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Manufacture of Biofertilizer and Organic Farming

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With the introduction of green revolution technologies, the modern agriculture is getting more and more dependent upon the steady supply of synthetic inputs. Intensive agriculture with the use of chemical fertilizers in large amount has, no doubt, resulted in manifold increase in the productivity of farm commodities but the adverse effect of these chemicals are clearly visible on soil structure, micro flora, quality of water, food and fodder. At this critical juncture, biofertilizers are useful supplement to chemical fertilizers. Organic farming has emerged as the only answer to bring sustainability to agriculture and environment. Biofertilizers is also an ideal for practicing organic farming.

Biofertilizers are the most advanced biotechnology necessary to support developing organic Agriculture, sustainable agriculture, green agriculture and non-pollution agriculture. Bio Fertilizer are natural and organic fertilizer that helps to keep in the soil with all the nutrients and live microorganisms required for the benefits of the plants. Today product like biofertilizers using the biotechnology techniques have proved that biological control is widely regarded as a desirable technique for controlling insects and pests, due to its minimal environmental impact and its avoidance of problems of resistance in the vectors and agricultural pests.

The increasing demand for biofertilizers and the awareness among farmers and planters in the use of biofertilizers have paved way for the fertilizer manufacturers and new entrepreneurs to get into biofertilizers production. It is one of the important components of integrated nutrient management, as they are cost effective and renewable source of plant nutrients to supplement the chemical fertilizers for sustainable agriculture.

This book gives a detailed process on manufacture of biofertilizers & organic farming. It contains chapters on biofertilizers, role of biofertilizer in crop production, production and distribution of biofertilizer, organic farming, method of organic farming, weed and pest management, and many more. This book will be very helpful to soil scientists, microbiologists, biologists, students, new entrepreneurs, fertilizer industry, organization engaged in biofertilizers production, training centres and to all those interested in the efficient use and recycling of wastes, resource management and sustainable farming.

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Sample Chapter:

BIOLOGICAL WASTES AS SOURCES OF BIOFERTILIZERS

In order to meet the nutrient needs of agriculture in the coming years, the Government of India's working group on fertilizers has estimated that 6.5 million tonnes (mt) of N + P2O5 + K2O will be needed by 2007-08 and 60 mt by 2010. On no account can fertilizers, or any single input provide such large quantities of plant nutrients. All available nutrient sources have to be made use of. In addition, integrated use of mineral, organics and recyclable wastes is accepted as the most appropriate strategy for sustaining high crop yields, minimising soil depletion and value-added disposal of what are traditionally labelled as "wastes".

This chapter present a current assesment of biological and industrial wastes as sources of plant nutrients and analyses various factors which determine their usefulness. Among biological wastes, materials covered are sewage sludge, biogas slurry, waste water, fish pond effluent and some wastes of food processing industry. Pressmud and phosphogypsum (biproduct of fertilizer industry) are also dealt with.

Significance of Waste Recycling

Nutrients and water being major constraints in the development of Indian agriculture, harvesting the nutrient energy of biological and industrial wastes is of prime importance for maximising the food, feed, fodder and fuel production in the country. Further, when these wastes are recycled through land for crop production, due to the degradative and assimilative capacity of soil the pollution of streams and/or rivers receiving these wastes can be minimised to a large extent as compared their direct disposal in water resources. Role of 4 R cycles in harvesting the nutrient energy of waste. Domestic and industrial waste waters are disposed on land (i) to use the nutrient potential for biomass production (ii) provide safe disposal to the waste water through the soil and (iii) prevent the pollution of streams and rivers.

Large potential for the exploitation of manurial value of biological and industrial wastes exists in India. Even at 50% collection of the total agro forest waste, more than 14.5 in ha of land can be manured at the rate of 10 t/ha annually. Further, the productivity of more than 48 m ha land can be improved through biogas slurry manure at 50% collection rate.

The domestic and industrial wastewaters amenable for crop production can help to increase the irrigated area by 170.4 x 103 hectares in the country. The prevention of environmental pollution through recycling of waste is difficult to quantify but it will be several times valuable as clean environment is today's need.

Nutrient potential of different biological and industrial wastes has been summarised in Table 1. The major sources are crop residues, animal excreta, rural compost (of which dung is again a major component) domestic and industrial waste water, forest litter, and city refuse. Since dung is a major component of rural compost, nutrient potential can be over estimated if cattle dung and rural compost are taken as independent materials which they are not. If 60% of the total dung available is fed into biogas plants, this can generate 470 mt of organic manure. Under the National Programme on Biogas Development about 350,000 biogas plants were set up during 2000 which produced 7.1 mt. of manure. Biogas manure is richer in plants nutrients compared to FYM and contains 1.65-1.84% N, 1.08-1.18% P2O5 and 1.24-1.83% K2O.

A NOTE ON BIOFERTILIZERS

The carrier based microbial inoculants being added to the soil to enrich the soil fertility are called biofertilizers. They are often known as microbial fertilizers or microbial inoculants. A biofertilizer may contain nitrogen fixing microbes or phosphate solubilizing microbes or spores of VAM fungi. It is supplied to the soil either by seed treatment or by spreading it over the field during cultivation. Biofertilizers reduce the use of chemical fertilizers in agriculture and cost of production.

The nitrogen biofertilizer may have nitrogen fixing bacteria or blue-green algae. The nitrogen fixing bacteria include Rhizobium, Azospirillum, Azotobacter Azotococcus, etc. Blue green algae such as Anabaena, Aulosira, Nostoc, Plectonema and Tolypothrix are used as nitrogen biofertilizers.

Preparations of phosphate solubilizing bacteria such Bacillus megatherium, B, subtilis, Xanthomonas and

Pseudomonas, are used as phosphate biofertilizers.
The spores of VAM fungi like Glomus, Gigaspora, Acaulospora, Sclerocystis and Endogone are used as VAM biofertilizers.
Biofertilizers have the following advantages-
i) Biofertilizers reduce the use of chemical fertilizers in agriculture.
ii) They never cause pollution in air, water and land.
iii) They secrete plant growth hormones to increase the plant growth.
iv) They reduce the attack by soil-borne pathogens,
v) They improve the quality of soil for more productivity.
vi) They can be mass produced by using renewable wastes.
vii) No special care is required while using biofertilizers.
viii) The farmers themselves can grow BGA biofertilizers *and Azolla* biofertilizer in their own lands.

Rhizobium

Rhizobium is a gram negative, aerobic, rod-shaped bacterium. It contains a refractive granule. It is a soil bacterium present in large numbers in rhizosphere of legume roots.
Rhizobium invades roots of legumes and forms nodules on the roots. Inside the root nodules, the bacteria exist in various pleomorphic forms called bacterioids. The bacterioids fix the atmospheric nitrogen into ammonia. They provide the fixed nitrogen for plant's use and draw nourishments from the root cells. This type of association is called symbiosis.
Different species of Rhizobium can fix 50-200 kg nitrogen/ha/ year in leguminous crops. Therefore, they have been recommended as nitrogen biofertilizers in agriculture.
Different species of Rhizobium show a great degree of host specificity. Hence they can be used as biofertilizers only for the specific crops-
i) ***R. meliloti*** **(Medic-Rhizobium):** Lucerne and Fenugreek.
ii) ***R. trifolii*** **(Clover-Rhizbium):** Egyptian clover and clover.
iii) ***R. Leguminosarum*** **(Pea-Rhizobium):** Lentil, pea, khesri (Lathyrus) and vetch.
iv) ***R. Phaseoli*** **(Bean-Rhizobium) :** Bean, kidney bean and French bean,
v) ***R. lupini*** **(Lupin-Rhizobium):**Lupines and white lupines.
vi) ***R. japonicum*** **(Soybean-Rhizobium):** Soyabean.
vii) ***Rhizobium sps.*** **(Chickpea-Rhizobium):** Chickpea and subabul.
viii) Rhizobium sps, **(Cowpea-Rhizobium) :** Sunnhemp, cluster bean, peanut, jack bean, lablab, horsegram, moth bean, green gram, blackgram and pigeonpea.

Production of Rhizobium Inoculants

Production of Rhizobium inoculant involves-
i) Isolation of Rhizobium
ii) Identification of Rhizobium
iii) Establishment of starter culture
iv) Mass culture
v) Mixing with carrier
vi) Packaging and storage.

1. Isolation of Rhizobium

Rhizobium occurs in the soil as well as in the root nodules of selective legumes. Rhizobium in the root nodules has least contaminants. Therefore, it is isolated from root nodules of a proper leguminous plant. The leguminous plant is carefully uprooted from the soil and the root system is washed with running water to remove the soil particles. Firm, undamaged, pink-coloured root nodules are selected visually and excised from the roots.

The root nodules are kept immersed in 0.1% potassium chloride solution or in 0.1% acidified mercuric chloride solution for 5 minutes to sterilize the surface of the nodules.
The sterilized root nodules are then washed 5 or 6 times with distilled water. They are once again sterilized by immersing them in 90% ethyl alcohol for 10 seconds and washed repeatedly with distilled water.
The root nodules are crushed gently in a small amount of distilled water using a pestle and mortar to get a suspension.
The suspension is diluted and inoculated onto YEMA (Yeast extract mannitol agar) medium in petri dishes. The culture plates are incubated at 28°C for about 10 days. Rhizobial cells form gummy colonies on the medium.

Components of YEMA medium

K2HPO4
-0.5 g
MgSO4.7H2O -0.2g
NaCl -0.1 g
Mannitol -10.0g
Yeast extract -1.0 g
Agar -20.0 g
Distilled water -1000 ml.

2. Identification of Rhizobium: YEMA medium is suitable for the growth of Rhizobium as well as Agrobacterium. Rhizobial colonies are identified from the culture in the following methods:
i) CRYEMA Test:A 2.5 ml of congo red dye is mixed with a litre of YEMA medium to prepare CRYEMA medium. Bacterial colonies on the YEMA medium are streaked on the CRYEMA medium and the petri dishes are incubated at 28 ± 2°C for 5-7 days.
Rhizobial cells uptake congo red very weakly so they 27-BT form white, circular, entire, raised, convex colonies. Agrobacterium colonies, if any, look like Rhizobial colonies, but show characteristic colour of congo red. The white colonies are picked up to produce Rhizobium inoculant.
ii) Microscopic Observation :Bacterial cells in the CRYEMA medium are stained with carbol fuschin and visualized under a compound microscope. This dye stains the -polyhydroxybutyrate granule in the Rhizobium. The cells of those colonies having -polyhydroxybutyrate granule are picked up to establish Rhizobium inoculant.
iii) **Glucose Peptone Agar Test (GPA Test):** Rhizobial colonies are streaked on YEMA medium and a master plate is made. Colonies in the master plate are transferred to GPA medium in a petri dish by replica plating. Rhizobium cannot grow in the medium, but Agrobacteria, if present in the colonies, grow into colonies. Those colonies in the master plate failed to grow in the replica plate are pure rhizobial colonies. They are picked up and grown in YEMA medium. This test is the confirmative test to test the purity of Rhizobial colonies.
iv)Nodulation Test; The same species of legume from which Rhizobia were isolated, is grown in sterile soil in sterile jars. Nutrient solution that lacks nitrogen source, is supplied through a hole at the base of the jars by inserting a cotton thread immersed in the solution. Each pure Rhizobial culture is then inoculated near the root of legume growing in a jar. After 3 or 4 weeks, the plants are carefully uprooted from the jars and visualized for root nodules. Presence of more root nodules indicates that it is the right strain of Rhizobium for that legume.
3. Establishing the Starter Culture:Pure rhizobial colony is transferred to a flask containing YEMA medium. The flask is kept on a rotary shaker system in a constant temperature room at 28±2°C. Pure culture of rhizobium appears within a week. It is known as starter culture or mother culture. A starter culture is frequently sub-cultured for maintaining it for a long time.

4. Mass culture of Rhizobium:Rhizobium is mass cultured in large bioreactors (fermenter) to prepare inoculant. YEM medium * or sucrose-mannitol medium is used for this purpose.

A suitable medium is formulated and filled into the bioreactor after proper sterilization. One litre of starter culture for 100 litres of medium is inoculated into the bioreactor.

The temperature inside the reactor is maintained at 28± 2°C. Sterile air is continuously supplied to the broth with the help of a proper device. The broth is stirred continuously by a stirrer system kept in the bioreactor. Cell counting is done a regular intervals to assess the growth rate of Rhizobium. Having reached 108-109 cells/ml, the broth is harvested to use as inoculant. Further maintenance of the broth in the bioreactor may lead to death of rhizobial cells due to the deficiency of enough nutrients.

ROLE OF BIOFERTILIZER IN CROP PRODUCTION

Biofertilizers have an important role to play in improving the nutrient supplies and their crop-availability in upland crop production. Although Rhizobium is the most researched and well known among these, there are a number of microbial inoculants with possible practical application in upland crops where they can serve as useful components of integrated plant nutrient supply systems. Such inoculants may help in increasing crop productivity by way of increased biological nitrogen fixation (BNF), increased availability or uptake of nutrients through solubilization or increased absorption, stimulation of plant growth through hormonal action or antibiosis, or by decomposition of organic residues.

The scope of this chapter is confined to microbial inoculants of N2-fixing bacteria, vesicular arbuscular mycorrhizae (VAM), phosphate solubilizers and plant-growth promoting rhizobacteria (PGPR) and their role in production of upland crops. Aspects determining the success of inoculant technology are discussed here rather than presenting an up-to-date account of literature on the performance of biofertilizers. Rhizobial inoculants are dealt with in detail as a general example and for others, our discussion is restricted to those points which are specific to a particular group of inoculants.

Nitrogen-fixing Bacterial Inoculants

Above every hectare of land at sea level, there are 78,000 tonnes of inert nitrogen gas (N2). Nitrogen is the most limiting nutrient for increasing crop productivity. Only a few procaryotic organisms are able to "fix" N2 directly through a biological process. Annually BNF is estimated to be around 175 million tons of which close to 79% is accounted for by terrestrial fixation. The N2 fixers involved are metabolically diverse but the process is similar and depends upon (i) nitrogenase (N2ase) enzyme complex, (ii) a high energy requirement (ATP) (iii) anaerobic conditions (for N2ase activity) and, (iv) source of strong reductant. Amongst N2-fixing bacteria viz; Rhizobium, Azospirillum, and Azotobacter, the most widely used inoculant is Rhizobium.

Rhizobium

Symbiotic N2-fixation by Rhizobium with legumes contributes substantially to total BNF. Rhizobium inoculation is a well known agronomic practice to ensure an adequate nitrogen nutrition of legumes in place of fertilizer N.

Table 1: Estimates of nitrogen fixed by some legumes.

Crop	Nitrogen fixed (kg/ha)	Crop	Nitrogen fixed (kg/ha)
Alfalfa	100-300	Lentil	35-100
Clover	100-150	Green gram	50-55
Chickpea	26-63	Pigonpea	68-200
Cluster bean	37-196	Soybean	49-130
Cowpea	53-S5	Peas	46
Groundnut	112-152	Fenugreek	44

Classification; The genus Rhizobium consists of six distinct species based largely on the cross inoculation group concept. The assumption in this classification is that those leguminous plants falling within a

particular infection group were nodulated by a particular species of nodule bacteria. More than twenty cross-inoculation groups have been established, but only seven have achieved prominence. The validity of the cross-inoculation groups has been questioned as many legumes are nodulated by rhizobia of other host-bacterial groups. With repeated evidence of anomalous cross-infection among the different plant groups, new classification has been proposed. The slow-growing rhizobia are grouped under the genus Bradyrhizobium and the fast growers under the genus Rhizobium.

The new classification is more complex as the same host may be nodulated by fast and slow-growing strains. Moreover, the agricultural significance of the cross inoculation groups still remains a key feature of the established taxonomic system. In this article we have used the classification based on cross-inoculation groups. The cross-inoculation groups and Rhizobium-host plant associations are listed below:

Cross-inoculation group	**Rhizobium species**	**Host genera**	**Legumes included**
Alfalfa group	*R. meliloti*	*Medicago*	Alfalfa
		Melilotus	Sweet clover
		Trigonella	Fenugreek
Clover group	*R. trifolii*	*Trifolium*	Clovers
Pea group	*R. leguminosarum*	*Pisum*	Pea
		Vicia	Vetch
		Lathyrus	Sweet pea
		Lens	Lentil
Bean group	*R. phaseoli*	*Phaseolus*	Beans
Lupine group	*R. lupini*	*Lupinus*	Lupines
		Ornithopus	Serradella
Soybean group	*R. japonicum*	*Glycine*	Soybean
Cowpea group	*Rhizobium sp.*	*Vigna*	Cowpea
		Cajanus	Pigeonpea
		Cicer	Chickpea
		Lespedeza	Lespedza
		Crotolaria	Sunnhemp
		Arachis	Groundnut
		Phaseolus	Lima bean
		Pucraria	Kudz

Need for Inoculation: The most important point is do we need inoculation of legumes in a region where these crops have been grown over long periods? Development of an inoculant industry in many countries has been largely motivated by the desire to introduce legume species to new areas. Most cultivated tropical soils are assumed to have relatively large populations (> 100/g dry soil) of rhizobia capable of nodulating the legumes grown in such soils. The need to inoculate the legumes grown on cultivated soils must be assessed by considering the interacting factors between the soil, the host plant and *Rhizobium.*

Presence of nodules on plant roots does not necessarily mean that sufficient N2 is being fixed for maximum benefit to the host plant. In groundnut or pigeonpea nodulation occurs naturally at most locations due to the cross-species promiscuity of the cowpea rhizobia. However, the ability to fix high amounts of N (efficiency) is governed by the symbiotic capability between *Rhizobium* and the host plant. Hence, it may be necessary to introduce superior (more competitive and efficient) strains of *Rhizobium* to ensure adequate N2fixation for maximum growth and yield of the host plant. In a survey of groundnut crops grown in farmers' fields in southern India, 52 out of 95 fields showed inadequate nodulation with less than 10 per cent N2-fixing

(acetylene reducing) activity of what can be obtained under reasonable field conditions. The results of surveys of farmer's gain and fodder legume crops also revealed poor nodulation in large areas and good noduation only in a few pockets. Poor nodulation in farmer's fields could be due to several lactors eg. lack of appropriate rhizobia in soil, deficiency or toxicity of a nutrient, unfavourable conditions like prolonged water logging, unsuitable pH, abundance of bacterial predators, pests and disease attack, etc. Although adequate nodulation was observed in some parts, ineffective nodules exceeded the number of effective nodules. Out of 87 groundnutrhizobial strains isolated from different parts of India, only 5 were found to be effective.

BIOFERTILIZERS FOR RICE ECOSYSTEM

Rice is grown in about 42 m.ha in India. It contributes 75 mt, (44%) to the total foodgrain production of 170 mt. Apart from water management, supply of nitrogen is a key factor in the realisation of potential yields from modern high yielding varieties. The rice plant absorbs about 20 kg N/t paddy produced. Due to the poor N-status of soils, N application is a must for harvesting moderate-high yields. Rice is estimated to receive 40% of the total fertilizer N applied in India.

Rice, however, is not exclusively dependent on fertilizers or FYM for external N supplies because the crop can receive sizable N input from green manures and certain biofertilizers. The most important biofertilizers for flooded rice are Azolla and Blue-Green Algae (EGA). Both can grow along side rice. In addition, Azolla can also be used as a green manure.

This chapter takes stock of available information on Azolla and BGA for flooded rice ecosystem. Any integrated N-supply system for flooded rice must feature one of these biofertilizers which have the potential to contribute 20-68 kg N/ha depending on the intensity of multiplication. Sustainability of rice production will depend on how well these inputs have been integrated with other sources of N. Both these biofertilizers are members of the plant kingdom and they themselves require certain inputs at optimum level for growth and N-fixation.

Azolla

The aquatic fern Azolla is distributed in both temperate and tropical rice growing regions, and fixes atmospheric nitrogen (N2) in symbiotic association with a heterocystous BGA, Anabaena azollae. Azolla contains 0.2-0.3% N on fresh weight basis and 3-5% N on dry weight basis. Azolla has been used as a fertilizer for rice in Vietnam and China for centuries. However, its use as a biofertilizer for rice in other countries is a relatively recent development. About 90 strains belonging to seven species are being maintained at CRRI, Cuttack which is the premier centre for Azolla research in India. Of the seven species, Azolla pinnata is most widely distributed in India.

Growth and N-fixation

The growth rate, total biomass and N content of Azolla provide the estimate of its potential for agricultural use. The environmental conditions and nutrient availability greatly influence fern growth. In India, the fresh weight of A. pinnata increases 2-6 fold in a week. The BGA in the Azolla cavities is very efficient in N-fixation and can meet the fern's total N requirement. However, the fern is able to utilize both fixed N and soil N simultaneously and maintains a high rate of N-fixation in presence of combined N. Under ideal conditions, it has a potential of fixing more than 10 kg N/ ha/day. At Cuttack, A.pinnata fixed 75 mg N/g dry wt./day and produced a biomass of 347 t fresh wt/ha in a year which contained 868 kg N, as much as in 1900 kg urea. About 30-100 kg N/ha can be fixed in a month.

Wide variability is observed among Azolla strains with regard to growth and N fixation. Among different A. pinnata strains, the Vietnam green and Bangkok strains performed better than the India (Cuttack) strain. One strain of A. caroliniana is found to fix more N than many A. pinnata strains. This A. caroliniana strain can grow round the year in rice fields and has better tolerance to snails, other pests and diseases. One crop of Azolla provides 20-40 kg N/ha to the rice in about 20-25 days. Even though the estimates of N input

vary considerably, the N-fixing potential of Azolla is fully established.

Factors Affecting Growth and N-fixation

Water: Azolla prefers to grow in a free-floating state. Good water control is desirable for its successful multiplication. The multiplication rate is drastically reduced if the soil is just moist and the fern dies upon complete drying. However, one strain of A. caroliniana is found to survive on the moist soil for a longer period as compared to the strains of other species. A water depth of 5-10 cm is recommended for good growth but depths upto 30 cm do not have any adverse effect.

Mineral Nutrients: AzoIla requires all the essential plant nutrients for normal growth. Because of its aquatic nature, these elements must be available in the water. The deficiency of any one element adversely affects its growth and N-fixation. In these respects Azolla behaves as an agricultural crop. Phosphorus is a key element and its deficiency results in poor growth, pink or red colouration, curling of roots and reduced N content. The effect of P and Ca deficiency on the growth and N-fixation is more intense than that of K or Mg deficiency. Threshold level of P in Azolla is about 0.2%-0.3% P on dry weight basis and its uptake by the plants increases with increasing levels of P in the growth medium as described later. Under favourable conditions, addition of one kg P results in fixation of about 5-10 kg N.

Azolla is considered to be an efficient scavenger of potassium and may serve as a K-source for rice in K-deficient soils. Iron is also important and deficient ferns turn yellowish, due to decreased chlorophyll content. Cobalt and molybdenum are required for efficient functioning of the N-fixing system. The deficiency of one element affects the uptake of others for example, P-deficiency results in increased uptake of Fe and Zn whereas Mg deficiency reduces the uptake of K but increases the uptake of Fe, Co and Mn.

Light: Both the partners of the fern-alga association carry out photosynthesis which helps it to maintain a high rate of N-fixation. Growth and N-fixation of Azolla are influenced by both quality and intensity of light. Azolla prefers a certain degree of shading, particularly during summer, and reaches its full at 25-50% of full sun light. When the fern and rice are grown together in a dual cropping system, Azolla growth is below its potential due to shading by rice canopy which increases with the advancement of rice growth. The shading effect is more in the wet season than the dry season. A. caroliniana is more tolerant to shading than other species. The growth of Azolla dual crop thus depends on leaf area index of rice, weather conditions and fertility status of flood water. The day length also affects the growth of Azolla. The growth is better at higher latitudes than in the tropics as a result of longer days during the Azolla growing season.

Temperature: Temperature is perhaps the most important environmental factor that limits the growth of Azolla and 25-30°C is optimum for most species. A.pinnata is successfully grown in the rice fields at Cuttack round the year (14-35°C) but its growth is better during July to December. Azolla growth and N accumulation in relation to water temperature and solar radiation are presented in Fig.2. The diurnal variation in temperature is important in determining the temperature response of Azolla. The temperature response varies among Azolla species/strains. A.filiculoides and A, rubra are cold tolerant whereas A. mexicana, A. microphylla, A. caroliniana, A. nilotica and some varieties of A.pinnata have better tolerance to high temperature. A. filiculoides does not grow well at high temperature but it can tolerate low temperature upto 5°C.

There appears to be a synergistic relation between tolerance to high temperature and light intensity. At high light intensities the optimum temperature for its growth shifts upwards. Temperature response is also influenced by population density. Tolerance to high temperature is low when Azolla attains a stationary phase. The high temperature causes a severe damage to Azolla indirectly through its stimulatory effects on population of Azolla pests. The extreme temperatures result in reddish brown colouration in Azolla but change in colour usually does not affect its N-fixing activity. The high temperature damage on Azolla can be reduced by shading, draining the field or flushing.

GREEN MANURING

The role of green manures in improving soil fertility and supplying a part of the nutrient requirement of crops is well known. Their use in crop production is recorded to have been practised in China as early as 1134 B.C. These are one of the main components of integrated nutrient supply system alongwith inorganic fertilizers and biofertilizers. In India, an estimated 6.2 million ha were green manured during 1988-89 (4% of the net sown area). Andhra Pradesh (AP) and Uttar Pradesh (UP) account for 60% of green manured area and 88% treated area was in the six states of A.P., Karnataka, Madhya Pradesh, Orissa, Punjab and U.P. This chapter provides an overall assessment of green manures, their significance and various management aspects in modern agriculture. Green manures can meet a part of the nutrient needs (particularly N) of crops for optimum production and to that extent can result in savings in fertilizer costs. These cannot completely replace fertilizer N if the goal is to harvest moderate-high yields on sustained basis.

Green Manures

Green manure refers to fresh plant matter which is added to the soil largely for supplying the nutrients contained in its biomass. Such biomass can either be grown in situ and incorporated or grown elsewhere and brought in for incorporation in the field to be manured. Just any plant cannot be used as a green manure in practical farming. Green manures may be plants of grain legumes such as pigeonpea, greengram, cowpea, soybean, or groundnut; perennial woody multipurpose legumes viz.,Leucaena leucocephala (subabul), Gliricidia sepium. Cassia stamea or non-grain legumes like Crotalaria, Sesbania, Centrosema, Stylosanthes and Desmodium.

Leguminous plants are largely used as green manures due to their symbiotic N fixing capacity. Some non-leguminous plants are also occasionally used for the purpose due to local availability, drought tolerance, quick growth and adaptation to adverse conditions.

An ideal green manure should posses the following traits.

- show early establishment and high seedling vigour
- be tolerant to drought, shade, flood and adverse temperature.
- posesses early onset of N Fixation and its efficient sustenance.
- have an ability to accumulate large biomass and N in 4-6 weeks
- is easy to incorporate.
- is quickly decomposable
- is tolerant to pests and diseases.

Leguminous Green Manures : These differ widely in nitrogen concentration and yield. Among 86 species used in India as green manures for rice their N contents ranged from 2.0 to 4.9% N. Earlierresults on the performance of some important green manure crops in lowland rice showed N-fixation of 74-134 kg/ha and about 200% increase on paddy yield over unmanured plots.

Green manure crops suitable for various cropping situations prevailing in India are listed in Table 1. Abundant availability of water and sufficiently long fallow period before raising the rice crop have made the green manuring a widely adopted practice in lowland rice ecosystems. Common green manure crops in rice fields of India and their potential of biomass and N contribution in 45-60 days of growth are provided in Table 2.

Table 1: Green manures suitable for some field crops

Field crop	Recommended green manure
Rice	Sunnhemp, Sesbania and Wild indigo *(Indigofera linctoria)*
Sugarcane	Sunnhemp
Finger millet	Sunnhemp
Wheat	Sunnhemp
Sorghum	Sunnhemp, Subabul *(Leucaena leucocephala)*
Banana	Leaves of *Gliricidia sepium*

Potato Lupin *(Lupinus albus),* Sunnhemp, Cowpea, Guar, Buck wheat *(Fagopyrum sp)* horse gram.

Non-grain Legumes: Recent evaluation of some of the promising green manure crops at Coimbatore indicated the potential of already popular *dhaincha* and ths newly introduced stem nodulating *S. rostrata*. The exotic stem nodulating *S. rostrata* of Senegalese origin has much promise for lowland rice especially with adequate irrigation. Another promising stem nodulating introduction from Madagascar is *Aeschynomene afraspera* which is capable of withstanding water stress to some extent. Its potential under Indian conditions has not been fully explored.

Though *Tephrosia purpurea* and *Phaseolus trilobus* grow rather slowly and accumulate much less N than *Sesbania,* they are more adapted to drought *T. purpurea* has the additional advantage of self-sowing and is not browsed by cattle. Hence in deltaic areas

Table 2: Some common leguminous green manure crops for rice fields and their potential N contribution.

Local name	Botanical name	Growing season	Green matter (t/ha)	Output in 45-60 days Nitrogen contribution (kg/ha)
Sunnhemp	*Crotolaria juncea*	Wet	21.2	91
Dhaincha	*Sesbania aculeata*	Wet	20.2	86
Pillipesara	*Phaseolus trilobus*	Wet	18.3	201
Greengram	*Vigna radiata*	Wet	8.0	42
Cowpea	*Vigna sinensis*	Wet	15.0	74
Guar	*Cyamopsis tetragonoloba*	Wet	20.0	68
Senji	*Melilotus alba*	Dry	28.6	163
Khesari	*Lathyrus sativus*	Dry	12.3	66
Berseem	*Trifolium alexandrium*	Dry	15.5	67

Table 3: Evaluation of green manures for rice based cropping systems at Coimbatore.

Green manures	Output in 60 days Biomass (t/ha)	N accumulation kg/ha	kg/ha/day	Special features
Crotolaria juncea (Sunnhemp)	16.8	159	2.65	Quick growing, easy seed production
Sesbania aculeata (Dhaincha)	26.3	185	3.08	High biomass accumulation, wide adaptability
Sesbania rostrata	24.9	219	3.65	Stem nodulating, tolerant to water logging
Tephrosia purpurea (Kolinji)	16.8	115	1.92	Drought tolerant, self seeding
Phaseolus trilobus	17.6	126	2.10	Green manure-cum-fodder-cum cover crop

where a single rice crop is grown due to limited water availability, T. purpurea is raised in the long rice fallow season without irrigation. After 3-4 months, it sheds seeds in the field which germinate after rice harvest in the next year. The green manure is incorporated 7-10 days before rice transplanting. Another drought tolerant green manure crop suitable for rainfed rice is wild indigo. It can contribute 62- 182 kg N/ha to the succeeding rice crop, depending on soil, climatic and cropping conditions.

Grain Legumes: Some annual grain legume crops are also used as green manure, after all or part of the

grain is harvested. Greengram stover incorporated in the soil after pod harvest contributed about 60 kg N/ha to the succeeding rice crop. Evaluation of several grain legumes with Sesbania and Crotolaria showed that greegram was the best, yielding about 11 grain and 2.5t dry matter/ha equivalent to 50 kg N/ha. Greengram, blackgram (Phaseolus mungo) and cowpea could provide about 50-60 kg N/ha for the succeeding rice crop.

In studies at Coimbatore cowpea was the best among the grain legumes tested, contributing about 65 kg N/ha in addition to about 500 kg grain/ha. Its residues can also be used to supplement N-supplies for rice. Hence after grain harvest the legume stover grown in the pre-rice season could be incorporated as green manure to meet the partial requirement of N, provided there is no competing demand for the stover as cattle feed.

As a comparison, S.rostrata produced more biomass and contained 2.5-3 times more N than grain legumes in 60 days. Where grains are harvested, the N-benefit to the following crop is reduced to the extent that absorbed N is taken away with the grains.

PRODUCTION AND DISTRIBUTION OF BIOFERTILIZERS

Biological routes of improving soil fertility for optimum crop production are vital components of integrated nutrient supply systems. These routes are operated by microorganisms who either synthesise plant- usable forms of nutrients (N2 to NH4) or increase the availability and root accessibility of nutrients already present in the soil, as in case of P. Though most of these organisms are present in the soil and have been on the job for centuries, as manageable agricultural inputs they have received attention only during the 20th century. Due to several reasons, their importance is on the increase and therefore their production and distribution aspects assume practical significance.

Such microorganisms have somehow come to be called as "biofertilizers" a term which many consider to be arbitrary, a misnomer and even slangish but nevertheless widely used. In the strictest sense, real biofertilizers are the green manures and organics (materials of biological origin which are added to deliver the nutrients contained in them). We believe that what are commonly referred to as biofertilizers should be referred to as inoculants after the name of microorganism they contain viz Rhizobium inoculant or Azospirillum inoculant.

This chapter deals with the various aspects of production, promotion and distribution of biofertilizers in the Indian context.

Definition and Classification

Microbial inoculants are biologically active products containing active strains of specific bacteria, algae, fungi, alone or in combination, which may help in increasing crop productivity by way of helping in the biological nitrogen fixation, solubilization of insoluble fertilizer materials, stimulating plant growth or in decomposition of plant residues. A number of biofertilizers are now available in India. Depending upon the nutrients provided, these can be broadly classified as follows:

Biofertilizer (BF)

Nitrogen Fixing Biofertilizer (NBF)		Phosphate Mobilising Biofertilizer (PMBF)	
NBF for legumes	NBF for cereals	Phosphate Solubiliser	Phosphate Absorber
Rhizobium	Azospirillum, Azotobacter Azolla, BGA	Pseudomonas Bacillus, Aspergillus,	VA-mycorrhiza (VAM) like Glomus

In India, systematic study on biofertilizers started 70 year ago with the first report of the isolation and identification of Rhizobium from different cultivated legumes by Joshi in 1920. This was followed by extensive research by Gangulee, Sarkaria and Madhok on the physiology of the nodule bacteria and its inoculation for better crop production. Important milestones in production, development and promotion of biofertilizers in India are presented in Table 1.

Today, Rhizobium and Blue-Green Algae can be considered as established biofertilizers; Azolla, Azospirillum and Azotobacter are at an intermediate stage and the rest are potential materials.

Practical Significance of Biofertilizers

Biological N-fixation accounts for 69% of total N-fixation (including fertilizer industry) in the world and non-biological processes for 31%. Inoculation with Rhizobium can help legumes to meet upto 80-90% of their N needs and the treatment increases grain yield by 10-15% under on-farm condilions. Benefits of symbiotic BNF by legume to subsequent cereal crops are common and measurable. Legume residues are usually high in N, have a narrow C: N ratio and generally mineralise faster to benefit subsequent crops.

Blue green algae can add about 20-25 kg N/ha to rice fields and to that extent fertilizer N can be saved or supplemented. In addition, BGA have been shown to benefit the rice plants by supplying growth promoting substances such as gibberellic and indole acetic acid. Temperature and available P are two most important factors which determine the success of Azolla. Azospirillum and Azotobacter have also shown promise as biofertilizers. At present there is a great demand for Azospirillum from farmers of Tamil Nadu as they have obtained significant responses in rice and sugarcane due to its inoculation.

Results with P-solubilising microorganisms invariably show that inoculation of seeds with these increases grain yield. These also have the potentiality of being used as co-inoculants for legumes which have high P requirement. VAM-fungi facilitate the accumulation of P by plants through mycelial network, but the multiplication of VAM on commercial scale is yet to arrive.

One tonne Rhizobium inoculant is equivalent to 100 t of fertilizer N (considering minimum N-fixation of 50 kg/ha and 0.5 kg/ha application dose) and 1 tonne of BGA is equivalent to 2 t of fertilizer N (considering minimum N-fixation of 20 kg/ha from 10 kg/ha application dose). Monetary benefits derived from the use of biofertilizers are presented in Table 2.

Requirement of Biofertilizers

Estimated annual requirement of Rhizobium innoculum varies from 1,250 to 15,000t. Highest requirements are apparently based on an over-simplified approach multiplying the total legume area by dosage/ha. If 25% of area is annually treated, 3750t inoculum is needed for 30 m ha,. Present production is about one-fourth of this.

Estimated requirement of BGA varies from 168,000t for treating 16.8 m ha under wetland rice to 230,000t for treating 23.6 m ha of rice in eight major states to as high as 400,000t apparently for inoculating the entire rice area in India with 10 kg/ha. The authors have also arrived at an estimate closer to that of Venkataraman. Present production is less than 0.1% of this.

Good estimates should actually be based on the native bacterial population per unit soil, nodulation map for Rhizobium, natural distribution of microorganisms, environments offering greatest potential and presence of any major constraints such as nutrient deficiencies. Requirements based on multiplication of total area by dosage/ha do not serve any purpose and provide exaggerated estimates which cannot be used as a basis for planning or setting up production facilities.

Production Technology of Biofertilizers

Rhizobium: Based on the physical nature and carrier materials used, various types of biofertilizers are manufactured by different producers. These are carrier based inoculant, agar based inoculant, broth culture and dried culture. New developments in biofertilizer productions like (i) freeze-dried inoculants (e.g. BAIF, IARI. India) (ii) Rhizobium-paste (e.g. KALO Inc. USA), (iii)granular inoculant (e.g. Soil implant of Nitragin ,

USA) (iv) pelleting (e.g. Pelinoc of Nitragin), (v) Polyacrylamide entrapped rhizobia (e.g. Agrosoke) and (vi) Pre-coated seeds (e.g. Prillcote of New Zealand) appear to be more promising for inoculation success in tropical legumes. Advantages and disadvantages of most of the types mentioned above have been critically examined and carrier based inoculant has been regarded as most suitable for commercial purposes. Since different species of Rhizobium bacteria infect different legumes, a whole range of inoculants are needed. Their production technology is however the same.

In India, septic methods of production of Rhizobium biofertilizer is followed comprising mixing of broth with unsterilised carrier. Sterilisation of carrier in'bulk is done in autoclave by most of the producers, where complete sterilisation is not achieved. The fool proof method of sterilisation of carrier material is through gam-a radiation but such facility is lacking. To achieve production of quality biofertilizer, carrier should be sterilised in sterilisable poly propylene pouches, inoculum introduced by injecting and cured for at least two weeks at 27-30°C before despatch.

THE SOURCE OF ORGANIC MATTER

A number of sources of soil organic matter exist, namely: (1) the roots of crops left behind at harvest, including the weeds turned under in the course of cultivation; (2) the algae met with in large quantities in rice fields, on the surface of the soils of tropical countries during the rainy season and to some extent in all soil; (3) green-manure; (4) farmyard manure; (5) artificial farmyard manure. In addition to these supplied, certain by-products of industries, such as oil-cakes and wool-waste, are also employed as sources of organic matter. These, however, are small in total amount and need not be considered. Except in China and Japan and to a limited extent in India, little or no use is made of night soil in crop production.

THE ROOT-SYSTEM OF CROPS

It is not always realized that about half of every crop the root-system remains in the ground at harvest time and thus provides automatically a continuous return of organic matter to the soil. The weed sand their roots turned in during the ordinary course of cultivation add to this supply. When these residues, supplemented by the fixation of nitrogen from the atmosphere, are accompanied by skilful soil management, crop production can be maintained at a moderate level without the addition of any manure whatsoever. A good example of such a system of farming without manure is to be found on the alluvial soils of the United Provinces, where the field records of ten centuries prove that the land produces fair crops year after year without any falling off in fertility. A perfect balance has been reached between the manurial requirements of the crops harvested and the natural processes which recuperate fertility. A similar, although not so striking a result, is afforded by the permanent wheat plot at Rothamsted, where this crop has been grown every year on the same land without manure since 1844. This plot, showed a slow decline in production for the - first eighteen years after which the yield has been practically constant. Systems of soil management such as these provide, as it were, the base line for the would-be improver. Nothing exists in the world's agriculture below this level. At the worst, therefore, the organic matter of a soil, constantly cropped without manure, does not disappear altogether. The wheel of life slows down. It does not stop.

SOIL ALGAE

One source of readily decomposable organic matter, which is available in India just at the moment when the cold season crops need it, is to be found in the shape of a thick algal film on the surface of cultivated soils during the second half of the rains. This film has also been observed in Africa, Ceylon and Java, and is probably universal during the rainy season in all parts of the tropics. As is well known, there are two periods in India when the crop is in greatest need of combined nitrogen: (1) at the break of the monsoon in June and July, and (2) when the cold season crops are sown in October after the rains. These latter are planted at a time when the available nitrogen in the surface soil is likely to be in great defect. The land has been exposed to heavy rain for long periods; the surface soil is often waterlogged. Nitrates under such conditions are easily lost by leaching and also by de-nitrification. The conditions are therefore altogether

unfavourable for any approach towards and ample supply of nitrate when sowing time comes round in early October. How do the cold weather crops obtain a sufficient supply of this essential food material? It is more than probable that the deficiency is made up for, in part at least, by the rapid decay of the algal film (which also appears to be one of the factors in nitrogen fixation) during the last cultivations preceding the sowing of the cold weather crop in October. It is possible that some changes may have to be made in soil management with a view to stimulating the growth of this algal film. One of the beneficial effects of growing a green-manure crop like sann hemp for composting, during the early rains, may prove to be due to the favourable environment provided for the rapid establishment of the algal film. On monsoon fallow land it will probably be found best to suspend surface cultivation during the second half of the rains when the film is most active. There is already among the cultivators of India a tendency to stop stirring the surfaced, from the middle to the end of the rains, even when this involves the growth of weeds. This coincides with the period when the algal film is most noticeable. The indigenous practices may therefore prove to be based on sound scientific principles. Here are ready to hand several interesting subjects which urgently call for study under actual tropical conditions. When this is undertaken, the investigation should include: (1) the conditions most favourable for the establishment of the algal film; (2) the part played by algae and associated bacteria in nitrogen fixation; (3) the role of algae in banking easily destroyed combined nitrogen during the rains; and (4) the supply of easily decomposable and easily nitrifiable organic matter for the use of the cold weather crops. In the rice fields of the tropics, the algal carpet is even more evident than on ordinary cultivated soils. The total weight of organic matter added every year to each acre of rice land in the shape of algal remains must be considerable and must serve as a useful addition to the store of organic matter. Apart from the fixation of nitrogen from the air, it may help to explain why such heavy crops of paddy can be obtained in India, year after on the same land, without manure.

GREEN-MANURES

Since the investigations of Schulz-Lupitz first showed how open sandy soils in Germany can be rapidly improved in texture by the incorporation of green-manures, the future possibilities of this method of enriching the land became apparent to the investigators of the Occident. After the role of the nodules (found on the roots of leguminous plants) in the fixation of atmospheric nitrogen was proved, the problems of green-manuring have naturally centred round the utilization of the leguminous crop in adding to the store of organic matter and combined nitrogen in the soil. At the end of the last century it seemed so easy, by merely turning in a leguminous crop, to settle at one stroke and in a very economical fashion the great problem of maintaining soil fertility. At the expenditure of a very little trouble, the soil might be made to manure itself. A supply of combined nitrogen, as well as a fair quantity of organic matter, might be provided without any serious interference with ordinary cropping. These expectations have led to innumerable green-manuring experiment all over the world with practically every species of leguminous crop. The results however have left much to be desired. In a few cases, particularly on open soils and where the rainfall, after the ploughing in of the green crop, is well distributed, the results have been satisfactory. On rice lands, where abundance of water ensures the maintenance of swamp conditions, somewhat similar results have been obtained. In the vast majority of cases, however, green-manuring has been disappointing. As a general method of soil improvement, the game is hardly worth the candle. On the monsoon fed areas of India the rainfall is often so uncertain, after the green crop is ploughed in, that for long periods decay is arrested. Sowing time arrives at a stage when the soil contains a mass of half-rotted material, with insufficient combined nitrogen and moisture for the growth of a crop. Failure results the crops raised after green-manure are worse than those obtained on similar land left fallow. For this reason green-manuring has not been taken up by the people in India, in spite of the experiments and propaganda of the Agricultural Department.

THE CHIEF FACTORS IN INDORE PROCESS

The Indore process enables the Indian cultivator to transform his mixed vegetable wastes into humus; in other words to become a chemical manufacturer. The reactions involved are those which take place under aerobic conditions during the natural decay of organic residues in the soil. The object of the process is to bring these changes under strict control and then to intensify them. A knowledge of the chemical processes involved and of their relative importance is therefore essential in applying the process to other conditions. These matters form the subject of the present chapter.

THE CONTINUOUS SUPPLY OF MIXED VEGETABLE WASTES

A continuous supply of mixed vegetable wastes throughout the year, in a proper state of division, is the chief factor in the process. The ideal chemical composition of these materials should be such that, after the bedding stage, the carbon-nitrogen ratio is in the neighbourhood of 33:1. The material should also be in such a physical condition that the fungi and bacteria can obtain ready access to, and break down the tissues without delay. The bark, which is the natural protection of the celluloses and ligning against the inroads of fungi and bacteria, must first be destroyed. This is the reason why all woody materials-such as cotton-stalks, pigeon-pea stalks and sann hemp are laid on the roads the crushed by the traffic into a fine state of division before composting. Still more refractory residues like the stumps of sugar-cane and millets, shavings, sawdust, waste paper and packing materials, old gunny bags and similar substances, must either be steeped in water for forty-eight hours or mixed with moist earth in a pit for a few days before passing, in small quantities daily, into the bedding.

The vegetable wastes which have been utilized at Indore for the last six years are the following:-

Residues available in large quantities: Cotton stalks, sann hemp either as green plants reaped before the flowering stage or as dried stems of the crop kept for seed, pigeon-pea stalks, sugar-cane trash, weeds, fallen levees.

Residues available in moderate quantities: Mixed dried grass, gram stalks, wheat straw, uneaten and decayed silage, millet stalks damaged by rain, residues of the safflower crop, ground-nut husks, ground-nut stalks and leaves damaged by rain, sugar-cane and millet stumps.

Residues available in small quantities: Waste paper and packing materials, shavings, sawdust, worn out gunny bags, old canvas, worn out uniforms, old leather belting.

The chemical composition of the above or of similar materials is given in Table 1.

It will be seen that the raw materials available at Indore differ greatly in chemical composition and particularly in the percentage of nitrogen. Many of these wastes, such as cotton-stalks, the stems of sann hemp and of the pigeon-pea, and cane trash, are too low in nitrogen for rapid composting. Others such as green hemp, reaped just before flowering, ground-nut residues and leguminous and other weeds contain higher percentages of nitrogen, a portion of which is certain to be lost during the process if these materials are composted singly.

A proper mixture of the various materials available, so that the nitrogen content of the mass throughout the year is kept uniform and sufficiently high, is the first conditions of success. For this reason it is necessary to collect and stack the various residues in such a manner that a regular supply of dry, mixed, vegetable wastes (as already stated with a carbon-nitrogen ratio in the neighbourhood of 33:1 after the material has been used as bedding) is available right through the year. This could only be accomplished at Indore: (1) by cutting the cotton-stalks soon after picking is over so as to secure the maximum number of leaves; (2) by growing a large area of sann hemp, which contains when withered as much as 2.3 per cent of nitrogen; and (3) by securing as much green weeds, ground-nut residues and fallen leaves as possible for the mixture. All these materials are rich in nitrogen, and help to bring the carbon-nitrogen ratio near the required standard. By stacking the various constituents in layers, not more than one foot thick, and by a judicious admixture with the residues richest in nitrogen, it is possible to provide a continuous supply of dry mixed material of the correct chemical composition. During the rains, a good deal of the raw material is in the form of fresh

green weeds, rich in nitrogen and soluble carbo-hydrates. These must be spread, in thin layers, on the grass borders of the fields alongside the roads and withered, before being carried to the stack or used as one of the constituents of the bedding. Only in this way can the most be made of this valuable material. Collecting weeds in temporary heaps on the borders of fields leads to serious waste of the soluble carbo-hydrates and also of the nitrogen.

MANUFACTURE OF BIOFERTILIZER BY THE INDORE METHOD

The aim of the Indore method of manufacturing compost is by means of a simple process to unite the advantages of three very different things: (1) the results of scientific research on the transformation of plant residues; (2) the agricultural experience of the past, and (3) the ideal line of advance in the soil management of the future in such a manner that all the by products of agriculture can be systematically converted into humus. An essential feature of this synthesis is the avoidance of anything in the nature of fragmentation of the factors. All available vegetable matter, including the soiled bedding from the cattle-shed, all unconsumed crop residues, fallen leaves and other forest wastes, farmyard manure, green-manures and weeds pass systematically through the compost factory, which also utilizes the urine earth from the floor of the cattle-shed together with the available supply of wood ashes from the black-smith's shop and the workmen's quarters. The only other materials employed are air and water. This manufacture is continuous right through the year, including the rainy season, when a slight modification has to be made to ensure sufficient aeration. The product is a finely divided leaf-mould, of high nitrifying power, ready for immediate use. The fine state of division enables the compost to be rapidly incorporated and to exert its maximum influence on a very large area of the internal surface of the soil.

The Indore process thus utilizes all the by-products of agriculture and produces an essential manure. Besides doing this any successful system of manufacturing compost must also fulfill the following conditions:-

1. The labour required must be reduced to a minimum. The process must fit in with the care of the work cattle and with the ordinary working of the farm.
2. *A suitable and also a regular carbon-nitrogen ratio must be produced by well mixing the vegetable residues before going into the compost pits.* Unless this is arranged for, decay is always retarded. The mixing of these residues, combined with the proper breaking up of all refractory materials is essential for rapid and vigorous fermentation and for uniformity throughout the process.
3. The process must be rapid. To achieve this it must be aerobic throughout, and must include arrangements for an adequate supply of water and for inoculation, at the right moment, with the proper fungi and bacteria. The general reaction of the mass must be maintained, within the optimum range, by means of earth and wood ashes. The maintenance of the proper relationship between air and water, so that no delay takes place in the manufacture, proved to be the greatest practical difficulty when evolving the process.
4. There should be no losses of nitrogen at any stage; if possible, matters should be so arranged that fixation takes place in the compost factory itself and afterwards in the field. To conserve the nitrogen, the manufacture must stop as soon as the compost reaches the nitrification stage, when it must either be used for banked. It can best be used as a top dressing for irrigated crops; it can be preserved, as money is kept in a bank, by applying it to the fields when dilution with the large volume of soil arrests further changes till the next rains.
5. There must be no serious competition between the last stages of the decay of the compost and the work of the soil in growing a crop. This is accomplished by carrying the manufacture of humus up to the point when nitrification is about to begin. In this way the Chinese principle of dividing the growing of a crop into two separate processes (1) the preparation of the food materials outside the field, and (2) the actual growing of the crop can be introduced into general agricultural practice.

6. The compost should not only add to the store of organic matter and provide combined nitrogen for the soil solution but should also stimulate the microorganisms.
7. The manufacture must be a cleanly and a sanitary process from the point of view both the man and also of his crops. There must be no smell at any stage; flies must not breed in the compost pits or in the earth under the work cattle. Theseeds of weeds, the spores of harmful fungi, the eggs of noxious insects must first be destroyed and then utilized as raw material for more compost. All this is achieved by the combination, in the compost pits during long periods, of high temperature and high humidity with adequate aeration.

ORGANIC MATTER AND SOIL FERTILITY

The ancients and the moderns are in the completest agreement as to the importance of organic matter in maintaining the fertility of the soil. This is evident when the methods of crop production in the time of the Romans are compared with the views now held by many of the leading experiment station workers in the Unites States and other parts of the world. In Roman times, the management of the manure heap had already reached an advanced stage. In 40 B.C. Varro drew attention to the great importance of the complete decay of manure before it was applied to the land. To bring this about, the manure heap, during the period of storage, had to be kept moist. In A.D. 90 Columella emphasized the importance of constructing the pits (in which farmyard manure was stored) in such a manner that drying out was impossible. He mentions the need of turning this material in summer to facilitate decay, and suggested that ripened manure should always be used for corn, while the fresh material could be applied with safety to grass land. The Romans therefore not only understood the importance of organic matter in crop production but had gone a long way towards mastering the principle that, to obtain the best results, it is necessary to arrange for the decay of armyard manure before it is applied to arable land.

Without exception, the investigators who took part in this conference laid the greatest emphasis on the importance of keeping up the supply of organic matter in the soil, and on discovering the most effective and the most economical method of doing this under the various conditions, as regards moisture, which the soils of the United States present.

During the 2,000 years which have elapsed since Varro wrote in 40 B.C. and the American investigators met there has occurred only one brief period during which the role of organic matter was to some extent forgotten. This took place after Liebig's Chemistry in its Application to Agriculture and Physiology first appeared in 1840. Liebig emphasized the fact that plants derive their carbon from the carbon dioxide of the atmosphere and advanced the view that, in order that a soil may remain fertile, all that is necessary is to return to it, in the form of manure, the mineral constituents and the nitrogen that have been taken away in the crop. The discovery of the true origin of the carbon of plants not unnaturally suggested that the organic matter in the soil was of little consequence. Nitrogen and minerals only remained, the latter being found in the plant ashes. When therefore analyses of the crops had been made, it would be possible to draw up tables showing the farmer what he must add in the way of nitrogen and mineral sin any particular case. These views and the controversies to which they gave rise, combined with the results of the Rothamsted experiments led to the adoption of artificial manures by many of the farmers of Europe. The Rothamsted experiments undoubtedly proved that if the proper quantities of combined nitrogen, phosphates and potash are added to the soil, satisfactory crops for many years can be obtained without the addition of organic matter beyond that afforded by the roots of the crops grown. Further, the results of hundreds of trials, in the course of ordinary farming practice, confirmed the fact that the judicious addition of nitrogenous artificial fertilizers can, in the great majority of cases, be relied on to increase the yield. It was only natural that results of this kind, combined with the important fact that the application of artificials often pays in practice, produced a marked effect on current opinion and also on teaching. For nearly a century after Liebig's ideas first appeared, the majority of agricultural chemists held that all that mattered in obtaining maximum yields

.was the addition of so many pounds of nitrogen, phosphorus and potassium to the acre. Beyond this the only other factor of importance was the liming of acid soils. The great development of the artificial manure industry followed as a matter of course.

The place of organic matter in the soil economy was forgotten. The old methods of maintaining soil fertility naturally fell into the background.

For a time all seemed to go well. It is only in comparatively recent years that experiment station workers have begun to understand the part played in crop production by the micro- organisms of the soil and to realize that the supply of artificials is not the whole story. Something more is needed. The need for the maintenance of the supply of organic matter soon became apparent. The view now beginning to be held is that, only after the supply of organic matter has been adequately provided for, will the full benefit of artificials be realized. There appears to be a great field for future experiment in the judicious use of artificials to land already in a fair state of fertility.

In all this however there was one important exception. In the Orient, the artificial manure phase had practically no influence on indigenous practice and passed unheeded. The Liebig tradition failed to influence the farmers of forty centuries. No demand for these products of the west exists in China. At the present day it would be difficult to purchase such a substance as sulphate of ammonia in the bazaars of rural India.

SOIL HUMUS, ITS ORIGIN AND NATURE

What is the origin and nature of the organic matter or soil ‘humus' and what part does it pay in soil fertility? These matters form the subject of the present chapter.

The organic matter found in the soil consists of two very different classes of material: (1) the constituents of plants and animals which have been introduced into the soil and are undergoing decomposition; various unstable intermediate products which have been formed under certain environmental conditions; substances like lignified cellulose which are more resistant to decomposition and which may persist in the soil for some time; and (2) a number of valuable materials which have been synthesized by the numerous groups of micro-organisms which form the soil population. The soil organic matter is thus a heterogeneous mass of substances which is constantly undergoing changes in composition. When its composition reaches a certain stage of equilibrium, it becomes more or less homogeneous and is then incorporated into the soil as ‘humus'. This definition of soil organic matter, which is due to Waksman, is of great importance. Soil organic matter or ‘humus' is not merely the residue left when vegetable and animal residues decay. It contains in addition the valuable materials synthesized and left behind by the fungi and bacteria of the soil population. Moreover it is a product of the general soil conditions which obtain in any particular locality, and therefore varies in composition and character from one soil type to another. It is not the same all over the world. The soil humus for example of the black cotton soils of India is not identical with that of the alluvium of the Indo-Gangetic plain.

The various steps in the formation of soil organic matter are somewhat as follows. When the fresh remains of plants or animals are added to the soil, a portion of this organic matter is at once attacked by a large number of the microorganisms present. Rapid and intense decomposition ensues. The nature of these organisms depends on the soil conditions (mechanical and chemical composition and physical condition) and on the soil environment (moisture content, reaction and aeration, and the presence of available minerals). The decomposition processes can best be followed by measuring one of the end products of the reaction-carbon dioxide. The rate of evolution of this gas depends on the nature of the organic matter, on the organisms which take part in the process and on the soil environmental conditions. As soon as the readily decomposable constituents of the plant and animal remains (sugars, starches, pectins, celluloses, proteins, amino-acids) have disappeared, the speed of decomposition diminishes and a condition of equilibrium tends to become established. At this stage only those constituents of the original organic matter,

such as the lignins which are acted upon slowly, are left. These and the substances synthesized by the micro-organisms together form the soil humus and then undergo only a slow transformation during which a moderate but constant stream of carbon dioxide is liberated. At the same time the nitrogen of this soil humus is similarly converted into ammonia which, under favourable conditions, is then transformed into nitrate. It will be clear therefore that the soil organic matter or humus is a manufactured product and that its composition is not every where the same, but will vary with the soil conditions under which it is produced. Like all manufactured articles, it must be properly made if it is to be really effective. Too much attention therefore cannot be paid to its preparation.

THE FORMATION OF HUMUS AS A RESULT OF THE SYNTHESIZING ACTIVITIES OF MICRO-ORGANISMS

Although the important part played by micro-organisms in the formation of soil humus has only very recently been fully understood, nevertheless the older literature contains a number of useful contributions to the subject. Most of these early papers appeared towards the end of the last century; many of them related to other branches of knowledge and were not written from the point of view of agriculture. They have been summed up by Waksman, from whose paper the following account has been prepared.

Post-Ramann and Muller considered that the ‘humus' bodies obtained from soil often consist of the chitinous remains of insects and animal excreta. Wettstein and Winterstein showed that chitin is characteristic of various fungi and not of bacteria. Schemook advanced the view that he protein nitrogen in the soil was mostly present in the bodies of bacteria and protozoa. Trussov showed that he proto and protozoa. Trussov showed that the protoplasm of fungi is a source of humus in the soil. Schreiner and Storey suggested that various characteristic constituents of the soil are probably synthesized by micro-organisms.

The early work on this subject has been considerably developed, first by Falck and more recently by Waksman. Falck showed that organic matter in forest soils can be transformed into different types of humus in at least three ways: (1) The yearly additions of raw organic matter are completely decomposed by fungi (microcriny) accompanied by the synthesis of fungus protoplasm, which serves as an excellent fertilizer for the forest trees. In this process the celluloses are decomposed completely, whereas the lignins are more resistant. (2) The decomposition of the organic matter is begun by fungi and then carried on by lower invertebrates and bacteria (anthracriny). The fungus mycelium as well as the original organic matter are devoured by various larvae producing a dark ‘humus' mass which, in the presence of bases, is oxidized by bacteria with the ultimate liberation of carbon dioxide and the formation of nitrate. (3) The formation of peat (anthrogeny), which Falck explains as resulting from the absence of an abundant fungus development.

Waksman carried the subject still further and called attention to the similarity between the carbon-nitrogen ratio of the soil organic matter and that of the protoplasm of the soil fungi and other micro-organisms, and suggested that these probably make up a large part of the soil ‘humus'. He further pointed out that when cellulose is added to the soil, it decomposes only in proportion to the available combined nitrogen present. This is because the decomposition is brought about the fungi and bacteria, both of which require combined nitrogen. The ratio between the amount of cellulose decomposed and the nitrogen required is about 30:1, so that, for every thirty parts of cellulose decomposed by the fungi and bacteria, one part of inorganic nitrogen (ammonium salt or nitrate) will be built up into microbial protoplasm. In the presence of sufficient combined nitrogen and under aerobic conditions, the decomposition of cellulose is very rapid. The same is true of vegetable wastes like straw, maize stalks, wood products and other materials rich in celluloses, pentosans and lower carbohydrates but poor in nitrogen. These facts explain the injurious effects on crop growth which follow the addition of straw and green-manure to the soil. The decomposition of these materials removed large quantities of combined nitrogen from the soil solution. The nitrogen is then temporarily stored in the form of microbial protoplasm, when for a time it is placed beyond the reach of the

growing crop.

Since Waksman's paper appeared in 1926, an important contribution to this subject has recently been made by Phillips, Weite and Smith. The result of these investigators (which agree with our experience at Indore) has removed the impression that lignin is comparatively resistant to the action of micro-organisms. Under suitable conditions, soil organisms are capable of decomposing lignin as found in lignified plant materials (corn-stalks, oat hulls, corn cobs and wheat straw), the rate of decomposition being as great as that of cellulose and pentosans.

THE ROLE OF HUMUS IN THE SOIL

From the immediately practical point of view, the actual role of humus in the soil is of even greater interest than its formation, nature and decomposition. This material influences soil fertility in the following ways:-

1. The physical properties of humus exert a favourable influence on the tilth, moisture-retaining capacity and temperature of the soil as well as on the nature of the soil solution.
2. The chemical properties of humus enable it to combine with the soil bases, and to interact with various salts. It thereby influences the general soil reaction, either acting directly as a weak organic acid or by combining with bases liberating the more highly dissociating organic acids.
3. The biological properties of humus offer not only a habitat but also a source of energy, nitrogen and minerals for various micro-organisms.

These properties physical, chemical and biological confer upon humus a place apart in the general work of the soil including crop production. It is not too much to say that this material provides the very basis of successful soil management and of agricultural practice.

WEED MANAGEMENT IN ORGANIC FARMING

Weeds have been defined in various ways, but the most commonly used definition is: "A weed is a plant that in a given situation is more determintal to agriculture than beneficial". It is common knowledge that weeds compete with crop plants for light, air, moisture and nutrients. But the full extent of economic harm which they cause and their direct effects on crop fields, are not generally realised. Weed problems have been accentuated with the increase in the use of inputs like seeds of high yielding varieties, fertilizer and irrigation. In cropped areas these inputs help in good growth of weeds, thereby causing severe competition between crops and weeds. In the non-cropped area, the weed problems have been observed in various types of aquatic environments, forests, railways, highways, industrial sites, airport and places of aesthetic value. Presence of weeds is a constraint and the effect is further accentuated by their improper management. In assured water conditions, where irrigation facilities are available, farmers use high doses of fertilizer, quality seeds and improved pest management techniques. High fertility accompanied by high moisture provides a situation where the intensity and growth of weeds are high and in many cases may adversely the affect the production potential of crops.

The estimated crop losses due to weeds, diseases, insect pests, etc. were nearly Rs.6000 million and Rs. 1,84,000 million during 1973-74 and 1989-90 respectively. Yield losses caused by weeds in some crop plants are given Table 1.

Management of weeds is an important component of production techniques as elimination of weeds is expensive and hard to achieve. The basic approach is to minimise production losses caused by weeds, though weeds may exist as a part of the whole ecosystem. A number of mechanical, ecological and chemical methods of weed control have been developed over centuries of experience. Weeds ‘are aggressive, persistent and ubiquitous. In order to prevent the accumulation of chemical residues in the soil to a dangerous level and to prevent shift in weed population, it is necessary to find alternative weed management techniques leading to minimum loss in crop production and least disturbance to the ecosystem.

CULTURAL METHODS OF WEED CONTROL

These methods are less expensive and less dangerous to neighbouring crops and orchards. As the long term and indirect efforts of weed control due to implementation of systematic changes become apparent, less intensive control is required.

Tillage

Even after the advent of chemical weed killers, tillage methods are still used in many situations as the most effective and economical methods of weed control. Most of the farmers in the developing countries practice some form of minimum tillage where mould board plough is used for the perennial weed control or for breaking sod in a crop-sod rotation. Ploughing, cultivating and harrowing make possible weed control before sowing the crop and there are appropriate tools that can do a satisfactory job even after weed emergence. The disc harrow and chisel plough are used for primary tillage operations. Discs, cultivators and harrows are used for seed bed preparation and cultivators, discs, rodweeders, harrow and rotary hoes for post-seeding weed control. New types of minimum tillage implements that cut and incorporate residues and ridge the soil in one operation are strongly advocated for organic agriculture. Discs are used for weed control in orchards and to a lesser extent rotavators. Roto tillers are used in smaller row crop operations. The younger and smaller the weeds are, the most efficient and economical will be their control. The role of tillage in weed control consists of:

a) Facilitating the germination of weed seeds, which can, then, be easily destroyed by mechanical means;

b) bringing roots or stolons to the soil surface where they will dry out under the sunlight.

c) repeated cultivation, thereby depleting the food reserve of the plant, and,

d) uprooting or smothering the weeds with soil.

Tillage combined with irrigation

One of the most effective means of weed control is irrigation before sowing with a quantity water just sufficient to wet the soil to the full depth of the future root system. Then cultivating the field superficially, before or during sowing (if a combined-tillage and sowing operation is carried out) will destroy the weeds that have germinated following irrigation. The crop seeds are sown in moist soil at a depth that is sufficient to ensure germination without additional irrigation. The surface soil dries out, effectively preventing germination of additional weeds with next irrigation. In view of the earlier irrigations in depth, the next irrigation can be delayed somewhat so that the crop has an edge in growth when the next wave of weeds appears, making selective control easy.

Timing

Timing of field operation is very important. It is better to incorporate residues as soon as possible after harvest. It is believed that this process conserves the more readily metabolised and leachable carbon substrates. There are two strategies for planting of field crops; which one is followed depends on the crop, the regional climate and the climatic conditions or other variables in a particular year. The first strategy is to plant the crop as early as possible to get a head start on weeds; the other is to plant the crop later. In both the cases, it is common to cultivate from once to many times after seeding to set back the weed growth relative to the crop, and to reduce the seed bank. For grains, weeds are commonly harrowed or rotary tilled at least once before the crop germinates and then one to several times after the crop has germinated and is well rooted. The interval between operations is timed to allow germination and some growth of a new generation of weeds. Hence, the objective in the timing of all the operations is to set weeds back long enough, or to start the crop sufficiently ahead of weeds, so that crop can maintain its advantage without assistance. Appropriate timing is crucial for controlling perennials. In theory, frequent mowing and tillage starves roots, taproots and rhizomes, but if a harrow is used and the soil is wet, target weeds may multiply. Use of deeper working implements and working in dry weather can be successful. Mowing operations are commonly timed to reduce seed set by annuals rather than as an efficient method of weed eradication.

Frequent and regular mowing of perennial weeds exhausts the food reserves of the underground storage organs, weaken the plants and may occasionally lead to their death, when environmental conditions become favourable.

Seeding rates and cultivar selection

It is a common practice in organic farming to exceed the recommended rates of seeding by upto 25 per cent to allow for losses during cultivation. Higher seeding rates, closer crop spacing ad use of cultivars the achieve canopy closure earlier than other varieties or that have a more competitive architecture (eg. are taller or have more tillers) are other strategies that enhance the suppression of weeds by crops. It is important to select varieties that emerge quickly and that have a thick and full canopy. Some crops such as forage crops are able to compete successfully with weeds; their inclusion in the cropping systems, especially if the weeds start active growth at time when the cultivated crop is already well developed. One of the traditional methods used for combating weeds is sowing a thick stand of the crop. Heavy seed rate gives the crop a distinct competitive advantage over the weed population in the field. However, where a relatively low plant population is one of the major means of adjustment to limited soil moisture supply, this method of weed control cannot be adopted.

Cropping systems

The important principles in designing organic farming systems are to maximize diversity and soil coverage. A succession of different crops facilitates weed control. Certain weeds are almost obligatory association of specific crop plants and if these are sown continuously, effective weed control my become impossible. Weeds, whose growth and propagation is favoured by a certain crop, may be weakened or checked by an appropriate succeeding crop. Annual weeds which thrive in the winter cereal are easily destroyed during a winter fallow proceeding the summer crop. The following principles may be followed for effective weed control.

- rotation of competitive crops (eg. forage grass or maize) andnon-competitive crops (eg. cotton or pulses).
- Use of perennial phases in crop rotation combined with moving or intensive rotational grazing to control perennials.
- Use of weed suppressing crops as cover crops.
- Undersowing cereals with fodder legumes
- Where there are very heavy infestation of weeds - summerfallowing
- Use of catch crop or trap crop: These are used for the control of parasitic weeds such as witch weed. A catch crop that is host tothe parasite is sown and ploughed under before the parasite produces seeds. A crop plant that is not a host to weed butinduces it to germinate is called as trap crop.

In monoculture cropping systems, several manipulable management and environmental factors have been shown to affect competitive suppression of weeds. Crop density, spatial arrangement, species and genotype and soil fertility are probably important for controlling weeds in intercropping systems.

PEST MANAGEMENT IN ORGANIC FARMING

Pesticides are chemical or natural substances that control pest populations by killing the pest organisms, be they insects, diseases, weeds or animals. In 1985, roughly 2300 million kg of chemicalpesticides were used worldwide. About 15 per cent of this, including 30 per cent of all insecticides, is used in the third world. During the traditional technology period in India, the use of synthetic pesticides was negligible and reserved for the high value crops only. The traditional crop varieties did not face much problem of pests and diseases and in the event of their occurrence traditional practices were able to reduce the menace. However, with the advent of green revolution, the new crop varieties and cropping sequences for intensive agriculture brought to the forefront problems of pests which caused tremendous losses to various crops and their produces. Pesticide consumption in India has shown steady increase from the mid-fifties both in quantity and coverage. The quantity of pesticides used rose from 200 tonnes in 1955 to 72000 tonnes in

1987 and the plant protection coverage increased from 2.4 million hectares in 1956 to 18 million hectares in 1984. However, use of these toxic substances, although essential, requires adequate caution and safety measures. Their influence in upsetting the ecological balance and polluting the environment is being increasingly felt. The following are the known dangers of using pesticides:

- Every year thousands of people are poisoned by pesticides,about half of them in the third world. In 1983 a total of about 2 million people suffered from pesticide poisoning and 40000 of the cases were fatal. Because of their toxicity, many pesticideslike DDT have been banned in industrialised countries, butthey are still being used in many developing countries.
- Over a period of time, pests build up resistance to pesticides, which must then, be used in even higher doses to have toxiceffect. Pest resistance builds up more rapidly in tropical than intemperate countries as biological processes are more rapid at higher temperatures. Resistance to pesticides was known for447 insects and mites, 100 plant pathogens,55 kinds of weeds,2 kinds of nematodes and 5 kinds of rodents.
- Pesticides kill not only organisms that,cause damage to crops but also useful organisms, such as natural enemies of pests. The incidence of pest attacks and secondary pest attacks may increase after pesticides have killed the natural enemies.
- Only a small portion of pesticides applied in field reaches the organisms that are supposed to be controlled. The major partreaches the air, soil, or water, where it has a damaging effect on living organisms. Aquatic organisms are particularly sensitive to pesticides.
- Pesticides that do not break down easily are absorbed in the food chain and cause considerable damage to insect-consuming animals, prey birds and ultimately human beings.

Due to population increase the problem today is food and nutrition security to mankind. Even though agrochemicals and pesticides are important tools in enhancing food supplies, excessive use of these chemicals has led to toxicity and pollution in the environment. The world pesticide market in 1981 was reported to be worth about US $ 13,000 million (user value, of which 20 per cent was from developing countries and 10 per cent market was from India).

Table 1. Pesticide market in the world

Pesticide	**Million USmce_markernbsp;**	**per cent of total**
Herbicide	8,600	42
Insecticide	6,100	31
Fungicide	4,100	21
Others (Fumigants defoliants, and desiccators etc.)	1200	6
Total	20,000	100

The growing disillusionment with highly toxic, broad spectrum synthetic pesticides and the expanding global awareness to avoid environmental degradation has shifted the pest management strategy from application of pesticides, to manage the pests with permanent, self-sustained, self-regulating, and ecofriendly biological pesticides without environmental backlashes. World wide, an estimated 67000 different pest species attack agricultural crops. In general, less than 5 per cent are considered to be serious pests. From 30 to 80 per cent of the pests in any geographic region are native to that region. In most instances, the pests which are specific for each region have moved from feeding on native crop to feeding on crops that were introduced into the region. For nearly a century and a half, various parasitic and predacious species have been used as biological control agents for a wide variety of pest species. Although approximately 3000 out of 67000 pest species in the world have been targets, of biological control, only 120 pest species

have been effectively controlled. As the remaining species have been only moderately or partially controlled, additional measures are continued to be used to control them. All the developmental stages of most of the insect pests of crop are subjected to attack by entomo-phagous insects, belonging to 224 families of 15 orders.

Hence the present approach is to develop new molecules which are highly effective at low active ingredient dosage level, less persistent and rapidly biodegradable, selective in action and safer to human beings and environment. These new concepts and technol-ogies can be broadly grouped as follows:

A) New molecular development:

A new class of highly activated insecticides/compounds that provide plants with resistance to insects.

B) New formulation technologies:

Less mobile and less volatile formulation to reduce hazard to man and the environment avoiding leaching and contamin-ation to water sources.

C) Biotechnology

i) Biopesticides: The exploitation of microorganisms in pest control has been receiving greater attention in the recent years and commercial products are now available. In 1988, the world microbial pesticide market was valued at US $ 70 million accounting for less than 0.5 per cent of the total pesticide market.

ii) Pheromones: Pheromones of around 800 insect species worldwide have been identified. Of these, over 400 are sexual attractants or aggregations. Pheromones have been synthesi-sed and are being marketed widely.

iii) Genetic Engineering

iv) Plant derived insecticides

v) New techniques to establish pest resistance to insecticides

PEST MANAGEMENT METHODS

Pest management methods can be categorised as biological, cultural and organically accepted chemical alternatives, with further subdivisions.

Biological alternatives

- Biological control by multicellular organisms including release of exotic parasites and predators, conservation and augmenta-tion of natural enemies, genetic improvement and allelopathy.
- Biological control by microbial agents-application of beneficial or antagonistic microorganisms or toxins synthesized by microbes.
- Management practices, including natural mulches, living mulches, trap crops and cover crops to enhance the population of natural enemies.

Organically acceptable chemical alternatives

- Oils and soaps -some horticultural oils and various fatty acids
- Botanical - toxins derived from plants such as pyretherumand ryania.
- Semio-chemicals - pheromones, allomones and kairomones including sex attractants, feeding attractants and repellents produced by insects and affecting the behaviour of other insects.
- Inorganic or elemental compounds such as elemental sulphur and some copper formulations.

Cultural alternatives

- Crop rotation - rotation of crops and fallow periods
- Physical controls - such as tillage, mowing, chopping and flaming
- Sanitation - removing non-crop hosts and infected hosts.
- Pruning and canopy management - physically manipulatingthe structure of the host plant.
- irrigation management-controlling water application and drainage.

- Strategic choices - choice of field, location, planting and intended harvest dates, vigorous cultivars. Plant density, transplanting etc.,
- Regulation - including mandatory host - free periods, host free zones, crop termination, seed indexing and detection.

RICE-FISH INTEGRATION OF ORGANIC FARMING

Rice and fish are the staples for the people in most Asian countries. Over 90 per cent of the world's area under rice, equivalent to approximately 134 million hectares, is grown under flooded conditions providing not only home to a wide range of aquatic organisms, but also offering opportunities for their enhancement and culture. Asia is the largest producer of rice (91%) with an average productivity of 3.9 t/ha. India has the maximum rice area, 44.5 Mha, although China with second largest area under rice, 30.5 Mha, is the world's largest producer of rice, with average productivity of over 6 t/ha. However, the productivity of the irrigated rice ecosystem, that accounts over 76% of the global rice production under continuous and intensive cropping conditions is either stagnating or declining.

Externalities of Green Revolution

With the introduction of high yielding technology although rice yield has increased substantially in irrigated rice tracts in India, there has been no significant increase in yield under rain fed and lowland rice ecologies that account for over 50 percent of rice area. Consequently, in states like Assam, Bihar, Orissa and Madhya Pradesh and Kerala the realized yield have been very low as compared to irrigated ecologies. There is a strong view that the Green Revolution paradigm adopted in these places in tune with the National agenda has been inappropriate owing to the complete neglect of the natural situations. The technology supposed to be scale and resource neutral has therefore been confined to the regions with favorable farming situation. It is argued that in states likn Kerala, the increase in productivity with the advent of high yielding technologies was not commensurate as compared to escalation in cost of production. This has been partly attributed to the high rainfall situations, undulating topography, and water logged rice-growing situations in high rainfall tropics at variance from that of the semi arid irrigated areas. These unique situations call for technologies tailored to the specific environmental conditions.

Some of the second generation problems in regions of high productivity have been identified as 1) declining or plateauing of farm productivity due to depletion of organic matter, coupled with depletion of soil fertility due to over mining of native nutrient reserve.2) declining fertilizer use efficiency, groundwater depletion due to overexploitation in utter disregard to level of natural recharge ability.3) increasing problems of salinity-alkalinity in the command areas due to excessive and indiscriminate use of irrigation water and 4)build up of disease- pest pressure by continuous cropping and increased varietal uniformity and excessive dependence of on indiscriminate use of pesticides that eventual emergence and resurgence of pests thereby increased cost on plant protection.

Lowland Rice Ecologies

Endowed with high rainfall, undulating topography, and water logged situations, the rice growing situations in high rainfall tropics are at variance from that of the semi arid irrigated areas. These unique situations call for technologies tailored to the specific environmental conditions in fragile rice ecologies. Over centuries, our forefathers have therefore evolved a farming strategy in consonance with the rigid environmental conditions such as saline to acid soil and rising flood conditions in these places. This calls for a shift to an ideal cropping/ farming system that ensure high productivity, reasonable economic returns and least risk to natural endowments. It has been highlighted that the high yielding technologies were highly productive and profitable in rotation with varied crops and cropping sequences.

Diversification- IPS Approaches

Since farming is the biological process of transformation of solar energy in to biomass involving the major resources, land and water, approaches that facilitate scientific and optimum utilization of production

potentials of natural and human resources must be the primary considerations for sustainable development. Full utilization of the production potentials through intensification and diversification will not only provide income and employment opportunities but also help to ensure the livelihood security of the people who subsist on them.

Integration of crops and livestock has been a sustainable and traditional practice in Kerala for over centuries. Under the homestead, approach prevalent, animals used to be raised on agricultural waste; animal power was used for agricultural operations; and animal dung was used as manure and fuel. During sixties and seventies with the advent of modern practices in farming involving extensive use of irrigation and agrochemicals, new vistas for increased crop productivity was opened. But there is strong view that in the process, the essential foundation for sustaining this production such as soil, water, forest and biodiversity has got eroded. The initial spurt in yield rate was also not sustained. These concerns lead us to the search for technologies that blend productivity, economic efficiency and ecological sus-tainability.

Vanishing rice lands - Economic sustainability issues

Rico holds the key to food security in Kerala. The gross are a under rice which was 8.75 lakh ha in 1975 has come down to 3.01 lakh ha in 2002-03. Out of the annual rice requirement of 37 lakh tons presently a little over 18 per cent, 6.8 lakh tons is produced internally. Out of the major 15 rice producing states in the country, Kerala ranks 8th in terms of productivity and ranks 14th in terms of area. In terms of cost of production of rice, Kerala ranks first with Rs.523/qtl of rice, while cost of production of rice in Punjab is only Rs. 183/ Qtl and National average being Rs.268/ Qtl. In a study conducted in Kuttanad, the major rice-growing tract in Kerala, it was demonstrated that with the introduction of high yielding technology, the cost of production of rice has increased dispropor-tionate to the value of output. While the cost increased 254 per cent during the last 10 years, the output price of paddy increased only by 95 per cent. This mismatch between the input cost and value of output is indicated by the paddy equivalence cost (PEC) of rice cultivation. The Paddy Equivalence Cost of cultivation for the base year 1988 was 1983 kg per ha, which increased to 3239 kg per ha in 1998. This means that a minimum yield of 32 quintals per ha is necessary to breakeven paddy cultivation in Kuttanad. And out of the 53 samples surveyed only 19 samples were observed to conform to the level of productivity. This has led to a drastic reduction in cropping intensity despite heavy investments to boost rice production. The average cropping intensity of rice in coastal wetlands in places such as Kuttanad in Kerala is barely 120 per cent which means that only 20 per cent of rice fields are utilized for more than one crop a year. These lands remain under utilized for most part of the year. By integrating aquaculture, these under utilized wet-lands can be brought to farming with enhanced profitability. Such an enterprise diversification would decease dependency of farmers on one crop alone for income, thus reducing the risks presently associated with rice monoculture.

Table 1 : Changes in cost and return (Rs/ha) of rice cultivation in Kuttanad, Kerala

Item	1988	1998	Hike	Percentage increase
Input Seed	483	1026	544	112.86
Fertilizer	1174	2249	1075	91.57
Plant protection	434	799	365	84.10
Manure	5	55	50	1000.00
Bullock power	371	101	-270	-72.78
Machine	215	1244	1029	478.60
Labour	2105	9786	7681	364.89
Other Inputs	256	871	615	240.23
Total	4560	1613	11571	253.75
Output	8129	1588	7755	95.40

Net return	+3087	-247		
Av. Yield (kg/ha)	3266	3320	54	1.65

Rice being the staple food of the people in these places, and the internal production is barely eighteen per cent of our requirement, this decline in area under paddy raise concern to food security. The labor opportunity for dependent labor is hampered as rice cultivation generates over 70 man-days of labor per ha. Located in the valley bottom wetlands and lowlands in the steep and undulating topography in these places the paddy lands in these places have a unique ecological function, like forest, by promoting recharge of ground water. However, with the poor profitability of paddy cultivation, the very existence and livelihood of the farmer is at stake. The options available for the State is to make paddy cultivation competitively profitable with the aid of technical inputs or to let the farmers adopt a sustainable integrated farming system, wherever possible. A combination of the above approaches is the one most desirable. Integration of fish along with rice is considered in this perspective for ensuring the diversity of food basket with out compromising on the sociological and environmental functions of these wetlands. In Kerala rice is cultivated mainly in lowlands and valley bottom areas of highlands and midlands and the coastal lowlands classified as niloms, or wetlands. In each of these locations, the paddy field or wetland plays a unique ecological function. In the coastal lowlands, paddy is often cultivated in locations where nothing else can be cultivated. Some spots are so hostile that even paddy can hardly survive eg. the Kari land of Kuttanad. However, the coastal wetlands comprising of Kuttanad, Kole, Poklkali lands constitute approximately 24 per cent of the paddy lands in the state and contribute to over 37 per cent of the rice output. Being close to the sea and exposed to the monsoon floods, diurnal and tidal flushing, the environment is even more hostile to for paddy in seaward locations such as karilands in Kuttanad and pokkali lands. However a unique symbiosis of paddy during monsoon season and fish/prawn during high saline months has been developed and practiced in pokkali lands in tune with the nature's rhythm.

CHOICE OF VARIETIES FOR ORGANIC FARMING

Widespread use of improved rice varieties since the 1960s has reduced food prices, for the poor and prevented millions of cases of childhood malnutrition. Without the development of the high yielding varieties, prices for developing country consumers would likely be as much as 40 per cent higher than they are today. The new varieties have also reduced costly food imports by almost 8 per cent and have eliminated the need to convert millions of hectares of forestland to agricultural uses as would have otherwise been required had yields remained at 1960 levels. The availability of high yielding varieties has prompted many of the world's poorest countries to invest in plant breeding programs and produce varieties suited to local environments and markets. The new plant types have also prompted massive government investments in agricultural infrastructure such as irrigation and fertilizer delivery systems.

In spite of the advantages of high yielding varieties, it should not be forgotten that the adoption of high yielding has led to the substitution of a large quantity of species for only a few and uniform varieties from a genetic point of view, which has caused a significant reduction in the genetic inheritance of cultivated species. Many agricultural species, varieties and breeds which have played an important role in the human diet and traditional cultures have practically disappeared over the last century.

In the last decade, the adoption of organic agriculture has indirectly established a rescue process of species, varieties and breeds threatened by under-use or extinction. Stronger collabora- tion has been evident among movements aiming to defend biodiversity and the organic agriculture movement. This is especially the case now that there is interest in traditional, speciality and organic products. For the rescue of varieties threatened by extinction, the development of a market is fun-damental and it is here that organic agriculture plays an important role as the price premium gives an additional value to the product. The restoration and enhancement of under-utilized species and varieties has been motivated by a food demand concerned with health and culinary traditions. Organic agriculture has allowed the maintenance and

improvement of species and varieties that otherwise would suffer strong genetic erosion or extinction

What is organic Agriculture?

Organic systems avoid the use of synthetic fertilizers, pesticides, and growth regulators. Instead they rely on crop rotations, crop residues, animal manures, legumes, green manures, off-farm wastes, mechanical cultivation, mineral-bearing rocks, and biological pest control to maintain soil health, supply plant nutrients, and minimize insects, weeds, and other pests.

Selection of rice varieties for organic farming

In general, rice planting dates, seeding rates, preferred varieties, and harvesting methods vary among regions, but they are largely the same for conventional and organic systems While choosing varieties for organic farming, the special considerations relevant to *organic* rice production has to be duly recognized. Weed control, management of soil fertility and minimizing pests and diseases are the principal challenges associated with organic rice production and according to the needs and requirements in each, varieties have to be chosen.

Weed Control

Weeds are a problem in both wetland rice as well as up lands, but it is more hazardous under up land conditions. Direct seeding of rice is receiving much attention in recent times since it reducesproduction costs. As cultural practices for rice shift from transplanted to direct seeded rice, weed problems will increase because rice and weeds can emerge together. Many weeds of irrigated ecosystems like Barnyard grass *(Echinocloa crus-galli)* can become more important /harmful in direct seeded rice since they are adapted for better growth under dry than wet conditions. While choosing varieties for upland rice, care should be taken to select varieties with initial vigour and increased growth rate so that they can compete with weeds and come up well. Short duration varieties are preferred for direct seeding in uplands, since they have higher growth rate compared to medium or long duration varieties.

Girija et.al. (2002) while evaluating upland varieties for their weed competitiveness at Regional Agricultural Research Station, Pat-tambi, noticed distinct difference in the weed suppression ability of the cultivars tested. Based on this, they classified the rice varieties into three groups viz., 1. Varieties, which can completely smother the weeds, 2. Varieties that show moderate tolerance and 3. Varieties that are smothered by competing weeds. Improved traditional varieties like PTB 28, PTB 29 and PTB 30 and land races like Karanellu belong to the first group. The improved upland varieties could grow fast and produce large no. of tillers, there by preventing the growth of weeds in between. Land races like Karanellu had long and droopy leaves, which prevented light interception by weeds there by reducing their growth. Research is underway to transfer the weed competitiveness of these varieties to high yielding varieties.

In transplanted rice in lowlands, crop rotations, land leveling, seedbed preparation, water management, and rotary hoeing are the primary weed-control practices followed to take care of the weeds. Here also, varieties having natural weed fighting capacity could be chosen to reduce the hazards from high weed growth. Use of allelopathic rice varieties having activity against a broad spectrum of target weeds could be a desirable choice. Cultivars that show allelopathic potential against important rice weeds have been identified in many countries viz., United States, Japan, Egypt and the Philippines. In the United States, evaluated more than 10000 accessions of rice for allelopathic effects against aquatic weeds like duck salad and red stem and could identify around 190 promising accessions. This included rice varieties from many countries including India. A list of Indian rice varieties showing allelopathic effects against duck salad and red stem are furnished in Table 1. Allelopathic cultivars that strongly inhibit root elongation of barnyard grass but weakly affect the shoot have been identified by Olofsdotter. In Egypt, identified Indian rice varieties that expressed allelopathic effects on Echinocloa cruss-galli and Cyperus difformis. L. at 3-4-leaf stage by inhibiting root development and emergence of the first or second leaf of both weeds. Kim and Shin, 1998 identified promising rice germplasm for allelopathic activity in Korea and new cultivars are being

generated using them.

Soil fertility

Maintaining soil fertility in organic cropping typically involves some combination of crop rotation with deep-rooted legume crops or green manure/cover crops, and applying rock minerals, animal manures, composts, and other approved organic amendments. Green manures have proven their positive influence in enhancing rice yields. Leguminous green-manure crops can supply 30 to 50 per cent of the nitrogen needs of high yielding rice varieties. The availability of green-manure nitrogen depends on the quantity, quality, and type of green-manure crop; the time and method of application; soil fertility; and cropping method. It has been observed that green manuring with Sunnhemp or Cowpea grown during summer months and incorporated in soil before transplanting rice could save about 60 kg N/ha for rice crop. Recent studies on economizing chemical fertilizers through organic manures in selected cropping systems under All India Co-ordinated Agronomic Research Project have shown that 25-50% N requirement of rice during Kharif season could be met through organic sources without any adverse effect on rice productivity. Yield response of rice varieties to organics indicated varietal differences to organic farming. Some varieties responded more to organics than to chemical fertilizers. Similarly, certain rice varieties responded to chemical fertilizers than to organics.

Emission of trace gases especially Methane from flooded rice fields has become a serious concern world over. Methane emission from lowland rice has been identified as resulting from organic matter fermentation and factors like incorporation of crop residues like rice straw can enhance the process. Varieties with low methane emission potential could reduce ‘hazards resulting from high methane emission and could be more rewarding under organic farming.

Insects and Diseases

Rice, both rain fed and irrigated is infested by a variety of pests and diseases. Intensive cropping of modern varieties under high inputs provided a favourable environment for many pests as a limited number of modern varieties began to be widely cultivated, the populations and economic importance of their associated pests increased and new pathogen strains and insect biotypes developed. The major insect pe.sts viz., Plant hoppers gall midge, stem borer, leaf rollers, rice bug, along with minor pests like case worm, thrips, ear cutting caterpillar, whorl maggot etc., cause serious damage to the rice crop in the tropics. Similarly, fungal diseases (leaf blast, sheath blight, brown spot, sheath rot, bacterial diseases (bacterial blight) and viral diseases (Tungro Virus, Grassy Stunt Virus) etc., can also devastate the crop. Excessive nitrogen levels are rarely a problem in organic production, since use of synthetic fertilizers is avoided, but timely control measures are a must to keep the damage under economic threshold levels. Timely planting, variety selection, and cultural practices to suppress weeds and encourage dense stands of rice will help control most of the biotic stresses mentioned above.

Use of resistant varieties can prove to be consistently and significantly more productive under high pest or disease pressure. Varieties with moderate resistance are a better choice since they allow pest populations to be maintained at levels that do not result in significant damage. Varieties with strong resistance reduce the populations of natural enemies that feed on the pest and could ultimately lead to resurgence of the pest. Table 3 gives a list of high yielding varieties combining resistance to various biotic stresses released by the Central Seed Subcommittee on Crop Standards, Notification and Release of Varieties. The different states have also released a number of varieties resistant to various biotic stresses. A list of high yielding rice varieties with multiple resistances developed by Kerala Agricultural University is furnished in Table 4 as to guide in choosing varieties for a particular situation.

Selecting varieties possessing multiple resistances could make the programme more effective. Again, the economic loss associated with each stress should be assessed before selecting a variety and high priority should be assigned to varieties resistant to a particular stress for which biological control measures are not

available, and low priority could be given for varieties resistant to such stresses where other low cost control methods are available. For eg. Use of varieties resistant to Bph and gall midge and adopting biological control measures for stem borer and leaf roller could take care of all the above pests. Similarly, selecting a blast resistant variety along with biological control measure for sheath blight could be a more effective method for controlling the two diseases rather than going for varieties resistant to both.

COASTAL AGRO-ECO SYSTEM IN ORGANIC RICE FARMING

Rice is well known to be a semi-aquatic plant grown under flooded condition almost throughout the season. The rice ecosystem is thus characterised by puddled (de-structured) soil with standing water. The practice of puddling itself causes at least two ill effects viz soil erosion and hard pan formation just below the plough layer. Thus preparation of land itself for growing rice causes continuous loss of fertile topsoil, especially during the first crop season of southwest monsoon The only advantage of this type of cultivation practice is effective weed control. Efficient fertilizer management is also a problem in rice soil specifically in case of N and K fertilizers due to their high solubility and leaching which in turn may cause pollution of ground water and/or neighboring water bodies. During the green revolution era, the substantial increase in production was due to the use of fertilizer responsive high yielding varieties. Thus fertilizers had an equal role in enhancing the production along with high yielding varieties.

Organic farming as promoted in the present form is aiming at demolishing the above main pillars of green revolution. Whether the newly constructed "organic pillar" can withstand the pressure of sustainability in terms of fertility, productivity, profitability and food security and ecological safety is the big question to be answered immediately since a long gap can cause stagnation in production which in turn cannot be afforded in the context of increasing population. In this protext, the real objective of the farming system should be to have an "evergreen revolution".

Organic rice farming and nutrient management in such an ecosystem should be viewed against this background. Sus-tainability should aim at developing farming systems that are productive and profitable, conserve the natural resource base, protect the environment from pollution and enhance health and safety on a long term basis or rather indefinitely. Organic farming without the use of inorganic synthetic chemicals in terms of fertilizers and pesticides is argued to be sustainable. However this statement should be critically analyzed to realize whether it is a truth or a myth.

Organic farming - the truths vs. myths

Chonkar in his R.V Tamhane memorial lecture during the annual convention of Indian Society of Soil Science has shown with data how certain myths got a walkover over reality in process of popularisation of organic farming According to him the myths are:

1. **Organic food tastes better and is of superior quality:** The traditional belief that organic manure promotes quality while mineral fertilizers promote quantity was shown to be over simplistic by Schuphan on the basis of trials conducted for over a decade. This is because irrespective of the source, plants absorb nutrients as ions and then metabolised into compounds, which determine the quality of produce such as flavour and shelf life which in turn is a genetically inherited property.
2. **Organic food is more nutritious and safer :** The mineral composition of a product is independent of the cultivation practice and slight variations are due to environmental and cultural factors. This concept may be derived from the belief that the hazards in the food are mainly derived from agrochemicals. In fact the microbes are the main culprits of food borne diseases and organic manures from animal sources have more chances of pathogen risk such as that of Salmonella, *Esherichia coli* etc,
3. **Organic farming is eco-friendly** : It is believed that organic farming keeps the soil healthy and does not pollute environment. At the same time one should remember that the end product of manure decomposition is nitrate and if one recommends manures on nitrogen equivalent basis, the release of these nitrates will not synchronies with crop demand and uptake and *so* can accumulate in soil or water

causing pollution. Further, addition of large amount of organic manure under submerged condition can cause evolution of green house gases like methane and carbon dioxide. Further, organic manures from animal sources and sewage and sludge contain at times very high concentrations of trace elements and heavy metals.

4. Organic farming improves soil fertility and chemical fertilizers deteriorate it. Long-term fertilizer experiments have proved beyond doubt that balanced application of fertilizers along with manures sustained yield.

5. Organic farming sustain higher yields : On long-term basis, partial substitution of fertilizers with organic sources was found to reduce the grain yield of rice significantly.

6. Enough organics are available to replace chemical fertilizers. Projections on the availability of plant nutrients from organic sources in India as worked out by Tandon (1997) as given in table-3 and the projected plant nutrient addition and removal show that all tapable nutrients from organic sources will barely able to meet the deficit of nutrients in soil after crop removal at the present level of crop production and fertilizer application. So what to say of replacing chemical fertilizers presently used.

Organics as a source of Plant nutrients

It is an established fact that without improving organic carbon status of the soil it is not possible to improve nitrogen status because of the constancy of CN ratio. Thus for effective nitrogen management organic manures are a must. This can be achieved by inclusion of legumes in the crop rotation in a rice- rice - legume rotation. Legume can also grown as a companion crop during dry sowing in first crop season and when flooded afterwards with the onset of southwest monsoon, legume may get incorporated as a manure to rice. Organic matter can also be added through FYM, compost @ about 4 - 6 t ha-1 Cattle manure being widely used as fuel for cooking in rural areas, alternate source of energy is to be found out or biogas plants must be established so as to tap energy without reducing the manurial value of cattle dung. But release of methane from the biogas plants from exposed parts of the fermentation well is a built in hazard of these plants.

Bio fertilizers enhance soil fertility by fixing atmospheric nitrogen, mobilising sparingly soluble forms of P, Zn etc. and also by enhancing decomposition of crop residues. Blue green algae (BGA) in rice field are contributing nitrogen to rice. BGA can fix even to the tune of 120 - 150 kg N ha if suitable temperature (25 - 30 °C) and good availability of P is assured. This is most suitable for coastal areas where the annual mean temperature is in the range of 25-30ºC.

The experiments on effect of P solubilizing organisms on crop yield that 5-10% yield increase svas obtained over uninoculated plots. Vesicular-arboscular mycorrhizae can help in skipping about 15 kg P ha-1 and also there is a carry over of VAM inoculums through rice stubbles to the succeeding wheat crop. It must be noted that the nitrogen fixation or nutrient release by microbes consume energy for the growth and multiplication of microbes which is released either from the host plant affecting its yield potential or as in the case of free living ones from the organic matter decomposition in the soil which in turn make the process inefficient and causes depletion of organic matter in tropical soils.

Sewage and sludge and industrial effluents contain variable quantities of plant nutrients and organic matter besides some toxic elements depending upon the source or origin.

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