TRICHODERMA SPP: MULTIFACETED MECHANISMS OF BIOCONTROL AND PLANT GROWTH PROMOTION

Kartikay Bisen, Vinay J Silas, Aneeta Yadav

Faculty of Agricultural Sciences and Allied Industries, Rama University, Kanpur-209217

Corresponding Author Email: kartikaybisen.fas@ramauniversity.ac.in

Abstract

Recent shift in trends of agricultural practices from application of synthetic fertilizers and pesticides to organic farming has brought into focus the use of microorganisms those carryout analogous functions. Exploitation of agriculturally important microorganisms in plant growth promotion and antagonistic potential is a well investigated area. Trichoderma spp. are widely acknowledged for their potential to parasitize plant pathogenic fungi and have been efficiently utilized for biocontrol of wide range of seed and soil borne phytopathogens.

Key Words: Biocontrol**,** Agriculturally Important Microorganisms, Secondary Metabolites, Formulation, Systemic Resistance

Introduction

Conventional farming around the world is primarily based on chemical fertilizers and pesticides for plant nutrition and disease management, a practice which pounded huge negative impacts on human and environment health. Globally, rising awareness of the hazardous effects of synthetic pesticides has increased the demand for safer alternatives. Various microorganisms are currently being explored and utilized as biological control agents (BCAs) or biopesticides. Popular BCAs include Trichoderma spp., Pseudomonas fluorescence, Bacillus spp., Ampelomyces quisqllalis, Agrobacterium radiobacter, non-pathogenic Fusarium, Coniothyrium, atoxigenic Aspergillus niger ().

Trichoderma spp. are filamentous ascomycetes which are frequently isolated from the soil of all climatic zones. The most typical habitats of these fungi include soil and rotting wood. These fungi may be found on sclerotia and other propagating forms of fungi in the soil environment. They colonise the grain, leaves, and roots of plants (Harman et al. 2004). They were also isolated from such unusual sources as marine bivalves, shellfish, and termites. Fungal species from the genus Trichoderma are characterised by rapid growth and abundant production of conidial spores as well as the capacity to produce sclerotia. These species produce several pigments, ranging from a greenish-yellow up to a reddish tinge, although some colourless specimens are also present. The conidia may also have diverse colouration, ranging from colourless to different hues of green or even grey or brown tinges. In addition to the industrial

ISSN PRINT 2319 1775 Online 2320 7876
 UGC CARE Listed (Group -I) Journal Volume 12, Iss 07, 2023

importance of the genus, certain Trichoderma species have the ability to antagonise plant pathogens.

Approximately, there are 1400 biopesticide products being sold worldwide (NAAS 2013). The total market share of biopesticides was around 0.2% of the total pesticides market during the year 2000 and it amplified to 4.5% by 2010. The market value is expected to reach around US$ 1 billion (Singh et al. 2012). In India, currently 34 microorganisms have been included in the schedule of Gazette of India for registration as biopesticide with Central Insecticide Board, Faridabad under section 9(3B) and 9(3) of the Insecticides Act, 1968 (Table1).

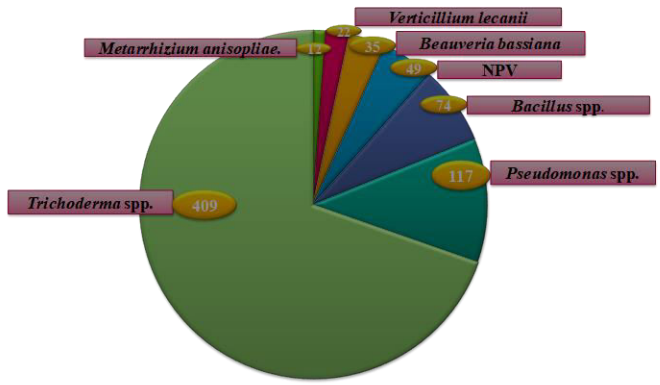

Figure 1 Share of Trichoderma based biopesticide in biopesticide market

Table 1: Microbes listed in Gazette of India for production of biopesticides and registration under section 9(3B) and 9(3) of the Insecticides Act, 1968

Bacterial	Fungal	Viral
Burkholderia cepacia	*Verticillium chlamydosporium*	*Grannulosis* viruses
Agrobactarium radiobacter strain 84	*Streptomyces griseoviridis*	Nuclear Polyhedrosis Viruses (NPV)
Agrobactarium tumefaciens	*Streptomyces lydicus*	
Erwinia amylovora (hairpin protein)	*Candida oleophila*	
Alcaligenes spp.	*Fusarium oxysporum* (non pathogenic)	
Photorhabdus luminescences akhurustii strain K-1	*Penicilliuim islanidicum* (for groundnut)	
Photorhabdus luminescences	*Pythium oligandrum*	
Serratia marcescens GPS 5	VAM (fungus)	
Bacillus subtilis	*Trichoderma* spp.	
Pseudomonas fluorescens	*Aspergillus niger* – strain AN27	
	Gliocladium spp.	
	Beauvaria bassiana	
	Verticillum lecanii	
	Metarrhizium anisopliae	
	Nomurea rileyi	
	Hirsutella sp.	
	Ampelomyces quisqualis	
	Phlebia gigantean	
	Coniotyrium minitans	
	Chaetomium globosum	
	Myrothecium verrucaria	
	Paecilomyces lilacinus	
	Piriformospora indica	

Trichoderma spp. in plant disease management

Trichoderma spp. are widely recognized for their pivotal role in plant disease management due to their multifaceted mechanisms of action. These beneficial fungi act as biocontrol agents by outcompeting pathogenic fungi for space and nutrients, producing antifungal metabolites, and inducing systemic resistance in plants. Trichoderma spp. colonize plant roots, enhancing root growth and nutrient uptake, which strengthens the overall health and resilience of the plants. They also secrete enzymes such as chitinases and glucanases that degrade the cell walls of pathogenic fungi, effectively inhibiting their growth and spread. Moreover, Trichoderma spp. can elicit plant defense responses, priming plants to better withstand pathogen attacks. The integration of Trichoderma spp. into agricultural practices offers a sustainable and eco-friendly alternative to chemical pesticides, reducing the environmental impact while promoting healthier crop production.

Table 2 List of diseases managed by Trichoderma spp.

Biocontrol Agent	Pathogen	Host
T. harzianum	Fusarium oxysporum	Cotton
T. viride	R. solani	Potato
T. viride, T. harzianum	Pythium aphanidermatum	Mustard
T. harzianum	Phytophthora capsici	Black pepper
T. harzianum T39	Botrytis cinerea	Tomato, Lettuce, Tobacco, Pepper
T. harzianum	Phytophthora capsici	Cucumber
T. virens	R. solani	Cotton
T. harzianum	P. capsici	Pepper
Trichoderma spp.	F. oxysporum f. sp. dianthi	Carnation
T. harzianum	Phytophthora and Pythium spp.	Cucumber
T. viride, T. virense	Sclerotinia sclerotiorum	Brinjal
T. viride, T. harzianum	Sclerotium rolfsii	Chickpea
T. harzianum	Rhizoctonia solani	Rice
T. viride	Ustilago segatum	Wheat
T. harzianum T-22	Colletotrichum graminicola	Corn
T. hamatum 382	P. capsici	Cucumber
T. asperellum T-34	P. syringae	Cucumber

	pv .lachrymans	
T. hamatum 382	Xanthomonas euvesicatoria	Tomato
T. virense	C. gaminicola	Maize
T. asperellum T-203	P. syringae pv. lachrymans	Cucumber
T. harzianum rifai	B. cinerea	Arabidopsis
T. harzianum	Plasmopara viticola	Grapevine
T. harzianum RU01	Uromyces appendiculatus	Bean
T. harzianum MUCL 29707	R. solani	Potato
Trichoderma spp.	P. capsici	Hot Pepper
T. atroviride	B. cinerea	Tomato
Trichoderma spp.	X. euvesicatoria, Alternaria solani	Tomato
T. asperellum SKT-1	P. syringae pv. tomato	Arabidopsis
T. arundinaceum	B. cinerea, R. solani	Tomato
T. harzianum	R. solani	Sunflower
T. harzianum and T. koningiopsis	Sclerotium rolfsii	Chickpea

The Mechanism of Biocontrol by Trichoderma spp.

Trichoderma spp. are a genus of fungi known for their potent biocontrol properties, playing a significant role in managing plant diseases and promoting plant health. These fungi employ a variety of mechanisms to suppress plant pathogens, enhance plant growth, and improve soil health, making them a valuable tool in sustainable agriculture.

Competition for Resources

One of the primary mechanisms by which Trichoderma spp. exert biocontrol is through competition for space and nutrients. Trichoderma fungi are fast-growing and can colonize root surfaces and the rhizosphere more effectively than many pathogenic fungi. By occupying these niches, Trichoderma spp. reduce the available resources that pathogens need to establish and proliferate. This competitive exclusion is a critical first line of defense against soil-borne diseases.

Mycoparasitism

Trichoderma spp. exhibit mycoparasitic behavior, directly attacking and parasitizing pathogenic fungi. This involves several steps: recognition, attachment, coiling around the pathogen, and secretion of lytic enzymes. Enzymes such as chitinases, glucanases, and proteases degrade the cell walls of the pathogenic fungi, leading to their destruction. This process not only kills the pathogens but also releases nutrients that can be utilized by plants and beneficial microorganisms.

Antibiosis

Another significant mechanism of biocontrol by Trichoderma spp. is antibiosis, which involves the production of secondary metabolites with antimicrobial properties. These metabolites include antibiotics, volatile organic compounds (VOCs), and non-volatile compounds that inhibit the growth of pathogens. For example, Trichoderma produces compounds such as gliotoxin, viridin, and peptaibols, which have been shown to have strong antifungal and antibacterial activities. These compounds can disrupt cellular processes in pathogens, leading to their death or reduced virulence.

Induction of Systemic Resistance

Trichoderma spp. can induce systemic resistance in plants, enhancing their ability to resist a wide range of pathogens. This phenomenon, known as induced systemic resistance (ISR), involves the activation of the plant's immune system. When Trichoderma colonizes plant roots, it triggers signaling pathways that lead to the production of defensive compounds such as phytoalexins, pathogenesis-related proteins, and reactive oxygen species. This heightened state of alert helps plants to respond more rapidly and effectively to pathogen attacks.

Promotion of Plant Growth and Health

In addition to their biocontrol properties, Trichoderma spp. promote plant growth and health through several mechanisms. They enhance root growth and development, increase nutrient uptake, and improve soil structure. Trichoderma spp. produce growth-promoting hormones such as indole-3-acetic acid (IAA) and solubilize phosphates, making essential nutrients more available to plants. Improved root systems lead to better water and nutrient absorption, contributing to overall plant vigor and resilience against stress.

Conclusion

The biocontrol mechanisms of Trichoderma spp. are complex and multifaceted, involving competition, mycoparasitism, antibiosis, induction of systemic resistance, and promotion of plant growth. These fungi offer an eco-friendly and sustainable alternative to chemical pesticides, reducing the environmental impact of agriculture while enhancing crop productivity and health. Understanding and harnessing these mechanisms can lead to more effective and sustainable disease management strategies, contributing to global food security and environmental conservation.

References

Andrade R, Ayer WA, Mebe PP (1992) The metabolites of Trichoderma longibrachiatum: Part 1. Isolation of the metabolites and the structure of trichodimerol. Can J Chem 70:2526–2535

Benitez T, Rincon AM, Limon MC, Codon AC (2004) Biocontrol mechanisms of Trichoderma strains. Int Microbiol 7:249–260

Cutler HG, Himmelsbach DS, Arrendale RF, Cole PD, Cox RH (1989) Koninginin A: a novel plant growth regulator from Trichoderma koningii. Agric Biol Chem 53:2605–2611

Degenkolb T, Döhren HV, Nielsen KF, Samuels GJ, Brückner H (2008) Recent advances and future prospects in peptaibiotics and mycotoxin research and their importance for chemotaxonomy of Trichoderma and Hypocrea. Chem Biodivers 5:671–680

Dickinson JM, Hanson JR, Hitchcock PB, Claydon N (1989) Structure and biosynthesis of harzianopyridone, an antifungal metabolite of Trichoderma harzianum. J Chem Soc Perkin Trans 1: 1885–1887

Dunlop RW, Simon A, Sivasithamparam K, Ghisalberti EL (1989) An antibiotic from Trichoderma koningii active against soilborne plant pathogens. J Nat Prod 52:67–74

Favilla M, Macchia L, Gallo A, Altomare C (2006) Toxicity assessment of metabolites of fungal biocontrol agents using two different (Artemiasalina and Daphniamagna) invertebrate bioassays. Food Chem Toxicol 44:1922–1931

Fravel DR (1988) Role of antibiosis in the biocontrol of plant diseases. Ann Rev Phytopathol 26:75–91

Harman GE, Howell CR, Viterbo A, Chet I, Lorito M (2004) Trichoderma species—opportunistic, avirulent plant symbionts. Nat Rev Microbiol 2:43–56

Harris GH, Jones ETT, Meinz MS, Nallin-Omstead M, Helms GL, Bills GF, Zink D, Wilson KE (1993) Isolation and structure elucidation of viridiofungins A, B and C. Tetrahedron Lett 34: 5235–5238

Javaid A, Ali S (2011) Herbicidal activity of culture filtrates of Trichoderma spp. against two problematic weeds of wheat. Nat Prod Res 25:730–740

Kishimoto N, Sugihara S, Mochida K, Fujita T (2005) In vitro antifungal and antiviral activities of c- and d-lactone analogs utilized as food flavoring. Biocontrol Sci 10:31–36

Kubicek CP, Estrella AH, Seiboth VS, Martinez DA, Druzhinina IS, Thon M, Zeilinger S, Flores SC, Horwitz BA, Mukherjee PK, Mukherjee M, Kredics ALD, Aerts A, Antal Z, Atanasova L, Badillo MGC, Challacombe J, Chertkov O, McCluskey K, Coulpier F, Deshpande N, Döhren HV, Ebbole DJ, Naranjo EUE, Fekete E, Flipphi M, Glaser F, Rodríguez EY, Gruber S, Han C, Henrissat B, Hermosa R, Oñate MH, Karaffa L, Kosti I, Crom SL, Lindquist E, Lucas S, Lübeck M, Lübeck PS, Margeot A, Metz B, Misra M, Nevalainen H, Omann M, Packer N, Perrone G, Rivera EEU, Salamov A, Schmoll M, Seiboth B, Shapiro H, Sukno S, Ramos JAT, Tisch D, Wiest A, Wilkinson HH, Zhang M, Coutinho PM, Kenerley CM, Monte E, Baker SE, Grigoriev IV (2011) Comparative genome sequence analysis underscores mycoparasitism as the ancestral life style of Trichoderma. Genome Biol 12:R40

Luo Y, Zhang D, Dong XW, Zhao PB, Chen LL, Song XY, Wang XJ, Chen XL, Shi M, Zhang YZ (2010) Antimicrobial peptaibols induce defence responses and systemic resistance in tobacco against tobacco mosaic virus. FEMS Microbiol Lett 13:120–126

Mukherjee PK, Horwitz BA, Kenerley CM (2012) Secondary metabolism in Trichoderma—a genomic perspective. Microbiology 158: 35–45

Parker SR, Cutler HG, Schreiner PR (1995a) Koninginin C: a biologically active natural product from Trichoderma koningii. Biosci Biotechnol Biochem 59:1126–1127

Parker SR, Cutler HG, Schreiner PR (1995b) Koninginin E: isolation of a biologically active natural product from Trichoderma koningii. Biosci Biotechnol Biochem 59:1747–1749

Poiriera L, Quinioub F, Ruiza N, Montagua M, Amiarda JC, Pouchus YF (2007) Toxicity assessment of peptaibols and contaminated sediments on Crassostrea gigas embryos. Aquat Toxicol 83:254–262

Sivasithamparam K, Ghisalberti EL (1998) Secondary metabolism in Trichoderma and Gliocladium. In: Kubicek CP, Harman GE (eds) Trichoderma and Glioclaudium, vol 1. Taylor & Francis, London, pp 139–205

Verma M, Brar SK, Tyagi RD, Surampalli RY, Valero JR (2007) Antagonistic fungi, Trichoderma spp. Panoply of biological control. Biochem Eng J 37:1–20

Vinale F, Flematti G, Sivasithamparam K, Lorito M, Marra R, SkeltonBW, Ghisalberti EL (2009) Harzianic acid, an antifungal and plant growth promoting metabolite from Trichoderma harzianum. J Nat Prod 72:2032–2035

Vinale F, Girona IA, Nigro M, Mazzei P, Piccolo A, Ruocco M, Woo S, Rosa RD, Herrera CL, Lorito M (2011) Cerinolactone, a hydroxylactone derivative from Trichoderma cerinum. J Nat Prod 75:103–106

Woo SL, Lorito M (2007) Exploiting the interactions between fungal antagonists, pathogens and the plant for biocontrol. In: Vurro M, Gressel J (eds) Novel biotechnologies for biocontrol agent enhancement and management. Springer, Amsterdam, pp 107–130