Role of Trichoderma in Natural Farming

[Article ID: SIMM0243]

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Abstract

Natural Farming is the process of transition towards a more local, resilient and adaptive agro-ecology based farming. This farming relies on using natural locally found products and inputs which the farmer can make on their own or buy from their local region, increase cropping intensity through multiple cropping systems, increasing soil organic matter and increasing soil health particularly microbial population. Natural farming is microbe intensive which sustains the nutrients. Many micro pest antagonists such as Pseudomonas, Bacillus, Trichoderma and other entomopathogenic microbes and earthworm, beneficial insects, and bees will be available in plenty in natural farming. Numerous studies documented the beneficial properties of avirulent *Trichoderma* strains which allow their use in plant protection, bio-stimulation, and biofertilization in natural farming.

Introduction

The news science of modern ecological farming being adopted by farmers includes Sustainable ecological farming, Natural Farming, Organic Farming, Agroecology, Regenerative Agriculture, Sustainable Agriculture, Biodynamic Farming, Permaculture, SPNF, ZBNF etc. "Natural Farming is the process of transition towards a more local, resilient and adaptive agro-ecology based farming." Common principles behind natural farming include

- Using natural locally found products and inputs which the farmer can make on their own or buy from their local region
- Increase cropping intensity through multiple cropping systems
- Increasing soil organic matter
- Increasing soil health particularly microbial population

Essential practices of Natural Farming

- Knowledge of the practices
- Technology beneficial today and for the next several decades
- Scientific validation of the biological systems and the natural processes happening in nature
- Creating values beyond yield, inputs and products; which embraces diversity, and supports the systemic transition process

Main approaches for adoption of Natural Farming

- Water and moisture management by using locally viable cropping systems, rain water harvesting, soil organic matter improvement and efficient irrigation systems.

- Increasing cropping systems through crop rotation, multiple crops, intercrops, poly crops, diversified farming systems and staggered production techniques.
- Sustainable soil nutrient management with minimum tillage, organic amendments, mulching, manuring, homemade biofertilizers and composting.
- Organic seed systems
- Livestock management
- Non-pesticidal management

Fungi and plant diseases

Plant diseases play a direct role in destroying natural resources in agriculture and are reported to be a major cause of reducing the annual level of food production in the world, which, depending on the source, is estimated at the level of 10–40%. According to the Food and Agriculture Organization of the United Nations (FAO), plant mycoses most often affect the five most important world crops—rice, wheat, corn, potatoes, and soybean. Presently, more than 19,000 species of fungi that cause diseases of crops are known worldwide. Most of the fungal phytopathogens belong to the Ascomycota and Basidiomycota phyla, the most serious of which are representatives of the genera *Cladosporium*, *Botrytis*, *Alternaria*, *Aspergillus*, *Verticillium*, *Pythium*, *Fusarium* (Ascomycota), and *Rhizoctonia* (Basidiomycota).

To protect the environment from the negative effects of chemical fungicides, various actions and strategies of sustainable food production systems are taken, including Integrated Pest Management (IPM) and organic farming as well as natural farming. One of these strategies is the use of Biological Control Agents (BCAs), based on living microorganisms or their metabolites, and products of natural origin that control the population of plant pathogens.

Experimental evidences have shown that a large number of bacterial and fungal strains have been employed as BCAs,including *Pseudomonas* spp., *Bacillus* spp., *Streptomyces* spp., *Trichoderma* spp., *Glomusmosseae*, *Gliocladium virens*, *Pythium oligandrum*, and *Beauveria bassiana*, which successfully control the soil-borne diseases of valuable crops caused by fungi, oomycetes, bacteria, and nematodes.

Trichoderma and its characteristics

Among filamentous fungi, most of the BCAs belong to the phylum Ascomycota and are mainly representatives of numerous species belonging to the genus *Trichoderma*. Numerous studies documented the beneficial properties of avirulent *Trichoderma* strains which allow their use in plant protection, bio stimulation, and biofertilization. The effectiveness of using *Trichoderma* in agriculture depends on their metabolic activity and the type of interaction with plants and other microorganisms. These fungi effectively colonize the rhizoplane, rhizosphere, and plant roots, and produce several metabolites with anti-microbial (cell wall degrading enzymes, antibiotics, volatile, and non-volatile compounds) and bio stimulating (phytohormones, Phyto regulators) features. Moreover, *Trichoderma* is known for its intensive absorption of root schedules and interaction not only with pathogenic microorganisms, but also interactions with the entire soil microbiome. *Trichoderma* is a dominant component of the mycobiome of various soil ecosystems (such as farmland, prairie, forests, salt marshes, and deserts) in all climatic zones, including temperate and tropical regions, Antarctica, and the tundra. The *Trichoderma* genus is classified as cosmopolitan, saprotrophic fungi, often living as endophytes of woody plants.

Biocontrol properties of Trichoderma

Trichoderma fungi act various complex direct or indirect mechanisms against fungal pathogens, which usually interact altogether in the biocontrol phenomenon. The direct impact on pathogens includes the production of cell wall degrading enzymes (CWDEs), synthesis of antibiotics, competition for space and nutrients (mainly carbon, nitrogen, and iron), and establishment of a direct parasitic relationship with the fungal pathogen. On the other hand, *Trichoderma* indirectly induces local or systemic plant resistance through products released from the cell walls of the plant host and the infecting microorganism.

1. The fungi of the *Trichoderma* genus are mostly classified as necrotrophic mycoparasites. Over 75 *Trichoderma* species with high mycoparasitic potential have already been described. The mycoparasitic effect of *Trichoderma* necrotrophs on fungal pathogens includes prey sensing and chemotaxis, adhesion to the host, and physical attack through intense branching and coiling around the host's hyphae.

2. *Trichoderma* strains are mainly characterized by the ability to secrete a set of extracellular enzymes, including chitinases, β-(1,3)-, β-(1,6)-glucanases, and proteases, which hydrolyze the main components of the pathogen's cell wall.

3. The *Trichoderma* species have been found to produce numerous secondary metabolites, over 370 of which belong to different classes of chemical compounds with strong antagonistic properties. Most *Trichoderma* strains produce non-volatile and volatile organic compounds (VOCs), the most important of which are peptaibols and polyketides. About 17 biotechnologically and agriculturally important species from the Longibrachiatum Clade, (e.g., *T. citrinoviride*, *T. longibrachiatum*, *T. pseudokoningii*, and *T. reesei*) produce several new peptaibols, mainly related to trichobrachins, suzukacillins,trichoaureocins,trichocellins, longibrachins, trichokonins, trichosporins, alamethicins, and brevicelsins.Moreover, *T.harzianum*

has been found to synthesize trichorzins (HA, MA, and PA), harzianins, trichotoxin, and trichokindins. Other than that, *T. atroviride* releases peptaibols, such as atroviridins A–C and neoatroviridins A–D, while *T. viride* produces trichotoxins A and B, trichodecenins, trichorovins, and trichocellins.

4. The antagonistic fungi can deprive pathogens of space and nutrients by colonizing a common habitat, i.e., plant tissues, rhizospheres, or phyllo spheres.

5. In natural farming, plant protection is done by natural phenomenon by plant immunity and push -pull effect of insects by crop diversity. The plant immunity is depending on the humus content and microbial diversity in the soil and plant (Rhizopsheric bacteria and Phyllospheric bacteria). Plants usually develop direct defence against insect herbivores and indirect defence to promote the effectiveness of natural enemies of insect herbivores. This is done by soil microbes. Many useful soils borne microbes (e.g. Root endophytic fungi, mycorrhizal fungi, plant growth promoting fungi, rhizobacteria and rhizobia) exert positive effects on plant growth and survival through direct and plant mediated mechanisms. These mechanisms promote plant growth and Induce Systemic Resistance (ISR) in plant. This is observed in case of natural ecosystems. Various plant species, both monocotyledonous and dicotyledonous, show an increased activity of the immune response in the presence of non-pathogenic fungi of the *Trichoderma.* Three types of induced resistance in plants are activated as a result of the MTI and ETI immune pathways induction by *Trichoderma*. Those are (1) systemic acquired resistance (SAR) effective against biotrophic pathogens, (2) induced systemic resistance (ISR) effective against necrotrophic pathogens, and (3) induced resistance (IR) effective in defence against biotrophic and necrotrophic pathogens and some abiotic stress factors. The SAR is characterized by the expression of pathogenesis-related (PR) protein genes and the production of salicylic acid (SA) as a signaling molecule. In turn, jasmonic acid (JA) and ethylene (ET) are crucial signalling molecules in ISR-type immunity. The IR immunity is activated by β-aminobutyric acid (BABA) and involves abscisic acid (ABA) as a signalling molecule.

6. Numerous strains of *Trichoderma* have been developed as biocontrol agents against plant diseases caused by bacteria, nematodes, and insects. The antibacterial activity of *Trichoderma* is most often attributed to the secretion of secondary metabolites, the most important of which are peptaibols, gliotoxin, polyketides, gliovirin, and pyrones. Recent studies demonstrated that *Trichoderma* can enhance plant protection against insect pests, such as aphids, thrips, moths, and caterpillars.

7. Numerous studies confirmed the ability of *Trichoderma* not only to colonize the rhizosphere soil, but also to colonize the root surface. The synthesis of the indole-3-acetic acid (IAA) hormone by *Trichoderma* results in the enhancement of the colonization capacity of the rhizosphere, rhizoplane, and roots of monocotyledons and dicotyledons. Several scientific reports indicate the ability of numerous species from the *Trichoderma* to synthesize GA's. The production of GA by the *Trichoderma* strain is positively correlated with the synthesis of phytohormone IAA and phytoregulator ACC-deaminase.

8. *Trichoderma* plays a crucial role in enhancing plant growth by the production of vitamins, increasing the solubility of nutrients contained in the rhizosphere (phosphates, Fe^{3+}, Cu^{2+}, Mn^{4+}, ZnO), and supplementing the plant with the necessary elements (mainly nitrogen, phosphorus, potassium, and microelements) for their proper growth and yield.

9. Natural farming is microbe intensive which sustains the nutrients. Each crop in natural farming has different association of microbes in rhizosphere which develop crop based microbial diversity which help in improving fungal: bacteria ratio for nutrient fixation. Many micro pest antagonists such as Pseudomonas, Bacillus, Trichoderma and other entomopathogenic microbes and earthworm, beneficial insects, and bees will be available in plenty in natural farming.

Conclusions

Trichoderma uses several complex direct and indirect biocontrol mechanisms, both against biotic stresses, such as wide spectrum of pathogenic microorganisms (fungi, bacteria, insects, and nematodes), and abiotic stresses—unfavourable environmental conditions. The knowledge about the extraordinary abilities of *Trichoderma* gained in recent years contributes to the creation of biopreparations based on strains with a comprehensive and beneficial effect on plants. These *Trichoderma* preparations will find wide application in organic farming as well as natural farming to combat plant diseases of various etiologies, where they have a chance to provide complete protection without the use of chemical pesticides. In turn, the resistance of *Trichoderma* to chemical pesticides will make it possible to combine these fungi in preparations with low concentrations of various, newly introduced and modified, chemical pesticides. Furthermore, *Trichoderma* has the great potential to become the basis of new phytoremediation technologies due to its resistance to a variety of toxic chemicals, both organic and inorganic, and increase plant tolerance to stress factors under conditions of xenobiotic contamination. Importantly, these solutions are in line with the idea of sustainable agriculture as well eco-farming practices.