Novel Ecofriendly Approaches for Controlling Soil Borne Fungal Pathogens: A Review

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Received:- 01 August 2021/ Revised:- 08 August 2021/ Accepted:- 16 August 2021/ Published: 31-08-2021

Abstract— *The application of chemical fungicides for controlling soil borne plant pathogens is rapidly increasing due to their potential to deliver desirable results in a short span of time. However their rampant use has made many invasive plant pathogens resistant to any chemical control making them way harder to eradicate or eliminate as compared to the past days. The uncontrolled use of chemical fungicides is also causing soil toxicity and water pollution leading to several health hazards. The aim of the review article is to highlight the recent advancements in the field of eco-friendly disease management using the extracts obtained from natural resources and biologically active antagonistic organisms. The review article highlights the management of Black scurf disease (Rhizoctonia solani) in Potato using Bacillus subtilis V26 strain and by using a mixture of cattle manure and date palm compost. Biological control of Fusarium wilt of tomato (Fusarium oxysporum f.sp. lycopersici) by the application of endophytic bacterial isolates from Silver Leaf (Solanum elaeagnifolium) has been also mentioned. The review includes the management of Late blight of potato (Phytophthora infestans) using antagonistic Poplar (Populus nigra) bud extracts and peptide extracts obtained from Common Horsetail (Equisetum arvense). The review article also mentions the innovative method of management of Black shank disease of tobacco (Phytophthora parasitica var. nicotianae) by colonization of tobacco roots with Paenibacillus polymyxa C5 strain. As per the article, Foot rot of rice or rice bakanae (Fusarium moniliforme) can be effectively managed by the application of antifungal Surfactin-A extracted from Bacillus subtilis NH-100 and NH-217 strains. The article highlights the potential of the Bacillus subtilis RH5 strain as a bioformulation for controlling Sheath blight of rice (Rhizoctonia solani). The extracts and the antagonistic biocontrol agents can be used in the effective management of some economically important soil-borne plant diseases as a novel, innovative and environmentally safe approach.*

Keywords— Soil-borne fungus, Bio control agents, Late blight, Black scurf.

I. INTRODUCTION

Soil borne diseases are considered a major hurdle in crop production. Soil borne plant pathogens such as *Rhizoctonia spp., Fusarium spp., Sclerotinia spp., Verticillium spp., Pythium spp., and Phytophthora spp*. can cause around 50%–75% yield loss for many crops such as wheat, cotton, maize, vegetables, fruit and ornamentals as reported to date [1, 2, 3].

Soil-borne fungal pathogens like Rhizoctonia, Fusarium, Pythium, Verticillium, Phytophthora, Sclerotinia, Rosellinia, etc. exist in the form of dormant propagules or spores and start growing when the micro-environment becomes favorable [7]. Infected seeds act as a primary source of infection that travels from one place to another, crossing demographic boundaries [7].

The significant problems caused by soil borne pathogens in crop production include reduced crop performance, decreased yield, and higher production costs. The threats of soil borne disease epidemics in crop production, high cost of chemical fungicides and development of resistance towards fungicides, climate change, new disease outbreaks and increasing environmental concerns along with soil health are becoming increasingly evident. In organic farming most of the soil borne fungal diseases can be controlled by stimulating bio-diversity in and above the soil, by feeding soil life with organic soil amendments and good soil management [4]. The review article summarizes innovations for controlling soil borne pathogens using antagonistic microorganism and plant extracts.

II. MANAGEMENT OF BLACK SCURF IN POTATO

Rhizoctonia solani is the causal organism of Black Scurf disease in Potato. It causes reduction in the potato yields by 10 % in plains and 25 % in hilly areas of India [7]. Some of the following methods can be applied for controlling the disease effectively.

2.1 Application of *Bacillus Subtilis* V26 as A Biological Control Agent

The ability of the V26 strain of *Bacillus subtilis* to produce chitosanase and proteases makes it a promising biocontrol agent for controlling *R. solani* by antibiosis [5]. The mycelial growth of *R. solani* reduced by 80 % when a supernatant (3 % v/v) of V26 culture was applied [5]. An increased concentration of supernatant (9 % v/v) resulted in vacuolization, hyphal deformation and cell wall disintegration of the pathogen [5]. The activity of chitosanase hydrolysed chitosan, which is the main constituent of fungal cell wall. The activity of protease degraded the protein linkages of external cell wall [5].

2.2 Control of Black Scurf and Stem Canker using Cattle Manure and Date Palm Compost

Fungi associated with cattle manure and date palm compost (CMC) significantly inhibited the radial growth of *R. solani* [6]. The antagonistic fungi caused lyses of *Rhizoctonia* mycelium and formed mycelia cords between the mycelia filaments of *R. solani* exhibiting mycoparasitism and anastomosis [6]. The antagonistic fungal isolates of CMC caused vacuolization and lyses of hyphae [6]. The inhibitory effect of CMC on *R. solani* got enhanced after its amendment with peat-sand [6].

III. MANAGEMENT OF FUSARIUM WILT IN TOMATO

Fusarium wilt is one of the most devastating diseases that are prevalent in major tomato-growing regions of the world [8]. It is caused by *Fusarium oxysporum* f.sp. *lycopersici* (FOL) that causes wilting of plants, yellowing of leaves, browning of vascular tissues, stunting and eventually death of the plant [8]. Following method can be applied for effective management of Fusarium Wilt of Tomato.

3.1 Biocontrol of *Fusarium Oxysporum* F.Sp *Lycopersici* by the Application of Endophytic Bacterial Isolates Obtained from *Solanum Elaeagnifolium* Stems

Endophytic bacteria isolated from the internal stem tissues of an invasive weed, *Solanum elaeagnifolium* (Silverleaf Nightshade or Silver Leaf) caused reduction in the severity of Fusarium wilt and vascular browning by 77-83 % and 76 % respectively [8]. Phylogenetic analysis based on Neighbor-Joining methods and Blast analysis of sequenced 16S rDNA gene homology suggests that the anti-fungal isolates belonged to *Bacillus tequilensis* str. SV 101 and *Bacillus sp* [8]. Cell-free filterate of *B. tequilensis* caused alterations in the macro-morphological traits of the colonies of *Fusarium oxysporum* f.sp. *lycopersici* (FOL) such as change in mycelial texture affecting the mycelial density exhibiting antibiosis [8]. The isolate of *Bacillus tequilensis* caused antibiosis of FOL by producing cell wall-degrading lytic enzymes like pectinase, chitinase and protease [8].

IV. MANAGEMENT OF LATE BLIGHT OF POTATO

Late blight of Potato (*Solanum tuberosum*) caused by *Phytophthora infestans* (Oomycetes) is considered as one of the most devastating and economically important diseases in Potato [9]. It was responsible for the disastrous Irish Famine of the 1850s causing emigration, starvation and death of millions of people and children together [9]. The disease symptoms include rusty brown necrosis spreading from surface to the centre of the tuber and brownish black lesions on the leaves [10].

4.1 Utilization of Poplar Bud Extracts for Controlling *P. Infestans*

Bud extracts of Black Poplar (*Populus nigra*) have been found to be effective against *Phytophthora infestans* making it suitable for application under low cost management of Late Blight of Potato [9]. The compound 'Populin' is the potential compound in the Poplar bud extracts that reduces disease severity in the potato plants [9]. Application of Populin inhibited the germination of encysted zoospores and/or sporangia of *P. infestans* that resulted in the decline of hyphal growth in the infected plants [9]. Populin 4 % (v/v) proved to be the most effective concentration for controlling various strains of *P. infestans* [9].

4.2 Application of Peptide Extracts obtained from Common Horsetail (*Equisetum Arvense*) for Inhibiting *P. Infestans*

Peptide extracts obtained from *Equisetum arvense* have proven to be an effective inhibitory agent for *Phytophthora infestans* [11]. The peptide extracts inoculated on potato tuber discs inhibited the appearance of the symptoms of *P. infestans* like

soporiferous layers and necrotic spots [11]. The extracts of Common Horsetail possessed inhibitory capabilities towards the activity of zoosporangium germination, zoospore output and the development of *P. infestans* [11]. The inhibitory or anti-oomycete effects of the extracts are closely associated with the conversion of Rubisco (ribulose-1, 5-bisphosphate carboxylase/oxygenase) into a number of biologically active anionic peptides. Besides Rubisco, the active peptide extract also contained chitinases and aquaporins [11]. These proteins are responsible for some defense functions related to extracellular biotic stress (fungal infections caused by pest damage) [11].

V. MANAGEMENT OF BLACK SHANK OF TOBACCO

Phytophthora parasitica var. *nicotianae* is the causal organism of Black Shank disease of Tobacco (*Nicotiana tabacum*) [12]. It is one of the most devastating diseases that occur in the tobacco being cultivated across the globe [12]. *P. parasitica* var. *nicotiane* is a soil-borne fungus that severely infects the basal part of the tobacco stem along with the roots that markedly reduces the overall yield [12]. Prominent appearance of black necrotic patches on the stem leading to wilting of plant, black discoloration of stem and ultimately shriveling of the stem is the main symptom of the disease [13].

5.1 Colonization of Tobacco Roots with *Paenibacillus Polymyxa* C5 Strain for Controlling Black Shank Disease of Tobacco

The application of *Paenibacillus polymyxa* C5 amended with Bio-Organic Fertilizer (BIO) preparation exhibited a biocontrol efficiency of 80 % on *P. parasitica* var. *nicotiane* [14]. The antagonistic *P. polymyxa* C5 strain formed a protective biofilm around the elongation zone as well as the tip of the roots growing in the soil [14]. The mechanism of colonization of *P. polymyxa* C5 on the tobacco roots is mainly responsible for the suppression of *P. parasitica* var. *nicotiane* [12]. Moreover, the inhibitory and diffusible antifungal compounds produced and released by *P. polymyxa* C5 strain caused permanent inhibition of *P. parasitica* var. *nicotiane* [14].

VI. MANAGEMENT OF FOOT ROT OF RICE

Foot rot of Rice is also called as Rice Bakanae disease. It is caused by *Fusarium moniliforme (Gibrella fujikorai).* Typical symptoms of the disease include chlorotic, slender and elongated primary leaves and rotting of the basal part of the stem [15]. The disease causes lodging of the plant causing significant reduction in the final yield.

6.1 Application of Surfactin-A Extracted from Bacillus Subtilis Nh-100 and Nh-217 Strain

Application of 2000 ppm of purified Surfactin-A extracted from *Bacillus* (SPB) NH-100 and NH-217 strains on *Fusarium moniliforme* showed a reduction in disease incidence by 84 % [16]. Surfactin-A was found to exhibit anti-fungal activity in various pH levels ranging from 5 to 9 [16]. The anti-fungal extract was stable even under variable temperatures like 20◦C, 50◦C, and 121◦C making it suitable for its utilization as a commercial bio-control agent [16]. Surfactins are known to form persistent bio-films around the substrate which makes it a potent bio-surfactant [16]. Lipopeptides present in the surfactants are the main antagonistic agents against the plant pathogens [16].

VII. MANAGEMENT OF SHEATH BLIGHT OF RICE

Sheath Blight disease in rice is one of the major production constraints in rice crop causing an overall yield loss of 10-30 % [17]. *Rhizoctonia solani* is the causal organism of sheath blight of rice. Appearance of circular, ellipsoid or oblong, water soaked greenish grey spots on the stem near the water level are the initial symptoms [18].

7.1 Utilization of *Bacillus Subtilis* Rh5 Strain as A Potential Biocontrol Agent

The RH5 strain of *Bacillus subtilis* exhibited antagonistic activity by significantly reducing the incidence of fungal pathogen *R. solani* by 84.41 % [17]. Formation of protective biofilm is the main mechanism behind the biocontrol activity besides production of a diverse range of secondary metabolites with antimicrobial properties [17]. Strains of *Bacillus* producing endospore have the ability to directly inhibit and suppress plant pathogens by producing several hydrolytic enzymes (glucanases, chitinases and proteases), antimicrobial peptides and volatile substances [17]. *Bacillus* strains indirectly suppress the plant pathogens by competing with them for nutrition or niche [17]. These properties of the *B. subtilis* RH 5 strain makes it a potential candidate for a commercial bioformulation for the management of sheath blight of rice.

VIII. CONCLUSION / FUTURE PROSPECTS

The review article efficiently demonstrates the potential of non-chemically synthesized products (plant extracts and bioformulations) in the management of some of the most devastating diseases like Late blight, Fusarium wilt, Black shank

and Sheath blight occurring on economically important crops such as potato, tomato, tobacco and rice respectively. The exact mechanisms behind the management of Black scurf of potato using *Bacillus subtilis* V26 and date palm compost; biological control of Fusarium wilt using bacterial isolates from Silver Leaf stems and management of Late blight of potato using poplar bud extracts and peptide extracts of Common Horsetail have been clearly described in the research papers of some scientists. However, besides the mechanism of biofilm formation by the antagonists, the principal biocontrol mechanism behind the management of Black shank of tobacco by colonization of roots by *Paenibacillus polymyxa* C5 strain; biocontrol of foot rot in rice by Surfactin-A and management of Sheath blight of rice by RH5 strain of *Bacillus subtilis* have not been clearly elaborated. Therefore, comprehensive research works are needed on those areas for making them commercially successful. The innovative approaches mentioned in the review article can be emphasized upon for their commercialization so that the farmers across the globe can quickly switch over from chemically synthesized fungicides to the eco-friendly bioformulations for effective management of major soil-borne plant diseases.

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