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Plant disease management and sustainable development using *Trichoderma*: A review

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Abstract
Avirulent expedient plant symbionts include *Trichoderma* spp. *Trichoderma* species function as a cost-effective and environmentally acceptable biocontrol agent in addition to being in plant-dependent organisms. They will establish themselves in various pathosystems, have little effect on the soil's equilibrium, and don't harm beneficial organisms that aid in the control of infections. *Trichoderma* is primarily employed as a biocontrol agent against several plant diseases. Asexual fungi known as *Trichoderma* spp. can be found in all sorts of agricultural soils as well as in rotting wood. *Trichoderma* species' hostile behaviour demonstrated that they parasitize a number of soil-borne and foliar plant diseases. *Trichoderma* acts as a biocontrol agent in plants through a number of different methods. However, due to its adaptability, its potential cannot be fully realised. *Trichoderma viride* was found to be most likely effective against *Fusarium oxysporum f. sp. ciceri,* followed by *Fusarium oxysporum f. sp. udum*, when its in vitro antagonistic activity against phytopathogens (*Sclerotium rolfsii, Fusarium oxysporum f. sp. ciceri, and Trichoderma viride*) was studied. This study provides an overview of the knowledge on *Trichoderma* as a biocontrol agent, its biocontrol activity, commercial production, and usage in plant disease management programmes. The information presented here strongly suggests that *Trichoderma* could be used as a secure, environmentally acceptable, and efficient biocontrol agent for many crop species.

Keywords: Activity, agriculture, antibiotics, biocontrol, mycoparasitism, *Trichoderma* species

Introduction
The organisms, genes or its products which do occur naturally and aid in suppression of the plant pest population are known as biocontrol agents and the process is called Biological control. In 1914, 'biocontrol' term was first promoted by Tubeuf and later on; in 1919, Smith added some more relevant interest to plant insects and pathogens. Distinct companies of bacteria and fungi are termed antagonistic microorganisms while weeds, insects, and pathogen of plants are called pests of plants. *Trichoderma* distributes its anamorph to genus 'Hypocreae' and generally, they are asexual filamentous fungi. They are free-living and deeply bilateral in soil, root, and foliar surroundings and can parasitize alternative fungi too (Harman *et al*., 2004) [30-31].

Usually, they are cosmopolitan and functional facultative anaerobes that can profusely colonize the roots and compete with rhizospheres. *Trichoderma* has great performance in biological cooperation as they have been employed as model microorganisms since they are recognized for rich construction of fungi toxic factors and extracellular proteins (Marra *et al*., 2006) [50]. As *Trichoderma* provides beneficial and cost-effective disease suppression methods, minimizes the use of chemicals; and being eco-friendly, it is gaining importance as a crucial biocontrol agent. *Trichoderma* have been involved in complex mechanisms, as they release a large number of heterologous proteins, affecting plant physiology and metabolism and induction of host defense. With new addition to the usefulness of this fungi, their course towards biocontrol promoter passes over many stages (Lorito *et al*., 2010) [48]. Suppression of plant pathogen chemically put forward many consequences like, the reduction of soil fertility, abasement in water resources, corrupt ecology and also disturb the surroundings (Ayala S, 2002 and Deshwal VK, 2003) [2, 18]. Therefore, management of the soil-borne plant pathogens and nematodes; by microorganisms, their products or genes has been recognized as distinct from the actual chemical treatment methods (Gerhardson B, 2002) [89]. They minimize the population and effects of soil-borne pathogens through distinct biocontrol technology like as ability to multiply rapidly for nutrients and space, releasing a huge amount of powerful plant degeneration stimulants which are highly toxic to any other macro and microorganisms.

Materials and Methods

Trichoderma Definition

Trichoderma is the most popular asexually reproducing fungi and is usually isolated from soil; approximately, all tropical and temperate soils accommodates about 101-103 culturable propagules per gram. Most of the biocontrol strains of *Trichoderma* do not have a known sexual stage but when they colonize the herbaceous plant and woody materials, teleomorph is often found as a sexual stage. Asexual forms of fungi display an immense level of genetic diversity in surroundings and can be used as products of economical and commercial interest. They can generate stimulants which help to degenerate the chitin and cellulose as they are creative manufacturer of extracellular proteins (Harman and Kubicek, 1998) [33]. Distinct strains can release more than 100 diverse metabolites that have familiar antibiotic action. Due to their "rhizosphere competence their capacity to colonise and thrive in close proximity to plant roots and the fact that they can exist in any type of habitat at high population densities, they have been used in agriculture. (Chet *et al.,* 1997) [14].

***Trichoderma* Biology:** *Trichoderma* are usually found in all types of surroundings; show a wide range of genetic diversity and have a relationship with mycoflora (Grinyer *et al*., 2004; Samuels, 2006; Zhang *et al*., 2007) [22, 62, 88]. They have been classified to in the order Hypocreales of Ascomycota as imperfect fungi and specifically confined from soil and decaying organic matter of plant (Howell, 2003; Küçük and Kivanç, 2003) [35, 41]. Distinct types of nutrients sources such as Potato Dextrose Agar, Malt Agar, and Czapek Dox Agar helps to propagate speedily, increase growth rate and also discharge conidia of diverse shade which can be analyzed by different shades of green color (Chaverri *et al*., 2003; Rey *et al*., 2001) [12, 57] and chlamydospores of thick-walled ware formed by few species of *Trichoderma* (Lu *et al*., 2004) [49]. Most of the species of *Trichoderma* have the capability to make parasitize to different other pathogenic fungal mycoflora associated with diseases and root rot, which is one of the most attributed features of this genus (Santoro *et al*., 2014; Verma *et al*., 2007) [65, 80]. They have been perceived as an impressive competitor for plant pathogens (Kim *et al*., 2012; Woo *et al*., 2006) [38, 83]. They are extensively found in distinct kinds of soils as opportunistic plant symbionts and also known as endophytic fungi (Chaverri *et al*., 2011) [13].

Morphological Attribute

Trichoderma can be identified morphologically by the process of the primary method of explanation using microscopic, media and cultural studies, which is not the definite process of distinguishing diversity among the species (Zhang *et al*., 2005). Under the ideal temperature, ranging between 25-30 ºC most of the *Trichoderma* species spread rapidly (Latifian *et al*., 2007) [45, 87]. Compounds like carbon and gas sources act as expansion mediums for them (Gao *et al*., 2007; Seyis and Aksoz, 2005) [21], and powder masses released by the sporulates of *Trichoderma* species can be recognized by green conidia (Chaudhari *et al*., 2011) [11]. Conidiophore usually consists of phialides and unicellular conidia at the tip of the hyphal arrangement which can't be observed in the first week of old media (Lu *et al*., 2004) [49]. Most of the species of *Trichoderma* have an ellipsoidal outline of conidia whereas some species have a globose type of conidia (Bissett *et al*., 2003) [4] and also smooth frame of conidia are present in some of the species of *Trichoderma* (Samuels *et al*., 2002) [63]. Green colors of conidia are usually observed but sometimes white, yellow, and gray can also be found which varied from species to species.

***Trichoderma* as Biocontrol Promoter:** The cosmopolitan and nonsymbiotic fungi are generally observed in decaying plant organic matter and soils (Harman *et al*., 2004 a) [30]. *Trichoderma* species are sufficiently present in most kinds of soils and they have biocontrol capability against many vital soil-borne pathogens and plant-parasitic diseases (Kushwaha and Verma, 2014; Olabiyi and Ruocco, 2013; Shahid *et al*., 2014) [44, 53, 67]. *Trichoderma* species have been popularized as biocontrol promoters for the management of different plant diseases (Weindling, 1932) [81]. They barraged alternative plant morbific fungi and helps to promote root and plant growth. Species of *Trichoderma* helps to protect against viruses and microorganisms and they also help to antagonize vital postharvest plant pathogenic fungus (Harman, 2006) [29]. They applied a distinct process for the management of infective plant pathogens and mycoparasitism, which always have competition for space and nutrition as they are elicited resistance of host cell.

There is a wealth of information in the literature about *Trichoderma* nutrition, but Rajput *et al*. (2014) [56] discovered that little was known about how certain carbon and nitrogen nutrients affect the production of *Trichoderma* antagonists in large quantities.

***Trichoderma* Ecology:** *Trichoderma* is typically located on the plant root surface and decaying bark of plant broken by the plant pathogens (Brotman *et al*., 2013; Samolski *et al*., 2011) [8, 61] and they are mostly cosmopolitan and omnipresent, available in diverse forms of soils (Olabiyi and Ruocco, 2013; Röhrich *et al*., 2013; Singh *et al*., 2014) [53, 58, 74]. Fragrance like Coconut due to 6-pentyl-2 pyrone helps to detect the rapidly increasing saprophytes as it acts as volatile compounds and most of the species are well known for the space and nutrient competitors (Tsai *et al*., 2008) [76]. *T. viride* and *T. polysporum* have characteristic to survive in cool temperature whereas *T. harzianum* can survive in hot conditions, which means that the atmospheric conditions affect the distribution of *Trichoderma* species (Sarhy-Bagnon *et al*., 2000) [66]. However, in South East Asia, *T. citrinoviride* has been reported which was not reported previously from the Asian countries (Zhang *et al*., 2005) [87]. *T. pseudookoningi* and *T. hamatum* have lots of tolerance behavior to excessive wet conditions, as compared to the other common species of *Trichoderma* (Kumar, 2007). They are commonly found in acidic soils and hence are omnipresent in nature (Carreras-Villasenor *et al*., 2012) [10].

***Trichoderma* Importance**: The *Trichoderma* species are solely responsible for the management of diverse kinds of infected plant diseases especially soil-borne morbific fungi belong to varied genera (El-Mohamedy and Alla, 2013; Gveroska and Ziberoski, 2012) [20, 25]. The species of *Trichoderma* vie similarly as survive within the territory of the advanced scheme and generally they are avirulent, expedient, and plant symbionts (Harman *et al*., 2004b) [31]. Their variety will increase when abundant healthy roots are present although, these are capable of winning root founder (Brotman *et al*., 2008) [7]. They develop the tolerance of a

plant by making available the micro-nutrients, phosphate; solubilization, and also in drought conditions, they broaden plant resistant capability. Some species of *Trichoderma* are used for commercial purposes and additionally, they degenerate advanced compounds of polysaccharides as they are economical producers of growth stimulants (Samanta *et al*., 2012) [60]. *Trichoderma* species typically don't harm the environment (Singh *et al*., 2008) [73]. As prominent alternatives to artificial chemicals (Gupta and Dikshit, 2010) [23], which developed interdependent relationships with plants instead of parasitic relationships (Brimner and Boland, 2003) [6], they reduce the likelihood of negative changes in people brought on by the use of artificial chemicals.

Exploration of *Trichoderma's* Ability to Upgrade Plant Resistance against Diseases: The conception of rising plant resistance by *Trichoderma* is widely accepted phenomenon. The pathogens that release aerial infection pointing to the induction of resistance mechanisms, got protected when the *Trichoderma* strains are found intercalary to the rhizosphere indicating systemic activation of defense (Harman *et al*., 2004) [30-31].

Bigirimana *et al.* (1997) [3] provided the first example of induced resistance in bean leaf sickness brought on by *Colletotrichum lindemuthianum* and *Botrytis cinere*. Yedidia *et al.* (1999) [85] later provided evidence in support of the theory through their research on cucumber phanerogam illness treated with *T. harzianum*. A wide range of metabolites produced by *trichomonas* serve as plant resistance elicitors and aid in the development of resistance against numerous plant diseases (Elad *et al.*, 2000) [19]. *Trichoderma* will improve plant growth by lowering elevated ethane levels which is harmful in the course of association and also elevating the antioxidative capability and overexpression of stress genes will conjointly suppress (Harman, 2000) [28].

Table 1: Different diseases controlled by *Trichoderma* spp.

S. No.	Involved pathogens	Name of Diseases	Name of Crops	References
1.	*Fusarium moniliforme Rhizoctonia solani*	Bakanae Sheath blight	Rice	Ng *et al*., 2015 Biswas and Datta (2013) [52 , 5]
2.	*Rhizoctonia solani*	Root rot	Chickpea	Gupta *et al*., 2005 [24]
3.	*Ustilago segetum*	Loose smut	Wheat	Singh (2004) [71]
4.	*Botryosphaeria beregeriana f. sp. piricola*	Ring rot	Apple	Kexiang *et al*., 2002 [37]
5.	*Fusarium oxysporum f. sp. lycopersici*	Fusarium wilt	Tomato	Komy *et al*., 2015 [39]
6.	*Rhizoctonia solani*	Dry root rot	Chilli	Bunker and Mathur (2001) [9]; Chosdon *et al*. (2021) [15]
7.	*Lasiodiplodia theobromae*	Die back	Guava	Yadav and Majumdar (2005) [84]

***Trichoderma* as a Bio-Control Promoter**

1. **Management of Diseases:** *Trichoderma* is a negative rhizosphere micro-organism and is extensively used against soil-borne diseases as a promising biocontrol agent. Distinct types of plant diseases can be controlled by the *Trichoderma* species as depicted above in table 1. For both foliar infection and soil-borne pathogens, they are reported to be highly effective. Against *Botrytis cinerea* in strawberry, cucumber, bean, and tomato and mildews in cucumber, general resistance was evoked by *Trichoderma* (Levy *et al*., 2015) [47]. To construct economical bio-control *Trichoderma* strains, and manufacture sensible impact agents of *Trichoderma* an exhaustive study is needed which can be important for the dominant plant diseases.
2. **Plant Growth Booster:** As an advertisement product and the initiative to prove the researched findings of beneficial effects of *Trichoderma* on plants was done by The Cornell University and BioWorks, Inc., Geneva, NY by the promotion of *Trichoderma*. Thousands of essays on crop plants have been conducted which mainly supported the fascinating results accomplished by *Trichoderma harzianum* strain-22 (Harman, 2000) [28]. Generally, in India, it's been used for control of Pythium rot, Fusarium wilt, and diseases of horticultural crops. Also, it has been tested against diseases in watermelon for the management of wilt disease. *Trichoderma* additionally helps to increase the yield of crops, being a growth-promoting agent that has been demonstrated by the application of *T. harzianum* in irrigated and dry areas (Sharma *et al*., 2012) [68]. As a biocontrol promoter, the adoption of *Trichoderma* is not a long story, however a reality that must be promoted for real-world success which can be currently concluded according to the market facts and information available (Harman, 2000) [28].
3. **Drought Tolerance:** *Trichoderma*, incorporates a dependent relationship with the host plant. The proteome and transcriptome of plants modified as a result of the interaction of *Trichoderma* metabolites or plant colonization. Under drought stress conditions, to support and enhance plant growth, fungi usually employed 3 mechanisms i.e. water-use efficiency, secretion of phytohormonal analogues, and alleviation of damage by reactive oxygen species. *Trichoderma* helps to avoid drought through morphological adaptations. It mediates drought tolerance via physiological and biochemical adaptations and enhances drought recovery.
4. **Mass Production:** For the mass culturing of *Trichoderma* spp. the foremost usually used solid substrates are sorghum grain (Upadhyay and*m* Mukhopadhyay, 1986) [78] and wheat bran-saw dust (Jogani and John, 2014) [36]. For the multiplication of *Trichoderma harzianum* and *Trichoderma viride* isolates, wastage of potato peeling, guava, spinach, brinjal, banana, papaya sugarcane, the medium of solid and liquid was reportable as a substrate. Molasses and brewer's yeast act as the expansion media used for the production of *Trichoderma* in liquid state fermentation (Sankar and Jeyarajan, 1996) [64], and for soy medium, Jaggery is widely used (Prasad *et al.*, 2002) [55]. The *Trichoderma* have relatively high monogenesis on solid substrates as compared to liquid media.

5. **Formulation:** Against the adverse environmental stress like high/low humidity, extreme pH, formulation helps to protect the a.i. (spores, conidia). If one expects the strain to return up to their expectations, the standard formulation is required. A minimum shelf-life of 2 years should be available for the final formulation at room temperature. The formulation should be stable over a range of 5 to 35ºC and must be simple to handle. Below are some of the major characteristics of a perfect formulation:
   - Should have capability to dissolve well in water
   - They should not be phytotoxic to agricultural plants, be dependable, and be reasonably priced for the control of plant diseases.
   - They ought to be strong enough to withstand unfavourable environmental conditions.
   - According to Kumar *et al*. (2014), they must be compatible with other agrochemicals.
   - They must have increased shelf life.

Table 2: Common commercial *Trichoderma* formulation used in India.

S. N	Pathogens controlled	Bio-control organism	Commercial product	Manufacturer/Supplier, Country
1.	*Pythium, Sclerotium, Fusarium, Rhizoctonia*	*Trichoderma virens*	Gliostar	GBPUAT, Pantnagar
2.	*Fusarium, Sclerotium, Pythium, Rhizoctonia*	*Trichoderma viride / T. harzianum*	Bioderma	Biotech International Ltd. India
3.	*Macrophomina* spp	*T. viride*	Antagon TV	Green Tech, Agro products, Rajaji Road Coimbatore
4.	*Fusarium, Rhizoctonia, Sclerotium, Pythium*	*Trichoderma* spp.	Monitor	Agricultural and Biotech Pvt. Ltd. Gujarat Department of Plant Pathology, MPKV, Rahuri
5.	*T. harzianum*	*Macrophomina* spp.	Trichostar	Green Tech, Agro products, Rajaji Road Coimbatore
6.	*T. viride*	*Fusarium, Rhizoctonia, Sclerotium, Pythium,* and alternative root rots; for *Botrytis* chemicals combination	Bio Fit	Ajay Biotech (India) Ltd. India (http://www.ajaybio.com)

6. **Delivery and Utilization Method:** The economical strain might fail to indicate its full potential, if correct formulations aren't applied in a very standardized manner. The performance of the *Trichoderma* strains gets affected by the application and delivery process. For the full exploration of the potency of *Trichoderma* strains, standardized methods of application and delivery should be adopted. The formulation of *Trichoderma* should be enforced through seed treatment, foliar spray, and soil application. They have great results on the management of tormentors and plant diseases when the formulation is mixed with the strain mixtures (Kumar *et al.*, 2014).

Table 3: List of commercially available *Trichoderma* and fungal biocontrol agents (Agrios, 2004; Das *et al*., 2021) [1, 16]

Name	Source	Target Pathogen	Host Crops	Applications	Formulations
Root shield, Plant shield T-22 Planter box	*Trichoderma harzianum* Rifai strain KRL-AG2 (T-22)	Root disease control *Fusarium, Pythium, Rhizoctonia, Thielaviopsis* and *Cylindrocladium*, PLUS *Phytophthora, Pythium (P. aphanidermatum),*	Farming and horticulture. Controlling pathogens encourages a healthier root system and increases the potential of the root mass. veggies, a greenhouse, and nurseries are appropriate media inclusions; Drench for use on vegetables, greenhouse plants, and nurseries.	Seed treatment, propagation material, drench, dip, spray, soil drench	Wettable Powder (WP) and Granules (Woo *et al*., 2014) [82]
F-Stop	*Trichoderma harzianum*	*Rhizoctonia, Pythium*	Ornaments and food crops	Seed treatment	Talc-based Formulation (Kumar *et al*., 2012) [42]
Soil Gard (GlioGard)	*Gliocladium* (*Trichoderma virens* GL-21)	*Rhizoctonia solani, Pythium*	Ornamentals, and food crops, greenhouses, nursery	Slurry, seed treatment	Granules (soil incorporation) (Woo *et al*., 2014) [82]
BINAB T	*Trichoderma atro viride* IMI 206040 (formerly *Trichoderma harzianum*)	Pathogenic fungi that produce wilt, take-all, root rot, internal degradation of wood products, decay in tree wounds, and Silver Leaf caused by *Chondrostereum purpureum* that is controlled by root contacts or pruning wound infection	Fruit Trees	Spray Pellets	(Woo *et al*., 2014) [82]
Promote	*Trichoderma harzianum* and *Trichoderma viride*	*Pythium, Rhizoctonia, Fusarium*	Transplants, Tree	Soil treatment	Talc-based and Liquid Formulation (Kumar *et al*.,

					2012) [42]
Rotstop	*Phlebia gigantea*	*Heterobasidion annosum*	Tree	Root treatment	Dry Formulation (Tubby *et al*., 2008) [77]
Trichodex (Sani-Root or Trichomic)	*Trichoderma harzianum*	*Botrytis cinerea, Collectotrichum spp., Monilia laxa, Plasmoparaviticola, Rhizopusstolonifera, Sclerotinia sclerotiorum, Fulvia fulva, Pseudoperonospora cubensis,*	Vegetables, ornamentals, fruits, turf: stimulates and protects root system, plantgrowth promotion	Seed and Soil treatment	Liquid Formulation (Woo *et al*., 2014) [82]
Tricholife	*Trichoderma viride*	It works well to treat crop problems such stem rot, root rot, and wilt.	Effective treatment for soil-borne infections that affect Bt crops include cotton, groundnuts, cumin, onion, and garlic as well as tobacco, sugarcane, bananas, papayas, and legumes.	Seed coating, spray	Wettable Powder (WP) (Woo *et al*., 2014) [82]
Trichostar	*Trichoderma viride*	Controlling soil borne diseases, collar, root, and stem rots, wilts, damping offs and leaf spots	Controlling plant diseases (cereals, pulses, sugarcane plantation crops, flowers, oilseeds) helps in the growth and development of plants and induces systemic resistance;	Seed coating, spray	Wettable Powder (WP) (Woo *et al*., 2014) [82]
TV190	*T. asperellum*	*Rhizoctonia solani*	Corn	Seed, Spray and Soil treatment	Granular and Liquid Formulations (Herrera *et al*., 2020) [34]

The Methods of Application and Delivery Process are Described Below (Singh, 2010)

Treatment of Seed: According to Jogani and John (2014), the recommended dose for formulations of talc and wheat bran-based seed treatments is @ 4 g/kg of seed. On the seed's surface, the treated *Trichoderma* propagules typically germinate. The germinating propagules of *Trichoderma* have the potency to colonize the seedling's rhizosphere and roots, once they are applied in the soils (Tewari, 1996). The seed is sprinkled with dry *Trichoderma* powder just prior to sowing. Commercial uses of antagonist dry powder range from 3 to 10 g per kg (Mukhopadhyay *et al*., 1992) [51]. For the management of sheath blight of rice, seed treatment with *Trichoderma* was found to be more effective (Das and Hazarika, 2000; Sriram *et al.*, 2000) [17, 74] and also helps to increase the crop yields as *Trichoderma* stimulates growth by influencing the balance of hormones such as IAA, gibberellic acid, ethylene and helps to control loose smut of wheat (Singh and Maheshwari, 2001) [70], and *R. solani* and *Pythium* spp. (Mukherjee and Mukhopadhyay, 1995).

Biopriming of Seeds: The method of bioprimming is treating seeds with biocontrol agents and incubating them in warm, humid settings until just before radical emergence. The sprouting conidia of *Trichoderma* typically assist in the formation of a layer around the seed in bioprimed seeds. They have greater ability to tolerate adverse conditions of soils. This method helps to suppress the biocontrol promoter that is applied to the seeds and also leads to the uniform emergence of seed plants, as this process has some of the potential advantages over easy coating (Kumar *et al*., 2014).

Dipping the Root of Seedling: In vegetable crops and transplanted rice, this process is highly applicable. The spore suspension is prepared by the process of mixing ten grams of *Trichoderma* powder with hundred gram of well rotten FYM per liter of water in which the seedlings or cuttings are dipped for ten minutes before the planting process, which helps to suppress the sheath blight sickness of rice (Vasudevan *et al*., 2002) [79]. This method also helps to improve the growth of seedlings in chilli, rice, and tomato (Singh and Zaidi, 2002) [72].

Management of Distinct Kinds of Diseases: *Colletotrichum* inflicting red rot of sugarcane, *Alternaria* spp. Inflicting *Alternaria* leaf spot disease, *Trichoderma* displays powerful antagonistic performance not only for these kinds of diseases but also for many other diseases like *Fusarium* spp. inflicting wilt disease in pigeon pea and *Paracercospora* spp. causing leaf spot disease of banana (Kushwaha and Verma, 2014) [44]. Regarding the suppression of plant diseases, it is better to use *Trichoderma* as biocontrol agents rather than the use of chemicals towards the microorganisms. To act as a decent bio-control promoter, the formulation should be prepared on exact concentration which can suppress the bacterial diseases too (Leelavathi *et al.*, 2014) [46].

Pest Resistance Capability: The majority of compounds have unique modes of action. A pathogen may develop resistance to a certain chemical if the chemical is applied repeatedly to a particular infectious agent. Therefore, using *Trichoderma* as a biocontrol promoter can lessen the usage of chemicals on plants and increase plant resistance to diseases by offering long-term protection. (Yedidia *et al*., 2000) [86].

Sensitiveness against Health and Atmosphere: The growers and the purchasers must have distinct kinds of sensitivity, as some of them valued to utilize more chemicals and some of them have majority against the use of biocontrol promoter for the restriction of plant diseases. Moreover among the individuals, awareness regarding the atmosphere will increases. So it is better to use biocontrol promoter that interferes with the plant pathogens, as they can leads to suppress the use of chemicals for the plant protection and have no more impact on surroundings (Harman *et al*., 2004) [30-31].

Long-Term Efficacy: As *Trichoderma* activates resistance against many diseases in plants, a single dose of operation of *Trichoderma* can offer future efficaciousness. Through dependent association with the plant roots, they can proliferate in the soil for a long period of time. But the period of efficaciousness is restricted and their effects last for many weeks (Harman *et al*. 2010) [32].

Trichoderma harzianum completely colonises roots as they expand and benefits plants for at least a season (Harman *et al*. 2000) [28]. *Trichoderma* spp. root colonisation frequently improves nutrient uptake and utilisation, crop yield, resistance to abiotic stress, and root growth and development (Saba *et al*. 2012) [59]. Viruses, bacteria, fungi, nematodes, and higher parasitic plants are just a few of the plant pathogens that *Trichoderma* has been used to successfully suppress biologically.

Conclusion and Future Perspective

To suppress and control disease, biological control appears to be an alternative to pesticides based on chemicals. *Trichoderma* is non-pathogenic to plants, according to scientists' findings, and must be prepared in a way that promotes the activity and survival of bacteria. Additionally, the unique idea of biocontrol requires a location outside of the lab to bear fruit in current industrial systems.

Sustainability is a crucial factor in the research into *Trichoderma's* potential as a biocontrol agent. Many species in this genus have the potential to be used as commercial biofungicides due to their ability to be adaptable plant symbionts and powerful mycoparasites. The development of trustworthy screening procedures that enable prediction of the biocontrol efficacy of a particular isolate by identification of the critical elements for this process will be the challenge in this area of research. To ensure a real positive impact on the environment, it is still necessary to examine the ecological impacts of the widespread use of a single (or few) fungal species in agriculture. In addition, farmers are also lacking in knowledge regarding its application. Therefore, the idea of commercialising *Trichoderma* needs to be enhanced, and cost-effective production methods need to be made more widely known. There is a connection between physiological and environmental conditions that impact BCA effectiveness and the incapacity of some biocontrol agents, such as *Trichoderma* species, to compete with phytopathogens. Therefore, molecular techniques and genetic engineering must be used to enhance BCAs so they can multiply and compete against a variety of phytopathogens. Therefore, this is required to support organisations working in this area.

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