The Andhra Agric. J 68 (4): 426-432, 2021

INVITED ARTICLE

Importance of Organic Farming in Sustainable Crop Production and Environmental Protection

Organic farming is a traditional method crop production which introduces a change in the farming system which aims at maximum out put in the cropping pattern and take care of optimal utilization of resources. The soil fertility can be maintained and improved on a sustainable manner by a system which optimizes soil biological activity in organic agriculture. The pest and disease management is attained by means of crop selection, rotation, water management and tillage in addition to use of biopesticides. The organic agriculture encourages a balanced host/predator relationship through augmentation of beneficial insect population.

Organic farming is practiced in more than 130 countries in the world covering an area of 35 Mha. In India, it is around 35 lakh hectares cultivated by more than one million farmers using organic principles and practices accounting for production of 33 lakh tonnes of rice, wheat, pulses, cotton, oilseeds, spices, tea, coffee, fruits & vegetables.

Organic farming should be taken as means of enhancing soil fertility, soil health and productivity without causing environmental pollution. High cost of chemical fertilizers, indiscriminate use of pesticides which affected human health, biodiversity in addition to causing environmental pollution and global warming due to rise in carbon pool, methane *etc* are causing major concern to the society in general and farmers in particular.

Today, India requires **not only nutritional security but also food security**. It is a fact that the nutritional requirement has been neglected grossly in an anxiety to enhance food production in the country. India stands at 124th position in the developmental

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He has travelled widely and served as member of BOS and Academic council in several universities. He has served as an expert in selection committees of SAU, ASRB etc. He was recipient of 15 national and international awards which include ICAR Best teacher award, ICAR cash prize, ICAR Junior and Senior Merit Fellowships, DST incentive award, Environmental Scientist of the year award from NESA, New Delhi. He has guided 10 Ph.D and 25 M.Sc students. He has served as HOD, Head of Institute of Organic Farming, Controller of Examination and Dean (PGS).

Index because of poor/malnutrition. In addition to poor health of human beings and animals, Indian soils too are starving for want of nutrients especially micronutrients. The country's poverty lies in the poverty of our soils. The nation's wealth lies in the fertility of its soils. The cosmetic approach to enhance food production through the application of higher amount of fertilizers, though, was successful in the beginning but later not only failed to meet the target but also has done considerable damage to the health of soil, human beings and animals.

Microbes-wheels of organic farming and architects of agriculture

Microbial inoculants are generally used in agriculture as biofertilizers to provide nutrients to crop plants or as bioagents (biofungicides, biopesticides) to suppress pathogens or crop pests. The success of inoculation always depends upon the ability of microorganisms to multiply and survive in the introduced environment. Further, inoculants will be useful only when the organism is viable and sufficient in number to bring out the desired changes.

Plant growth promoting bioinoculants

Symbiotic nitrogen fixers

Several prokaryotic organisms posses the ability to reduce the gaseous atmospheric nitrogen to ammonical form with the help of the enzyme "Nitrogenase" present on their cell membrane. The best and commonly known example is the inoculation of rhizobia to legumes. Due to host specificity problem, rhizobiologists still follow cross inculcation grouping to inoculate legumes. *Rhizobium* fixes atmospheric nitrogen under symbiotic conditions in the root nodules of legumes and in turn will be benefited from supply of photosynthates from leguminous plants.

Frankia

This is an actinomycetes which fixes atmospheric nitrogen in non leguminous tree species like *Casuarina, Alnus, Myrica, Hippophe* etc. It produces very big root nodules resembling cricket ball or tennis ball which are the sites of nitrogen fixation. *Frankia* is playing a key role in afforestation program.

Associative symbiotic nitrogen fixers

Azospirillum, Acetobacter diazotrophicus (Glucanobacter diazotrophicus), Herbaspirillum are few associative symbiotic nitrogen fixers that enter the host cortical cells to reduce gaseous atmospheric nitrogen in addition to production of growth promoting substances.

Free living nitrogen fixers

Azotobacter, Beijerinckia, Derxia, Azomonas etc reduce gaseous atmospheric nitrogen with in their cell system and release the same to the soil for plant root absorption.

Azotobacter or *Azospirillum* can be used to enhance nitrogen nutrition in cereals like paddy, wheat, maize sorghum, millets like Ragi, Foxtail millet etc , all vegetables , plantation crops , fruit crops , flower crops , oil seed crops sunflower ,sesame, niger etc commercial crops like sugarcane, cotton etc . *Acetobacter diazotrophicus (Glucanobacter diazotrophicus)* is an excellent biofertilizers for sugarcane.

Azolla

It is an aquatic fern floating on the surface of water. The leaves of Azolla hosts millions of cyanobacterial cells in their lobes symbiotically . Azolla posses both major and micronutrients and thus act as a green manure . In addition to this , Cyanobacteria present in Azolla leaves fixes atmospheric nitrogen with the help of Nitrogenase enzyme present in the specialized cells called as Heterocysts . There are few important species in Azolla *viz. A. pinnata* , *A. microphylla*, *A.caroliniana A.filiculoides*, *A.nilotica* , *A.mexicana* etc. This is a very good biofertilizers for paddy cultivated under submerged (puddled) condition. China, Japan, Malaysia, Vietnam, Thailand etc are few other countries using Azolla in paddy cultivation. It is also used as a fish feed in aqua culture in few countries.

P-solubilizing microorganisms

The availability of P in soil to plants dependent on soil pH. Many a times, soil phosphorus is in the bound form and thus unavailable to plants. Soil phosphorus will be precipitated as calcium or megnesium phosphate under alkaline pH conditions. Several bacteria and fungi (*Bacillus megatherium, B.polymyxa, Pseudomonas striata, Aspergillus awamori, Penicillium funiculosum Burkholderia, Serratia marcescens etc*) are known to produce organic acids like citric, succinic, glutamic, maleic, L-ketoglutaric, fumaric and tartaric acids which are helpful in solubilization of phosphates. These organic acids have been shown to chelate cationic portions of insoluble phosphate compounds. Of the several mechanisms that have been proposed in solubilization of phosphate, production of organic acids is considered to be the most significant but other products such as CO_2, H_2S, chelating agents, humic substances, siderophores and protons are also reported to be involved in the process.

Several factors influence P solubilization under field conditions which include soil type, nature of insoluble phosphatic compounds, ability of phosphate solublizing microorganisms and plant genotype. The physical condition of soil, pH, organic matter and plant nutriens directly or indirectly influence P-solubilization process . The environmental conditions such as temperature, moisture, aeration, humic acids *etc.* control the growth and activity of P-solubilizers.

Several studies conducted by scientists clearly indicated the possibility of getting better crop yields with the inoculation of P-soulbilizers along with the application of rock phosphate as compared to super phosphate.

P-solubilizers can be used for all types of crops especially when p-fixation is under alkaline condition.

P-mobilizers

Mycorrhizal fungi are known to mobilize several nutrients from soil with the help of radiating hyphae. However, uptake and translocation of immobile nutrients have been given importance in mycorrhizal studies. These fungi also are helpful in mobilizing moisture from soil, production of growth promoting substances and suppression of soil borne root infecting pathogens. The major bottleneck in mycorrhizal research is its inoculum production. Being obligate symbionts, Arbuscular mycorrhizal (AM) fungi are maintained as pot cultures(Axenic culture) using a suitable host and substrate .Significant increases in plant growth and yield of several crops due to AM inoculation have been reported by many scientists. P-response studies with the inculcation of efficient strains of AM fungi indicated the possibility of a net saving of 20-50 per cent of recommended P in many crops .VAM can be used for all types of crops.

Potassium mobilizing bacteria

Indian soils do not have any problem of K availability. Hence very little work on K mobilizing microorganisms has been carried out by the scientists. K mobilizing bacterium, *Frateuria aurentia* from banana rhizosphere in Orissa was found to enhance nutrition and growth of several crop plants.

Plant growth promoting rhizomicroorganisms (PGPR)

The plant growth promoting rhizomicroorganisms (PGPR) improve plant growth through production of phytohormones, enhanced nutrient uptake and/ or suppression of plant diseases. The PGPR are otherwise referred to as plant health promoting rhizomicroorganisms (PHPR). The extensively studied PHPR are *Pseudomonas fluorescens*, *P. aeruginosa*, *Arthrobacter*, *Methylobacterium*, *Bacillus subtilis*, *Burkholderia cepacia* in addition to several nitrogen fixers and P-solubilizers.

Decomposers

Plant and animal residues are made up of many polymers like cellulose, hemicelluloses , lignin , pectin, protein etc. Among these polymers lignin is very difficult for decomposition. *Phaenerochaete chrysosporium* , *Pleurotus* , *Trichoderma* , *Paecilomyces* etc known as white rot fungi are useful in degradation of polymers in to monomers through production of substrate specific enzymes like cellulose, pectinase, protease, lignin peroxidase,amylase, invertase etc and thus useful in the preparation of compost. Inoculation of such organisms reduces the time taken for decomposition of agricultural and industrial wastes.

Microbial inoculants in disease and pest management

Plant diseases and crop pests are contributing 23-30 per cent of losses in crop production throughout the world. The chemical control of plant diseases and crop pests is spectacular but this is relatively a short term measure as it is causing ecological problems in addition to accumulation of harmful chemical residues in soil, water, food grains, animal feed *etc*. Hence biological control of plant diseases and crop pests is gaining importance.

Several microorganisms have been successfully used to control soil borne disease and crop pests.

Microbes in plant disease management

Trichoderma

Trichoderma harzianum and *T. viride* are very well known for their biological deterrent activities. They suppress pathogenic fungi y forming physical bond with the root system of plants , establishing itself in the rhizosphere and thereby preventing other pathogens from colonizing the soil. This bond and continual growth of the *T. harzianum* throughout the root system forms a physical barrier to root infecting plant pathogens. Secondly, *Trichodema* releases chitinase which break down the cell wall of pathogens . It is known to produce several antimicrobial compounds viz dermin, trichodermin , viridin which suppress the soil borne root infecting pathogens . *Trichoderma* can be effectively used as seed treatment before sowing to prevent damping off disease, wilt disease etc.

Pseudomonas fluorescens

This bacterium belongs to fluorescent pseudomonads group which is a potential biocontrol agent in addition to its p-solubilization capacity. The antifungal metabolite 2,4-diacetyl phloroglucinol play a major role in the biocontrol capabilities of *P.fluorescens* .Few strains are known to produce antibiotic compounds viz. pyrolnitrin, phenazine-1-carboxylic acid etc which are known to control take-all disease of wheat. The other mechanism explained by the scientists includes production of siderophores (Iron chelating compounds) by *P.fluorescens* which play a key role in the suppression of pathogens.

This can be used as seed treatment before sowing of seeds or as spray for standing crop.

Paecilomyces lilacinus

It is very much effective in control of root knot nematodes. The spores of this fungus acts by infecting , parasitizing and killing eggs , juveniles and young adults of phytophagous nematode species.

Bacillus subtilis

It is a bacterium very effective in control of fire blight disease in paddy by production of an antibiotic subtilin.

Microbial inoculants used for biocontrol of plant diseases

Pathogen/Disease	Crop	Biocontrol agent
Sclerotium rolfsii	Tomato, beans	*Trichoderma viride*
	groundnut	*T. harzianum* and *T. hamaturn*
Fusarium udum (wilt)	Redgram	*T. viride*
Borytis cinerea (Grey mold)	Grapes	*T. viride*
Rhizoctonia solani (Damping off, root rot)	Greengram, cotton	*T harzianum* + *Pseudomonas fluorescens* + VA mycorrhiza
Phytophthora cepasia (root rot)	Black pepper	*T harzianum* + VA mycorrhiza
Gaemannomyces graminis var. *tritici*	Wheat	*Pseudomonas fluorescens*
Pythium (Damping off)	Brinjal	*T harzianum*
Fusarium oxysporum	Bengal gram (wilt)	*T harzianum*
	Banana (panama disease)	*P fluorescens*
Meloidogyne incognita	Tomato	
M javanica	*Capsicum*	*Pochonia lamydosporia*
(Root knot)	Brinjal	*Paecilomyces lilacinus*
Ralstonia solanacearum	Potato	*Bacillus cereus B. subtilis*

Advantages of using biocontrol agents

1. Avoid adverse effect on the beneficial microbes including antagonists in soil.
2. Avoid environmental pollution of soil, air and water
3. Cost effective (less expensive)
4. Avoid the development of resistant strains in pathogen.

Mechanisms of plant disease control by bioagents

There are several mechanisms followed by bioagents in plant disease control. The important mechanisms are 1. Competition 2. Antibiosis 3. Antifungal enzyme production 4. Hyper parasitism 5. Induced systemic resistance.

Desirable characters of biocontrol agents

1. It should grow easily on available nutrients (adaptabiliy) and survive in the rhizosphere or spermosphere.
2. The antibiotics produced by the bioagent should not cause damage to host plants or other associated antagonists
3. They should have better tolerance/adaptability to varied environmental extremities.
4. The spore germination should be rapid and prolific. The bioagents also should have better adaptability for large scale production and handling.

Microbial inoculants used for biocontrol of crop pests

Pest	Crop	Bioagent
Bollworm	Coffee	*Beauveria bassiana*
Shoot borer	Sugarcane	NPV, GV
Berry borer	Cotton, pulses	
Fruit borer	Brinjal	*Bacillus thuringiensis*
Dimond blackmoth	Tomato	
	Cabbage	
Borers, pyrilla,	Groundnut	*Metarrhizium*
White grub	Rice	*anisopliae*
	Sugarcane	
Spodoptera litura *Helicoverpa armigera*	Cotton, pulses, castor, soybean	*Nomuraea rileyi*
Aphids, Mealy bugs	Oilseeds, grapes	*Verticillium lecani*
Mites	Citrus, coconut	*Hirsutella thmpsonii*
Leaf hoppers, Beetles	Coconut	*Metarrhizium anisopliae*
Rice borer	Rice	Granulosis virus
codling moth	potato	
Mosquito larvae	-	*Bacillus sphaericus*

There are approximately 280 biopesticides available in the market involving bacteria (37%), fungi (5%), viruses (3%) *etc*. In addition to these microbial insecticides, several botanicals (plant extracts), neem based products, natural enemies, trap crops, pheromone traps, agronomic practices *etc* are being used to avoid chemical insecticides which cause environmental pollution.

Key to success in biocontrol

1. Selection of an efficient strain of antagonist
2. Adequate growth and sporulation on mass culture media
3. Advance application of bioagents to provide enough time for interactions with pest/pathogen
4. Favorable soil temperature, moisture, pH *etc*. which influence the growth and development of the bioagent
5. Competency of bioagents.

Thus microbial Inoculants play a key role in soil fertility, productivity and soil health. They can be regarded as wheels of Organic Farming and architects of agriculture.

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