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Research Article

BIOLOGICAL CONTROL OF PATHOGENS: THE MECHANISMS AND IMPLICATIONS

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A B S T R A C T

There are three main enemies of plants - namely pathogens, pests and weeds and all these operate in natural conditions. It is a must to control the pathogens for proper growth of plants and yields from the crops. There may be many alternative means to control pathogens but biological control happens to be a much more useful alternative, as this is safer for the environment also. It is of course the reasons that biological control of plant diseases has attracted the attention of so many researchers and agencies. This paper deals with the concept of pathogens, biological control and its positive outcomes for the plants, ecology as well as human beings.

INTRODUCTION

Biological control induced by other organisms to eliminate or restrict the activities of pathogens, pests and weeds, the three natural enemies of agriculture, operates under natural conditions (Whipps, 2001). The methods of biological control of fungal disease of plant are increasingly drawing attention of plant pathologists and soil microbiologists. Biological control is one of the viable eco-friendly preposition which can minimize the plant diseases (Cook, 1985).This is of course the reason behind the choice of researchers from the fields of biology, entomology and plant pathology for emphasizing the application of "biological control", and managing the plant diseases. The organism that suppresses the pest or pathogen is referred to as the biological control agent (BCA) (Pal & Gardener, 2006). It was Harry Scott Smith who at the 1919 meeting of the Pacific Slope Branch of the American Association of Economic Entomologists, in Riverside, California used the term "biocontrol of pathogens'. According to DeBach & Hagen, (1964), it became a popular method of controlling plant diseases after widespread advocacy by the entomologist Paul H. DeBach (1914-1993).

Today, the world is aware with the problems of environmental degradation caused by chemical pesticides used in agriculture, forestry and public health. These pesticides are used for the protection of plant from diseases, caused by pathogens, but the use of huge amount of pesticides is not good for soil and aquatic ecosystems. Now-a-days, one of the most important causes of soil and water pollution is chemical pesticides.

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Thus, the biological control is the best method for the protection of plants from diseases. The biological methods are environmentally safe, because they do not cause any socio-economic, political and environmental problems encountered very often with chemical pesticides.

The biological control of plant diseases has recently become an area of intensive research in view of the hazardous impact of pesticides and other agro chemicals on the ecosystem. Chet and Hardwar *et.al*, (1979) define the biological control as any condition under which survival activity of a pathogen is reduced through the agency of any other living organisms (except man himself) with the result that there is a reduction in the incidence of the disease caused by the pathogens. According to Baker (1983), one of the best and most effective methods of biological control is host resistance. The broad concept and dimensions of biological control make it obvious that it is a fascinating field of plant disease management (Cook 1985). If one biotic agent acts upon another in a manner to limit its population then a state of biological control operates. Snyder (1960) reported that the biological control relies largely upon an interruption of host parasite relationship through biological means.

There are many methods and approaches of biological control (Fisher *et.al.* 1949; & Heder *et al*., 1979). In the studies of biological control of plant pathogens, soil-borne pathogens have been the main target for researchers (Baker 1989; Papavizas 1985; Baker and Cook (1974). As evidenced by studies, many plant diseases are caused by soil-borne pathogens, despite this, only few successes in biological control have been reported on the commercial scale.

The hope for controlling the plant diseases by manipulating the associated micro flora is increasing and encouraging the knowledge about beneficial organisms, naturally existing in soil that save the same niche with pathogens in the basic approach of biological control (Park, 1965; Cook and Baker, 1983). De *et.al.* (1996) have suggested that the biological control may also involve mycoparasitism, the parasitism of one fungus by another. The host fungus may be lysed physically excluded from developing fruiting bodies or have the parasitic hyphae coiled around it so restricting growth and development.

Pathways of Mechanisms

Baker (1985) has explained biological control of plant pathogens and some pathways of mechanisms involved in it (Figure-1)

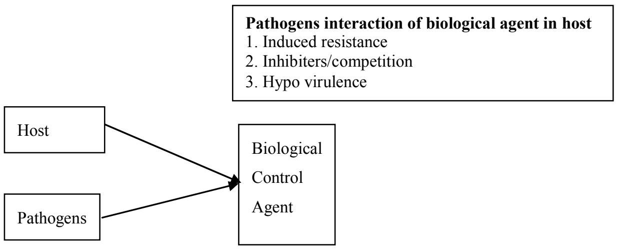

Figure The biological control of plant pathogens and some pathways of mechanism involved in it. (Source - Baker, 1985)

Gardener and Fravel (2002) opine that success of biological control depends upon intensive knowledge and also an understanding of cost and profit. Figure 2 presents a general pest management programs. It indicates that cropping system should begin with sound cultural practices for promoting health of the plants and crops. The crop rotation is a good choice from this point of view. Tillage is also very useful in disrupting pest and pathogen life cycles, bury weeds, and prepare seed beds of optimal moisture and bulk density. Besides, proper management of soil fertility and moisture can also be helpful in controlling pathogens.

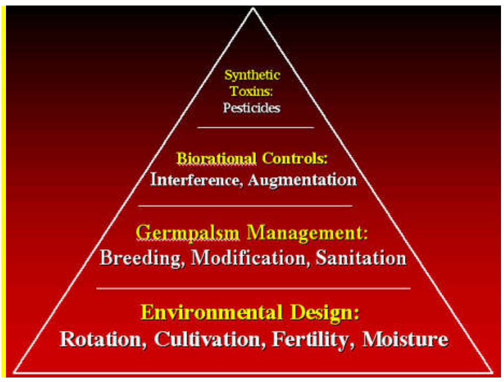

Fig 2 General model for an integrated pest management (IPM) program.

Biocontrol Agents

Fungi and bacteria are the main biological agents that have been studied for the control of plant pathogens particularly soilborn fungi (Kulik 1995). A range of hyperparasitic and antagonistic microbes have been found responsible for increase in suppressive soil, most of which are fungi such as *Trichoderm, Pencillium, Gliodadium* etc. (Puri,. 1995; Suárez-Estrella *et al*. 2013).

The biocontrol agent's interaction in the host creates a resistance response and making the pathogens a virulent (hypo virulent). Cook and Baker (1983) have termed it 'protective inoculation'. Environment plays a significant role in the success of biological control, because environment modulates the above effects (Shirzad *et.al*., 2012). Table 1 shows the types of antagonisms leading to biological control of plan pathogens.

Table 1 Types of interspecies antagonisms leading to biological control of plant pathogens. (Source: Pal & Gardener, 2006)

Type	Mechanism	Examples
Direct antagonism	Hyperparasitism/ predation	Lytic/some nonlytic mycoviruses *Ampelomyces quisqualis* *Lysobacter enzymogenes* *Pasteuria penetrans* *Trichoderma virens*
Mixed-path antagonism	Antibiotics	2,4-diacetylphloroglucinol Phenazines Cyclic lipopeptides
	Lytic enzymes	Chitinases Glucanases Proteases
	Unregulated waste products	Ammonia Carbon dioxide Hydrogen cyanide
	Physical/chemical interference	Blockage of soil pores Germination signals consumption Molecular cross-talk confused
Indirect antagonism	Competition	Exudates/leachates consumption Siderophore scavenging Physical niche occupation
	Induction of host resistance	Contact with fungal cell walls Detection of pathogen-associated, molecular patterns Phytohormone-mediated induction

Mechanisms of Biological Control Antagonism

The mechanism of antagonism in soil is a very complicated phenomenon. In this case one organism inhibits the growth of others growing around it (Singh *et.al.* 1997). Antagonism includes the antibiosis, competition and exploitation mechanisms. (Jackobson 1965; Park 1965).

Antibiosis

Park (1965) suggested that the antagonistic interactions mainly include antibiosis. According to Garrett (1970), antibiosis is very useful to decide the competitive saprophytic ability of a fungus. Garrett (1970) defined the competitive saprophytic ability of a fungus as a measure of the production of organic substrate colonized by the fungus in the soil. Pandey and Upadhyay (1997) demonstrated the production of antibiotic substances and antibiotic activities in invitro experiments. The antibiotics reduce the saprophytic survival ability of pathogenic microorganisms in soil.

Competition

Competition represents a negative relationship between two populations in which both populations are adversely affected with respect to their nutrients and space. Soil microbes also compete for carbon and nitrogen sources. Competition results in the establishment of dominant microbial population and exclusion of population of unsuccessful competitors. The result of saprophytic competition of microorganisms is influenced by their respective inoculum potentials. The activity and multiplication of the pathogens is inhibited by certain harmful chemical substances which are secreted by saprophytic microorganisms (Jacobson, 1965).

Exploitation

In the case of exploitation, the one microbial population is parasitic or predatory on the other and thus inhibits its growth. Many fungi are parasites on other fungi (mycoparasitism) or predators on nematodes and through this action they reduce the number of pathogens. Boosalis (1956) studied the mycoparasitic interaction of *Penicilllum vermiculaium* on *Rhizoctonia solani* in soil and found that *Coothynum minitans* and *Sporidesimum sclerotivorum* are successful mycoparasites, against *Scleroiinia sclerotivorum* respectively in suppressing the prop gules in soil (Huang, 1977; Ayers & Adans 1979). Garrett (1975), reported that the pathogenic root infecting fungi can survive saprophytically in soil on organic matter by competing with other saprophytes or on dead host tissue invaded during the parasitic phase. According to same pathologists the soil habitats do not provide pure culture conditions but are open to colonization by a number of microorganisms in the soil population (Campbell, 1985). Those microorganisms which have low competitive saprophytic ability are able to grow vigorously as saprophytes in pure culture. These saprophytic fungi may be efficient pathogens. Schmidt (1979) reported that the outcome of soil antagonism may be reverse by relatively small environmental variation. Rai and Upadhyay (1983) investigated the saprophytic colonization of pigeon pea substrate by *Fusarium udum* in relation to moisture, pH, temperature, chemical treatments and microbial antagonism and stated that the saprophytic colonization was set at 220°C, pH between 7-9 and soil moisture content between 0.5 and 30%. The colonization of pigeon pea was suppressed by antagonism from *Penicillium citrinum, Aspergillus niger, A. flavus, A. terras, Micromonospora globosa* and *T. viride.*

Since the establishment of a fungus colony on a substrate, competition and antibiosis interaction play a crucial role. These interactions also check which species occupy a substrate and which will not. It is actually a substrate that is vital to the establishment of biological control agents in any environment. The activities of these biological control agents prevent the progress of the growth of the pathogens. According to some researchers substrate also play an important role in the distribution pattern of antagonists. If colonization is superficial, much of the substrate will remain uncolonized and potentially available to other microbes, whereas more colonization of a substrate will prevent this phenomenon (Agrawal and Hasija, 1986).

PGPF as Biocontrol Agents

Fungi play an important role as a biological agents. According to some research reports, the rhizosphere fungi can induce both plant growth promotion and disease suppression effects. Baker (1988) reported that the *Trichoderma spp.* increase the growth of plant and also work as biocontrol agents (Chet and Baker 1981; Elad *et.al*. 1982). According to some researchers the growth of *Rhizoctonia solani* and *Sclereotium rolfsii* is controlled by *T.harzianum* (Wells *et al* 1972, Elad *et al* 1980). Chet *et al* (1979) have suggested that the dumping off beans, peanut and egg plants caused by S. *rolfsii* and *R. solani* can be controlled by *T. harizonum* at field level. Chet and Baker *et.al*. (1981) reported that seedling blights and dumping-off disease caused by *Fusarium spp.* and *T. horzianum* was controlled by *T. viride.* Chet and Baker (1981) suggested that *T. viride* also is effective against *R. solani* and *Phythium spp.* Harman *et al*. (1980) reported that the disease of peanut caused by *S. rolfsii* and dumping-off disease of tobacco caused by *Phythium aphanidermaium* was reduced by wheat bran preparation of *T. horzianum* (also Mukhopadhyay *et al*., 1986).

PGPF isolated from the rhizosphere of turfgrass and cultivated crops displayed the ability of both plant growth promotion and disease suppression against several soil borne diseases (Hyakumachi, 1994). The suppressive effects of PGPF against diseases, however varied depending on the genera or species or types of pathogens. The degree of suppression of the disease is also altered with inoculum of the pathogen and PGPF. (Larkin and Fravel, 1998). It has also been reported that the PGPF were capable of inducing systemic protection in cucumber against *Colletotricum orbicular,* the anthracnose pathogen (Alabouvette & Couteaudier, 1992). Certain PGPF have also been reported to suppress the all disease of wheat (Dewan *et.al*, 1989). Though the mechanisms of PGPF for growth promotion and disease suppression have not yet been properly determined, yet PGPF seem to offer a great potential as biochemical agents (De & Nizamuddin, *et al*., 1996; Ting,*et al*., 2011).

CONCLUSION

The role of biological control in controlling the pathogens is of vital importance. The use of pesticides causes a number of problems for the ecology, as it is not eco-friendly. The chemical agents used in controlling crop pathogens cause various types of environmental and human health hazards. The biological control seems to be a very significant alternative in controlling and managing the harms caused to the environment and also human beings by the pathogens. This technique needs to be promoted in the wider interest of ecology, animals, and the people also. It is also expected that this technique will decrease the loss in crop production which will obviously lead to increased profit for farmers as well. We have to prefer biological control practices to manage the plant disease and promoting crop health to ensure high yields and enhancing the status of our food growers (Rzewnicki, 2000; Van Arsdall, & Frantz C. 2001; Paulitz & Belanger, 2001

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