha^{-1}$)	Dehydrogenase ($p\ Kat\ g^{-1}$)
0.0 + 0.2	8.21	0.19	280.6	18.0	2.15
2.5 + 0.2	8.25	0.17	304.2	25.3	3.18
5.0 + 0.4	8.35	0.23	329.2	26.9	2.05
$S\ E_d$	0.08	0.03	30.6	5.8	0.98

Decrease in cone index will favor root growth, while a combination of more water retention at field capacity and increase in infiltration rate along with better root system improves use of rain water by the crop. Increase in both available K and P improves their supply to the crop. However, increase in pH and EC indicated the accumulation of soluble salts including sodium. This is expected because manure contains salt and under arid conditions rain fall is too low to leach salts deep in the profile but evaporation is high to cause upward movement of salts to the surface layer. This in the long run may cause salinity/degrade soil. Hence, monitoring manure quality/appropriate management is essential. It was observed that neem cake reduced dehydrogenase activities, while organic matter enhanced the activities. Neem cake is primarily applied to control termites. It is thus suggested to apply sufficient quantity of compost i.e. organic matter to maintain activities of the microorganisms at higher level. However, research is required to decide the optimum combination for rates of neem cake and compost. This study confirmed the earlier findings that application of 5 $t\ ha^{-1}\ yr^{-1}$ compost is the best.

Manure application

FYM applicators for surface and subsurface application of manure were improved and tested in the field (Fig. 28). The distribution of FYM at the rate of 5.0 t ha^{-1} was uniform, after which clusterbean crop was raised. Improvement in yield was observed over the traditional method when manure was applied with applicator and incorporated in soil (Table 5).

Fig. 28. Prototypes of surface and subsurface manure applicators.

Table 5. Effect of method of compost application (5.0 t ha^{-1}) on performance of clusterbean crop

Treatment	Height of crop (cm)	No. of pods (m^{-2})	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
No manure	45.6	403	962.9	1188.9
Manure application and incorporation in soil with traditional method	47.2	609	1338.2	1483.2
Surface application of manure with applicator	48.8	598	1308.3	1452.9
Surface application of manure with applicator + incorporation in soil	51.2	764	1446.8	1522.3
CD 5%	1.9	53.9	64.8	164.8

Pest management

At the organic farm there was a large diversity of pollinators which included different types of honeybees, wasps, syrphids and many other dipterans and hymenopterans due to different types of flowering plants.

During the hot season in the arid region coccinellid beetles hibernate in protected places. Ladybird beetles seek shelter behind bark, under leaves or farm residue, or in other protected places. Aphid populations on cumin and psyllium declined sizably due to coccinellid beetles (Fig. 29).

Fig. 29. Ladybird beetle devouring aphids on cumin.

Eggs of *Chrysoperla* sp. were seen in good numbers on henna and ber plants. Reduction in number of caterpillars causing damage to pearl millet leaves was seen due to predation by Chrysoperla larvae (Fig. 30).

Fig. 30. Chrysoperla larva devouring larva of a pest.

Neem seed kernel extract spray either prophylactic or initial stage of pest attack is very effective

Neem cake found to be effective in controlling soil pests like termite and white grub. Plant mortality due to termites was negligible (less than 5%) with the use of neem seed kernel.

Enhanced floral diversity on the farm with mustard, coriander, fennel and dill was found to increase the number and diversity of coccinellids and syrphids in the winter season.

Senna plant in the fields also supported parasitoid population as they have extrafloral nectaries which provided food to beneficial insects during off-season. Plants of mustard, ajwain, fennel grown in the organic plots during winter season helped in attracting many types of syrphids which predated on aphids on cumin and psyllium crops.

Trees, maize, pearl millet plants in the field provide perching sites to predatory birds. These birds feed on caterpillars and other insects. Some died khejri trees in the field were not removed and left as such in the field. These served as shelter to birds like owls and eagles which in turn controlled the population of rodents. Large populations of castor semilooper (*Achaea janata*) reduced dramatically due to predation by birds such as red-vented bulbuls.

Pests were kept below economic threshold level with the integrated use of following eco-technologies:

- Soil application of neem cake @ 300 kg ha^{-1}
- Use of well prepared compost @ 5.0 t ha^{-1}
- Trichoderma viride application in soil and seed treatment
- Use of healthy seed and also free from weed seeds
- Hand weeding and mulching
- Prophylactic spray of neem seed kernel extract solution (5.0%) at regular interval
- Use of pheromone traps according to the pest
- Regular monitoring of crop health conditions and timely spray of biopesticides.

Performance of crops

Contribution of legumes: Legumes contributed 25-30% higher yield in the subsequent crop. During winter season crops of cumin and psyllium were grown in rotation with sesame and clusterbean. Cumin yield of 566 kg ha^{-1} and psyllium yield of 808 kg ha^{-1} were obtained in the treatments of organic inputs + clusterbean in rotation (Table 6). During winter, crops were irrigated with harvested rainwater.

Table 6. Effect of rotation and level of manuring on the yield of rabi crops

Crop sequence	Yield of crop (kg ha^{-1})					
	Cumin			Psyllium		
	Manure application(t ha^{-1})			Manure application(t ha^{-1})		
	2.5	5.0	7.5	2.5	5.0	7.5
After sesame	229.4	374.3	459.8	424.7	578.8	672.9
After clusterbean	407.9	489.3	516.4	629.4	786.2	808.3

Crop resilience to rainfall variability: Crop resilience to climatic variability enhanced with the use of organic manure as shown with the two-year data. Since crop yield is the ultimate product of all the interactions therefore only yield comparison is given. Average annual rainfall of the area is 366 mm mostly spread over 7-20 rainy days.

During 2009, because of low (208 mm) as well as highly erratic (only 4 good rainy days and 2 long dry spells of 17 and 29 days) rainfall, crops faced drought conditions. The severity was further increased by dry hot winds during milking stage of sesame and clusterbean crops in September. With this set of conditions crops in the conventional plots failed, however, crop grown with organic inputs and timely interculture for moisture conservation could yield up to 30-40% of the average yield. Yields of 196.3 kg ha^{-1} of sesame and 206.8 kg ha of clusterbean were obtained.

During 2010, rainfall was 460 mm during the cropping season and it was above normal. However, incorporation of organic matter maintained optimum aeration and moisture in the soil resulting in good crop growth, while in the conventional plots crop growth was stunted and produced poor yield.

Crop yield comparison: There is apprehension that organic system is poor yielder. However, findings at CAZRI shows that the initial developmental stage of organic system may be low yielder but after 2-3 years once the system is developed the yield levels are comparable to the conventional (chemical input based) system. At third year, yields of sesame 886.6 kg ha^{-1}, clusterbean 630.2 kg ha^{-1}, cumin 516.9 kg ha^{-1} and psyllium 808.4 kg ha^{-1} were recorded. This is comparable to the average yield of conventional system (Table 7). As mentioned earlier 2009 was a drought year therefore, data could not follow the trend. However, organic performed better.

Table 7. Yield comparison of organic with conventional system

Year	Crop yield (kg ha^{-1})							
	Sesame		Clusterbean		Cumin		Psyllium	
	Org	Con	Org	Con	Org	Con	Org	Con
I^{st} year (2008)	343.9	467.3	476.3	493.9	323.3	496.3	382.3	523.9
II^{nd} year (2009)	196.3	0.0	206.8	0.0	423.9	496.3	485.7	510.7
III^{rd} year (2010)	886.6	523.9	630.2	308.6	516.6	497.2	808.4	786.3

Org = organic, Con = conventional

Partitioning of sink: In a separate experiment on pearl millet it was observed that as the manure level increased, percentage of sink to grain increased from 15.7 to 19.8% (Table 8). It may be due to balanced nutrition through compost that was utilized by plant for grain formation

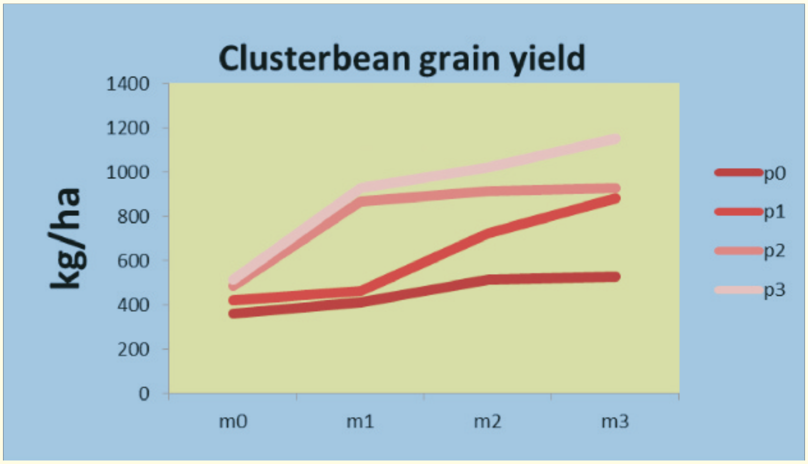
Table 8. Partitioning of sink in pearl millet

Level of manure (t ha^{-1})	Yield of plant part (g m^{-2})				Total biological yield (g m^{-2})
	Root	Stem	Leaf	Grain	
0.0	173.8 (25.1)	152.6 (22.0)	257.2 (37.2)	109.3 (15.7)	691.8
2.5	546.9 (27.7)	395.2 (20.7)	658.9 (34.2)	352.6 (18.0)	1951.6
5.0	692.8 (27.8)	429.6 (16.6)	908.4 (35.8)	501.3 (19.8)	2530.7

Values in parentheses are the percentages of total biological yield

Integrated effect of nutrition and protection on crop performance

The effect of level of manuring was conspicuous on grain yield of clusterbean (Fig 31). There was only 99.5% increase in yield from lowest (p0) to highes level (p3) of pest management. Effect of level of manure application was conspicuous as the increase in yield was 49.8%, 77.7% and 95.5% with the application of manure 1.5, 3.0 and 4.5 t ha^{-1}, respectively over control. There was 105.5% increase in yield of sesame from no manuring to highest level (4.5 t ha^{-1}) of manuring. Also the effect of level of pest management was conspicuous as the increase in yield was 29.7%, 36.9% and 56.1% with the level of pest management p1, p2 and p3, respectively over control (Fig 32).



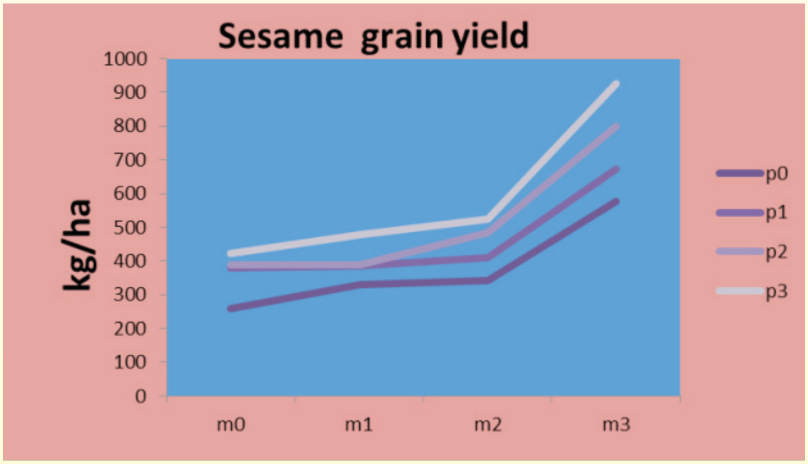


Fig. 31 & 32. Effect of nutrition (m0-m3) and protection (p0-p3) treatments on clusterbean and sesame grain yield.

Legend of treatment

m0 = no manure application

m1 = manure application @ 1.5 t ha^{-1}

m2 = manure application @ 3.0 t ha^{-1}

m3 = manure application @ 4.5 t ha^{-1}

p0 = no pest management

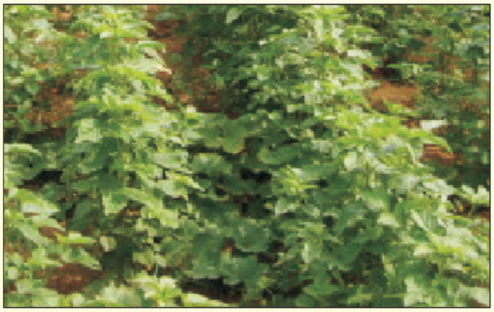
p1 = soil application of neem cake @ 400 kg ha^{-1}

p2 = foliar spray of biopesticide as and when required

p3 = p1+p2

Economics

Organic system took three years for development. Once the system is developed most of the inputs e.g. seed, manure, biopesticides, etc. are made with local resources. Therefore, major cost of cultivation becomes negligible and only expenditure is on the labor work for seeding, weeding, spraying, harvesting etc. Benefit/cost ratios 1.79, 3.06 and 2.74 were obtained with the application of manure @ 0.0 t ha^{-1}, 2.5 t ha^{-1} and 5.0 t ha^{-1}. This shows that if there is limitation of manure, application of 2.5 t ha^{-1} manure is recommended. Although, production will increase with up to 5.0 t ha^{-1} manure application, if available.



Organic clusterbean

Organic sesame

Organic cumin

Organic psyllium

PROMOTION OF ORGANIC FARMING NEEDS INTEGRATED EFFORTS

Considering the export demand and contribution in the economy of this region, it is need of the hour to do integrated efforts for quality organic production. The efforts are needed to be taken up at four levels: Policy, research, production and marketing. Integration of technologies and programs, and coordination among various agencies are the prime requirements. For example, development of package of organic production may not be much effective until and unless promotion policies and good market facilities are available. Some of the policy suggestions are:

1. **Priority to organic farming in ongoing programs:** Organic farming needs not to be promoted as a new program as it may cause overburden on ongoing programmes. It would be better if organic farming is taken on priority in all rural development programs e.g. Watershed Development, Swaran Jayanti Swarojgar Yojana, MNREGA, Rastriya Krishi Vikas Yojana, Food Security Mission and National Mission on Sustainable Agriculture etc.

2. **Popularization of organic farming without compulsion of certification:** In rainfed areas farmers are very poor and unable to afford the cost of certification. Promoting organic farming with the compulsion of certification has made negative impact on adoption. Instead, at initial stage organic farming should be promoted for improving soil fertility, reducing cost of production and other environmental advantages.

3. **Dissemination of organic farming in holistic manner:** Most of the agencies are promoting organic farming in piecemeal approach e.g. only use of vermicompost, only integrated pest management, only integrated nutrient management/soil health programmes etc. and making confusion among the farmers. While organic farming is an integrated approach for nutrient recycling, conservation of natural resources, water conservation, crop rotation/diversification etc. So it must be inclusion of all these aspects which can make a sustainable organic farming in real term.

4. **Encouragement of decentralized input supply:** Encouragement may be given to produce all inputs for organic farming in a decentralized manner at local level so that not only local resources can be utilized but also employment at village level can be generated. In Tamil Nadu, Trichograma and Trichoderma cultures are prepared at large scale by women self-help-groups in the villages and used as biocontrol agents on the crops.

5. **Adoption of improved methods of composting:** Majority of the farmers in the rainfed areas apply animal and crop waste in un-decomposed form to the soil, as a result the availability of nutrients to the plants decreases and also invites several pests. It would be better to apply these materials after composting them with any of the suitable methods. These methods can be popularized and financially supported under the "Clean Village Scheme" of the central and state governments.

6. **Awareness and capacity building:** Demonstrations, trainings, conferences, seminars, farmers fairs, etc. may be organized to make a general consensus about organic farming and good organic management.

7. **Subsidy on organic inputs:** Provision of subsidy may be made for organic inputs to make organic produce more competitive.

8. **Promotion of high value crops:** The demand of spices and medicinal plants is increasing when grown organically, so it must be promoted in the various agro-climatic zones (Table 9). Export of four high value crops of low rainfall areas (cumin, clusterbean as guar gum, sesame and psyllium) brings about ₹ 20000 millions annually.

Table 9. Potential high-value crops for organic farming in different agro-climatic regions

Agro climatic zone	Average rainfall (mm)	Crops*
Arid	100-300	Cumin, psyllium, senna and clusterbean
Transitional	300-450	Fenugreek, cumin, aloe, sesamum, mung bean and fennel

*with limited or life saving irrigations

9. **Development of organic clusters of villages:** Available clusters of villages of watershed programs may be converted into organic cluster of villages by providing technical support. This will be cost effective and make easier the group certification process of organic produce.

10. **Research orientation:** Research has been done on various components of organic farming by ICAR institutes and SAUs, yet the research is needed to integrate the efforts and assess their effects. Besides, following aspects of research may be taken simultaneously:-

a. Assessment of economic and ecological returns from organic *vis-a-vis* intensive agriculture system

b. Development of organic farming models for each sub agro-ecological zone for long term study

CONCLUSION

In low rainfall areas the major constraints for large scale production are water scarcity and poor soils. However, these constraints can be converted into opportunities in terms of economic and ecological returns through organic farming for better life of the inhabitants. This will not only boost the economy of this region but will also improve the productivity of natural resources, soil health, quality food, generation of employment, reduction of migrations, etc. for overall sustainability of the region. Some monopoly high value crops of this region like seed spices are having great international demand if produced organically. The need of the hour is to do research on development of easy and economic technologies, development of processing and marketing infrastructure and financial as well as technical support for quality organic production.

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