Microorganisms in Combating Plant Diseases

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Introduction

Tropical with warm and humid climate in India provides ideal conditions for development and spread of diseases of crops cultivated under intensive crop cultivation. The losses are going to increase with change in agricultural practices and the agriculture production is often derailed from the target due to losses caused by biotic and a biotic stresses. The losses caused by biotic stresses and the archaic nature of plant production measures were recognized in recent years. The losses due to weeds, diseases and insects have been estimated to be around 40% in the developing or under developed countries. Out of these losses, 18% is produced by disease producing microorganism. Management of crop disease by using chemicals is regular practice and yielded considerable amount of reduction of diseases. Although several methods are followed for this purpose, disease control by chemicals is the promising one especially under intensive cropping programmes. Chemicals, on the other hand, may cause problems with residues left on crops, and chemical fungicides and bactericides used in plant disease management are growing more expensive, as well as leaving non-biodegradable toxic compounds. Plant diseases can acquire resistance to fungicides and bactericides in some circumstances.

Due to consideration of above ill effects, it becomes inevitable to develop a bio-based, eco-friendly, biodegradable plant derived pesticides or microbial pesticides in order to control plant pathogens. Now, the researchers are forced to look for the alternate strategy, which counter the problems created by chemicals is biological way of control of the diseases. A replacement of chemicals for disease control is not at all anticipated in the near future, but considerable progress has been made in reducing the negative effect of pesticides on the environment by using biological method of disease control.

In biological control, use of beneficial microorganisms against the pathogenic microorganisms, the beneficial microorganisms are called as biocontrol agents / antagonistic organisms. Biological control of pathogen is achieved by artificial introduction of antagonistic microorganisms into the environment. Several species of fungi, bacteria and actinomycetes are used as biological agent against the plant pathogen. Fungi antagonistic includes *Trichoderma viride, T. harzianum, T. hamatum, T. lignorum, T.koningii, T. pseudokoningii, Chaetomium globosum, Pencillium citrinum, Myrothecium roridum, Epicoccum purpurescens* are reported to be antagonistic against different pathogens. The bacteria *Pseudomonas fluorescens* and Bacillus *subtilis* are used as biocontrol agents against many soil borne as well as foliar pathogens in plants. Beside this uses of bacteriophages, bedllovibrio and a virulent microbial strains (induced resistance) have also shown to be antagonism.

Mode of action of antagonists

The antagonists may act in different ways to control the pathogens.

a. Competition

The microorganisms compete for space and nutrients for their survival in their natural habitats. It occurs when two or more organisms require the same thing and the use of this and use of this by one reduces the amount available to the other. This mode of action is possible when antagonist is introduced in the soil to control the root rot disease. The highly virulent, stable antagonists can possess the high competitive ability in the soil ecosystem. Competition for substrates is the most important factor for heterotrophic soil fungi. Plant growth promoting rhizobacteria have competitive ability in rhizosphere. Generally the bacterial have the capacity to colonize in root region as rapidly. So this leads to suppression of growth of pathogen in the soil as well as in leaf surface (Kohl *et al*., 2019). *Pseudomonas fluorescens and Bacillus subtilis* have this mechanism in the rhizosphere region of plants.

b. Antibiosis

Antibiosis is a condition where the metabolites are secreted by underground parts of plants, soil microorganism, plant residues etc. Antibiosis plays an important role in biological control of plant diseases. It occurs when the pathogen is inhibited or killed by metabolic products of the antagonists (Raaijmakers and Mazzola, 2012). Antagonists are shown to produce antibiotics, which affect the growth of the pathogen. The fungal antagonist such as *Gliocladium virens* produces glioviridin and gliotoxin and *Penicillium citrinum* is known produce an antibiotic citrinin. The antibiotic production was determined in most of the antagonistic organism when it was interact with the pathogens. There are reports of antibacterial antibiotic produced by antagonistic bacteria. There are termed as bacteriocins and these are proteinaceous substances produced by some strains of bacteria which are antagonistic to closely related species or some other strains of same bacteria. *B.subtilis* produce Bulliform and bacteriocin isolated from Corynebacterium michiganense control the tomato canker disease.

c. Lysis

It implies disintegration or destroying of pathogenic propagules during the action by releasing cell wall degrading enzymes by biocontrol agents. It is the complete or partial destruction of a cell by enzymes. Lysis may be differentiated into two types, endolysis and exolysis. Endolysis (autolysis) is due to nutrient starvation or antibiosis and death of a cell by the cell's own enzymes or toxins or other factors. Endolysis does not usually involve the destruction of the cell wall. Exolysis (heterolysis) is the destruction of cell of an organism by the enzymes of another organism. The chitinases or cellulases produced by an organism will destroy of cell wall of other organism.

d. Mycoparasitism / Hyperparasitism

Mycoparasitism is the phenomenon of one fungus being parasitic on another fungus. Mycoparasitism or hyperparasitism occurs when the antagonist invades the pathogens by secreting enzymes such as chitinases, celluloses, glucanases and other lytic enzymes. The parasiting fungus is called hyperparasite and the parasitized fungus as hypoparasite. In mycoparasitism, two mechanisms operate among involved species of fungi. The events like coiling, penetration, branching and sporulation, resting body production, barrier formation and lyses are takes place during fungus and fungus interaction (Jeffries, 1995). *Trichoderma viride* will express mycoparasitism mechanism on root rot and wilt fungus.

e. Hydrogen cyanide

Many rhizobacteria are able produce hydrogen cyanide and this has been shown to play a role in biological control of plant diseases and increasing the yields. Pseudomonas *spp*., produce hydrogen cyanide in rhizosphere and which inhibit the growth of plant pathogens.

f. Induced Systemic Resistance (ISR)

ISR is the activation of defense mechanisms of a plant by an agent likely a fungus, bacteria, virus, chemical etc., and the plant become resistant to a number of plant pathogens. Sometimes, the plants inoculated with avirulent strain of pathogens or non-pathogens leads to induced systemic plant resistance against subsequent challenge by pathogens. The biocontrol agents bring about induced systemic resistance (ISR) through the physical and mechanical strength of cell wall as well as changes in physiological and biochemical reaction of host leading to the synthesis of defense chemicals against challenge inoculation of pathogens (Wiesel *et al.*, 2014). Accumulation of pathogensis related proteins (chitinase, B-1, 3 glucanase), chalcone synthase, phenylalanine ammonia lyase, peroxidase, phenolics, callose, lignin and phytoalexins are takes place following interaction with biocontrol agents.

Not only activation of defense mechanisms, bio control agents also secretes plant growth hormones like Auxins, Cytokinin, Gibberellins etc. These hormones suppress the deleterious pathogens and promote the growth of plants and simultaneously increase the yield. This was found in rice when seeds treated with *Bacillus subtilis* or dipped in *Pseudomonas fluorescens*.

g. Production of siderophore

They are extra cellular small compounds, which selectively binds iron (Fe3+) siderophores are generally produced both by aerobic and facultative anaerobic bacteria under low iron stress condition. Several reports conformed that *P. fluorescens* produced siderophore (pyroveridin) and this compound is useful in improving seedling health in crop like cotton and tomato (*Pieterse et al.*, 2014). Plant growth promoting rhizobacteria produce siderophore compound which will uptake Ferric ion and condition leads to starvation of pathogens for the want of ferric ion in soil.

Use of fungal antagonists

Among the fungal antagonists, *Trichoderma* is the most widely used fungal organism to control a variety of plant diseases especially in crops like pulses and oil seeds. Nowadays, for the management of root rot diseases, *Trichoderma* antagonists have been recommended particularly in areas of Tamil Nadu, Andhra Pradesh and Karnataka. Commercial formulation of the fungal antagonists is developed in other countries and used as seed or soil treatment in the disease management programme.

Use of bacterial antagonists

The bacteria viz., *Bacillus subtilis, Agrobacterium radiobacter K – 84, Pseudomonas fluorescencs, Serratia sp, Azotobacter* and *Streptomyces* have been proved as effective against foliar as well as root diseases. A few biocontrol agents which are registered or available in the market. The following tables have the information on bacterial agents used against various diseases.

S. no.	Biocontrol Agent (s)	Against the disease (s)
1	*Agrobacterium radiobacter* K–84	Crown gall of coriander (*Agrobacterium tumifaciens*)
2	*Bacillus subtilis*	Wilt of red gram
3	*Pseudomonas fluorescens*	Rice sheath blight (*Rhizoctonia solani*), pythium damping off in cotton, cowpea root rot and fusarial wilt of banana.

Use of bacteriophages

They are viruses that attack bacteria and usually destroy them. A number of phages have now been discovered for many phytopathogenic bacteria such as pseudomonas glycinea, *Xanthomonas campestris pv. citri* in citrus, *Xanthomonas campestris pv. malvaceraum* in cotton etc., (van Lenteren *et al.*, 2018). This can be applied as spray are lost in the host when inoculated alone but when the receptor are present, phages not only multiply and reach higher population and also survive for a much longer period in the host. Best control was achieved when phages were applied first. Repeated application of phage lysate was considered necessary for successful biological control, however much work is needed before bacteriophages can be used in management of bacterial diseases.

Application of biocontrol agents

Biocontrol agents are applied as seed, soil and foliar application in the crop protection programme, but the application prior to pathogen attacks will provide protection to the crops. Normally fungal antagonist (commercial formulation) are recommended @ 4g/kg of seed application and fungal bacterial antagonist formulation of biocontrol agents have been developed in other countries, they are listed in the following table.

Sl.No	Product name	Biocontrol agent	Target *pathogen*	Source
1	Tricodermin	*Trichoderma spp*	*Pythium* spp	Bulgaria and Russia
2	Gliogard	*Glicladium virens*	*Rhizoctonia solani*	USA
3	Dagger G	*Pseudomonas fluorescens*	*R.solani*	USA
4	Conqueror	*Pseudomonas fluorescens*	*R.solani*	Australia
5	Quantum 4000	*Bacillus subtilis*	*Fusarium* spp	USA
6	Mycostop	*Streptomyces griseoviridis*	*Alternaria brassicola*	

Advantages of biocontrol agents

- Persistence nature of biocontrol agents
- When biocontrol agents applied in the soil, they will exist in the environment for many years. They will provide long lasting and permanent control against the diseases.
- Environmentally safe.
- They did not leave any toxic residues in the ecosystem.
- They can be easily amenable for mass multiplication packing, distribution and successfully applied in crop protection
- Effective as prophylactic treatment.
- Cost effective.

Constraints in using biocontrol agents

- It requires a through understanding of the biology and ecology of the pathogen as well as biocontrol agents.
- Most known biocontrol agents are generally specific to a single pathogen species but the ideal biocontrol agents should be able to control more than one pathogen.
- Normally biocontrol agents have slow or delayed action on the pathogens.

Future thrust in biological control

People are more conscious and concerned about pesticide residues in food and water and they are aware that these biocontrol agents are environmentally safe. This is providing the impeities for suitable biocontrol agents as a substitute to chemicals. Generally, biocontrol agents have narrow host (pathogen) range. So, using biotechnological methods. Scientist can improve the agents with wide host range, high virulence and long storage effect. In recent year's effort have been made to increase the efficacy of biocontrol agents through biotechnology. The challenges of biocontrol are, however, not only to create genetically engineered superior agents but also to develop in expensive easily applied preparations that remain viable under less than optimum conditions. On the other hand, genetically engineered biocontrol agents should passed through a number of experiment on and human health. Because, sometimes they yield negative impact in the ecosystem.

Conclusion

In view of the loss due to plant diseases, the farmers can explore all available possible ways to reduce the usage of chemicals including beneficial microorganisms. The ecofriendly management of disease in agriculture to boost production without deteriorating the environmental health is the need of the day and so to keep the ecosystem for a long time the future generation.

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