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Some Agricultural Significant Fungi of Himachal Pradesh: A Meta-Analysis

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Abstract

Himachal Pradesh is a hilly state situated in the heart of Himalaya in the Northern part of India. The state extends between 30º22'40' – 33º12'20'' North latitudes and 75º44' 55''– 79º04'20'' East longitudes. There are large numbers of fungal species in H.P. most which are pathogenic and caused by harmful impact on the crop and plants. But there are some species of fungi which are caused the significant role in the plant growth and prevent the plant from diseases. The most abundant species of fungi which are agriculturally significant found in the Himachal Pradesh are *Candida oleophila, Trichoderma harzianum* and arbuscular mycorrhizal fungi (*Glomus fasciculatum*) ectomycorrhizal fungi. Also, association of fungi with plant helps in defending against plant pathogens that indirectly promotes plant growth. Now day's fungi are used in many regions of the world as a biological pest control. Beneficial fungi play a significant role in numerous physiological processes including minerals and water uptake, stomatal movement, photosynthesis and biosynthesis of compounds and mitigation to environmental stress like heat, salinity, cold and heavy metals.

Candida oleophila is a yeast-like fungus which is also obtained from the various fruits skin like papaya, pears, apple etc. Most of the species of Candida are ubiquitous. *Trichoderma harzianum* species are ubiquitous in nature and found in all climatic zone (including temperate and tropical regions, tundra and Antarctic), nearly all soil types (crop fields, desert and marsh) and unusual niches such as lakes, marine bivalves, air, termites and shell fish. There are several antagonistic mechanism used by Trichoderma, mainly the antibiosis and mycoparasitism where it is used as biocontrol agents directly attack the plant pathogen by secreting lytic enzymes. *Glomus fasciculatum* found in association with great variety of cultivated plants and plants of natural forest communities. It helps in the increases plant growth and development by improving the rooting of micropropagated plantlets. They contribute to plant nutrition acquisitions by influencing the chemical and microbial ecology of the mycorrhizosphere.
Keywords: *T.harzianum*, Postharvest, Biofertilizer, *Candida oleophila*, *Glomus fasciculatum*, Biological Control, Antagonistic Fungi, Disease Control, AM fungi, Sesbania sesban, Micropropagation.

Introduction

Agricultural practices are now being implemented worldwide and a variety of methods are being exercised to meet sustainable, ecological, and economic development with the aim of increasing the yield simultaneously protecting the biosphere (Kour et al. 2020; Rastegari et al. 2020). The rising demand for food with the population increase has been a major concern worldwide. The pressure to fulfill the demands the growing population and reduce the hunger problems has led to the advancement of novel scientific technologies and agronomic practices (Kour et al. 2020). Himachal Pradesh is a hilly state situated in the heart of Himalaya in the Northern part of India.

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The climatic conditions vary from hot and sub-humid tropical in the Southern tracts to cold, alpine and glacial in the Northern and Eastern Mountain ranges with increasing elevation. Two-thirds of the area is covered by very dense evergreen to deciduous forest types. Himachal Pradesh has 12 major national parks and sanctuaries to conserve the flora and fauna of the main Himalayan range. However, the main threat for extinction of floral diversity is no doubt, the activities of human beings, but plant diseases also contribute to decline. The changeable geographical and climatic conditions of the state are favorable for the growth and development of plant pathogens. Bacteria, fungi and viruses have been reported as plant pathogens from the state of which rusts contribute as the main fungal group reported here. Now day's fungi are used in many regions of the world as a biological pest control. Beneficial fungi play a significant role in numerous physiological processes including minerals and water uptake, stomatal movement, photosynthesis and biosynthesis of compounds and mitigation to environmental stress like heat, salinity, cold and heavy metals. Fungal biofertilizer were helped for agriculture users to manage plant disease as well as the environment defence its capacity to unproved crop production (Kour et al 2020; Suman et al 2016). In recent year, the development of fungi for biochemical of disease, pests and weeds have received a significant amount of interest among the community of scientists and researchers. The most abundant species of fungi which are agriculturally significant found in the Himachal Pradesh are *Candida oleophila, Trichoderma harzianum* and arbuscular mycorrhizal fungi (*Glomus fasciculatum*) ectomycorrhizal fungi. Also, association of fungi with plant helps in defending against plant pathogens that indirectly promotes plant growth. So, use of fungi as a biofertilizer in agriculture plays an essential role in plant development by availing several minerals and growth regulators like auxin and gibberellins (Kour et al. 2019). *Candida oleophila* is an effective biocontrol agent and it is used to control the post harvest disease of fruit and vegetable among the antagonistic yeasts. The biocontrol activity and stress tolerance in *Candida oleophila* I-182 was also constructed. *C. oleophila* protect apple against most harvested decay. The biocontrol roles of Trichoderma species have emerged as an attractive choice in agriculture sector due to their environmentally friendly nature over synthetic pesticides (Mukherjee et al. 2012, 2013). *Glomus fasciculatum* arbuscular mycorrhizal fungi (AMP) are symbiosis formed between fungi of order Glomales and Roots of more than 80% of the extent terrestrial plant texas. We focused on studies conducted on the same agricultural significant fungi of Himachal Pradesh. There are various species of fungi they play significant role in the agriculture such as *Candida oleophila*, *Trichoderma harzianum* and *Glomus fasciculatum* etc. In this study we conducted a Meta analysis with more than 40 research papers to investigate the interactions between fungi and plant biotic stressors and their effects on plant growth performance. More performance was reduced in root-feeding than in shoot-feeding and in rotting than in wilt-fungal pathogens. All papers for our Meta-analysis should meet the following criteria :- (I). Studies should include pair wise control and experimental treatments. (II). Studies should report the definite identify information of fungi, biotic stress and host plants.

Material and Method

Study Area

Himachal Pradesh is a hilly state situated in the heart of Himalaya in the Northern part of India. The state extends between 30º22'40' – 33º12'20'' North latitudes and 75º44' 55''– 79º04'20'' East longitudes. The total area of the state is 55,673km2, covered with high mountains to plain grasslands. It is a mountainous state with elevation ranging from about 350 to 7,000 meters above sea level. The climatic conditions vary from hot and sub-humid tropical in the Southern tracts to cold, alpine and glacial in the Northern and Eastern mountain ranges with increasing elevation. There are large number of fungal species are found there.

Resources

This meta-analysis was based on executive bibliographilic survey of literature published in various national and international journals, monographs, online books on different agriculturally significant fungal species. For this meta-analysis we are going through various online sites of different universities and various research papers of different journals. We are going through the online sites of Dr. Yashwant Singh Parmar University of Horticulture and Forestry and CSK Agriculture University of Himachal Pradesh, Palampur. There is large number of species of fungi which occurred in H.P. but only few of them are agriculturally significant to the plants and crops. We are going through other site like Google Scholar, Science direct journals and Research gate and getting the information about it.

Selection of Species

There are large numbers of fungal species in H.P. most which are pathogenic and caused by harmful impact on the crop and plants. But there are some species of fungi which are caused the significant role in the plant growth and prevent the plant from diseases. The diverse growth of fungal communities is the key components of soil plant systems, where they engaged in an intense network of rhizophere, endophytic, phyllospheric interaction. After the detailed studies of the different literatures, we found some species of fungi which are useful in agrosystem and also reduce the cast as well as chemical fertilizers, restored the soils natural fertility and will also protect abiotic and biotic stress. Species distribution was assured on the bases of their occurrence on plant host, their families and their geographical distribution. A brief description on taxonomy and occurrence of these fungal species in different regions of H.P. is also presented. In order to confirm the validation of the gathered information, a review of literature was also carried out.

Results and Discussion

Candida oleophila: Yeast occurs in all natural environments particularly in sugar rich environments, skin of fruits, fermented foods and exudates of plant and has been described as potent antagonists of various plant pathogens. *Candida oleophila* is a yeast-like fungus which is also obtained from the various fruits skin like papaya, pears, apple etc. These all fruits are found in various districts of Himachal Pradesh like Hamirpur, Shimla and Solan etc (Sonali et al. 2021). So, the *Candida oleophila* is a pseudomycelial fungus which is yeast like fungi and use to protect papaya, apple, etc. from post harvesting. *Candida oleophila* strain O is single celled yeast which is found naturally on the plant tissue (fruits, flowers, and wood) and in water. It was originally isolated from golden delicious apple and is intended for the use as an antagonist to control the fungal pathogens. Most of the species of Candida are ubiquitous. They are mostly found on plant. *Candida oleophila* is a yeast – like fungus is grow partly as yeast and partly as elongated cell resembling hyphae. There are three different morphologies for the fungi species *Candida oleophila* that is yeast like, pseudohyphae and hyphae.

Significance

The yeast *Candida oleophila* are currently the rapidly growing research area with a significant role in increased food production and plant yield is "biocontrol". The phenomenon of biocontrol agent helps to sustain the food crop quality and to reduce the risks that result from the increased utilization of hazardous chemical and synthetic pesticide. In spite of the development water management practice, an agriculture practice that has posed to be the effective management of plant diseases, new techniques in agronomy, the development of disease resistance varieties, there are broadly used for the management of the disease (Kour et al. 2019; Yadav et al. 2020). Several postharvest diseases are biologically balance by using fungal. *Candida oleophila* strain O was also found to be very effective for controlling *Penicillium digitatum* and *Penicillium italicum* two devastating postharvest pathogens of Citrus (Lahlali et al. 2004; Lahlali et al. 2005). Applications of yeasts for biocontrol of fungi in agriculture postharvest technology, forest industry and food science present a new area of biotechnology. *Candida oleophila* is an effective biocontrol agent used to control postharvest disease of fruits and vegetables. *C. oleophila* I-182 was the active agent used in first generation of yeast based commercial product Aspire, is recommended for the control of postharvest decay of citrus and pome fruits. Among the antagonistic yeasts *C.oleophila* has been reported to be an effective biocontrol agent against several postharvest pathogens that cause decay in variety of the fruits including apple (El-Neshawy and Wilson, 1997), grapefruit (Droby et al. 2002), kiwi fruit (Wang et al.2018), banana (Bastiaanse et al. 2010) and pear (Niel et al. 2019). Several modes of actions for the biocontrol activities of *C. oleophila* I-182 have been demonstrated, including completion for nutrients and space (El-Neshawy and Wilson, 1997), induction of pathogenesis related genes and proteins (Droby et al. 2002; Liu et al. 2018), production of extracellular lytic enzymes (BarShimon et al. 2004) and superoxide anion production (Macarisin et al. 2010). The yeast *Candida oleophila* are generally commercial product Aspire, is recommended for the control of postharvest decay of various fruits like Citrus, apple, pome fruits etc. The involvement of fungal cell wall degrading enzymes is also play a role in the mechanism of action of yeast antagonists. The yeast *Candida oleophila* is capable of producing and secreting various cell wall degrading enzymes, including exo-β-1, 3-gluconase, chitinase and protease. Exo-β-1, 3-gluconase, chitinase and protease are act as lytic enzyme on the disease causing *Penicillium digitatum* and these enzymes are also help to degrade the cell wall of *Penicillium digitatum* and decrease its efficiency to cause disease on various fruits. *Candida oleophila* and exo-β-1, 3-glucanase are also had inhibitory effects on spores germination and germ tube elongation and also more inhibitory to the fungus. Exo-β-1,3glucanase is also act as biocontrol agent against *Botryis cinerea* on apples (Grevesse et al. 2003). The yeast *Candida oleophila* Montrocher (strain 182) is the basis of the commercial product Aspire, which is commercially used against the decay of the Citrus and apple fruit (Wishiewski et al. 1991). A pre-treatment of the yeast, *Candida oleophila* with 5Mm H2O2 for 30 minutes (sublethal) increased yeast tolerance to subsequent lethal levels of oxidative stress (50Mm H2O2), high temperature (40ºC) and low pH (pH4). Compared with non–stress adapted yeast cells, stress adapted cells exhibited better control of apple fruit infections by *Penicillium expansum* and *Botryis cinerea* and had initially higher growth rates in apples wounds. There are three *Candida oleophila* strain (L06, L07 Smooth and L07 rough) were evaluated in-vivo and in-vitro as biocontrol agents against *Penicillium expansum* on postharvest 'Holden delicious' apples (Malus domestica Borkh). The production of exo-β-1, 2-glucanase by the *Candida oleophila* is a possible mode of action for the efficient biocontrol of *Penicillium expansum* on post-harvest apples (Guerrero, Cesar et al.2014). *Candida oleophila* strain O is isolated from the surface of apples (Jijakli et al., 1993) effectively reduce the infection of three major post harvest diseases caused by *Penicillium digitatum, P. italicum* and *Geotrichum candidum* on the Citrus species. Anthracnose can be controlled by using post harvesting application of prochloraz or propiconazole or by hot water treatment in combination with the fungicides. However, in papaya, hot water dip treatment affects the ripening process and the use of fungicides for extended periods may cause the emergence of strain of fungus resistant to these fungicides. Further, the residues of

fungicides present on the fruit may be harmful to consumers. In most of banana growing areas, crown rot is principally controlled by postharvest fungicides treatment but alternative methods, including biological control are being sought because of (i) the emergence of resistance to some commonly used fungicides. (ii) Environmental problems linked to damping of fungicides mixture use at packing stations and (iii) consumer aversion to chemical residue in food. *C. oleophila* Montrocher strain O is a very important biocontrol agent for the crown rot disease of banana which is cause by *Colletotricum musae*. The use of fungi as biocontrol agents is greatly beneficial due to their metabolic diversity and efficiency that enhance the chances of finding the apt isolates for biocontrol and their relative environmental safety as they are primarily decomposers O is primarily through competition for nutrients and pre-colonization of plant wound sites, although information provided to the agency suggests that production of β-1, 3-glucanases (i.e., hydrolytic enzymes that can degrade fungal phytopathogen cell walls) may also make a restricted contribution to its antagonistic activity.

Trichoderma harzianum*:* *Trichoderma harzianum* species are ubiquitous in nature and found in all climatic zone (including temperate and tropical regions, tundra and Antarctic), nearly all soil types (crop fields, desert and marsh) and unusual niches such as lakes, marine bivalves, air, termites and shell fish. *T. harzianum* isolated from the Solan and Sirmour district of the H.P. whereas they grow in the green coloured cluster. It also occur in the Shimla region of H.P. *T. harzianum* were isolated from rhizophore soil of bean, maize, tomato, and radish in some district of H.P. (Ahmad and Barker1987). *T. harzianum* are highly successful colonizers of their habitats, reflected both by their proficient utilization of the substrate at hand and their secretion capacity for antibiotic metabolites and enzymes. Till date a huge species of Trichoderma has been reported. The phylogenetic profiling of Trichoderma species reported from diverse source worldwide.

Significance

The biggest advantage of using biocontrol agents is that they can eliminate the specific pathogen effectively from the site of infection and can be used in combination with biofertilizers (Mehta et al. 2013; 2014). Biocontrol agents avoid problem of resistance and also induce systematic resistance among the crop species. *T. harzianum* (T-35) controlled Fusarium wilt in cotton and muskmelon when applied in both naturally or artificially infected alluvial vertisol and sandy-loam soils respectively. The most commonly used BCAs of genus Trichoderma is *Trichoderma harzianum*, *T. flavofuscum* and *T. viride*. There are several antagonistic mechanism used by Trichoderma, mainly the antibiosis and mycoparasitism where it is used as biocontrol agents directly attack the plant pathogen by secreting lytic enzymes such as chitinase, β-1, 3-glucalose, cellulose and proteases (Haran et al.1996; Balasubramanian 2003). At present this genus consists of more than 260 species (Bissett et al. 2015; du plessis et al. 2018) and about 35 established species of Trichoderma are of economic importance either because of their ability to produce enzymes and antibiotics or use as biocontrol agents (Hjeljord and Tronsmo 2005; Kubicek et al.2003). Different strain of *T. harzianum* leads to the production of antibiotic and thus these strains have the ability to reduce wheat take all (Ghisalberti et al. 1990. Ahmed et al. 2009 studied the production and purification of their celluloses from T.*harzianum* exoglucanose (EXG), endoglucanose (EG) and β-glucosidose (BGL). Due to high cost of chemical inducers for these enzymes, there s a need to find some cheap organic inducers from agriculture wastes so that mass production of Trichoderma species could be increased. Studies on enzymes produced by *T. harzianum* are essential to find more proficient and low-cost enzymes, where will be useful in different steps of the hydrolytic process of biomass degradation. Oscillation of *T. harzianum* with diethofencarb plus carbondazium or its mixture with the iprodione in the vineyard reduced the diseases by 64-68% in post harvested rot initiated by *Botrytis cinerea* (Elad 1994). Observation of mycoparasitic potentiality of three species of Trichoderma, *T. harzianum*, *T. viride*, *T. hamatum* toward reducing the consequence of the pathogen on crop was evaluated. All the three tentative species of Trichoderma were capable to synthesize lytic enzymes. In fields it showed their ability to decrease the occurrence of the wilt diseases to a reasonable level where the *T. harzianum* is superior over the other (Ojha and Chatterjee 2011). Experiential evidence of the efficiency of three *T. harzianum* isolates (T2, T10 and T12) as biological control agents against charcoal rot in Glycine max L. was evaluated. Isolate T12 of *T. harzianum* shows extensively higher inhibition effect than T2 and T10 isolated. Therefore, the study supported the applicability ofT12 isolate as possible alternate to biocontrol of charcoal rot in soybean (Khalilli et al. 2016). In the study of Pascale et al. 2017, the influence of two Trichoderma strains and their secondary metabolites were reported on *Vitis vinifera* in terms of stimulation of antioxidant activity, disease resistance and plant growth promotion in the grapes.

Glomus fasciculatum: The symbiotic relationships between plants and mycorrhizal fungi are now recognized to be important to the health and productivity of many plant taxa. Under certain conditions mycorrhizae may enhance growth (Gerdemann1986), protect the host plant from pathogens (Marx1972) or both. *Glomus fasciculatum* found in association with great variety of cultivated plants and plants of natural forest communities. The root colonization was seen in arbuscules, vesicles, and mycelium form. Different types of mycelia like Y-shaped, H-shaped, coiled, beaded and parallel mycelia were reported in the roots of different plants. In some cases, extensive mycelial growth was also observed. *G. fasciculatum* are naturally occurring fungal symbionts in apple rhizophere. Their association with roots increased tolerances to wide range of root diseases in apple plants. The infection with mycorrhizal fungi elicits a resistance mechanism by the host which suppresses the subsequent infection by fungal pathogens. Plant inoculations with indigenous AM fungi exert a pro-biotic influence on the management of these diseases (Narender K. Bharat 2017). During survey of five different apple orchards in Himachal Pradesh, (Parmod et al 2006) found *G. fasciculatum* as most widely occurring species with highest spore count. The predominance of *G. fasciculatum* under varying soil condition might be due to the fact that they are widely adaptable to the varied soil conditions and survive in both acidic and alkaline soils (Pande and Tarafdar 2004). It isolated from the Kullu district of H.P. It showed 80% frequency of occurrence in soil collected from various locations of Kullu region. The occurrence of *G. fasciculatum* associated with the cherry roots might be due to biological characteristics of rhizosphere under host species mycorrhizal dependency and host plant mediated alteration of soil micro-environment (Wu et al. 2009). Glomus is most common and largest genus within the phylum Glomeromycota that form symbiotic relationship with plants roots. The genus includes species of arbuscular mycorrhizal fungi that frequently form abundant spores in soil and roots.

Singnificance

One of the most effective microorganisms involved in the stabilization of soil structure is arbuscular mycorrhiza (Miller and Jastrow 2000). They are economically important type of microorganisms and are exploited commercially in forestry and agriculture. Arbuscular mycorrhiza is a monophyletic lineage of obligate mycobionts (Schwarzott et al. 2001). They form symbiotic associations with plant roots belonging to phylum Glomeromycota (Owen et al. 2005). About 80-90% of explants species are mycorrhizal as phylum is an ancient from of symbiosis in plants. The ability of arbuscular fungi to form hyphae for nutrient uptake with highly favorable surface area to volume ratio and to secrete enzymes and organic acids is due to the mutualistic association (Owen et al. 2015). Mycorrhiza along with plant roots interface through their extra radical hyphae. Hence, they improve plant nutrient uptake mainly phosphate (Jakobsen et al. 2002; Bucher 2015), manganese, nitrogen and zinc. Arbuscular mycorrhiza is also beneficial to improve the nutrient acquisition of plants in soils with a low fertility rate. They serve as a substitute for reduced fertilizer input and lead to sustainable agriculture (Galvez et al. 2001). *G. fasciculatum* increased plant tolerance to salinity, drought and metal pollution (abiotic stress) and pathogenic infection, herbivore (biotic stress) (Auge 2004). It helps in the increases plant growth and development by improving the rooting of micropropagated plantlets. They contribute to plant nutrition acquisitions by influencing the chemical and microbial ecology of the mycorrhizosphere. In a disturbed ecosystem, they help to improve energy flow, nutrient cycling and plant establishment. The symbiosis by *G. fasciculatum* fungi helps to stimulate the synthesis of secondary plant metabolite which is essential for the plants to tolerate environmental induced stresses and beneficial to human beings through their antioxidant activity and protective nutrient compounds. It enhances the soil bioremediation as they are involved in phytoremediation use of plants for the uptake of pollutants. They are beneficial in revegetation and restoration of contaminated and disturbed areas as they keep in allowing toxicity of metals to plants by reducing the translocation of metal from the root to shoot. Its fungal hyphae improve the soil stability, water retention and binding property through the extra radical mycelial network. The only practice adopted worldwide for its management is soil fumigation with chemical fumigants. But soil fumigation with chemical has failed to provide a sustainable growth of new seedling as it also destroyed beneficial soil microflora including *G. fasciculatum* besides other environmental issues. *G. fasciculatum* live in association with the roots of many plants species including apple and benefit the host plants by increasing growth, nutrient uptake and defence mechanisms (Bharat and Bhardwaj 2001). The present study was planned to find out a potent indigenous *G. fasciculatum* fungal isolate and see its effect on growth of apple seedlings grown in apple replant disease (ARD) soil. In Himachal Pradesh, cherry occupies an area of 450 hectares with production of 202 metric tons fruit (Anonymous, 2014). The deterioration in environmental conditions due to indiscriminate use of synthetic inputs in modern agriculture has promoted the concept of organic agriculture, which relies on organic inputs and use of beneficial microorganisms. *G. fasciculatum* are known to benefit plant establishment by increasing resistance to environmental stresses, enhancing plant nutrient acquisition, water relations, diseases resistance and improving soil quality (Sally Smith et al. 2011). It showed the most promising and synergistic effects on vegetative growth of Capsicum annum. *G. fasciculatum* fungi improve plant growth profoundly through increased of phosphorus, nitrogen and nutrients. This study has demonstrated the interaction effect of *G. fasciculatum* species and Zn fertilization to improve productivity parameters with better plant growths, leaf nutrient uptake by the apricot seedlings. Among different *G. fasciculatum* fungi, the inoculation with *G. fasciculatum* and an application of 5.0mg Zn kg-1was the most effective treatment (Sunil et al. 2013) enhanced uptake of P is generally regarded as the most important benefit that *G. fasciculatum* provide to their host plant, and plant P status is often the main controlling factor in the plant fungal relationship (Koide et al.2000). Zn nutrition is also commonly reported as being influenced by *G. fasciculatum* fungal association, through the uptake of Cu and Fe has been reported (Clark and Zeto, 2000). Nitrogen concentration of grain and roots were increased by both mycorrhizal inoculation and P application compared to control, but lower P levels together its mycorrhizal inoculation gave the highest N concentration of grain in the present study. Mycorrhizal inoculation provides optimum yields at limited P soil levels. Low P fertilization levels combined with mycorrhizal inoculation provides optimum yield at lower cost (A.I. Ilabas and S. Sahin 2005). A variation in development of *G. fasciculatum* in roots of different medicinal plant species of fabaceae family has been observed. All medicinal plant and the extent of *G. fasciculatum* infection are controlled by the host plant as well as environmental factors.

Future recommendation

Chemical based control is very effective, but there are some disadvantages associated with the use of these chemicals. The most dangerous thing with the use of these chemicals is the toxicity which they impart to the soil. That is why today people avoid the use of chemical-based fungicide, which has presented a new era in the development of fungicide. The genes present in the fungi, *Candida oleophila*, *Trichoderma harzianum* and *Glomus fasciculatum* has the ability to enhance host plants resistance against phytopathogenic fungi and control the post harvest decay in citrus and pome fruits. During the last 20 years, several biological control agents have been widely investigated for use on different crops and pathogens. With the aim of extending the use of biofungicides, there have been many studies on the application of various combinations of control agents, and on the application integrated with physical and chemical means of protection.

The mechanism involved in the suppression of plant pathogens by different species of fungi:-

Species name	Biocontrol Factors	Host Organism	Significance
Trichoderma virens "Q" strain	Induction of plant phytoalexin by antibiotic compound gliovirin.	Phythium, Rhizopus, Oryzae	Enhances Biomass production and promotes lateral root growth.
T. harzianum, T.- 203, *T.virens*, isolate GL3 and GL21	Antibiotics gliotoxin and gliovirin and other inhibitory metabolites	Phythium ultimum, Rhizoctonia solani, Meloidogyne incognita	Inhibiting the plant growth
Glomus fasciculatum	Alpha – pinene,beta – crimene, d- linalool, geraniol	Coriandrum sativum	Reduce the damaging potential of the soil- borne pathogens
G. mosseae	Chlorophylls, phenolic compounds, carotenoids, anthocyanins	Lactuca sativa	Inoculation improves the root system , photosynthetic efficiency
Candida oleophila	BCA in combination with CaCl2 Solution controlled blue mold disease of apples.	Apple, pears	Control post harvest disease of fruits and vegetables
C. albicans	Beta- Glucanase Mp65 and Beta- 1,3 – glucanosyl tranferase Phr 1	Yeast (a type fungus)	Harmless commensal in the gastrointestinal and genitourinary tracts.

Conclusion

The present meta-analysis is based on the agriculture significance of some fungi species in Himachal Pradesh and worldwide. Fungi are a group of eukaryotic organisms which includes the non–chlorophyllous plants or organisms. There are large number of fungi species which are act as the parasitic organisms or pathogen for various plants and animals. But mostly fungi cause various dangerous diseases in plant and cause the loss in crops. Many fungi species are being developed and mass produced as a commercially available biocontrol agents and are used in agriculture to promote the growth of plants and increase plant defence mechanisms. Some fungi species such as *Candida oleophila*, *Trichoderma harzianum*, *Glomus fasciculatum* etc. play significant role in agriculture in worldwide and especially in Himachal Pradesh. *T. harzianum* suppresses the severity of diseases by antagonizing the pathogens and improves the growth of the plant through different modes of actions through the combination of mechanisms such as the production of cell wall degrading enzymes, antibiotics, competition for the growth production and key nutrition etc. *Candida oleophila* are also act as biocontrol agents to control the post harvesting diseases caused by *Penicillium expansum* in some important fruits such as apple, grapes, papaya etc. *Glomus fasciculatum* are help to increased plant tolerance to salinity, drought and metal pollution etc. Fungi are renewable source of nutrients and sustain soil health. The fungal endophytes are use against the proliferation and infection of the plant pathogen in competition. Mycorrhizal fungi are also help to enhance the tolerance of plants abiotic stress etc. So that the fungi as biofertilizers, biocontrol agent is very important and environmentally friendly as compare to the other harmful chemical pesticides, herbicides etc. So, the fungi are use as biocontrol agent, biofertilizers etc. and it play significance role in agriculture.

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