AGRO TECHNOLOGY *of* ORGANIC FARMING

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GRASSROOTS INSTITUTE

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ORGANIC MANURE

Organic manure has been time-tested material for improving the fertility and productivity of soils. It is however only during the last 10-15 years that these have been incorporated into integrated nutrient supply system for intensive high-yielding cropping sequences in contrast to the subsistence level production of the past. Organic manure is a very broad term. It covers manure made from cattle dung, excreta of other animals, rural and urban composts, other animal wastes, crop residues and, last but not the least, the green manure.

Materials such as farmyard manure, composts and crop residues that are bulky and supply low quantities of major plant nutrients are termed as bulky organic manure. Concentrated organic manure, such as oil cakes, slaughterhouse wastes, fishmeal, guano, shoddy and poultry manure are comparatively richer in NPK.

Farmyard Manure (FYM): This is the most commonly used organic manure in India being readily available. It consists of a mixture of animal-shed wastes containing dung, urine and some straw. An application of 10 ton well rotted FYM/ha can add 50-60 kg N, 15-20 kg P_2O_5 and 50-60 kg K_2O (Table.1).

Composts: These are prepared through the action of microorganisms on wastes such as leaves, roots and stumbles, crop residues, straw, hedge clippings, weeds, water hyacinth, bagasse, sawdust, kitchen wastes, and human habitation wastes. These materials undergo intensive decomposition under medium-high temperatures in heaps, windrows or pits with adequate moisture. In about 3-6 months, an amorphous, brown to dark brown humidified material called compost is obtained. It is more stable in form, valuable source of plant nutrients, helps in maintenance soil organic matter and in improving soil physical condition and biological activity. Composts are broadly divided into two groups such as rural compost and town or urban compost.

Important factors which need to be maintained at optimum level for efficient composting are C:N ratio, particle size, blending or proportioning of raw materials, moisture, aeration, temperature, destruction of pathogens and parasite and use of microbial activators.

Technologies for Quicker and Better Compost Production

Two handicaps common to all bulky manure are their low nutrient content and large volume (bulk). Major developments to upgrade the nutrient content of composts and to hasten the composting process so that materials of better quality can be obtained in less time are briefly discussed here with particular reference to low-cost technologies (Gaur, 1982, 1990a).

<u>Compost Accelerator/Inoculants</u>*:* Strains of microorganisms that can hasten the process of composting of organic residues have been isolated (Bhardwaj and Gaur 1985; Misra et al. 1981; Gaur et al. 1982; Kapoor at al. 1978). Such microbes are cellulolytic and lignolytic type of microorganisms. Work on the cellulolytic fungi as compost inoculant, particularly at IARI has been reviewed (Gaur 1987; Gaur and Mathur 1990). Several types of wastes were chopped to 5-6 cm size and filled in the pits. Homogenized fungal culture *Trichurus spiralis, Paeciliomyces fusisporus, Trichoderma viride* and *Asperquillus* sp. was then added at 300 gm/ton material. Moisture was initially maintained at 100%. Rock phosphate at 1% was added to narrow down the C:P ratio of substrates used and to hasten the composting process. After every 15 days, samples are drawn and composting mass turned upside down.

Within 8 to 10 weeks a good quality compost from paddy straw could be prepared containing around 1.7% N and C:N ratio 12.3. The beneficial effect of cellulolytic fungi in composting of dairy farm wastes has been reported (Tiwari et al. 1989). They also reported the beneficial effect of 10% cattle dung as inoculant and 2% rock phosphate in composting of wool waste containing 66.9% organic carbon and 4.6% N. The final product was obtained after 10 weeks of composting. It contained 20.6% OC and 10.0% N with a C:N ratio of 2:1 (Tiwari *et al.* 1989b).

The use of efficient cellulolythic culture not only helped in preparing compost in 8-10 weeks but also reduced the bulk 5-10%. The enrichment of total N was pronounced in the presence of the inoculants. Similar observations have been recorded with mixed crop wastes, sugarcane trash etc. at Hissar, Ranchi and Pune. This indicates the potential of the cultures for rapid composting of dry and wide C:N ratio organic materials.

<u>Enrichment of Compost by Bio-inoculants</u>: Enrichment of compost with N-fixing bacteria and P-solubilising fungi is one of the possible ways of improving nutrient content of final product. This objective can be achieved by introducing efficient microbial inoculants. Inoculation with *Azotobacter* and phosphate solubilising culture in present of 1% rock phosphate is a beneficial input to obtain good quality compost that is rich in N and available P_2O_5. Humus content was also significantly higher in material treated with microbial inoculants. The quality of compost produced from dairy farm waste was improved by its inoculation with *Azotobacter* and *Aspergillus awamori* (Tiwari et al. 1989). Similarly sugarcane trash compost containing 1.34% N with a C:N ratio of 26 was obtained with bio-inoculants. Using chopped straw, compost with 1.78% N and C:N ratio of 13.3 was produced with inoculants as against 1.30% N and C:N ratio 20 without bio-inoculants. Banana leaf compost prepared with similar biotechnology contained 2.8% N and a C:N ratio of 11.6 against 1.90% N and C:N ratio of 19.3 in control treatment.

The effect of this technology was also tested in improvement of the quality of urban compost prepared at mechanical compost plants (Gaur 1983). Nitrogen gain of almost 100% was recorded with the combined inoculation of *A. chroococcum* and *B. polemical* in rock phosphate amended compost. The quality of urban compost can be improved by blending it with sewage sludge in a ratio of 2:1 (Gaur 1983). Nitrogen content of the blended urban compost with and rock phosphate was augmented to 1.42% and 1.29% as compared to 0.60% N in urban compost alone.

GREEN MANURING

The role of green manure 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 practiced in China as early as 1134 B.C. These are one of the main components of integrated nutrient supply system along with inorganic fertilizers and biofertilisers. 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. (FAI 1990).

This chapter provides an overall assessment of green manure, their significance and various management aspects in modern agriculture. Green manure can meet a part of the nutrient needs (particularly N) of cops for optimum production and to that extent can result in savings in fertiliser costs. These cannot completely replace fertiliser N if the goal is to harvest moderate-high yields on sustained basis.

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 manure may be plants of grain legumes such as pigeon pea, green gram, cowpea, soybean, or groundnut; perennial woody multipurpose legumes viz., Leucaena *leucocephala (*subabul*), Gliricidia sepium, Cassia siamea* or non-grain legumes like *Crotalaria, Sesbania, Centrosema, Stylosanthes* and *Desmodium.*

Leguminous plants are largely use as green manure 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 (FAO 1997; IRRI 1988; Cosico 1990):

- show early establishment and high seedling vigour
- be tolerant to drought, shade, flood and adverse temperature.
- possess 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 Manure: These differ widely in nitrogen concentration and yield. Among 86 species used in India as green manure for rice their N contents ranged from 2.0 to 4.9% N (Vachhani and Murthy 1964; Ghai et al 1985). Earlier results 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 a paddy yield over unmanured plots (Sanyasi Raju 1952).

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 (Abrol and Palaniappan 1998).

Table.1: Green manures suitable for some field crops

Field crop	Recommended green manure
Rice	Sunnhemp, Sesbania and Wild indigo (*indigofera tinctoria*)
Sugarcane	Sunnhemp
Finger millet	Sunnhemp
Wheat	Sunnhemp
Sorghum	Sunnhemp, Subabul (*Leucaena leucocephala*)
Banana	Leaves of *Gliricidia spium*
Potato	Lupin (Lupinus albus), Sunnhemp, Cowpea, Gaur, Buck wheat(*Fagopyrum sp*)

Adapted from Krishnamurthy (1978), Sharma et a.l *(1991)*

Non-grain Legumes: Recent evaluation of some of the promising green manure crops at Coimbatore indicated the potential of already popular *dhaincha* and the 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* that is capable of withstanding water stress to some extent. Its potential under Indian conditions has not been fully explored.

Though *Tephrosia purpurea* and *Phaselous trilobus* grow rather slowly and accumulate much less N than Sesbania, they are more adapted to drought (Palaniappan et al 1990a). *T. purpurea* has the additional advantage of self-sowing and is not browsed by cattle.

Hence in deltaic areas where a single rice crop is grown due to limited water availability, *T. purpurea* is raided in the long rice fallow season without irrigation. After 3-4 months, it sheds in the field that 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 crop, depending on soil, climatic and cropping conditions (Garrity and Flinn 1988).

Grain Legumes: Some annual grain legume crops are also used as green manure, after all or part of the grain is harvested. Green gram stover incorporated in the soil after post harvest contributed about 60kg N/ha to the succeeding rice crop (Rekhi and Meelu 1983). Evaluation of several grain legumes with Sesbania and Crotoria showed that green gram was the best, yielding about 1 ton grain and 2.5 ton dry matter per hectare equivalent to 50 kg N/ha (Meelu et al. 1986). Green gram, black gram (*Phaseolus mungo*) and cowpea could provide about 50-60 kg N/ha for the succeeding rice crop (Kulkarni and Pandey 1988).

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

			Output in 45-60 days	
Local name	Botanical name	Growing season	Green matter (ton/ha)	N-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 sinesis*	Wet	15.0	74
Guar	*Cyamposis 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

Adapted from Abrol and Palaniappan (1998).

BIOFERTILIZERS

Definition and Types of Biofertiliser: The term "Biofertiliser" is a popular misnomer. It refers to living organisms that augment plant nutrient supplies in one way or the other. In the strictest sense, real biofertilisers are the green manures and organics (materials of biological origin which are added to deliver the nutrients contained in them). But, in this document we will restrict biofertiliser to (i) carrier-based inoculants containing cells of efficient strains of specific microorganisms (mainly bacteria) used by farmers for enhancing the productivity of the soil either by fixing atmospheric N or by solubilising soil P or by stimulating plant growth through synthesis of growth-promoting substances; (ii) Blue green algae or Cyanobacteria; and (iii) Mycorrhizae.

Biofertilisers may be broadly classified into Nitrogen Biofertilisers (NB) or Phosphate Biofertilisers (PB). Nitrogen biofertilisers are now under use. Phosphate biofertilisers are also in use but on a lesser scale and are yet to be standardized.

Importance and Contribution of Biofertilisers in Agriculture

Majority (75%) of the farm holdings in India are small and marginal. Marginal farmers having <1 ha till 54.6% of the total farm holdings, while small farmers having 1-2 hectares holding constitute 1.8% of total farm holdings. It is very difficult for them to purchase and use recommended fertiliser doses at current prices. They need to exploit other less expensive nutrient sources to the maximum. In order to raise their incomes and living standards, these landholders must maximize crop productivity per unit area in the most cost effective manner. Biofertilisers, based on renewable energy source, are a cost effective supplement to chemical fertilizers and can help to economize on the high investment needed for fertilizer use as far as N and P are concerned.

Biofertilisers make number of positive contributions in agriculture, for example:

- They supplement fertilizer supplies for meeting the nutrient needs of crops.
- They can add 20-200 kg N/ha (by fixation) under optimum conditions and solubilise/ mobilize 30-50 Kg P_2O_5/ha.
- They liberate growth-promoting substances and vitamins and help to maintain soil fertility.
- They suppress the incidence of pathogens and control diseases.
- They increase crop yield by 10-50%, N-fixers reduce depletion of soil nutrients and provide sustainability to the farming system.
- They are cheaper, pollution free and based on renewable energy sources.
- They improve soil physical properties, tilth, and soil health in general.

Associative and free living microorganisms are believed to contribute to sustainability of flooded rice production system. Approximately, 50% of the N requirement of flooded rice is met from the pool of soil N which is believed to be maintained through BNF by associative and free living microorganisms. Contributions from non-symbiotic N_2 fixation in upland agriculture are generally not substantial, although N_2 fixation of the order of 160 kg N/ha has been reported for sugarcane (Urguiaga et al. 1989).

Biofertilisers: Their Description and Characteristics

Rhizobium:

Genera

Azorhizobium for stem nodulation (Sesbania rostrata); *Bradyrhizobium* (soybean, lupin, cowpea miscellany i.e. cowpea, greengram, redgram, chickpea, groundnut); *Rhizobium* (pea, lentil, bean, lathyrus, berseem, lotus)

Contribution

1. Direct contribution of N symbiotically with legume:

Alfalfa	100-200	kg N/ha
Groundnut	50-60	kg N/ha
Pigeonpea	168-200	kg N/ha
Lentil	90-100	kg N/ha
Clover	100-150	kg N/ha
Greengram/blackgram	50-55	kg N/ha
Chickpea	85-110	kg N/ha
Pea	52-77	kg N/ha
Cowpea	80-85	kg N/ha
Soybean	60-68	kg N/ha

2. Residual nitrogen benefit for the succeeding crop.

Recommended for legumes

- Pulses: Chickpea, pea, lentil, blackgram, greengram, cowpea, pigeonpea
- Oil seeds: Soybean, groundnut
- Fodders: Berseem (*Egyption clover*), Lucern

Response

Increase in yield 10-35%

Azotobacter:

Number of species

7 [*A. beijerinckii, A. chroococcum, A. paspali, A. vinelandii, A. agillis* (now categorised under the genus *Azomonas*), *A. insignis, A. macrocytogenes*]

Contribution

1. 20-40 mg BNF/g of C-source equivalent to 20-40 kg N/ha;
2. Production of growth promoting substances like vitamins of B-groups, Indole acetic acid and gibberellic acid;
3. Biological control of plant disease by suppressing *Aspergillus*, *Fusarium*.

Recommended for

Rice, wheat, millets, other cereals, cotton, vegetables, sunflower, mustard, flowers.

<u>Azospirillum:</u>

Number of species

4 (*A. liproferm, A. brasilense, A amazonese, A. halopraeferens/ seropedicae*)

Contribution

1. 20-40 mg N fixed/g malate equivalent to 20-40 kg N/ha;
2. Results in increased mineral and water uptake, root development vegetative growth and crop yield.

Recommended for

Rice, millets maize, wheat, sorghum, sugarcane, and co-inoculant for legumes.

Response

Average increase in yield 15-30%.

<u>Blue Green Algae or Cyanobacteria:</u>

Important Genera

Anabaena, Aulosira, Nostoc, Calothrix, Tolypothrix, Scytonema, Westelliopais, Anabaenopsis, Cylindrospermum, Plectonema, Gloecocapsa

Contribution

1. Fixation of about 20-30 kg N/ha in submerged rice fields.
2. Production of Auxin, Indole Acetic acid, Gibberellic acid.

Recommended for

Submerged rice

Response

Average increase in yields 15 - 20 %

<u>Azolla</u>:

Number of species

7 (*A. caroliniana, A. filliculoides, A. mexicana, A. nilotica, A. azollae, A. microphylla, A. pinnata, A. rubra)*

Contribution

1. Fixes of about 40-80 kg N/ha symbiotically with *Anabaena azollae.*
2. Used as green manure because of its large biomass and high N content.

Recommended for

Submerged rice field, within maximum temperature of 38°C.

Response

Average increase in yield 15-20%.

Phosphorus-Solubilising Microorganisms:

Microorganism	Important genus	Important species
Bacteria	i) *Bacillus*	i) *B. megaterium* var. phosphaticum, *B. circulans, B. subtilis, B. polymyxa*
	ii) *Pseudomonas*	ii) *P. striata, P. liquifaciens, P. putida.*
Fungi	i) *Aspergillus*	i) *A. awamori, A. fumigatus, A. flavus*
	ii) *Penicillium*	*ii) P. digitatum, P. lilacinum*

(Some *Streptomyces* sp. can also solubilise Phosphorus significantly).

Contribution

1. These microorganisms possess the ability to bring insoluble soil phosphate into soluble forms by secreting several organic acids.
2. Under favorable conditions they can solubilise 20-30% of insoluble phosphate and crop yield may increase by 10 to 20%.

Recommended for

All crops

Mycorrhiza:

Genus	Species
1. *Glomus*	*Glomus fasciculatum, Glomus mosseae*
2. *Gigaspora*	*Gigaspora nigra*
3. *Acaulospora*	*Acaulospora scrobiculata*
4. *Scleocystis*	*Sclerocystis clavispora*
5. *Endogone*	*Endogone increseta*

Contribution

1. enhances uptake of P, Zn, S and water.
2. promotes more uniform crop, increases growth and yield.
3. enhance resistance to root disease and helps drought stressed plant.
4. improves hardiness of transplant stock.
5. reduces stunting on fumigated soil.

Recommended for

Forest trees, forage grasses, maize, millets, sorghum, barley, leguminous crops.

Biofertiliser Application Technology

Biofertilisers have to be properly applied to the seed or the soil. For this, appropriate application guidelines are available. First step is to purchase the right type of biofertiliser of good quality from a reputed source and use it before the expiry date. Some hints while buying biofertilisers are:

1. Different crops can require different biofertilisers. Be certain to have the right one. The name of the crop should be mentioned on the packet. For pulses

and other legumes only *Rhizobium* of the right type for that crop should be used. Just any type cannot be used. It is not to be used for other crops.

2. Be certain that the inoculant is fresh. Look for the expiry date after which the inoculant cannot be depended upon to produce good results, as it may not contain required number of bacteria. Use before expiry date.
3. use products made by a reputed manufacturer with ISI mark.
4. The package should provide clear instruction and the name and address of the manufacturer should be clearly printed on the bag. Only then buy it.

<u>Rhizobium</u>:

- Dissolve 50 g country sugar *(gur* or *shakkar)* in half a liter (500 ml) water and heat for 15 minutes. Some producers directly add gum acacia as adhesive in the product. In such cases the addition of *gur* or *shakkar* is not needed. Farmers are advised to follow the instructions on the packet.
- Add 200 g gum arabic to the solution and cool to room temperature.
- Mix biofertiliser (150-200 g) in it to form slurry.
- Add seeds required to plant one acre (0.4 ha) to inoculums slurry.
- Mix seeds with inoculums slurry by hand.
- Dry seeds in shade on a plastic sheet/paper.

Seeds are ready for being sown. Sowing during hot period of the day should be avoided. The amount of-culture, water and sticker needed/ha depends on the seed size and seed rate because the objective is to coat/cover the seed with the biofertiliser slurry. There should be a minimum 24 hour gap between seed treatment with a fungicide and biofertiliser treatment to avoid any harmful effect of the agrochernical on the biofertiliser.

An overall idea of the suitable quantities of inoculant (biofertiliser) and sticker for various legumes is provided in the following Table.3.

Table.3: Suitable quantities of Rhizobium inoculant and sticker for inoculating legume seeds

Legume solution	Seed wt (g)	Inoculant (g)	Gum arabic (ml)
Groundnut	100	10	4.0
Chickpea	100	7	3.5
Pigeonpea	100	8	3.5
Soyabean	100	10	3.0
Lentil	50	5	2.0
Subabul	50	10	3.0
Greengram	100	9	3.5
Cowpea	100	8	3.5

<u>Azotobacter</u>:

- Make a slurry of the carrier based biofertiliser using minimum amount of water.
- Dry the seeds in shade and sow.
- For transplanted crops, dip the roots of seedlings in the above slurry for 2030 minutes and then transplant the seedlings.
- In case of sugarcane, *Azotobacter* application may be needed more than

once during early growth. In that case, second and further treatments can be given by pouring the slurry near the root zone. The biofertiliser can also be mixed with farmyard manure and broadcast close to the root zone.

Azospirillum:

Application technique is similar to that described for *Rhizobium.* For transplanted rice, the roots of rice seedlings can be dipped in the biofertiliser slurry for 20 minutes before transplanting. In Tamil Nadu, 600 g of *Azospirillum*/ha is recommended for sorghum and maize using rice kanji as binder. For pearl millet and finger millet an application rate of 2 kg (10 packets)/ha of *Azospirillum* is recommended.

For rice nursery also, 600 g/ha *Azospirillum* culture is recommended. It is to be mixed with water in which seeds are soaked overnight before sowing in the nursery. In the main field, a further application of 2 kg *Azospirillum* (10 packets)/ha is recommended. It is to be mixed with 25 kg FYM plus 25 kg soil and broadcast over the field before transplanting. Another method recommended is to prepare slurry of 1 kg *Azospirillum* biofertiliser in 40 liters water and dip the roots of rice seedlings in it for 15-30 minutes before transplanting.

Blue Green Algae:

Application of dried blue green algal flakes at the rate of 10 kg/ha is recommended to the farmers. The biofertiliser is to be applied 10 days after transplanting rice. For best performance of BGA the field should have adequate level of available phosphorus. In Tamil Nadu, the recommendation is to broadcast 10 kg of powdered BGA flakes/ha 10 days after transplanting rice. A thin film of water is maintained over the field. Blue green algae multiple well during March-September.

Azolla:

As a Green Manure

Plough and level the field about 15 days before transplanting rice. Divide it in subplots of 300-400 m^2 each. Flood the sub-plots and puddle them properly. Inoculate fresh *Azolla* at 3-4 t/ha (3-4 kg per 10 m^2). After 2-3 weeks, drain the water from the field and incorporate the *Azolla* into the soil. Transplant rice seedling within a week. Nitrogen fixation by *Azolla* is satisfactory if the field does not suffer from nutrient deficiencies, particularly that of P, and the temperature as well as moisture is optimum.

As a Dual Crop

Inoculate *Azolla* in standing water at the rate of 3-4 ton/ha about 1-2 weeks after transplanting rice. It will grow fast, multiply and fix N while the rice crop is growing. After 3-4 weeks, the water is drained and *Azolla* can be buried in the soil right where it is growing and incorporated with a weeder or other suitable implement. Repeated incorporation of *Azolla* is needed. As a dual crop, *Azolla* can be grown more than once for the same rice crop to get additional benefit. Upon decomposition, it will release the fixed N for use of the rice crop. *Azolla* can be grown as a dual crop even after it has been incorporated as green manure before planting rice. The rate of inoculum needed is lower for multiplication plots or where *Azolla* is raised as a green manure than for dual cropping in the rows of growing rice crop. Usually, the amount of inoculum recommended is 0.1-0.3 kg/m^2 (1-3 ton/ha) for multiplication plots and 0.5-1.0 kg/m^2 (5-10 ton/ha) for dual cropping. In Tamil Nadu, an inoculation rate of 1 ton/ha is recommended for the dual crop. This is to be inoculated 3-5 days after weeding.

P-Solubilising-Biofertilisers:
For the application of Phosphate Solubilisers, the best method is seed treatment. Other methods like seedling treatment and soil treatment are also in practice.

Seed Treatment

- Prepare the slurry of 200 g. of biofertiliser in 200-500 ml. of water.
- Pour this slurry slowly on 10-25 kg seeds. Mix the seeds evenly with hands to get uniform coating on all seeds.
- Dry the treated seeds in shade and sow immediately.

Seedling Treatment

- Prepare a suspension of 1-2 kg of biofertiliser in 10-15 litres of water.
- Dip the seedlings from 10- 15 kg of seeds into the suspension for 20-30 minutes and transplant the treated seedlings immediately.

Soil Treatment

- Prepare the mixture of 2-3 kg. of biofertiliser in 40-60 kg of soil/compost.
- Broadcast the mixture in one acre (0.4 ha) either at sowing or 24 hours earlier.

VA-Mycorrhizae:
The Bharatiya Agro Industries Foundation (BAIF) is engaged in distributing VAM inocula in India. Besides, BAIF, the University of Agricultural Sciences at Bangalore, T.N. Agricultural University at Coimbatore, The Energy & Resource Institute at New Delhi and IARI at New Delhi also distribute VAM inocula on a small scale. They have standardized the following application procedures:

Application for Nursery Plants
The nursery plants are propagated by sowing seeds, raising seedlings and by bare root cuttings in plastic bags or pots. In all these methods, 4 to 5 g (one teaspoonful) of appropriate VAM inoculum is placed 3 to 5 cm below the seed or the lower portion of the bare root cuttings, followed by normal plant cultivation practices.

Application for Seedlings Grown on Raised Seedbed
Here, the appropriate inoculum is applied by soil incorporation. About 6 kg of inoculum is mixed with soil sufficient for 25 m^2 area and covered with a thin layer of soil. In most cases, population of the seedlings is sufficient for transplanting 1 ha area. It is necessary to remove the inoculated seedlings from the raised seedbeds carefully so that the VAM associated with roots are not affected and are effectively transferred along with the seedling to be transplanted. For optimum benefits, root treatment with slurry of 250 g inocula in one litre of cow dung should be done at the time of transplanting.

INTEGRATED PEST MANAGEMENT

Pests including disease-causing organisms, insects, mites, nematodes, weeds, and vertebrates lower the quality and yield of agricultural products when left unmanaged. Control of pests and their resulting damage has been an objective of farmers sine humans first began cultivating crops and raising livestock. The majority of these activities have been moderately successful. However, evolution of agricultural practices, and evolution of pests create a constantly changing series of new problems that need resolution. Fortunately, the practice of pest control has continued to advance making it possible to produce a variety of crops in different regions of the world with fairly predictable results.

Farmers became increasingly dependent upon pesticides because they were reliable, economical and labor- saving. In certain crops and regions, pesticides have even been used for purposes of expending soil conservation. In many situations, pesticides permitted the production of crops in areas where they could not be previously grown, during times of the year when pest pressure is greatest, and without the need for strategies of rotation or fallow periods. Extended seasons and post harvest pesticide use permitted fresh products to be available to consumers for periods far longer than ever before, and reduced the risk of potentially dangerous toxins developing in processed products.

Many plant-feeding insects do not significantly damage agricultural crops because they are kept under natural control by other organisms. However, some of these organisms that exert natural control can be killed by chemical applications, resulting in the plant-feeding species becoming a new pest species that is then often referred to as a secondary pest.

Pest resistance to a chemical can develop rapidly because the life cycles of many pests are relatively short. In a pest population, some individuals will be genetically resistant to pesticides applied for their control. Even when a high percentage of the population is killed, these few individuals survive, reproduce and pass the genes that have allowed them to resist the pesticide to the succeeding generation. Thus, a pest population develops which can be managed only with higher dosages of the chemical; finally the pesticide will no longer control the pest. Most pesticides have a limited effective life. Resistance has been reported in almost 500 species of insects and mites, 100 species of plant pathogens, 50 species of weeds, 5 species of rodents, and 2 species of nematodes.

Pesticides generally kill a broad spectrum of plant-associated organisms, only a fraction of which are the target pests. Some of these effects impact agriculture directly. Various organisms that provide a food source for biocontrol agents when the pests are not abundant, and those organisms which function in decomposition and mineral recycling in the soil may also be affected. In addition, under some conditions pesticides have phytotoxic effects on agricultural crops resulting in reduced yields or quality.

Organisms that are peripherally associated with agricultural systems have been known to be affected as well. Persistent soluble pesticides may filter into the soil and be carried away by irrigation or rainwater into streams where they enter the food chain via consumption by microorganisms, invertebrates, fish and possibly higher organisms. The best-known example is DDT. People may come in contact with pesticides most commonly during application and entry into treated areas.

The impact of pesticides use on the environment is complex, and not always fully understood. Some pesticides are extremely slow to break down due to natural processes, and lose their toxicity very slowly. A few pesticides have been found to move through soil, and have been detected in groundwater. As the ability to detect minute amounts of chemicals has increased, the potential extent of contamination has come under increasing scrutiny. Unfortunately, the ability to detect contamination has surpassed our ability to accurately assess possible impacts.

Concept of Integrated Pest Management

As early as the 1950's, pest researchers wrote of the danger of relying on a single pest control technology such as pesticides. These individuals recognized the potential contribution of pesticides, but also viewed the technology in the broader context of the agricultural production system. The philosophy of "integrated control" or "integrated pest management" was developed.

Integrated Pest Management (IPM) is an ecologically benign pest control strategy that is part of the overall crop production system. "Integrated" because all appropriate methods from multiple scientific disciplines are combined into a systematic approach for optimizing pest control. IPM tactics employed must be compatible with each other and with social, environmental and economic factors. "Integrated" inherently implies interdisciplinary efforts that are crucial for the successful development and application of IPM programs. "Pests" include all organisms which impact the production of food and fiber, and IPM strategies may be developed which are appropriate for pests of human health, forests and urban areas as well. "Management" implies acceptance of pests as inevitable components, at some population level of an agricultural system.

The IPM approach is to use a series of tactics to reduce overall pest populations. Pesticides or other control tactics are applied only after all other relevant tactics have been deployed or when their need is justified by knowledge of pest biology, established decision guidelines, and the results of field monitoring. Ideally, IPM programs consider all available management options including taking no action.

The concept of the treatment threshold is a key element of IPM systems. It has been repeatedly referred to as the "economic threshold" meaning the pest population density at which control measures must be applied to prevent an increasing pest population density at which control measures must be applied to prevent an increasing pest population from reaching the point where crop loss would exceed the cost of control.

Although IPM employs a variety of pest control tactics, biological approaches are often stressed. In fact, the first mention of "integrated control" in the scientific literature involved the selective use of pesticides in walnuts to preserve parasites of the walnut aphid. However, integrated strategies have been part of some pest management systems without a label for the past 100 years. For example, growing seed tubers in isolation and also suppressing insect vectors of the viruses managed suppression of “potato decline” caused by viruses. Cultural controls are also important IPM tactics, and include a broad range of production practices intended to render the crop and related environments less favorable for the pest. Proper tillage practices, crop rotation and water management are effective cultural controls in the management of many types of pests including soil pathogens, nematodes, weeds, vertebrates and soil arthropods. The destruction of crop residues is important in the management of many pests. Chemical controls can be used as IPM tactics as well. When they are available, selective pesticides that kill only the target species are generally desirable because they are the least disruptive to the crop ecosystem. The choice of pesticides should also consider the safety of workers, and the potential for pest resistance developing when only one chemical or class of chemical is used extensively.

Crop Rotations

Crop rotation provides other economic and environmental benefits to corn/soybean producers. Crops grown in rotation are generally more productive than crops grown continuously due to improved soil moisture, soil tilth, nutrient availability and pest control. The benefits of particular tillage systems are more complex to evaluate. Conventional plow-disk systems aid in pest management in general, but unfortunately promote soil erosion and surface runoff on sloping lands. Minimum and no-till systems greatly reduce soil erosion and surface runoff, but require increased pest management inputs. The type, duration and management of crop rotations are influenced by regional and local environmental, edaphic, agronomic and economic conditions.

Life cycles of insects that attack plant roots are particularly susceptible to disruption by removal of the food source when crops are rotated. The strategy of altering planting date to avoid injury during peak pest population pressures could be equally as effective as rotations in some instances. Rootworms are managed by rotation of corn with other crops, because the pest is limited in mobility and corn is its only food source during the larval stage. However, some northern corn rootworms have adjusted to crop rotations by having their diapauses extend through a growing season. Additionally, crop rotations may increase populations of their insect larvae. Crop rotation is important for control of soybean cyst nematodes; but it seems to have relatively less impact on sect pests of soybeans.

Available Now

* Crop rotations may reduce incidence of stalk rots indirectly because leaf

blights make corn more susceptible to stalk rots. Eyespot, anthracnose, and southern corn leaf blight are generally less common on corn grown in rotation than on corn grown continuously.

* Crop rotation decreases damage to soybeans from soybean cyst nematodes, *Alternaria leafspot*, anthracnose, bacterial blight, *Cercospora leafspot*, pod and stem blight, mildews, Septoria brown spot, stem canker and other diseases. Many bacterial and fungal pathogens that survive on crop debris eventually die if residues decay before the next crop of soybeans is planted.
* Population increases of many weed species are interrupted by rotating to more competitive crops or to crops in which the weeds are more easily controlled.
* Soybean cyst nematode is effectively managed by rotation to non-host crops.
* Burial of crop residue is the most effective method to reduce damage caused by slugs and vertebrate pests.
* Plow-tillage and surface-tillage control armyworm through early season destruction of plants attractive for oviposition.
* Reducing early season weed growth minimizes cutworm problems in all tillage systems.
* Stalk borer damage is reduced by tillage, or in conservation tillage, by late summer weed control (especially giant ragweed and grasses) to eliminate oviposition sites.
* Seed corn maggot damage is reduced by tillage or by elimination of surface mulches.
* Lesser cornstalk borer damage is avoided by use of non-tillage systems, maintaining high amounts of surface mulch, especially from double cropping.

Biological Control

Biological control is the use of living organisms, or products thereof, to reduce the magnitude and extent of problems caused by pests. Although it is widely believed that successful biological control is difficult to achieve in annual row crops, especially in regions where little permanent or natural vegetation can be found, many successful examples exist in both corn and soybeans, mostly for insects. Enthusiasm must be tempered, however, by the knowledge that no practical biological control has yet been found for many pests. Weeds are by far the most troublesome class of pests, and relatively few biologicals are available for use against them.

Examples of classical biological control that are available or show strong promise include importation and release (with permanent establishment) of predators, parasites and pathogens. A related successful approach involves mass rearing and release of the natural enemies on an as-needed basis. Although predators and parasites require specialized release techniques, microorganisms can usually be applied in a manner similar to that used for chemical pesticides. Viruses, fungi, and especially the endotoxin of the bacterium, *Bacillus thuringiensis*, commonly called Bt, are being used this way. *B. thuringiensis* is highly commercialized, whereas most other are still under research and development.

Recently, some new and innovative biological approaches have been developed. For example, certain insect pests require and use specialized weed habitats during part of their life cycle. Removing or modifying these weeds from the vicinity of the corn or soybean field can disrupt the pest's life cycle greatly, thereby, reducing crop damage.

Available Now

* *B. thuringiensis* is used as a crop protectant in corn against European corn borer and in soybeans against green cloverworm and soybean looper.
* Naturally occurring insect predators of mites, aphids and caterpillars in both corn and soybeans can be conserved by selective cultural practices. These predators include *Amblyseius, Aphidoletes, Chrysopa*, and *Hippodamia*.
* Selective weed management is effective to suppress insect pests. Examples include eliminating winter annuals from fields where corn will be planted to remove oviposition sites for black cutworm, and mowing or eliminating grass from field borders in the spring to remove armyworm oviposition sites and in the summer to remove European corn borer "action sites".
* Insect parasites and predators are mass-reared for release on an annual basis against some pests. Proven parasites include *Pediobius foveolatus* against Mexican bean beetle and *Trichogramma* spp. against European corn borer. The green lacewing, *Chrysosperla carnea,* is effective against aphids, caterpillar eggs, and mites.
* A fungus *Colletotrichum gloeosporioides* that can be applied as a spray for controlling northern joint vetch, a weed in rice and an occasional pest in soybean in limited areas.
* Biological control of the musk thistle with the weevil *Rhinocyllus conicus*.

Agricultural Chemicals

Biologically enhanced IPM will not likely eliminate chemical pesticide agents in the control of weeds and diseases. Although not all pathogens that cause plant disease are transmitted by insect vectors, IPM programs may effectively reduce incidence of some diseases through insect control. Changing cultural patterns such as to minimum-, or no-tillage, will change the weed or disease complex, but will not keep others worm developing. Instead of trying to eliminate pesticides, IPM approaches should integrate pesticide usage. In addition, management of some weeds by biological organisms will be difficult because weed competition with the crop could possibly be yield-reducing by the time a biological achieved control.

With the advent of more effective and safer compounds, pesticides are likely to continue to be important tools for corn and soybean production even in more biologically intensive IPM programs.

Available Now

A wide variety of chemical, and a few biological, pesticides are presently available. With these available pesticides, along with proper tillage, rotations, etc., most economic pests that attack or compete with corn or soybeans can be adequately managed.

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