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Novel potential of *Trichoderma* Spp. As biocontrol agent

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Abstract
Non-judicial use of noxious fungicides results into ill effects on human health and putative to environment. It has provided opportunity to device alternative control measure plan. *Trichoderma* specie due to its mycolytic enzyme secretions has high potential to combat with the destructive plant pathogens. It fights with competitive pathogen for space and food by stopping its activities and keeling the pathogen thus play significant role in enhancing the growth of the crops of economic importance. Various bio-control based fungicides have been formulated and distributed globally. Present study elaborates the importance of *Trichoderma* spp., its significant role as biocontrol agent and world distribution of various commercially available *Trichoderma* spp. based bioproducts.

Keywords: *Trichoderma* sp., biocontrol, biopesticide, environment friendly

Introduction
Disease management in economical important crops is very crucial to maintain the quality and quantity of the produce. Beside good agronomic practices, different strategies have been adopted to prevent and control plant diseases. Farmers rely on deadly poisoning chemical formulation which are not only toxic to their health [53, 13, 12, 72] but also heavily pollute the ecosystem [52] and surface water resources [43]. Non-judicious use of broad spectrum fungicides against target fungal pathogens imposes undesirable impacts on non-target organisms [19]. However, biological methods of disease control are efficient, eco-friendly, cost effective and safe for human health [55, 67]. *Trichoderma* spp. has attained scientific attraction due to its biocontrol activity against various aerial, root and soil pathogens of economic importance [16, 11, 44, 69, 30]. It belongs to genus Deuteromycotina and family Hyphomycetes.
Trichoderma has five species viz., *Trichoderm akoningii*, *T. harzianum*, *T. pseudokoningii*, *T. longibrachiatum* and *T. viride* [44, 30]. Apart from antifungal activities, it also reported to enhance growth in various crops viz., cucumber (*Cucumis sativus*), bean (*Phaseolus vulgaris* L,), carnation (*Dianthus caryophyllus*), pepper (*Capsicum annum* L.), wheat (*Triticum aestivum*) and maize (*Zea mays* L.) [30]. Some strains are also used in antibiotics and enzymes production on industrial level [73]. About 90 % different strains of *Trichoderma* are being used as bio-control agents [54] however, two new species viz., *T. pleurotum* and *T. pleuroticola* were reported green mold disease causing agent of Oyster mushroom [59]. Present review study was done to collect information highlighting the worldwide utilization of *Trichoderma* sp. as novel bio-control agent.

Trichoderma Genus
Trichoderma term has been derived from two words thrix (hair) and derma (skin). It is free living filamentous fungi that reproduce asexually. It is a good biocontrol agent as it is widely spread, strong opportunistic invaders, avirulant plant symbionts, competes for food and act as mycoparasite. On the basis of these properties this fungi is ecologically sound and ubiquitous [16].

Habitat
Trichoderma occurrence is worldwide and is commonly found associate with root, soil and plant debris [34], forest humus and orchids [38] Strains of *T. harzianum* is reported to persist most commonly in all of the habitats specially kitchen waste decomposition and has adopted acidic environments more efficiently [66]. Survival of Trichoderma is due to diversified

Survival of Trichoderma is due to diversified metabolic system which make them enable to dominate in soil and compete with nature [16].

Morphological Characters

Specie identification and differentiation in this genus is possible to study the morphological features viz., culture color and structure of conidiophores/ conidia, etc [48]. *Trichoderma* colonies grow fast at 25°C on nutritional artificial media. Wooly colonies with scattered blue or yellow-green patches can be observed when the conidia formation took place and sometimes concentric rings also become visible [78]. Septate hyphae, conidiophores (hyaline), phialides, and green colored conidia (round or ellipsoidal) are observed. Two species viz., *T. longibrachiatum* and *T. viride* may also produce chlamydospores. Phialides (solitary or organized) [47, 23, 15].

Biodiversity of *Trichoderma*

Most of the *Trichoderma* species have morphologically similarity and that's why they were considered as a single species: *T. viride* for many years. After the discovery of new species, Rifai [68] proposed nine morphological species aggregates. DNA methods brought additional valuable criteria to the taxonomy of *Trichoderma* which are being used today for studies that include identification [29] and phylogenetic classification [45]. Most isolates of the genus *Trichoderma* that were found to act as mycoparasites of many economically important aerial and soil-borne plant pathogens, have been classified as *T. harzianum* Rifai [23]. Due to the fact that the species *"harzianum"* is generally considered as a group made of mycoparasitic and biocontrol strains, and there is large morphological plasticity that results in character overlaps with other species, the identification of the species may be difficult. Several authors have reported a large genetic variability among *T. harzianum* isolates [24]. In fact, it has been demonstrated that at least four distinct species are present within the biocontrol *T. Harzianum* aggregate: *T. harzianums. str. T. atroviride, T. longibrachiatum* and *T. asperellum* [29]. Co-evolution of organism's antagonistic to pathogens results in many *Trichoderma* strains being inactive against fungi other than those against which they were originally selected. This is strongly advantageous in that they are less likely to act against non-target organisms, but it does mean that a new selection process must take place for each crop/pathogen combination [25].

Growth Promoting Activities

Root growth in bitter gourd, loofha and cucumber was detected by using several strains of *Trichoderma* sp., isolated from rhizosphere. Significant increase in seedling height, leaf area, root exploration and root dry weight was recorded to produce by the application of *Trichoderma* strainst under greenhouse conditions [49]. Addition to this, increase in chlorophyll concentration was also observed due to *Trichoderma* application increased seedling germination and control of seed borne *M. phaseolina* was observed when Mung bean seeds were treated with conidial suspension of three *Trichoderma* sp. viz., *T. hanianum*, *T. hamatum* and *T. viride* [62].

Application of *T. viride* and *T. harzianum* alone and in combination with bio-fertilizers promotes plant growth effectively. It was observed that 50% *Trichoderma* sp. alone or in combination with bio-fertilizers significantly reduce disease incidence against *M. phaseolina* and the shoot length, root length nodulation and grain yield was noticed significantly enhanced [32]. In another study, *Bacillus thuringiensis*, *Rhizobium meliloti*, *Aspergillus niger* and *Trichoderma harzianum* were tested against root rot fungi viz. *M. phaseolina*, *Rhizoctonia solani* and *Fusarium* sp. Apart from disease reduction, shoot length, shoot weight root length and root weight was also noticed to be enhanced by the application of *Trichoderma* among all the tested agents [14].

Selection of *Trichoderma* Strains

If a stain of *Trichoderma* shows successful result in *in vitro* assays, then a further selection should be done on the basis of following criteria such as: 1) activity *in vivo* using experimentally induced diseases on plants, 2) tolerance of high or low temperatures (necessary to survive other IPM treatments), 3) suitability for formulation as foliar sprays and/or soil enhancements (e.g. high sporulation levels, rapid growth in bulk conditions), 4) specificity (strains should be inactive against beneficial organisms and plant crops), 5) long-term survival in field conditions, 6) interactions with other *Trichoderma* strains already present in the cropping systems, 7) compatibility with agrochemicals used in the crop, or 8) shelf life and inoculum efficacy under commercial conditions.

***Trichoderma* Genes**

Trichoderma strains can be applied by using several methods for both biocontrol and plant growth promotion and it is now clear that hundreds of separate genes and gene products are involved in the processes of mycoparasitism, antibiosis, competition for nutrients or space, tolerance to stress through enhanced root and plant development, solubilization and sequestration of inorganic nutrients, induced resistance and inactivation of enzymes produced by pathogens [54]. Some of these genes have been identified, cloned from *Trichoderma* spp. (that offer great promise as transgenes to produce crops that are resistant to plant diseases since transgenic expression of high levels of chitinolytic and glucanolytic *Trichoderma* enzymes do not affect plant morphology, development or yield, or infection by arbuscular mycorrhizal fungi),patented and used to transgenic ally increase plant disease resistance [50] but most of them are still unexploited for developing new biotechnologies.

Mechanism of Action

Selection of active *Trichoderma* strains is important in designing effective and safe bio-control strategies. Many species of *Trichoderma* have different strategies for fungal antagonism, and indirect effects on plant health (such as plant growth promotion effects and fertility improvements). Some strains have great potential for antibiotic production, and their suitability for use in bio-control systems must be carefully assessed [31]. However, many other active strains have no antibiotic capacity but still they are likely to be more useful in food production systems. *Trichoderma* bio-control strains have evolved multiple mechanisms for both directly attacking other fungi and indirectly enhancing plant and root growth [29, 30].

Rhizosphere competent strains of *Trichoderma* colonize the root system of the plant and result in the increased development of root and/or aerial systems and crop yields [28]. Other activities, like the induction of plant systemic resistance and antagonistic effects on plant pathogenic nematodes [71] have also been described. These facts strongly suggest that during the plant-*Trichoderma* interactions, the fungus participates actively in protecting and improving its ecological niche. The dual roles of antagonistic activity against plant pathogens and promotion of soil fertility make *Trichoderma* strains appealing alternatives to soil fumigation technologies such as methyl bromide.

Strains of *Trichoderma* can also play a positive role in biodegradation [81] and act as competitors to fungal pathogens in their saprophytic phases, especially when nutrients are a limiting factor [74]. Strains have been observed as promoting activities of nonpathogenic bacteria [80] and mycorrhizal fungi [10]. In the 1990s, the ability of *Trichoderma* strains to synthesize substances inducing SAR-like responses in plants was shown [17]. Molecules produced by *Trichoderma* and/or its metabolic activity also have potential for promoting plant growth [84]. Application of the species *T. harzianum* to plants resulted in improved seed germination, increased plant size, and augments of leaf area and weight [3]. The scenario of combined systemic biofungicides and plant growth promoters has great market potential if the molecular basis of the activities can be identified.

The strong biodegradation and substrate colonization performances of *Trichoderma* strains is due to amazing metabolic versatility and a high secretion potential which leads to the production of a complex set of hydrolytic enzymes. Similarly, cell wall degrading enzymes (CWDEs) lead to the mycoparasitic process that is able to hydrolize cell wall of various hosts [41]. Among others, chitinases [15], b- 1, 3- glucanases, b-1,6-glucanases [2], a-1,3-glucanases [1] and proteases [23, 75] have been described as important components of the multi-enzymatic system of *Trichoderma* strains. Some of these proteins display strong antifungal activities when are applied *in vitro*, alone and/or combined, against plant pathogens [29, 30]. Some lytic enzymes can be involved in both antagonistic and saprophytic processes providing an evolutionary advantage to strains with both biodegrading and antagonistic potential, for the efficient colonization of different ecological niches in soil. A principal role in mycoparasitism has been attributed to chitinases [50] and glucanases [9]. However, fungal proteases may also be significantly involved in cell wall degradation, since fungal cell walls contain chitin and glucan polymers embedded in and covalently linked to a protein matrix [40]. In another study the biocontrol mechanism, endochitinase and exochitinase production was assayed by using liquid media amended with colloidal chitin amended broth. All the tested isolates resulted into maximum endochitinase, exochitinase activity and cellulase activity [4].

The production of secondary metabolites by *Trichoderma* strains also shows great variety and application potential. *Trichoderma* strains seem to be an inexhaustible source of antibiotics, from the acetaldehydes gliotoxin and viridin, to alpha-pyrones [41], terpenes, polyketides, isocyanide derivatives, piperacines, and complex families of peptaibols. All these compounds produce synergistic effects in combination with CWDEs, with strong inhibitory activity on many fungal plant pathogens [50]. The potential of genes involved in biosynthetic pathways of antibiotics e.g. polyketides and peptaibols [70, 82] with applications in human and veterinary medicine is not been explored yet.

Trichoderma is not only a good biocontrol agent, but also a general fertility promoter. In the absence of pathogens, application of appropriate *Trichoderma* formulations (following solarization and/or preceding fumigation with authorized and environmentally-friendly chemicals) can also serve to promote plant growth and crop precocity, increase fruit production and reduce chemical treatments.

Antagonistic Behavior of *Trichoderma* Sp.

Bio-control agents have adopted various mechanisms of action such as antibiosis, competition, induction of host resistance in host plant, production of growth stimulating factors and predation to perform antagonistic activity [58]. First time *Trichoderma* was used against plant diseases in 1930s and up till now various species have been reported to parasitize fungal pathogens by producing antibiotics [29]. Same like plant growth promoting fungi (PGRP), Potential of *Trichoderma* sp. was extensively studied [76]. Antagonistic activity of *Trichoderma* sp. against various spoil born and foliar pathogens viz., *Sclerotium rolfsii*, *Colletotrichum gloeosporioides* and *C. capsici* was reported [46]. Study revealed that antagonistic activity lies in the coiling ability of *Trichoderma* sp around the host hyphae by apressoria formation and also by the production of cell wall degrading enzymes viz., Chitinases [4], β 1, 3 Glucanase and Protease [2, 21]. Antagonism was also reported against *R. solani*, *Fusarium moniliforme* and *Phytophthora capsici* [42].

Mutants are being developed to enhance the bio-control potential of *Trichoderma* sp. which is being used to increase metabolite production and enhancing antagonistic potential against wide range of plant pathogens [65]. Significant growth inhibition in *Pythium* sp. isolated from *Lycopersicon esculentum* –Mill was reported [61] due to volatile metabolite production by *Trichoderma* sp. Antagonistic behavior of two fungi viz., *T. harzianum* and *T. viride* was studied against wilt and wet rot in chickpea and concluded that soil application rather than seed treatment before sowing results in promising disease reduction [60] and antagonism was also noticed by the application of *T. harzianum* and P*seudomonas fluorescens* against *Chrysalido carpus lutescens* (cane palm) caused by *Helminthosporium* infection [39].

Biocontrol Potential of Trichoderma Sp. against Various Pathogens

Genus Trichoderma is a natural bio-agent and is well known for suppressing the plant pathogens by several mechanisms. Some strains of *Trichoderma* sp. had been identified as potential bio-control agents of plant pathogenic fungi. It has been reported to possess potential to demolish mycotoxin production of *F. verticillioides* [2] and colony growth inhibition of *M. phaseolina* by *T. virens* (*Gliocladium virens*) application [51]. *F. moniliforme*, causal agent of stalk rot of maize was controlled by using *Trichoderma* isolates taken from phyllosphere and rhizosphere and found them effective against the test pathogen [75].

In another study, *T. viride* and *T. harzianum* was also investigated for bio-control activity alone and in combination with bio-fertilizers against *M. phaseolina*. From the recorded data, it was concluded that 50% *Trichoderma* sp. alone or in combination with bio-fertilizers significantly reduce disease incidence and enhanced the plant growth [32]. *Trichoderma* spp. was reported to inhibit fungal infection of roots caused by soil borne pathogens such as *M. phaseolina*, *Rhizoctonia solani*, *Fusarium* and *Pythium* sp. on various crops of economic importance [5]. As the application of chemical pesticides is harmful for the environment and also problematic for human life so biological agents are best alternative and eco-friendly. Various fungal bio-fertilizers viz., Binab T WG, Bioderma H, Biofox C, Biofungus, Ketocin and Koni etc., are commercial prepared and globally available [76].

Fungal growth inhibition of *F. oxysporum* f. sp. *cubense* causal agent of *Fusarium* wilt of abaca was also studied by using the potentials of *T. viride* and yeast in the laboratory by dual culture method [6, 7, 20]. *Trichoderma* and yeast (Davao isolate) were found highly effective in inhibiting fungal growth and disease. Various isolates *Trichoderma* spp. was evaluated against charcoal rot of melon caused by *M. phaseolina*.

Cell free metabolites of *T. harzianum* and *T. virens* showed maximum inhibition of test fungus. They also conducted experiments to find out protective action of *Trichoderma* spp. as percentage of standing plants against root rot disease on plants treated with the antagonists + test fungus and also alone pathogenic fungus as control treatment. Percentage of standing plants in treatments containing *Trichoderma* + *M. phaseolina* was observed high as compared to treatments of pathogenic fungi alone [18]. Cumulative effect of *T. viride* + *T. harzianum* + *T. hamatum* against *F. oxysporium* f. sp. *ciceri* was studied and derived results showed significant percent inhibition of the fungal growth [56]. In another study, soil was amended with *T. koningii* against *Fusarium* wilt of tomato caused by *F. oxysporum* f. sp. *lycopersici* and disease severity in treated soil was reported to reduce in tomato plants and also their yield and growth was increased [2]. Antifungal activities of various bio-agents like *Bacillus thuringiensis*, *Rhizobium meliloti*, *Aspergillus niger* and *Trichoderma harzianum* was tested against root rot fungi viz. *M. phaseolina*, *Rhizoctonia solani* and *Fusarium* sp. All tested agents were found effective against root rot fungi. Maximum reduction of infection was reported to produce by *Trichoderma* sp. [14]. Four fungal agents viz., *T. hamatum*, *T. harzianum*, *T. polysporum* and *T. viride*. were tested for their bio-control activities against *M. phaseolina*, pathogen of Eggplant root rot. Maximum inhibition zone was produced by *T. harzianum* as compared *T. hamatum* [64].

Bio-control efficacy of *T. harzianum* and *Pseudomonas fluorescens* was also tested against leaf spot disease in *Chrysalido carpuslutescens* (cane palm) caused by Helminthosporium infection. It was recorded that disease incidence was significantly low by the application of *Trichoderma* and *P. fluorescens* while disease was completely inhibited by spore suspension of *Trichoderma* [39].Bio control potential of Trichoderma sp. was evaluated against *Sclerotium rolfsii* and *Fusarium ciceri* on chickpea plants (*Cicer argentums c.v. Annigeri*) by roll paper towel technique and were found better antagonists and also plant growth promoters [4].

In another study efficacy of Carbendem 50% WP, various antagonists and botanical extracts was studied against *F. oxysporum* f. sp. *psidii* the causal agent of Guava wilt and found that high concentrations of Carbendazem like 100, 1000, 10,000 ppm effective against the radial growth of the pathogen. *Trichoderma* sp. was noticed to produce significant zone inhibition of target fungus followed by *A. niger*. Chemical control was noticed as a short term control and bio-control method was found preferably better than chemical control [77].

Trichoderma spp. are also reported to produce antibiotics and can induce systemic and localized resistance to numerous plant pathogens viz., *Phytophthora palmivora*, *Rhizoctonia solani*, *Fusarium* spp., *Sclerotium rolfsii* and *Pythium* spp. *Trichoderma* spp. are used as biocontrol agents since 1930s, but there were introduced in Viet Nam two decades back and Trichoderma viride, T. harzianum, T. hamatum were observed predominant species. BIMA, Trico-ĐHCT, Promot Plus WP, Vi – ĐK, NLU-Tri, Bio – Humaxin Sen Vang and Fulhum axin are commercially available Trichoderma spp. based biocontrol products which are utilized in many ways against plant pathogens [25, 26].

Antagonistic potential of *Penicillium digitatum* was evaluated in comparison to *Trichoderma* and *Aspergillus* spp. against *Macrophomina phaseolina* under *In vitro* conditions and *P. digitatum* was found highly effective antagonist followed by *Trichoderma* spp. Due to harmful impact of *P. digitatum* on human health, *Trichoderma* spp, could be a best option as biocontrol agent [35].

In-vitro antagonistic activity of *T. viride*, *T. harzianum*, and *P. fluorescence* was carried out to manage Fusarium wilt in Groundnut. Maximum inhibition of fungal germination was reported to produce by *T. viride* followed by *T. harzianum* and *P. fluorescens* respectively [63, 64, 80]. Antifungal ability of some isolated agents of *Trichoderma* sp. were tested against plant pathogenic fungi such as *R. solani*, *F. moniliforme* and *Phytophthora capsic*, which are commonly present in arable soil. Among tested strains DT3.2, 2.2 and 2.3 exhibited highest antifungal activity against target pathogens [42].

Commercially Available Trichoderma Spp. Based Bioproducts

Trichoderma spp. is considered as widely studied fungal agent as microbial bio-control agent (MBCAs) in agriculture and are marketed in the form of bio-pesticides, bio-fertilizers, growth promoter and natural resistance inducers. A comprehensive survey was conducted to access the geographical distribution of various *Trichoderma* spp. based products commercially available to manage the diseases of agricultural importance (Table 1 and 2).

Table 1: Distribution of *Trichoderma* spp. based Bio-products available in the worldwide market

Region	Countries	# of comm. Products	# of Register Products	Label Description (Single Characteristics and Combinations)									Product Formulation					
				FUNG	STIM	FERT/ NUTR	ISR	Others	F + ST	F + ST + FERT + ISR	F + ST + FERT	Other Combos.	WP	Gran	Liq	Solid	Pell	Others
Africa	South Africa, Kenya, Zambia, Morocc, Tunisia	9	9	7	1	-	-		1	-	-	-	4	-	-	-	-	SC-1 (Conc. Susp.)
Asia	China, India, Indonesia, Japan, Korea, Russia, Vietnam, Philippines	100	8	79	2	2	-	F+NEM=2; F+INS=1	7	1	2; +DEC=2	2	51	0	12	6, Rice 1	0	Emuls-1; Not Indic-38
Europe	BE, CZ, DK, EE, ES, FI, FR,HU, IE, IT, NL, SE, SI,UK) Moldavia, Ukraine, Israel	57	21	24	2	-	-	-	14	3	2	3	27 (Bees 1)	13	5	4 (Peat 1, Coco 2)	1	Powder-2
North America	USA, Canada	29	19	16	4	-	-	-	-	3	3	3	19 (Bees 1)	15	5	3	1	Flow-1
Pacific	Australia, New Zealand	22	10	8	1	4; +DEC=2	-	-	2; +ISR=3	2	-	-	13	3	-	1 Dowels	1	Flakes-2
South-Central America	Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Equador, Honduras, Mexico, Panama, Peru, Uraguay, Venezuela	40	22	32	--	-	1	NEM=1	1; +ISR=1; +ISR+NEM =1	-	1	2	24	3	6	3 (Rice 1)	1	Emuls-1; Not Indic-7
Multiple Regions	ca. 17	16	15	11	-	-	-	-	1	2	2	-	13	3	-	-	1	-
	TOTAL	273	104	177	9	8	1	5	31	11	12	2	151	37	28	17	5	13
	%Ag		38.1	64.8	3.3	2.9	0.4	-	11.4	4.0	4.4	-	55.3	13.6	10.3	6.2	1.8	-

Fungicide (FUNG), plant growth Stimulator (STIM), Fertilizer or improved Nutrient uptake (FERT/NUTR), Decomposer (DEC), Induced Systemic Resistance (ISR), OTHER – Nematocide (NEM), Insecticide (INS); and combined characteristics.

Product Formulations: Wettable Powder (WP), Granules (Gran), Liquid (Liq), Solid substrate (Solid), Pellets (Pell), other formulations: Concentrated Suspension (SC), Emulsion (Emuls), Dry flowable (Flow).

Table 2b. *Trichoderma* spp. based bio-products being registered more recently in different countries worldwide

Chemical name –*Trichoderma* spp.	Species Strain; Synonyms; Related Chemicals	Commercial Product Name (Manufacturer/Distributor)	Country Indicated for Registration
T. asperellum	*T. asperellum*	Ecohope, Ecohope-Dry (Kumiai Chemical Industry Co. Ltd.)	Japan
	T. asperellum	Quality WG (Laboratório de Biocontrole Farroupilha Ltda.)	Brazil
	T. asperellum	Trichodermax EC (TURFAL - Industria e comércio de produts biológicos e agronômicos Ltda.)	Brazil
	T. asperellum	Trichotech (Dudutech K Ltd)	Kenya
T. harzianum	*T. harzianum*	Antagon WP (Bio Ecológico Ltda.)	Colombia
	T. harzianum	Trichobiol WP (Control BiológicoIntegrado ; Mora Jaramillo Arturo Orlando – Biocontrol)	Colombia
	T. harzianum	Unite WP (Agrimm Technologies Limited)	Australia, New Zealand
	T. harzianum DSM 14944	Agroguard WG, Foliguard (Live Systems Technology S.A)	Colombia
	T. harzianum isolate DB 104	Romulus (DAGUTAT BIOLAB)	South Africa
	T. harzianum strain 21	Rootgard (Juanco SPS Ltd.)	Kenya
	T. harzianum strain kd	Eco-T (Plant Health Products (Pty)Ltd.)	South Africa, Kenya and Zambia; in process FR, UK, Morocco, Tunisia and India
	T. harzianum strain SF	Bio-Tricho (Agro-Organics)	South Africa
	T. harzianum strains ESALQ-1306, ESALQ-1303	Trichodermil (ItaforteBioProdutos)	Brazil
	T. harzianum	Supresivit (Fytovita, Ltd.)	Czech Republic
	T. harzianum IIHR-Th-2	Ecosom-TH (Agri Life)	India
	T. harzianum strain B77	Eco-77 (Plant Health Products)	South Africa; Kenya, Zambia
	T. harzianum T-22 (ATCC 20847)	Tricho D WP (OriusBiotecnologia)	Colombia, Equador, Panama, Peru, Chile
	T. harzianum, Glomus intraradices and Pseudomonas	Micover Gold e Plus (Agrifutur)	European Union
T. harzianum, T. koningii	*T. harzianum, T. koningii*	Promot WP (Biofa AG, Bio-farming systems)	R in Germany; Kenya (temp. 2010)
T. harzianum, T. koningii, T. viride	*T. harzianum, T. koningii, T. viride*	Fitotripen WP (Safer Agrobiologicos)	Colombia
T. harzianum, T. virens	*T. harzianum, T. virens*	Bio Traz, BioFit (Biomycota)	Chile
T. virens	*T. virens G-41*	G-41 Technical, BW240 G, BW240 WP Biological Fungicide (BioworksInc)	USA
T. virens, T. harzianum, T. parceanamosum	*T. virens, T. harzianum, T. parceanamosum*	Trichonativa (Bio-InsumosNativaLtda)	Chile
T. viride	*T. viride*	Biocure F (T. Stanes and Company Limited)	EU; available India
	T. viride	Bio-Shield, Bioveer (Ambika Biotech)	India
	T. viride 16, T. lignorum	Mycofungicyd, Trichodermin (Bizar-agro LTD)	Ukraine
Trichoderma spp.	*Trichoderma spp.*	Excalibur Gold, Excalibur Green (ABM)	USA
	Trichoderma spp.	Registration of Trichodermacontaining products indicated, but not specified	China
	Trichoderma spp.	Tricho Plus (Biological Control Products (Pty)Ltd)	South Africa
	Trichoderma spp.	Trichozam (Hardware & Lumber Limited (Agro Grace Division)	Honduras, Colombia
	Trichoderma Td82 and Td84	Solstice (Metcalf Biologicals)	Australia
Temporary Registration	*T. viride, T. harzianum, T. koningii and Trichoderma spp.*	ICB Nutrisolo SC e WP (ICB BIOAGRITEC Ltd)	Brazil
Temporary Registration	*Trichoderma spp. (6 strains)*		Brazil
Use permit only	*T. harzianum A-34*	Trichosav-34 (Institute for Research in Plant Protection (INISAV))	Cuba
Use permit only	*T. harzianum A-55*	Trichosav-55 (Institute for Research in Plant Protection (INISAV))	Cuba

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