Review On Bacillus Species for Plant Pathogens as Versatile Weapons

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Abstract--- *Plant pathogens are the major threat for beneficial agricultural production. The three families of Bacillus lipopeptides - iturins, surfactins, and fengycins were primarily investigated for their antagonistic activity in a broad range of potential phytopathogens, including fungi, bacteria and oomycetes, in the frame of biological control of plant diseases. Chemical-based pesticides are currently considered to be reliable and an effective step for the control of agricultural pests. Chemical pesticides are vastly effective and suitable to use, but they pose a potential threat to the environment and life on earth of all kinds. The use of biological control agents for plant pathogens management is therefore considered as a more efficient and sustainable method for secure and beneficial agricultural productivity. In the field of biopesticides, biocontrol agents based on Bacillus plays a fundamental role. Many species of Bacillus have been shown to be effective against a wide range of plant pathogens. The goal of this paper is to present biocontrol potential of Bacillus species relative to their antagonizing characteristics to plant pathogens.*

Index Terms--- *Lipopeptides, Bacillus species, colonization, systemic induced resistance, antibiotics.*

I. INTRODUCTION

To maintain a healthy and rapidly growing world population, it is important to monitor plant diseases in order to produce abundance and quality of feed, food and fibre. For the control or eradication of plant diseases, different types of plant disease management methods may be adopted[1]. Agrochemicals have played a very significant role in improving the quantity and quality of crops over the past centuries. On the other hand, there has been a change in people's attitude towards chemical fertilizers and pesticides, [2]due to the rising threats of environmental pollution and residual outcomes of pesticides on human health and also on the earth's ecosystem.

Earlier research work has repetitively reported that natural antagonistic microorganisms can control numerous plant pathogenic diseases. Many strains of these microbes, however, have the ability to overcome pathogenic diseases of plants under different crop conditions, and few of them have the ability to control a wide range of plant pathogens[3]. Most belong to the genus Bacillus among the bacterial antagonists, and there are some other important genera, but they are less important than Bacillus. The use and number of Bacillus species that are antagonistically essential, is increasing very fastly[1], [2]. Bacillus species have a remarkable ability to rapidly reproduce, resistant to unfavorable environmental conditions, as well as a wide range of biocontrol capabilities. By triggering induced systemic resistance (ISR) in plants, volatile compounds produced by B. subtilis also play a vital role in promoting plant growth and activating plant defense mechanism[4]. Several microorganisms are identified as potential biocontrol agents for

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example Pseudomonas flurescens, Hypericum gramineum and some Streptomyces species[5]. In addition, Trichoderma and Ulocladium atrum are capable of controlling various bacterial and fungal diseases. They typically show control effectiveness varying from 30% - 50%[1], [4], [5]. Bacillus species, due to their ability to produce strong, resistant endospores and antibiotics that control a wide range of plant pathogens, have become attractive biocontrol agents.

I.I. Bacillus- A Source of Bioactive Compounds:

The utilization of valuable microorganisms (biopesticides) is considered one of the most capable methods for secure and rational crop management practices. Members of the genus Bacillus are often considered microbial factories for the development of a wide range of potentially, inhibitory, biologically active molecules for the growth of phytopathogens [6]. A spore-forming capability also makes these bacteria among the best candidates from a technical point of view for the production of effective biopesticide products [7]. Rhizobacterium B. subtilis is one of the most widely used and well-studied species which has an average of 4% - 5% of its antibiotic synthesis genome and is capable of producing more than two dozen structurally dissimilar antimicrobial compounds.

Various groups of Lipopeptides can confer benefit in different ecological niches for the production of Bacillus strains[8]. The output of iturin seems to be limited to B. amylo liquefaciens and B. Subtilis. Surfactin or closely related alternatives for example lichenysin have been isolated from B. pumilus, B. coagulans and B. licheniformis[9]. Recent advances show that they can function not only as ‘killers’ or antagonists’ by inhibiting phytopathogen development, [10] but also as ‘spreaders’ by encouraging root colonization and by reinforcing host resistance capacity as ‘immunostimulators’.

I.II. Antibiotics and Lipopeptides-based Weapons:

Species of Bacillus synthesize different types of lipopeptides based on secondary metabolites with definite activities against plant pathogens that give them unique importance in biotechnology, agriculture and pharmaceutical industries[2]. Approximately 2428 antimicrobial peptides from different organisms such as archaea (2), bacteria (237), fungi (12), protists (7), animals (1819) and plants (310) have been recognized. Among these, 756 of peptides have different degrees of antifungal characteristics[11]. The mechanisms by which microbes cause fungi to die include distraction, blockage and creation of holes in the cell membranes and cell wall of the fungi. Many peptides are also involved in degenerating intracellular fungal organs such as mitochondria and nucleic acid.

In addition to the synthesis of various surfactant materials, the genus Bacillus synthesizes several effective surfactant and amphiphilic lipopeptides consisting of iturins, mycosubtilin and bacillomycins, these bacteria also develop plipastatin or fengycins with the modification of plant culture conditions[2], [4], [12]. Characterization based on the incidence of D-and L-amino acids and variable hydrophobic studies showed that all of these fall under two groups: macrolactones (fengycins, plipastatins and surfactins) and cyclic peptides (iturinics)[2]. Iturinics induce the leakage of cells by inserting their hydrophobic tails into the cytoplasmic membrane and creating pores in the cell membrane by auto-aggregation[11].

B. Cereus and B. Subtilis to prevent phospholipase A2 produces plipastatins, which plays a major role in various cytological processes (acute hypersensitivity and inflammation)[2], [11]. B. Subtilis synthesizes other lipopeptides, like plipastatins, which are described as isoform lipopeptide mixtures that vary depending on the amino acid composition and hydrophobic tails. Table 1 summarizes the Bacillus-based antibiotics and lipopeptides.

Table 1: - Mode of action and target pathogens of *Bacillus*-produced antibiotics and lipopeptides.

Bacteria	Active compound (s)	Strain	Mode of action	Target pathogen (s)
B. subtilis	Antibacterial peptide AMPNT-6	NT-6	Destroying and blocking the cell wall and forming holes in cellular membranes	*Vibrio parahaemolyticus*
B. subtilis	Subtulene A, iturin A	SSE4, RB14	Solubilization and Disruption of the lipid bilayer	*C. gloeosporioides and S. rolfsii*
B. subtilis	Antibiotics plipastatins A and B	NCIB 8872	Inhibit phospholipase A2	*Fusarium oxysporium, Aspergillus flavus*
B. vallismortis	Surfactic and fengycin	BS07	Cell wall disintegration and plant growth promotion	*Pectobacterium carotovorum SCC1, Phytophthora capsici, and Colletotrichum acutatum*
B. amyloliquefaciens	WH1fungin	WH1	Case reduction in callose production by inhibition of glucans synthase	*Rhizoctonia solani*
B. thuringiensis	Fengycin	SM1	Act on cellular organs and cell membrane and inhibited DNA synthesis	*Candida albicans*
B. polymyxa	Antifungal protein	VLB16	Cause malformation of fungal hyphae due to severe alteration of cell morphology	*R. solani and Pyricularia grisea*
B. sonorensis	Sonorensin	MT39	Antibacterial and fungal activity	*L. monocytogenes and S. aureus*
B. coagulans	Lactosporin	ATCC 7050	Cause leakage of ions from the microbial cells	*M. luteusand, L. monocytogenes*

I.III. Promoting Plant Growth as an Indirect Weapon:

Many researchers have discussed that B. Subtilis has the ability to promote growth of plant and yield by improving nutrient absorption by increasing plant hormone production and decreasing the production of ethylene that assist root colonization of bacteria[13]. Such microbes also play a key role in promoting plant growth, apart from the antagonistic function of Bacillus species, by enhancing the biosynthesis of plant hormones (indole-3-acetic acid (IAA) and gibberellic acid (GA3))[14] that are closely related to the availability of plant nutrients.

Species of Bacillus plays an important role in promoting plant growth. Compared to the untreated plants, higher levels of defense-related enzymes (polyphenol oxidase (PPO), peroxidase (PO) and superoxide dismutase) and plant growth-promoting hormones (GA3 and IAA) were found in treated plants. Such plant growth-promoting hormones improve plant nutrient absorption ability and enable the plant to protect against different biotic and abiotic stresses[16]. It was confirmed that diluted cultural filtrate of B. amyloliquefaciens considerably improved maize seedlings growth[4], [12].

The Bacillus strain SH1RP8 showed a tolerance of 8 percent to salinity, when employed to sand dune plant Peucedanum japonicum[2]. It improved 51.7% dry weight and 10.9% shoot growth when grown in general soil. Lin et al. [12] isolated 33 vinegar waste strains of bacteria. After screening via self-developed screening process, he found out that all of the Bacillus strains were extremely antagonistic to 8 fungal pathogens and had the ability to generate IAA, whereas 5 strains exhibit plant growth-promotion capabilities. According to a scientist who studied Bacillus species RM-2 strain and found that the bacterial strain had many useful features including deaminization activity of acetyl-CoA carboxylase (ACC), fungicidal activity, development of IAA and production of ammonia. Compared to the untreated control, the stains significantly increased seed germination, leaf area, fresh and dry weight, shoot and root size, as well as pods, seed and grain yield.

Enzymatic Weapons:

Bacillus species are also capable of producing enzymes such as β-1, 3-glucanase and chitinase with a very high lytic activity in addition to the development of antibiotics and evocation of systemic resistance in plants against a number of plant pathogenic diseases. Such lytic enzymes synthesized by species Bacillus have been shown to be very vigorous in the degradation of fungal cell walls. Studies have shown that many defense-related oxidative enzymes like PO, PPO and PAL have also been produced by Bacillus organisms. These oxidative phenolic compounds and enzymes induced lignin which plays a function in reduction defense-related obstruction by producing structural changes against plant pathogens in the cellular defence system[20]. The enzyme-related defense activities have been demonstrated in different plant species and against different plant pathogens.

Phenolic compounds are highly efficient against pathogens of fungal plants and thus play an important role in the protection of plants. PPO also plays a key role in the elicitation of plant defence against different plant pathogens[2], [4]. The basic purpose of releasing hydrolase is to use the nutrient saved in substrate by converting it in available form from unavailable form. In addition, in conjunction with some other substances, bacteria release extracellular enzymes to overcome competition with the other microbial agents. Most soils have enough plant nutrients but are present in insoluble form because plants are unable to absorb these nutrients for normal growth. Chitinases and β- 1, 3-Glucanases have played an active role in plant defense against a number of plant pathogens, while PO and PAL have been actively involved in plant tissue phenylpropanoid breakdown.

Many hyper-parasitic Bacillus species develop chitinases and glucanases (laminarinase) hydrolytic enzymes of the fungal cell wall. A number of B. Subtilis for their chitinolytic activities have been registered. Based on its abundance in nature, Chitin holds second place among the polysaccharides. There is a variety of chitins provided in nature with a variety of structures, and therefore bacteria synthesize a variety of chitinases. Chitinases are categorized into 18, 19, and 20 glycosyl hydrolases, according to the amino acid sequence. The use of modern biotechnology has enhanced the activities of these bacterial enzymes. Homologically-based enzymatic modeling played a major role in improving bacterial enzyme activity. β -galactosidase activity has been enhanced sixty-six times while DNA shuffling and scanning has improved substrate activity one-thousand times.

II. CONCLUSION

Bacillus-based biological control means for plant pest management offers an attractive, friendly and efficient process. The genus Bacillus produces a number of compounds that can be used to control a wide range of plant pests. Due to adverse environmental conditions, sustainable growth and development of biological agents under field conditions is still an issue. For effective control of plant pests and diseases, a large number of Bacillus strains have been produced. The genus Bacillus has the ability to produce compounds belonging to the multiple classes of antibiotics that can be used to regulate a wide range of pathogenic diseases in plants. Bacillus-originated lipopeptides plays a very important role in the bio-control of plant pathogens. Although, recent progress has provided us with some beneficial understanding of lipopeptide interactions with additional interacting pathogens, the studies are mainly focused on the physiochemical activities and a wider view of the mechanisms are still lacking.

Under greenhouse conditions, the combined use of Bacillus species with different mechanisms of action can increase their effectiveness. Spore-forming capability and genetically engineered plants with Bacillus genes are given as an effective solution to many pathogenic diseases in plants. Consideration should therefore be given to developing cost-effective and sustainable products based on spores. Inaugurating the presence and functioning of biologically significant microbes in a specific environment is the first step towards understanding their mode of action and nature to regulate pathogens in that environment.

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