NEW ERA AGRICULTURE MAGAZINE

Exploring the Diverse Functional Roles of Trichoderma spp. in Sustainable Agriculture

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Abstract: -

The overuse of chemical pesticides and fertilizers has had a number of detrimental effects on both human health and the environment. They reduce soil fertility, strengthen pathogen resistance, suppress microbial activity, and increase greenhouse gas emissions. Chemical insecticides alone are ineffective and unsuitable for controlling plant diseases. To achieve sustainability in agriculture, organic insecticides and fertilizers should be prioritized. In recent years, innovative farmers have begun using Trichoderma as a substitute for conventional pesticides and fertilizers. The main reasons for its low adoption among farmers are its slow rate of colonization and reproduction, susceptibility to biotic and abiotic stressors, inadequate pathogen eradication, and high cost. To overcome these obstacles, several strains of Trichoderma that have a broad host range on infections, can multiply and colonize quickly, and are least impacted by environmental factors should be found. Additionally, in order for Trichoderma to be widely adopted, farmers need be informed about its significance in agriculture through a variety of extension services. As a biofertilizer, bioremediator, and biocontrol agent, trichoderma may be a practical and sustainable substitute. However, the application of Trichoderma at the farmer level is still unsatisfactory, and its use is restricted to research operations. Therefore, the purpose of this study, which is based on a critical analysis of research works from researchers around the world, is to disclose the current state of Trichoderma use, as well as its significance, modes of action, application and multiplication techniques, obstacles to widespread adoption, and suitable solutions.

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Introduction:

In addition to having a number of detrimental effects on human health, the careless use of chemicals in the name of intensive agriculture has deteriorated the environment and soil quality. They increase pathogen resistance to pesticides and put non-targeted species at danger. Additionally, the extensive use of chemicals in agriculture causes biodiversity loss and greenhouse gas emissions. Therefore, in order to achieve agricultural sustainability, it is imperative to look for agricultural practices or procedures that are safe for the environment and human health. According to Norman et al. (2000), sustainable agriculture is an all-encompassing approach that strives for overall farming success while taking into account environmental friendliness, the quality of human and animal life, low economic expenses, and the least amount of risk to all the contributions farmers make to their community. According to Abo-Elyousr et al. (2014), sustainable agriculture is essential to ensuring food security for the world's fast-growing population. Therefore, in order to implement sustainable agriculture, we must first reduce the use of heavy chemicals and prioritize the use of organic pesticides and fertilizers. In this sense, Trichoderma may be the right bioagent that is essential to achieving the objective of sustainable agriculture. It can be used as a bio-fertilizer, bio-control agent, and bio-remediator. As a result, it offers a lot of potential for sustainable farming practices like organic farming, integrated pest management (IPM), and integrated nutrient management (INM).

Trichoderma are asexual fungus that can withstand all soil pH ranges. They reproduce by chlamydo spores and ascospores. 25–35°C is the ideal temperature. It has a great potential for outbreaks and is highly dominant over all other fungi. It is typically found in plant roots as a dominant fungus and symbiont, and it is thought to be antagonistic to other fungi. According to Benitez et al. (2004), Trichoderma has a strong ability to compete with other microorganisms by creating an environment in the soil that is more acidic, which is detrimental to other pathogenic microbes, and by producing iron chelating compounds, which absorb soil iron compounds and make other microbes deficient in iron. Through the manufacture of specific metabolites such growth regulators, enzymes, antibiotics, and siderophores, Trichoderma limits the growth of other pathogenic bacteria through three key mechanisms: antibiosis, competition, and mycoparasitism. The majority of the 89 species of the genus Trichoderma, which are found all over the world, are useful in agriculture. Agriculture has long made use of trichoderma. Since the

1920s, Trichoderma's antagonistic activity against the majority of infections has been recognized. In a similar vein, Trichoderma is increasingly being used as a biofertilizer and to manage soil and seed-borne plant diseases. However, compared to chemical pesticides and fertilizers, its adoption rate is lower. Its uptake by farmers worldwide is still unsatisfactory. Its adoption may face obstacles that are on par with or greater than the use of chemical pesticides and fertilizers, and these obstacles must be recognized. Therefore, the purpose of this study is to identify the various applications of Trichoderma, as well as its mode of action and application techniques, as well as the obstacles to its widespread adoption, and to offer suitable solutions by critically analyzing the circumstances.

Trichoderma as a substitute for chemical pesticides and fertilizers

If all farmers were aware of the advantages of using Trichoderma in agriculture and the detrimental effects of chemicals, they would undoubtedly choose it. Farmers benefit from trichoderma since it is inexpensive and environmentally friendly. Trichoderma is widely employed to manage a variety of plant diseases, including bacteria, viruses, fungi, nematodes, and many higher plant parasites. It is widely employed and has a far wider range of applications because of its long-term persistence on soil and other parts. Along with stem length, thickness, and chlorophyll content, it also improves plant growth, development, and yield. Sachdev and Singh (2020) discovered that Trichoderma and plants interact to produce volatile compounds that aid in pest control. Chemical pesticide residues linger in the soil for a while, damaging the soil ecosystem and making plants more poisonous. Unlike chemicals, Trichoderma can metabolize a range of high and low molecular weight polycyclic aromatic hydrocarbons and reduce or eliminate harmful substances in soil. In addition to suppressing the growth of pathogens, Trichoderma has the ability to build resistance and improve a variety of physiological processes in plants. It promotes micronutrient uptake, reduces the need for artificial NPK fertilizers, and aids in phosphate solubilization. Chemical fertilizers quickly lose their nutrients through volatilization or leaching, but Trichoderma persists in soil for a long time. We can verify that Trichoderma can be a practical and sustainable substitute for chemical pesticides and fertilizers after taking all of these factors into account.

Using trichoderma as a biofertilizer

Through many biological processes, Trichoderma provides nutrients to the plants. Unlike synthetic fertilizers, they enhance microbial activity and soil characteristics. Compared to chemical fertilizers, they can sustain soil fertility for a longer amount of time. They can be used in the field either by themselves or in conjunction with biofertilizer and other chemicals. According to Haque et al. (2010), applying 50% nitrogen fertilizer and 50% trichoderma enhanced biofertilizer can boost tomato and mustard yields by 108.36% and 125.45%, respectively, over control conditions.

In a similar vein, Doni et al. (2017) found that applying Trichoderma enriched biofertilizer in an SRI system boosted rice plant height, photosynthetic rate, chlorophyll content, stomatal conductance, and tiller and panicle numbers. Additionally, Trichoderma may make micronutrients more accessible to plants. After 60 days of tomato plant transplantation, Khan et al. (2016) discovered that minerals such as K, Cu, Fe, and Zn levels in the roots zone were considerably greater with 100% Trichoderma loaded biofertilizer than the required dose of NPK. Compared to farmyard manure (FYM) at the same dosage, Trichoderma enriched biofertilizers are twice as effective at raising brinjal yield characteristics. In comparison to urea, Wang et al. (2018) found that viable and nonviable T. viride could reduce ammonia volatilization by up to 42.21% and 32.42%, respectively. Therefore, in addition to preserving soil fertility, microbial activity, and soil structure, Trichoderma spp. can boost fertilizer usage efficiency and thereby reduce environmental pollution.

Trichoderma as bioremediator: The term "bioremediation" describes the use of possible bioagents to break down environmental contaminants. The amount of chemical residue in the environment is growing daily, which is seriously endangering human health as well as causing a significant loss of biodiversity. In this sense, using Trichoderma may be a practical and sustainable treatment.

Difficulties in adopting Trichoderma instead of chemical pesticides and fertilizers

The effectiveness of Trichoderma and its contribution to bettering agricultural practices around the world have been highlighted in numerous papers. However, aside from the realm of words, it has very little use in the actual agricultural field. The use of biocontrol agents is still restricted in commercial agriculture, despite the fact that numerous researchers have studied the subject and published thousands of papers on it.

Although Trichoderma has the potential to transform agriculture, as detailed in various academic publications, there is currently no practical and cost-effective way to use it in the field of agriculture. According to Topolovec-Pintaric (2019), biocontrol agents such as Trichoderma are rarely used in underdeveloped nations that rely heavily on agriculture. When compared to chemical use, full-scale production, marketing, and licensing procedures are unfavorable, and the products of biocontrol agents are too costly to be considered for use. Using biological agents like Trichoderma in a system where chemical fungicides offer a better and more cost-effective match is the main difficulty. Harman (2000) identified four main causes for businesses' lack of interest in commercializing the use of biological agents as a seed treatment to safeguard the seeds.

The reasons were as follows: (i) highly effective chemical pesticides for seed protection were available; (ii) chemicals were less expensive than biologicals; (iii) chemically treated seeds had a longer shelf life than biologicals; and (iv) chemicals' effects could withstand a greater range of temperatures and other environmental conditions than biologicals. Chemical pesticides and fertilizers work quickly and can be beneficial in a short amount of time. Additionally, chemical-based insecticides have the power to completely eradicate pest populations. However, compared to conventional pesticides and fertilizers, Trichoderma sometimes takes longer to develop, is only effective in favorable conditions, and often lowers rather than entirely eliminates a pest population. Additionally, because there are already many better, market-favored short-term alternatives to bio-control agents, the pesticide corporations do not want to take a chance by investing in their commercialization.

Conclusion

Agriculture can only become sustainable if organic insecticides and fertilizers are prioritized. As a biofertilizer, bioremediator, and biocontrol agent, Trichoderma is a desirable substitute for artificial pesticides and fertilizers. Its usage in managing numerous plant pathogens, such as fungi, nematodes, viruses, bacteria, etc., has increased due to its capacity to compete with various other harmful species. Trichoderma may be useful in managing plant diseases through a variety of mechanisms (mycoparasitism, competition, antibiosis, induced resistance, etc.). In addition to helping the soil absorb nutrients, trichoderma also plays a part in boosting the effectiveness of chemical fertilizers. It increases microbial activity and enhances soil qualities. Various Trichoderma species have been found to be bioremediators of environmental contaminants, including petroleum products and heavy metals. It has demonstrated efficacy as a biocontrol agent against many plant diseases. These arguments lead us to the conclusion that it has a great deal of promise for achieving the objective of sustainable agriculture. Despite these benefits, it is not as frequently used as chemical insecticides and fertilizers. The main obstacles to its widespread adoption are its slow action, inability to completely eradicate plant diseases, high cost, and limited use in favourable environments. Future study should therefore focus on isolating and identifying several strains of Trichoderma that are effective against a variety of pathogens, tolerant of both biotic and abiotic stress, and have a high rate of colonization and reproduction. Farmers should be informed about the benefits of Trichoderma and the negative impacts of artificial pesticides and fertilizers. Additionally, strategies like integrated pest management (IPM) and organic farming should be prioritized for the widespread use of Trichoderma.

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