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BioControl Agents - Antagonistic Magicians against Soil Borne Pathogens: A Review

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ABSTRACT: Biological control agents are the core to Integrated Pest and Disease Management (IPDM) strategy with a defined objective of sustainable agriculture. With the current food production strategy involving lots of chemical input raised the cost of produce and threat to the environment leading to the foundation of biological management practices. Various groups of bioControl agents viz. *Bacillus* spp., *Pseudomonas* spp., *Streptomyces* spp., *Trichoderma* spp.etc has been shown to have profound effect against soil-borne pathogen being highly race specific. Their efficacy can be explored in one or the other way like showing Hyperparasitism, Antibiotics (Plipastatins), Induced Systemic Resistance (ISR) like β-1,3 glucanase by *Bacillus mycoides*. Several known secondary metabolites like Gliotoxin in case of *Trichoderma* spp., 2,4-diacetylphloroglucinol (DAPG) in case of *Pseudomonas* spp. are found to be antagonistic against a wide range of soil borne pathogen viz. *Rhizoctonia* spp., *Verticillium* spp. in addition to the plant's Systemic Acquired Resistance (SAR) mechanism to tackle diseases which can be enhanced with these microbes. The major challenge in writing this paper lies insorting out the information from the redundant one to avoid mess in our works cited pages meanwhile properly balancing the most actual studies as well as prominent researchers of the decade who contributed in the development of particular topic which was mitigated with distribution and compilation of literature in a master file dealing from general to specific and tried to describe the topic in modern as well as fundamental work in 1:2 ratio. This review paper will examine various bioControl agents, their mode of action, secondary metabolite production and their effectiveness in managing soil borne diseases.

Keywords: *Pseudomonas* spp., *Trichoderma* spp., ISR, SAR, Secondary metabolite, Soil Borne Pathogen

I. INTRODUCTION

Since time immemorial, agriculture and its associated industry have made an important contribution to the growing GDP of the country. Indian agriculture saw various revolutions ranging from the green revolution to the pink revolution. However the aim of maximum output, also resulted in a significant land decline, costing sustainability. But people and government agencies in the evolving era started to reflect on organic production that aims at maximum and sustainable production simultaneously. This paper discusses the bioControl agents mainly focusing on *Trichoderma* spp., *Pseudomonas* spp. and *Bacillus* spp. as well as their potentiality against soil borne pathogen.

Biological control agent refers to the use of any natural or modified organism; gene products which antagonists the effects of other undesirable organism and at the same time favoring desirable organisms viz. crops, beneficial insects, or microorganisms. In their mechanism of action these agents induce various factors in the plants such as enhanced resistance (SAR) against a pathogen or competition pressure is exerted on them for food and space; interacting via antibiosis mechanism or secreting antimicrobial compounds that are unfavorable to the pathogen; kill and invade pathogen spores as well as mycelium, cell, and endospores of pathogen. Thus, these agents become suitable alternatives for plant disease management as well as to chemical fertilizer.

Agustino Bassi was the first person to demonstrate microorganism has some antagonistic effect on other with *Beuvaria bassiana* which causes muscardian disease in silkworm in 1834 (Anonymous, 2021).

However the term was 1st coined by H.S. Smith in 1919 (Doutt, 1964). Later with advancement of golden era of microbiology the use of biotechnology such as genetic engineering has allowed us to enhance the properties of these agents in terms of their compatibility and effectiveness (production of toxic compounds), their suitability to adapt and survive in various abiotic and biotic stress condition. This increases the potential for improving the properties of these bioControl agents in par with molecular approaches (Singh *et al.*, 2020).

The biggest question is why to use bioControl agents before using chemicals. So, understanding its perspective:

- Bio control agents reduce acute and long-term impacts of chemicals on humans, animals, non-target organisms as well as environment.
- It also reduces the specific risk to water and the environment in ecological term.
- It behaves like homoeopathic medicines, i.e. has the capacity for permanent reduction of soil and foliage borne pathogen.
- No need of safeners thus cutting its costs and danger to the farm workers.
- Also surging organic food demand by consumer is pulling their use till now.
- Biological management techniques are also being used in domestic applications as mosquito abstract. Example: Citronellol oil. Example:
- The risk of pest resurgence is lower (Moazami, 2019, Cumagun, 2012).

A. Importance of Plant Diseases

It has been estimated that diseases, insects, and weeds together annually destroys around 31 percent and 42 percent of crop production of all crops produced worldwide. However, these losses are usually lower in the more developed countries than in developing countries. Of the total estimated 36.5% of global crop losses 14.1% caused by diseases, 10.2% by insects, and weeds accounts 12.2% loss (Agrios, (2005), Alexopoulos *et al.*, (1996).

Anonymous, (1994), Hillocks *et al.*, (1998), Cobb, (1914).

B. Management of plant diseases

Plant diseases so far managed with the advent in technology and experience from previous agricultural champions, but at what cost?

People have relied on the use of many poisonous chemicals to combat plant diseases and other pests for centuries. Long and short-term use of such chemicals necessitated their use not only for plants, but also for soil and soil-borne microorganisms, which profited from their use. Their effects are antagonistic to non-target microbes as well as humans, in addition to killing of harmful microorganisms. List of Potential bioControl agents against soil borne pathogen are mentioned in Table 1.

These effects restrict the volume of land available per year for agriculture, the varieties of plants which can be planted on fields and entail their use annually as of millions of kilogrammes of pesticides to process crops, fumigate soils, spray plants and fruit postharvests ascending the prices of crop production via such activities. On the other side, some examples of the pest ressurgence were also found where the minor pests or diseases occupied the region (ex: Kernal bunt of wheat in Punjab).

Table 1: List of Potential bioControl agents against soil borne pathogen.

S. No.	BioControl agent	Pathogen	Disease	Reference
1.	*Coniothyrium minitans*	*Sclerotinia sclerotium*	Root rot	Pertot *et al.*, 2015.
		Sclerotinia trifoliorum	Root rot	
2.	*Gliocladium catenulatum*	*Rhizoctonia, Pythium, Phytophthora, Didymella, Botrytis, Cladosporium, Penicillium, and Plicaria*	Rotting	
		Verticillium, Fusarium	Wilting	
		Alternaria, Helminthosporium	Blight/leaf spot	
3.	*Purpureocillium lilacinum*	*Meloidogyne spp.*	Root knot nematodes	
		Radopholus similis	Burrowing nematode	
		Heterodera spp. *and Globodera* spp.	Cyst nematodes	
		Pratylenchus spp.	Root lesion nematodes	
4.	*Pythium oligandrum*	*Botrytis, Gaeumannonyces, Ophiostoma, Phoma, Pythium, Sclerotinia and Sclerotium*	Root Rot	
		Alternaria, Pseudocercosporella	Leaf Spot	
		Fusarium	Wilting	

5.	*Streptomyces lydicus*	*Rhizoctonia, Pythium, Phytophthora, Phytomatotricum, Aphanomyces, Monosprascus, Armillaria, Sclerotinia, Postia, Geotrichum*	Root Rot	Himmelstein *et al.*, 2010.
		Fusarium Verticillium,	Wilting	
6.	*S. tsusimaensis*	*F. oxysporum* f. sp. *ciceris*	Wilting	Gopalakrishnan *et al.*, 2011.
7.	*P. fluorescens*	*Plasmodiophora brassicae*	Root rot	Ganeshan & Kumar September 2005.
8	*P. fluorescens* *P. putida*	*Pythium ultimum*	Root rot	Cassinelli *et al.*, 1993.
9.	*P. fluorescens*	*X. oryzaepvoryzae*	BLB	Meena *et al.*, 2001.
10.	*P. fluorescens*	*Magnaporthe grisea*	Blast	Karpagavalli *et al.*, 2002.
11.	*P. fluorescens* biovar I and III	*Helminthosporium sativum*	Brown spot	Wang-Ping *et al.*, 1999.
12.	*P. fluorescens*	*R. bataticola*	Root rot	Shaid Ahamad *et al.*, 2000.
13.	*P. fluorescens*	*Heterodera cajani*	Cyst nematode	Latha *et al.*, 2000.
14.	*P. fluorescens*	*P. solanacearum*	Wilt	Thara & Gnanamanickam 1990).
15.	*P. fluorescens*	*Phytophthora cinnamomi*	Root rot	Sorokina *et al.*, 1999).
16.	*Trichoderma lingorum*	*Polyporus sanguineus*	White rot	Kundu and Chaterjee, 2003.
17.	*T. viride*	*Macrophomina phaseolina*	Dry root rot	Raghuchander *et al.*, 1997.
18.	*T. viride*	*Fusarium oxysporium*	Wilting	Dubey *et al.*, 2001.
19.	*T. harzianum*	*Macrophomina phaseolina*	Dry root rot	Raghuchander *et al.*, 1997, Mishra *et al.*, 2011.
		Fusarium oxysporium	Wilting	Dubey *et al.*, 2001.
20.	*T. viride*	*Fusarium solani* *F. oxysporium* f sp. *Lycopersici* *Sclerotinia sclerotium*	Wilting Root rot	Balaji and Ahir, 2011. Jadon, 2009.
21.	*T. harzianum*	*Fusarium solani* *F. oxysporium* f sp. *Lycopersici* *Sclerotinia sclerotium*	Wilting Root rot	Balaji and Ahir, 2011. Jadon, 2009.
22.	*T. viride*	*Rhizoctonia solani*	Root rot	Sharma *et al.*, 2003.
23.	*T. harzianum* *T. viride*	*Alternaria alternate*	Leaf spot	Kapoor. 2008.
24.	*T. viride*	*Pythium vexans*	Damping off	Bhai and Thomas. 2010.
25.	*T. harzianum*	*F. oxysporium* f.sp. *dianthi*	Wilt	Shanmugam *et al.*, 2008.
26.	*T. pseudokoningii*	*Chaetomium globosum*	Minor root rot	Johnson and Palaniswami, 1999
28.	*T. harzianum*	*Pythium aphanidermatum*	Damping off	Johnson and Palaniswami, 1999
29.	*T. resse*	*Penicillium spp.* *Aspergillus niger* *Sclerotinia rolfsii*	Rot	Mukherjee *et al.*, 1997. Haware *et al.*, 1999. Pandey, 2003. Poddar *et al.*, 2004.
30.	*T. harzianum*			
31.	*T. viride*			
32.	*T. harzianum* *T. viride*	*Ganoderma lucidum*	Wilt	Karthikeyan *et al.*, 2006.
33.	*T. harzianum*	*Phomopsis thaeae*	Blight	Deb and Dutta, 1999
34.	*T. harzianum*	*Glomerellacingulata*	Anthracnose	
35.	*T. harzianum* *T. viride*	*Fusarium udum*	Wilt	Ram *et al.*, 2011.

Plant pathology has a key challenge to minimise loss in food grain production and at the same time increased food quality with an aim of safeguarding the ecosystem which can be achieved by modern day technologies such as genetic engineering, bio-formulation, RNA silencing, and so on can be used in combination with traditional activities or ITK to feed the vast increasing 8 billion people economy (Agrios, 2005).

C. Mode of action of bioControl agents

There are different mode of actions used by bioControl agents against phytopathogens viz., Induced resistance, Competition, Hyperparasitism, Antimicrobial metabolite productions. The first two have indirect interactions with pathogens and the latter two consists of direct interaction with the pathogen. Induced resistance are screened by complex bioassays on plants, it has broad pathogen specificity and lower dependency on environment and risk of resistance but the dependency on plant physiology is high (Kohl *et al.,* 2019). The second mode of action is competition for food and nutrients, in this mode of action the bioControl agents are screened by simplified bioassays and it has broad pathogen specificity. It is totally dependent on environmental conditions and consists low risk of pathogen resistance. Hyperparasitism consists of aspects same as the Competition but it has specific pathogen interactions. Production of antimicrobial metabolites has broad pathogen specificity and moderate dependency on environmental conditions and low risk of pathogen resistance. They are screened by simple bioassays (Kohl *et al.,* 2019).

Induced resistance and Priming: BioControl agents produce chemical stimuli which triggers the host defense mechanism of host plant through biochemical changes that expresses resistance to the subsequent infection of pathogens (Nega, 2014). The stimuli which produced by plants are known as "PAMP'S (pathogen associated molecular pattern). The stimuli which is produced by microorganisms for induction of resistance are known as "MAMP's (microbe associated molecular pattern) (Kohl *et al.,* 2019). In plants resistance against pathogens can be two types 1. Systemic acquired resistance (SAR), where resistance is induced directed at infected tissue or spread through plant (Kohl *et al.,* 2019). This type of resistance is mediated by salicylic acid which help in production pathogenesis related enzymes and proteins (Nega, 2014). SAR type of resistance is mainly shown in necrotic pathogens (Conrath *et al.,* 2015). Another type of resistance is 2. Induced systemic resistance (ISR) where an nonpathogenic bacteria is used for acquiring resistance (conrath *et al.,* 2015). ISR is mediated by ethylene or jasmonic acid (Nega, 2014). The examples of ISR is production of peroxidase, chitinase and β-1,3-glucanase in sugar beet by a *Bacillus mycoides* (Bargabus *et al.,* 2003), production of 2, 3-butanediol in Arabidopsis by *B. subtilis* GB03 and IN937 (Ryu *et al.,* 2004), production of lipopolysaccharide in Arabidopsis by *Pseudomonas putida* (Meziane *et al.,* 2005) and production of siderophore in cucumber by *Serratia marcescens* 90-166 (Press *et al.,* 2001). The above two resistance mechanisms are decreased in the absence of stimuli. To enhance the defense mechanism not only in the presence of stimulus but also for future and long lasting system for faster defense mechanism is carried out by "priming of plant with stimuli" (Mauch-Mani *et al.,* 2017).

Fig. 1. Shows effect of bioControl agent as a growth promoter.

Competition. This type of mode of action is most suitable for disease control of necrotic pathogens. Generally necrotic pathogens invade the host tissue, colonize in that tissue and absorb the nutrients present in it. Some of the necrotic pathogens won't able to complete their lifecycle on host tissue therefore they live as saprophytes on necrotic lesions of plant tissues in soil, crop residues and other nonhost residues. During this time the pathogens survive independently of hosts depending upon the species. It is known fact that microbes depend upon the exogenous nutrients during their saprophytic stages. The dependence of nonbiotrophic pathogens on the exogenous nutrients make these pathogens vulnerable to the nutrient competition (Kohl and Fokkema, 1998). So the bioControl agents which are highly competitive and absorb the nutrients faster can be targeted at the necrotic pathogens. These bioControl agents reduce the production of primary inoculums of necrotic pathogens on which the infection from diseased tissues to healthy tissues are blocked (Kohl and Fokkema, 1998). Examples, in apple *Venturia inaequalis* is controlled by *Microsphaeropsis ochracea* (Carisse *et al.,* 2000). In Rose *Botrytis cineria* is controlled by *Clonostachys rosea* (Morandi *et al.,* 2003).

Several species of soil borne pathogens such as *Fusarium* and *Pythium* which are infecting through mycelial contact are susceptible to other soil born microbes than that directly infect by germination on plant tissues (Nega, 2014). The soil microbes colonize in areas where there are high abundance of water and carbohydrates which are readily available and utilizes root mucilage. The microbes produce iron binding ligands known as siderophores that sequester the iron from environment, microbes that produces large amounts of siderophores can be used as bioControl agents against pathogens that produce less siderophores (Bakker *et al.*, 1993. Van Loon, 2000. Whipps, 2001. Lutenberg and Kamilova, 2009).

Hyperparasitism: The direct interaction between two organisms in which other organism gains the nutrients from its host is parasitism, the organism which gains the nutrients is known as parasite. The interaction of plant pathogen is known as hyperparasitism. This kind of interactions are generally observed in fungi which are known as "mycoparasities" and rarely observed in bacteria. In bacteria, hyperparasite *Bdellovibrio bacteriovorus* uses cytoplasm as its host of gram negative bacteria for nutrients (McNeely *et al.*, 2017). In biotrophic mycoparasitism, the parasite gain nutrient from host fungus via haustoria without killing the host (Kohl *et al.*, 2019). In necrotrophic hyperparasites they invade host cell after killing the host cell. The main mechanism involved in this kind of parasitism is that they produce cell wall degrading enzymes (CWDE's) sometimes in combination with the other metabolites which lead to opening of cell wall and disorientation of cytoplasm. Since fungi cell wall are made up of chitin and glucans the enzymes produced are chitinases, β-1,3-glucanases and proteases and in case of oomycote fungi cellulases enzyme is produced. CWDE's are generally produced in environment during the decomposition of organic matter from dead plants and fungal hypae which plays a major role in nutrient recycling in ecosystem (Kohl *et al.*, 2019). Hyperparasites produce CWDE's in low amounts in micro-niches where they intact with their hosts (kohl *et al.*, 2019). Generally, there are four classes of hyperparasites, obligate bacterial pathogen, hypoviruses, facultative parasites and predators (Nega, 2014). The example of obligate bacterial pathogen is *Pasteuria penetrans* which is used against root knot nematode (Nega, 2014). The example of hypovirusesis *Cryphonectria parasitica* which is used against chestnut blight (Nega, 2014). A part from hyperparasitism microbial predation is also present which is non pathogen specific and the control of diseases are less predicted. Example of predation is *Trichoderma* which produces chitinase in the decomposing bark that parasites *Rhizoctonia solani* (Sharma and Bhat, 2001).

The development of resistance by plant pathogens against hyperparasitism by biological control agent is not yet reported (Kohl *et al.*, 2019). However, they produce resting spores such as endospores, chlamydospores and sclerotia against the naturally occurring bioControl agents hyperparasitism (Kohl *et al.*, 2019).

Fig. 2. Antagonistic activity of fungal bioControl agent *Trichoderma spp.* against pathogen.

Antimicrobial metabolites: Antimicrobial metabolites are secondary metabolites produced by microorganisms that is of heterogenous nature and organic, consists low molecular weight which suppresses the growth and metabolic activities of other microorganisms (Thomashow *et al.*, 1997). Many microorganisms produce metabolites in small quantity in nature. The metabolites produced by actinomycetes are 8700, bacteria (2900) and fungi (4900) (Berdy, 2005). Antimicrobial metabolite production is often considered as most desired mode of action against other microorganisms as it suppresses the growth and activity in resource limited conditions (Raaijmakers and Mazola, 2012). The broad spectrum metabolite production is reported from the microbes such as *Agrobacterium*, *Bacillus*, *Pantoea*, *Pseudomonas*, *Serratia*, *Stenotrophomonas*, *Streptomyces*. List of secondary metabolites produced by potential bioControl agents are mentioned in Table 2 and Table 3.

List of several secondary metabolites produced by bioControl agents:

Table 2: Secondary metabolites produced by potential bioControl agents (*Trichoderma spp*).

S. No.	Name of the metabolite	Produced by bio control agent	Phytopathogens/ Target pathogens	References
1.	Epipolythiodioxopiperazines:			
	Gliotoxin	*Trichoderma viride*	*R. bataticola, P. aphanidermatum. R. solani, M. phaseolina, S. rolfsii*	Brain (1944).
	Gliovirin	*Trichoderma longibrachiatum,Trichoderma virens*	*R. solani, Pythium ultimum*	Stipanovic *et al.*, (1982)

2	Peptaibols			
	Alamethicin -F30	*Trichoderma viride*	*P. aphanidermatum*, *R. solani*	Brewer *et al.*, (1987).
	Trichokonins 6, 7 and 8	*Trichoderma koningii*	*R. solani*, *Fusarium oxysporum*, *Verticillium dahliae*, and *Botrytis cinerea*.	Yan *et al.*, (2006).
	Trichorzianine A1 and B1	*Trichoderma harzianum*	*P. ultimum, Botrytis cinerea, Sclerotium rolfsii, Fusarium oxysporum*	Goulard *et al.*, (1995).
3	Pyrones			
	Pyrone 6-PP	*T. viride*, *T. koningii* and *T.* harzianum	F. *oxysporum*, *R. solani*, *Candida albicans*, *Penicillium* spp., *Cryptococcus neoformans*, and *A. fumigatus*	Vinale *et al.*, (2008). Collins *et al.*, (1972). Claydon *et al.*, (1987). Simon *et al.*, (1988).
4	Butenolides:			
	Harzianolide and T39 Butenolide	*T. harzianum*	*Gaeumannomyces graminis* var. *tritici*, *P. ultimum*, *R. solani*, and *B. cinerea*	Almassi *et al.*, (1991). Vinale *et al.*, (2006). Vinale *et al.*, (2009).
	5-Hydroxyvertinolide	*T. longibrachiatum*	*Mycena citricolor*	Andrade *et al.*, (1992).
5	Pyridones			
	Harzianopyridone	*T. harzianum*	*Pythium ultimum*, *Rhizoctonia solani*, *Botrytis cinerea and Gaeumannomyces graminis* var. *tritici*,	Vinale *et al.*, (2006). Dickinson *et al.*, (1989).
6	Azaphilones			
	Harziphilone and Fleephilone	*T. harzianum*	*P. ultimum*, *G. graminis* var. *tritici*, and *R. solani*	Nakano *et al.*, (1990). Vinale *et al.*, (2006).
	T22azaphilone	*T. harzianum*	*B. cinerea*, *P. cinnamomi*, and *L. maculans*	Vinale *et al.*, (2009).
7	Koninginins			
	Koninginins A, B, C, D, E and G	*Trichoderma koningii*, *T. harzianum*	*G. graminis* var. *tritici*, *F. oxysporum*, *Bipolaris sorokiniana*, *P. cinnamomi*, and *Pythium middletonii*	Cutler *et al.*, (1989). Almassi *et al.*, (1991). Ghisalberti *et al.*, (1993). Dunlop *et al.*, (1989).
8	Steroids			
	Stigmasterol	*T. koningii* and *T.* harzianum	*Rhizoctonia solani*, *Sclerotiumrolfsii*, *Macrophomina phaseolina*, and *Fusarium oxysporum*	Ahluwalia *et al.*, (2015). Ahluwalia *et al.*, (2013).
	3,5,9-trihydroxyergosta-7,22-dien-6-one and ergosterol	*Trichoderma spp*	*Pyricularia oryzae (grisea)*, *Candida albicans*, *A. niger*, and *Alternaria alternata*.	Xuan *et al.*, (2014).
9	Anthraquinones			

	6-methyl-1,3,8-trihydroxyanthraquinone, 1-hydroxy-3-methylanthraquinone , and 1,8-dihydroxy-3-methylanthraquinone	*T. harzianum*	*Rhizoctonia solani*, *Sclerotium rolfsii*, *Macrophomina phaseolina*, and *Fusarium oxysporum*	Ahluwalia *et al.*, (2015).
10	Lactones			
	Cremenolide	*T. cremeum*	*R. solani*, *B. cinerea*, and *F. oxysporum*	Vinale *et al.*, (2016).
	aspinolide C	*T. arundinaceum*	*B. cinerea* and *Fusarium sporotrichioides*	Malmierca *et al.*, (2014).
	Cerinolactone	*T. cerinum*	*Rosellinianecatrix*	Arjona-Girona I *et al.*, (2014).
11	Trichothecenes			
	Trichodermin	*T. brevicompactum*	*R. solani*, *B. cinerea*, and *Colletotrichum lindemuthianum*	Shentu *et al.*, (2014).
		T. harzianum	*Cochliobolus miyabeanus*, *Rhizoctonia solani*, *Colletrotrichum lindemuthianum*, *Fusarium oxysporum*, *T. cucumeris*, *C. gloeosporioides*, and *Botrytis cinerea*	Shi *et al.*, (2009). Sha *et al.*, (2013).

Table 3: Secondary metabolites produced by potential bioControl agents (*Pseudomonas fluorescens*).

***Pseudomonas fluorescens*:**

S. No.	Bio control agent	Secondary metabolite produced	Phytopathogen	reference
1	*Pseudomonas fluorescens*	2,4-diacetylphloroglucinol (DAPG)	*Thielaviopsis basicola*, *Fusarium oxysporum* f. sp. *lycopersici*, *Fusarium oxysporum* f. sp. lini, *Gaeumannomycesgraminis* var. *tritici*, *Pythium debaryanum*, *Pythium ultimum*, *Rhizoctonia solani*.	Keel, Christoph *et al.*, (1992).
		Extracellular protease – AprA	Nematodes	Siddiqui *et al.*, (2005).

Antibiotics produced by *Bacillus* spp: The production of plipastatins A and B by *Bacillus subtilis* (strain NCIB 8872) will show effect on the *Fusarium oxysporum and Aspergillus flavus* by inhibiting the phospholipase A2 enzyme (Volpon and Besson, 2000). *Bacillus subtilis* (SSE4, RB14) produce Subtulene A, iturin A which show effect on *colletotrichum gloeosporioides and sclerotium rolfsii*by disruption and solubulization of lipid bilayer (Thasana *et al.*, 2010 and Ohno *et al.*, 1995). *Bacillus subtilis* (B29) produces protein-B29 inhibits the growth of phtopathogens such as *F. oxysporum, R. solani, F. moniliforme, and Sclerotinia sclerotiorum* by inhibiting the growth of mycelium (Li *et al.*, 2009). Another species of bacillus genes, *B. amyloliquefaciens* (AS 43.3) produces active compounds such as Surfactin, iturin, fengycin, a bacillibactin, bacilysin, bacillaene, difficidin, and macrolactin which affects the phytopathogens *Fusarium* head blight in wheat by Pores formation in cell wall and cell membrane by disrupting the lipid bilayer (Dunlap *et al.*, 2013). *B. amyloliquefaciens* (WH1) produces secondary metabolite WH1fungin which targets the pytopathogen *Rhizoctonia solani* by Case reduction in callose production by inhibition of glucans synthase (Qi *et al.*, 2010). *B. polymyxa* (VLB16) produces antifungal protein which affects phytopathogens such as *R. solani* and *Pyricularia grisea* by Causing malformation of fungal hyphae due to severe alteration of cell morphology (Kavitha *et al.*, 2005).

CONCLUSION

BioControl agents are the most important and efficient source to tackle the diseases caused by soil borne pathogens. Since control of soil borne pathogens is not possible by traditional chemical methods, using bioControl agents are only hope rather than going for other management practices such as soil solarization.

BioControl agents use various mechanisms to suppress the growth of bioControl agents which include, induction of CAMP'S AND MAMP'S which stimulate the resistance against pathogens, competing for food and nutrients against pathogens, parasitic nature upon the host pathogen and obtain nutrients from it, production of various secondary metabolites which affect the growth and development of pathogens. Since the resistance of soil borne pathogens against various mechanisms performed by bioControl agents are less reported, use of bioControl agents can be a potential tool to control soil borne pathogens for long term. In agro-ecology point of view, use of chemical methods affect the survival of soil micro-biota the supplementation of bio control agents with various other management practices not only help the soil micro-biota but also residual effect of various chemicals in food can also be minimized. In the economics point of view, the cost required for application of bioControl agents is comparatively less than the chemical methods. From the above discussions it is clearly evident that the use of bioControl agents in future will be increased and with the integration of molecular approaches new strains of bioControl agents and their mechanisms against soil borne pathogens will be developed.

The current review paper have attracted attention of plant pathologist towards biological control of plant diseases. Many review literature indicated that bioControl agents could be attractive and an effective strategy with minimal environmental concern.

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