

Tolerance of *Trichoderma asperellum* Isolates to Chemical Fungicide and Their Antagonistic Activity against *Phytophthora infestans*

by Elika Joenarti

Submission date: 19-Apr-2021 03:38PM (UTC+0700)

Submission ID: 1563412196

File name: A.5._jurnal-tolerance_of_trichoderma.pdf (619.04K)

Word count: 4178

Character count: 23835



36



Tolerance of *Trichoderma asperellum* Isolates to Chemical Fungicide and Their Antagonistic Activity against *Phytophthora infestans*

Elika Joeniarti^{1*}, Ni'matuzahroh² and Kusriningrum³

¹Department of Agrotechnology, Faculty of Agriculture Wijaya Kusuma Surabaya University, Indonesia.

²Department of Biology, Faculty of Science and Technology Airlangga University, Indonesia.

³Department of Animal Husbandry, Faculty of Veterinary Medicine Airlangga University, Indonesia.

37

Authors' contributions

7

This work was carried out in collaboration between all authors. Author Elika designed the study, managed the literature searches, wrote the protocol, and wrote the first draft of the manuscript. Author Ni'matuzahroh managed the analyses of the study. Author Kusriningrum performed the statistical analysis. All authors read and approved the final manuscript.

Original Research Article

Received 27th June 2013

Accepted 16th October 2013

Published 9th November 2013

ABSTRACT

Trichoderma constitute filamentous fungi which are frequently used as biocontrol agents against plant pathogenic fungi. The tolerance of these fungi to chemical fungicides is a prerequisite for biocontrol agents for their application to suppress the growth of some soil-borne pathogens. The objectives of this study were to evaluate tolerance of *Trichoderma asperellum* local isolates TK and TS from Batu-East Java, to mefenoxam fungicide, as well as to identify *in-vitro* the antagonistic activity of *T. asperellum* against the plant pathogen *Phytophthora infestans* by using dual-culture method. Thus, an integrated approach of chemical and biological methods was used to control the growth of *P. infestans*. This study was conducted at the Department of Biology, Faculty of Science and Technology Airlangga University, Indonesia, during March through December, 2012. *T. asperellum* isolates TK and TS were evaluated *in-vitro* for their efficacy against *P. infestans* and tolerance to 5000 ppm mefenoxam. The results showed that the growth of the two *T. asperellum* isolates on Potato Dextrose Agar (PDA) medium supplemented

*Corresponding author: E-mail: elika_joe@yahoo.co.id;

with 5 mL/L mefenoxam was up to 67%, while their antagonistic activity against *P. infestans* in dual-culture was 5,08% and 16,37%. The results are expected to help in selection of potential biocontrol agents.

Keywords: *Trichoderma*; *biocontrol agents*; *mefenoxam*; *Phytophthora infestans*.

1. INTRODUCTION

⁴² Genus *Trichoderma* are important biocontrol agents (BCAs) against several soil-borne pathogens. *Trichoderma* used different⁴³ mechanisms to control pathogens includes mycoparasitism, secretion of antibiotics, competition for space and nutrients, as well as secretion of lytic enzymes [1]. According to [2], the activities of *Trichoderma* as BCAs mainly depend on physicochemical factors of environment where they are subjected.

The fact that the individual use of chemical control caused environmental pollution, it triggered the existence of the IPM (Integrated Plant Disease Management) strategy²⁶. A part of the IPM strategy is to combine biological control with chemical fungicide. Emerging strategies for plant disease management involve biological and integrated control by applying antagonistic microorganisms alone or in combination with fungicides [3,4,5,6]. Several studies have shown that a large number of plant-beneficial microorganisms e.g. yeasts, yeast-like fungi, filamentous fungi and bacteria, protect plants against postharvest [7,8,5,6] and/or soil-borne pathogens [9,10,11,5].

The chemical control is increasingly limited because of environmental and toxicological risks as well as the onset of fungicide-resistant strains of fungal pathogens. Moreover, the legal limits of chemical residues left by pesticides in imported fruit are much lower in some countries, thus discouraging the use of chemical products. Biocontrol by antagonistic microorganisms appears to be a promising tool for fungal disease and minimizing the use of fungicides [12,8]. Nevertheless, BCAs are often insufficient to control diseases when applied alone in field under practical conditions. Therefore, integrated approaches based on the combination of BCAs and fungicides or alternative means have been suggested to prevent a resistance increase in the pathogen population and limit risks due to intensive use of chemicals [13].

For successful biological control of pathogens, BCAs that tolerate chemical fungicides are needed. There is an emerging necessity for *Trichoderma* which would be a prerequisite for their application in combination of chemical and biological control [14]. Some strains of *Trichoderma* show compatibility with fungicides as they are tolerant to fungicides and successfully used in the IPM strategy [15,16]. It was reported that integration of both control strategies showed a positive association, by reducing infection, compared to their individual applications [17].

Mefenoxam belongs to a class of phenylamides, systemic fungicides specifically for controlling plant pathogens of Oomycetes e.g. *Phytophthora*, *Pythium*, and *Peronospora* [18,19]. According to FRAC (Fungicide Resistance Action Committee) Classification, phenylamides are a class of high risk fungicides that cause pathogen resistance. Whereas, the effects of mefenoxam to BCAs *Trichoderma* existence are still unknown.

The objectives of this study were to assay tolerance of *T. asperellum* isolates TK and TS isolates at 5000 ppm *mefenoxam* as well as to identify *in-vitro* the antagonistic activity of *T. asperellum* isolates TK and TS against *P. infestans* by using the dual-culture method.

45

2. MATERIALS AND METHODS

2.1 Isolation of *Trichoderma* Species

Six local isolates of *Trichoderma* spp. were used in this study and isolated from rhizosphere soil of horticulture crops including onions, potatoes, banana, carrots, and celery in Batu-East Java, Indonesia and were maintained on PDA medium (Difco™, USA). Two isolates (TK and TS) were identified as *T. asperellum*, while the other four isolates (TB, TP, TS2, and TW) have not been identified at the species level. Pathogenic fungi of *P. infestans* were obtained from the culture collection of Balai Penelitian Tanaman Hortikultura Bandung-West Java, Indonesia and were maintained on V8 juice Agar (Campbell Soup Co., USA). *Mefenoxam* (PT. Syngenta Indonesia) was obtained as a commercial fungicide.

2.2 Fungistatic Activity

In-vitro fungistatic activity of *mefenoxam* was studied on PDA medium. *Mefenoxam* was dissolved in sterile distilled water and supplemented to autoclaved medium, resulting PDA-*mefenoxam* plates in various concentrations. A mycelial plug of five-day-old *T. asperellum* isolates TK and TS culture were grown on PDA and transferred to PDA-*mefenoxam* plates. Tolerance of *T. asperellum* isolates TK and TS to *mefenoxam* were estimated according to colony diameters and compared to average colony diameters from non-supplemented media after seven days of incubation [20,21,22].

2.3 Dual Culture Technique

For dual-culture, a mycelial plug of *P. infestans* (5mm diameter) from a seven-day-old culture was placed on PDA-supplemented 5000 ppm *mefenoxam*, about one centimeter from the edge of Petri dish. After 72 hours, a mycelial plug of *T. asperellum* isolates TK or TS from the colony margin a five-day-old culture was placed at an opposite side on the same Petri dish. Similarly, Petri dish inoculated with *P. infestans* alone was used as control. The treatments were replicated three times and incubated at 28°C for seven days. The antagonistic activity of *T. asperellum* isolates TK and TS were estimated according to two criteria, i.e. the pathogen growth inhibition radius and the antagonism class system described by [23]. Radius growth inhibition was calculated in relation to the growth of the control as follows:

$$\% \text{ inhibition of radius mycelial growth} = \frac{X-A}{X} \times 100\%$$

34

where X was the radius growth of pathogen in the control plate and A was the radius growth of pathogen in presence of *Trichoderma* [24,25,26].

1

2.4 Statistical Analysis

The data of all experiments were statistically analyzed using ANOVA (analysis of variance) and LSD (Least Significant Difference) test to determine the statistically significant differences [27].

3. RESULTS AND DISCUSSION

3.1 Tolerance *T. asperellum* Isolates TK and TS to 5000 ppm Mefenoxam

The two *T. asperellum* isolates TK and TS showed growth greater than 50% on PDA-5000 ppm mefenoxam plates (Fig 1). This described that both isolates were able to grow when they were exposed to chemical fungicides.

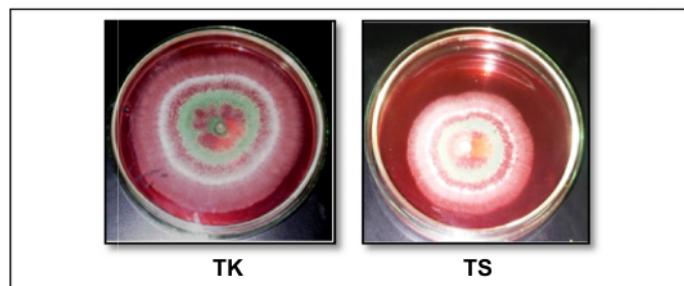


Fig. 1. In-vitro growth of *T. asperellum* isolates TK and TS on PDA-5000 ppm mefenoxam plates seven days after incubation

While, morphological characters of these isolates that are expressed in the shape and colour of the colony are presented in Table 1. This result indicated that *T. asperellum* isolates TK and TS tolerant to mefenoxam and they were considered as resistant isolates to mefenoxam fungicide at recommended maximum concentration for field application.

Table 1. Morphological expression of *T. asperellum* isolates TK and TS at 5000 ppm mefenoxam seven days after incubation

Isolates	Colony Characteristic	Radial growth (mm)	Tolerance to mefenoxam (%)	Category of resistance
TK	colony radial, white-green	62 ^a	67.1	Resistant
TP	colony radial, dark green	61 ^{ab}	65.9	Resistant
TW	colony radial, white-green	59.3 ^{abc}	63.5	Resistant
TS	colony radial, white-green	57 ^{abcd}	61.2	Resistant
TS ₂	coloni spread, dark green	51 ^e	54.1	Resistant
TB	colony spread and radial, das ^g green	51 ^e	54.1	Resistant

*The number followed by the same letter in the same column were not significantly different at LSD=5%; *Resistant: radial growth on medium supplemented mefenoxam > 50% of that on non-supplemented media, Intermediate: radial growth on medium supplemented mefenoxam >40-50% of that on non-supplemented media, Sensitive: radial growth on medium-supplemented mefenoxam < 40% of that on non-supplemented media [28,29]

The ability of *Trichoderma* to withstand chemical stresses including those associated with mycoparasitism has been well studied. The two *T. asperellum* isolates TK and TS used in this study are evidently tolerant to 5000 ppm *mefenoxam*. Both isolates were able to grow when exposed to chemical fungicides without the loss of ability to sporulate and germinate. This result also clarified that *T. asperellum* isolates TK and TS were resistant isolates to *mefenoxam* fungicide which could rapidly grow at recommended maximum concentration for field application. According to [30], the tolerance of *Trichoderma* is one of the keys to ecological success and is a prerequisite for IPM implementation. [31] explained that the ability of *Trichoderma* to tolerate relatively high concentrations of a variety of synthetic and natural toxic compounds, depends on the efficiency of the cell detoxification mechanisms supported by a complex system of membrane pumps. Unfortunately, the mechanism of defence system are still fully unknown.

Tolerant describes a capability of organisms to survive under various surrounding pressure particularly diverse environmental effects [32]. Tolerance of fungi to chemical fungicides related to ABC-transporter gene have been intensively published in the last few years. It was hypothesized that ABC-transporter has an important role in a number of processes such as resistance to environmental toxicants produced either by soil microflora or introduced by human activity [31]. In this study, the rapid growth of *T. asperellum* isolates TK and TS on PDA-5000 ppm *mefenoxam* plates indicated that both isolates developed a tolerance mechanism to chemical fungicide pressure. Fungicide resistance is classified into two types, i.e. qualitative and quantitative resistance [33]. Furthermore, quantitative resistance constitutes a cell physiology reaction which is mediated by keeping the intracellular fungicide concentration still low. Several mechanisms may lead to this type such as: synthesis of efflux transporter secreting drug molecules to the extracellular space; modification of plasma membrane causing reduced fungicide permeability; synthesis of enzymes degrading fungicide molecules; over expression of the gene encoding the fungicide target; and utilization of alternative metabolic pathways.

3.2 Antagonistic Activity of *T. asperellum* Isolates TK and TS to *P. infestans*

T. asperellum isolates TK and TS had a high mycelial growth rate on both PDA-supplemented *mefenoxam* and PDA-non supplemented which are associated with the ability to control pathogenic fungi. The following data (Table 2) shows the mycelial growth of *T. asperellum* isolates TK and TS which were isolated from Batu-East Java, Indonesia.

Table 2. The mycelial growth of *T. asperellum* isolates TK and TS on both PDA-supplemented *mefenoxam* and PDA-non supplemented

<i>Trichoderma</i> isolates	Diameter colony (mm)	
	PDA	PDA+mefenoxam
TB	90	51
TS2	90	51
TS	90	57
TW	90	59
TP	90	61
TK	90	62

47

These isolates were assessed for their antagonistic activity against *P. infestans* on PDA-5000 ppm *mefenoxam*, as presented in Table 3. The result showed that TS isolate exhibited

a better inhibition to mycelial growth of the pathogen (16,37 %) than TK isolate (5,08%). The following antagonisms degree in dual culture was scored on scale of 1-5 as proposed by [23]:

1. Antagonist completely overgrew the pathogen and covered the entire medium surface.
2. Antagonist overgrew at least two third of the medium surface.
3. Antagonist and the pathogen each colonized one half of the medium surface (more than one third and less than two third) and neither organism appeared to dominate each other.
4. The pathogen colonized at least two third of the medium surface and appeared to with stand encroachment.
5. The pathogen completely overgrew the antagonist and occupied the entire medium surface.

Table 3. The antagonistic activity of *T. asperellum* isolates TK and TS against *P. infestans* on PDA-5000 ppm mefenoxam seven days after incubation

<i>Trichoderma</i> Isolates	Radial growth of pathogen (mm)	Growth inhibition of pathogen (%)	Antagonism score
TS	24.67 ^e	16.37	4
TK	28.00 ^{bcd}	5.08	4
TS ₂	28.00 ^{bcd}	5.08	4
TB	28.67 ^{bc}	2.81	4
TP	30.00 ^{ab}	0	5
Tw ₅	32.00 ^a	0	5

*The numbers followed by the same letter in the same column were not significantly different at LSD=5%

*Antagonism score according to [23]

In dual-culture, the two *T. asperellum* isolates TK and T₁₈ grew rapidly and covered the entire agar surface plates (Fig. 2). It indicated that its rapid growth gave an important advantage in the competition for space and nutrients against pathogen.

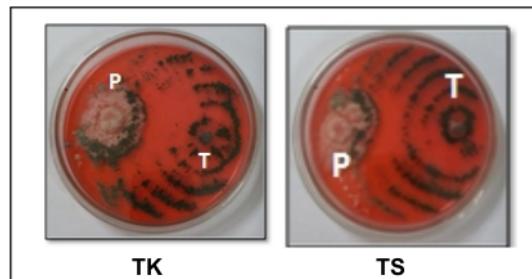


Fig. 2. Antagonistic activity of *T. asperellum* isolates TK and TS against *P. infestans* on PDA-5000 ppm mefenoxam seven days after incubation

Inhibition of plant pathogenic fungi by different species of *Trichoderma* was studied under ²⁹ in vitro conditions by many researchers [34,35,36]. *T. asperellum* are used as BCAs against a wide spectrum of plant disease-causing organisms, including fungi and nematodes

29

[37,38,39]. These species have also an antibacterial activity through the production of trichotoxin peptaibols [40]. The result of this study obviously demonstrated that *T. asperellum* isolates TK and TS were able to suppress the growth of pathogen although their ability was classified as low antagonistic activity. Similarly, [41] reported that *T. asperellum* showed the lowest inhibitory effect to *Fusarium oxysporum* f. sp. *phaseoli* (20.3%), it were compared to *T. reesei* (32.2%) as well as *T. atroviride* and *T. koninngii* both at 28.8%. Likewise, [42] stated that the low suppression observed, in some cases, in peat enriched with *T. asperellum* T-34 is consistent with results obtained for peat enriched with another *Trichoderma* strain combined with *Chryseobacterium*. According to [43], variations in the inhibitory potential may be due to the differences in the quantity and quality of the inhibitory substances produced by the antagonistic agents. Surely, the tested *Trichoderma* isolates also determine the variability of efficacy.

Although, their ability to pressure pathogen was considered low, *T. asperellum* isolates TK and TS used in this study evidently have rapid growth. These would give an important advantage in the competition for space and nutrients against pathogen, since competition constitutes an actual important mechanism of biological control. A competition may lead to pathogens control as long as the growth of BCAs result in reduction or inhibition of pathogen population. It was suggested that competition is most likely to be a successful biological control strategy depending on rapid colonization of *Trichoderma*, before pathogens established [1]. According to [2], the nature of competition is fungistatic or inhibitor. *Trichoderma* with rapid growth will be the winner of the competition for space and nutrients. Furthermore, they can provide colonization of rhizosphere allowing rapid establishment within microbial communities.

The other result of this study showed that tolerance of *T. asperellum* isolates TK and TS to 5000 ppm mefenoxam do not have a positive correlation with their antagonistic activity against *P. infestans* (Fig. 3).

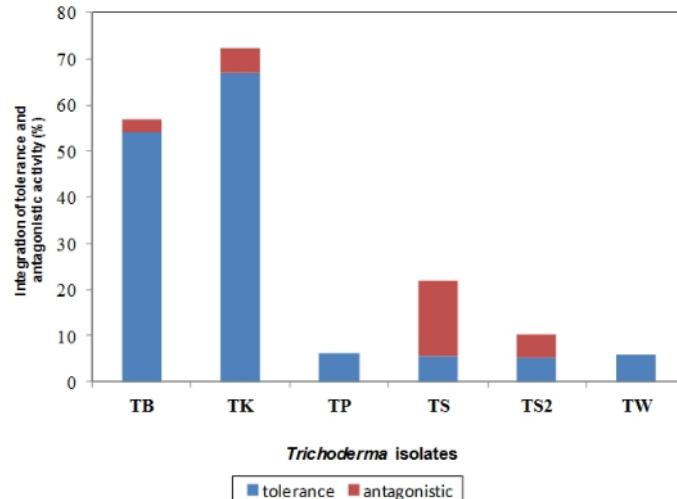


Fig. 3. Integration of tolerance to 5000 ppm mefenoxam and antagonistic activity of all *Trichoderma* isolates collected from Batu against *P. infestans*

The TK isolate showed high tolerance to *mefenoxam* but low suppression for pathogen. While, the highest antagonistic activity against *P. infestans* was demonstrated by the TS isolate which had lower tolerance to *mefenoxam* 5000 ppm than TK isolate.

4. CONCLUSION

The local isolates of *T. asperellum* TK and TS can be used as BCAs to protect potato plants from *P. infestans*, since they were tolerant to 5000 ppm *mefenoxam* up to 67%. Moreover, their rapid growth would evidently be a competition support to BCAs against plant pathogens. It is possible to develop *Trichoderma* tolerant of chemical fungicides without the decrease of the antagonistic activity. Nonetheless, further studies of integration on utilization of the local isolates as BCAs as well as chemical fungicide under field conditions is still recommended.

13 CONSENT

All authors declare that 'written informed consent was obtained from the patient (or other approved parties) for publication of this case report and accompanying images.'

39 ACKNOWLEDGEMENT

We thank to the Directorate General of Republic Indonesia Higher Education for funding this study through Doctoral Degree Scholarship. The f₃₈ is called "Beasiswa Pendidikan Program Doktor" (The Doctoral Programme Education Scholarship).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

- 14 1. Herman GE, Kubicek CP. *Trichoderma & Gliocladium*. Taylor & Francis Ltd; 1998.
15
2. Mohiddin FA, Khan MR, Khan SM, Bhat BH. Why *Trichoderma* is Considered Super Hero (Super Fungus) Against the Evil Parasites? *Plant Pathology Journal*. 2010;9(3):92-102.
3. Paulitz TC, Belanger RR. Biological control in green house systems. *Annu Rev Phytopathol*. 2001;39:103–133.
4. De Curtis F, Lima G, Vitullo D, De Cicco V. Biocontrol of *Rhizoctonia solani* and *Sclerotium rolfsii* on tomato by delivering antagonist bacteria through a drip irrigation system. *Crop Protection*. 2010;29:663–670.
5. De Curtis, Lima G, De Cicco DV. Efficacy of biocontrol yeasts combined with calcium silicate or sulphur for controlling durum wheat powdery mildew and increasing grain yield components. *Field Crops Research*. 2012;134:36–46.
6. Lima G, Castoria R, De Curtis F, Raiola A, Ritieni A, and De Cicco V. Integrated control of blue mould using new fungicides and biocontrol yeasts lowers levels of fungicide residues and patulin contamination in stored apples. *Postharvest Biol. Technol*. 2011;60:164–172.

7. Andrews JH. Biological control in the phyllosphere. *Annu. Rev. Phytopathol.* 1992;30:603–635.
8. Ippolito A, Nigro F. Impact of application of biological control agents on postharvest ⁵²
diseases of fresh fruits and vegetables. *Crop Prot.* 2000;19:715–723.
9. Hoitink HAJ, Fahy PC. Basic for the control of soilborne plant pathogens with composts. *Annu. Rev. Phytopathol.* 1986;24:93–114.
10. Weller DM. Biological control of soil borne plant pathogens in the rhizo- sphere with ²⁵
bacteria. *Annu. Rev. Phytopathol.* 1988;26:379–407.
11. Haas D, De'fago G. Biological control of soil-borne pathogens by fluorescent ³²
Pseudomonas. *Adv. Rev. Microbiol.* 2005;3:307–319.
12. Janisiewicz WJ, Korsten L. Biological control of postharvest diseases of fruits. *Annu. Rev. Phytopathol.* 2002;40:411–441.
13. Droby S, Wisniewski M, Macarisin D, Wilson C. Twenty years of postharvest biocontrol ⁹
research: is it time for a new paradigm? *Postharvest Biol. Technol.* 2009;52:137–145.
14. Hatvani L, Manczinger L, Kredics L, Szekeres A, Antal Z, Vagvolgyi C. Production of *Trichoderma* strains with pesticide-polyresistance by mutagenesis and protoplast fusion. *Antonie van Leeuwenhoek.* 2006;89:387–393.
15. Dutta S, Chatterjee NC. Raising of carbendazim-tolerant mutants of *Trichoderma* and variations in their hydrolytic enzyme activity in relation to mycoparasitic action againsts *Rhizopus stolonifer*. *Journal of Plant Diseases and Protection.* 2004;111(6):557-565.
16. Khan MO, ⁴⁹Ahzad S. Screening of *Trichoderma* Species for Tolerance to ²³
fungicides. *Pak.J.Bot.* 2007;39(3):945-951.
17. Srinivas P, Ramakrishnan G. Use of native microorganisms and commonly recommended fungicides in integrated management of rice seed borne pathogens. *Ann. PL Protect. Sci.* 2002;10(2):260-264.
18. Gisi U, Ziegler H. Phenylamides (acylalanines and related): Metalaxyl, metalaxyl-M, furalaxyl, benalaxyl, ofurace, oxadixyl. In: Plimmer JR, editors. *Encyclopedia of Agrochemicals.* John Wiley, New York. ³⁵ 2002.
19. Muller U, Gisi U. Newest aspects ³⁵ nucleic acid synthesis inhibitors—metalaxyl-M. In: Krämer W, Schirmer U, editors. *Modern Crop Protection Compounds.* Wiley-VCH, Weinheim, Germany; 2007. ²⁰
20. Zhonghua Ma, Yoshimura MA, Michailides TJ. Identification and Characterization of Benzimidazole Resistance in *Monilinia fructicola* from Stone Fruit Orchards in ⁴⁸ California. *Applied and Environmental Microbiology.* 2003;69(12):7145-7152.
21. El-Katatny MS, El-Komy HM, Shaban GM. Effect of Benomyl on Chitinase and β-1,3-glucanase Production by Free and Alginate Encapsulated *Trichoderma harzianum*. ²² *Food Technol.Biotechnol.*2004;42(2):83-88.
22. Hetong Y, Ryder M, Wenghua T. Toxicity of Fungicides and Selective Medium Development for Isolation and Enumeration of *Trichoderma* spp. In: Agricultural soils. ²¹ International Subcommision on *Trichoderma* and *Hypocreales* Taxonomy, China;2008.
23. Bell DK, Wells HD, Markham CR. *In vitro* antagonism of *Trichoderma* species against ¹² fungal plant pathogens. *Phytopathology.* 1982;72:379-382.
24. Matroud S, Zamani MR, Motallebi M. Antagonistic effect of three species of *Trichoderma* sp. on *Sclerotinia sclerotiorum*, the causal agent of canola stem rot. *Egyptian Journal of Biology.* 2009;11:37-44.

- 10
25. Amin F, Razdani VK, Mohiddin FA, Bhat KA, Banday S. Potential of *Trichoderma* species as biocontrol agents of soil borne fungal propagules. *Journal of Phytology*. 2010;10(2):38–41.
 26. Singh A, Islam MN. In vitro evaluation of *Trichoderma* spp. against *Phytophthora nicotianae*. *Int. J.Expt. Agric.* 2010;1(1):20-25.
 27. Kusriningrum RS. Perancangan Percobaan. Airlangga University Press, Surabaya; 2012; 43-97. Indonesia.
 28. Parra G, Ristaino JB. Resistance to *Mefenoxam* and *Metalexyl* Among Field Isolates of *Phytophthora capsici* Causing *Phytophthora* Blight of Bell Pepper. *Plant Dis*. 2001;85:1069-1075.
 29. Jiahuai Hu. *Phytophthora nico⁵⁰iae* : Fungicide Sensitivity, Fitness, and Molecular Markers. Disertation. Faculty of the Virginia Polytechnic Institute and State University; 2007.
 30. Lorito M, Woo SL, D'Ambrosio M, Harman GE, Hayes CK, Kubicek CP, Scala F. Synergistic interaction between cell wall degrading enzymes and membrane affecting compounds. *Mol. Plant-Microbe Interact*. 1996;9:206-213.
 31. Ruocco M, Lanzuise S, Vinale F, Marra R, Turrà D, Lois Woo S, Lorito M. Identification of a New Biocontrol Gene in *Trichoderma atroviride*: The Role of an ABC Transporter Membrane Pump in the Interaction with Different Plant-Pathogenic Fungi. *The American Phytopathological Society*. 2009;22(3):291–301.
 32. Chaparro AP, Carvajal LH, and Orduz S. Fungicide Tolerance of *Trichoderma asperelloides* and *T. harzianum* strains. *Agricultural Sciences*. 2011;2(3):301-317.
 33. Deising HB, Reimann S, Pascholati SF. Mechanisms and Significance of Fungicide Resistance. *Brazilian Journal of Microbiology*. 2008;39:286-295.
 34. Buragohain AM, Das BC, Islam M. In vitro studies of *Trichoderma* species against *Sclerotium rolfsii* Sacc. *J.Agric.Sci*. 2000;13(1):99-100.
 35. Etebarian HR, Scott ES, Wicks TJ. *Trichoderma harzianum* T39 and *T. virens* DAR 74290 as potential biological control agents for *Phytophthora erythroseptica*. *Eur. J Plant Pathol*. 2001;106:329-337.
 36. Sanchez V, Rebollo O, Picaso RM, Cardenas E, Cordova J, Gonzalez O, Samuels GJ. In vitro antagonism of *Thielaviopsis paradoxa* by *Trichoderma longibrachiatum*. *Mycopathologia*. 2007;163:49-58.
 37. Watanabe S, Kumakura K, Kato H, Iyozumi H, Togawa M, Nagayama K. Identification of *Trichoderma* SKT-1, a biological control agent against seedborne pathogens of rice. *J Gen Plant Pathol*. 2005;71:351–356.
 38. Nagayama K, Watanabe S, Kumakura K, Ichikawa T, Makino T. Development and commercialization of *Trichoderma asperellum* SKT-1(EcochopeH), a microbial pesticide. *J Pestic Sci*. 2007;32:141–142.
 39. Sharon E, Chet I, Viterbo A, Bary-Eyal M, Nagan H, Samuels GJ, Spiegel Y. Parasitism of *Trichoderma* on *Meloidogyne javanica* and role of the gelatinous matrix. *Eur J Plant Pathol*. 2007;118:247–258.
 40. Chutrakul C, Alocer M, Bailey K, Peberdy JF. The production and characterization of trichotoxin peptaibols by *Trichoderma asperellum*. *Chem.Biodivers*. 2008;5:1694–1706.
 41. Otadoh JA, Okoth SA, Ochanda J, Kahindi JP. Assessment of *Trichoderma* Isolates for Virulence Efficacy on *Fusarium oxysporum* F. sp. *Phaseoli*. *Tropical and Subtropical Agroecosystems*. 2011;13:99-107.

42. Trillas MI, Casanova E, Cotxarrera L, Ordovás J, Borrero C, Avilés M. Composts from agricultural waste and the *Trichoderma asperellum* strain T-34 suppress *Rhizoctonia solani* in cucumber seedlings. Biological Control. 2006;39:32–38.
43. Sallam NMA, Abo-Elyousr KAM, Hassan MAE. Evaluation of *Trichoderma* Species as Biocontrol Agents for Damping-Off and Wilt Diseases of *Phaseolus vulgaris* L. and Efficacy of Suggested Formula. Egyptian Journal Phytopathology. 2008;36:81-93.

8

© 2014 Joeniarti et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/3.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

41 Peer-review history:

The peer review history for this paper can be accessed here:
<http://www.sciedomain.org/review-history.php?id=295&id=24&aid=2485>

Tolerance of *Trichoderma asperellum* Isolates to Chemical Fungicide and Their Antagonistic Activity against *Phytophthora infestans*

ORIGINALITY REPORT

24%
SIMILARITY INDEX

20%
INTERNET SOURCES

19%
PUBLICATIONS

10%
STUDENT PAPERS

PRIMARY SOURCES

- | | | |
|---|---|-----|
| 1 | medcraveonline.com
Internet Source | 1 % |
| 2 | ijpbs.net
Internet Source | 1 % |
| 3 | link.springer.com
Internet Source | 1 % |
| 4 | www.entomoljournal.com
Internet Source | 1 % |
| 5 | agriscience.scientific-work.org
Internet Source | 1 % |
| 6 | elfosscientiae.cigb.edu.cu
Internet Source | 1 % |
| 7 | Submitted to Higher Education Commission
Pakistan
Student Paper | 1 % |
| 8 | amb-express.springeropen.com
Internet Source | 1 % |
-

9	www.labome.org Internet Source	1 %
10	www.jabonline.in Internet Source	1 %
11	www.mdpi.com Internet Source	1 %
12	Sahar Abdelrazek, Philipp Simon, Micaela Colley, Tesfaye Mengiste, Lori Hoagland. "Crop management system and carrot genotype affect endophyte composition and <i>Alternaria dauci</i> suppression", PLOS ONE, 2020 Publication	1 %
13	www.hindawi.com Internet Source	1 %
14	fungalbiolbiotech.biomedcentral.com Internet Source	1 %
15	www.journalmrji.com Internet Source	1 %
16	Yohei Yoshioka. "Systemic resistance induced in <i>Arabidopsis thaliana</i> by <i>Trichoderma asperellum</i> SKT-1, a microbial pesticide of seedborne diseases of rice", Pest Management Science, 01/2012 Publication	1 %

17	Internet Source	1 %
18	comunicatascientiae.com.br Internet Source	1 %
19	www.ajol.info Internet Source	1 %
20	zwblxb.magtech.com.cn Internet Source	1 %
21	Submitted to Universidad Nacional de Colombia Student Paper	1 %
22	Saira Espinosa, Judith Figueroa, Peter G. Kevan, Carlos Baéz, Victor Solarte, Guy Smagghe, Andres Sánchez. "Chapter 12 Advances in the Implementation of Apivectoring Technology in Colombia: Strawberry Case (<i>Fragaria x ananassa</i>)", Springer Science and Business Media LLC, 2020 Publication	<1 %
23	www.omicsonline.org Internet Source	<1 %
24	www.scialert.net Internet Source	<1 %
25	Verginer, Markus, Erich Leitner, and Gabriele Berg. "Production of Volatile Metabolites by	<1 %

Grape-Associated Microorganisms", Journal of Agricultural and Food Chemistry, 2010.

Publication

- 26 Hye-Min Lee, Zakaullah Khan, Sang-Gyu Kim, Nam-In Baek, Young-Ho Kim. "Evaluation of the Biocontrol Potential of Some Medicinal Plant Materials Alone and in Combination with *Trichoderma harzianum* Against *Rhizoctonia solani* AG 2-1", The Plant Pathology Journal, 2011 <1 %
- Publication
-
- 27 calag.ucanr.edu <1 %
- Internet Source
-
- 28 Agnes W. Kiriga, Solveig Haukeland, George M. Kariuki, Danny L. Coyne, Nikolai V. Beek. "Effect of *Trichoderma* spp. and *Purpureocillium lilacinum* on *Meloidogyne javanica* in commercial pineapple production in Kenya", Biological Control, 2018 <1 %
- Publication
-
- 29 Anuj Bansal, Mohammad Shahid. "Pathobiological Identification of *Trichoderma* sp.", Journal of Pure and Applied Microbiology, 2016 <1 %
- Publication
-
- 30 ggfjournals.com <1 %
- Internet Source
-

31

ijlssr.com
Internet Source

<1 %

32

Zhang, Hongyin, Renping Li, and Weimin Liu.
"Effects of Chitin and Its Derivative Chitosan
on Postharvest Decay of Fruits: A Review",
International Journal of Molecular Sciences,
2011.

<1 %

Publication

33

R. Radjacommare, S. Venkatesan, R.
Samiyappan. " Biological control of
phytopathogenic fungi of vanilla through lytic
action of species and ", Archives Of
Phytopathology And Plant Protection, 2010

<1 %

Publication

34

You Zhou, Shuting He, Guoshu Gong, Shirong
Zhang, Xiaoli Chang, Na Liu, Xiaofang Sun,
Xiaobo Qi, Kunhao Ye, Yiyu Wang. "Soil fungal
diversity in three nature reserves of
Jiuzhaigou County, Sichuan Province, China",
Annals of Microbiology, 2014

<1 %

Publication

35

"Modern Crop Protection Compounds", Wiley,
2019

<1 %

Publication

36

Submitted to University of Port-Harcourt
Student Paper

<1 %

Submitted to University of Ulster

37

<1 %

38

researchoutput.csu.edu.au

Internet Source

<1 %

39

Nurul Huda, Nova Rini, Muslih ., Slamet Hidayat. "Problem and Solution Models for Halal Tourism Development in West Java", KnE Social Sciences, 2020

Publication

<1 %

40

Grazia Campanile, Angela Ruscelli, Nicola Luisi. "Antagonistic activity of endophytic fungi towards Diplodia corticola assessed by in vitro and in planta tests", European Journal of Plant Pathology, 2007

Publication

<1 %

41

bmccomplementmedtherapies.biomedcentral.com

Internet Source

<1 %

42

hdl.handle.net

Internet Source

<1 %

43

Raffaello Castoria. "Host Responses to Biological Control Agents", Post-harvest Pathology, 2009

Publication

<1 %

44

Submitted to Universiti Kebangsaan Malaysia

Student Paper

<1 %

45

www.issr-journals.org

<1 %

-
- 46 Das, I.K.. "Biocontrol of charcoal rot in sorghum by fluorescent pseudomonads associated with the rhizosphere", Crop Protection, 200811
Publication <1 %
- 47 P. Narayanasamy. "Crop Disease Management", Wiley, 2017
Publication <1 %
- 48 hrcak.srce.hr
Internet Source <1 %
- 49 www.rjpbc.com
Internet Source <1 %
- 50 "Integrated Pest Management of Tropical Vegetable Crops", Springer Science and Business Media LLC, 2016
Publication <1 %
- 51 Sheridan L. Woo, Matteo Lorito. "Chapter 6 EXPLOITING THE INTERACTIONS BETWEEN FUNGAL ANTAGONISTS, PATHOGENS AND THE PLANT FOR BIOCONTROL", Springer Science and Business Media LLC, 2007
Publication <1 %
- 52 Chanchaichaovivat, A.. "Screening and identification of yeast strains from fruits and vegetables: Potential for biological control of
<1 %

postharvest chilli anthracnose (*Colletotrichum capsici*)", Biological Control, 200709

Publication

- 53 D. Vitullo, R. Altieri, A. Esposito, F. Nigro, M. Ferrara, G. Alfano, G. Ranalli, V. De Cicco, G. Lima. "Suppressive biomasses and antagonist bacteria for an eco-compatible control of *Verticillium dahliae* on nursery-grown olive plants", International Journal of Environmental Science and Technology, 2012
- <1 %

Publication

Exclude quotes Off

Exclude bibliography Off

Exclude matches Off