

Integration of biological and physical tactics for management of tomato root rot under humid conditions of Nagaland

H. Hajong¹, L. Daiho^{1*}, S. Banik¹, and N. K. Adhikary^{2*}

¹Department of Plant Pathology, ²ICAR-AICRP on Vegetable Crops, School of Agricultural Sciences, Nagaland University, Medziphema Campus- 797106, India

* Email: nayan.bckv@gmail.com / dihrii61@gmail.com

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ABSTRACT

Tomato (*Solanum lycopersicon* Mill) is a popular vegetable crop cultivated throughout the world. Root rot caused by *Rhizoctonia solani* is reported to be one of the most devastating diseases of tomato. This research planned with aimed to effectively manage the tomato root rot disease by physical, biological, chemical methods and their combinations. The field experiment was conducted at School of Agricultural Sciences, Nagaland University, Medziphema campus. Under in vitro tests, bio-agents such as *Trichoderma harzianum*, *T. harzianum*-14, *T. virens*, *T. asperellum*; and fungicides namely azoxystrobin, mancozeb, copper oxychloride and chlorothalonil were evaluated for their inhibitory effect on *R. solani*. Among the antagonists, *T. harzianum*-14 was found most effective against *R. solani* with 67.43% inhibition under in vitro condition. Among the fungicides, mancozeb and copper oxychloride gave 100% inhibition against the pathogen. Compatibility test indicated that *T. harzianum*-14 was compatible with mancozeb at 0.25% concentration with 13.21% inhibition. Under field condition, integration of soil solarization for four weeks, soil treatment with *T. harzianum*-14 and spray with mancozeb (T_9) showed minimum disease incidence (22.22%) and plant height (69.53 cm), maximum branches number 8.20, number of maximum fruits/plants 35.77 and root length 24.83 cm. Highest average yield was obtained from the integrated management application (T_9) with 179.17 q/ha.

Keywords: Integrated management, mancozeb, *Rhizoctonia solani*, soil solarization, tomato, *Trichoderma harzianum*-14.

INTRODUCTION

Tomato (*Solanum lycopersicon* Mill), an annual and popular crop, belonging to family solanaceae, is cultivated everywhere. Tomatoes are reckoned an essential component of healthy nutritious diet because they contain minimal fat do not have harmful cholesterol. They are rich in ascorbic acid, vitamin A, potassium and folate. In addition, tomatoes are abundant in non-nutritive phytochemicals, which include carotenoids like lycopene, phytoene, and β -carotene, as

well as polyphenols such as flavonoids, flavanones and flavones (Tan *et al.*, 2010). Tomatoes are susceptible to many fungal diseases, including leaf spot, *Cercospora* leaf mould, *Fusarium* wilt, *Verticillium* wilt, grey leaf spot, powdery mildew, white mould, *Alternaria* stem canker, corky root rot, *Fusarium* crown and root rot, *Fusarium* foot rot, southern blight, and buckeye rot. These diseases, along with insect pests, represent major constraints to tomato production, contributing significantly to reductions in

agricultural productivity and substantial annual crop losses worldwide (Hasan *et al.*, 2020). In India, root rot is reported to be very destructive disease of tomato caused by *R. solani*. Root rot fungus when combined with root knot by nematode, *Meloidogyne incognita* can cause yield losses up to 38.64-56.74% in tomato crop (Upadhyay and Dwivedi, 2008).

The host range of *Rhizoctonia* spp. is very wide. It causes yield and quality losses on field crops, vegetables, ornamentals, shrubs, trees and development of diseases like crown rot, stem canker, damping off, root rot etc. (Chandel and Sharma, 2014). Yield reduction annually up to 108,000 metric tonnes is estimated to cause by *Rhizoctonia* root rot (Wrather *et al.*, 1997). The pathogen, *R. solani* is very difficult to manage as the survival rate of sclerotia is very high and wide host range (Groth and Bond, 2006). The pathogen, reported to be a cosmopolitan and a soil inhabiting fungus, several strains are known to exist and is a known phytopathogen of water hyacinth (Opande *et al.*, 2017).

Due to wide host range and long saprophytic survival ability of *R. solani* in soil, the pathogen once established in the field, management of the disease is quite challenging (Kumar *et al.*, 2011). Management of soil borne sclerotia producing pathogen like *R. solani* with chemical fungicides which is also very expensive and a difficult affair. However, under *in vitro* condition, management of *R. solani* with *Trichoderma* spp. has been found very effective and *Trichoderma* thrives in partially sterilized soil. It is, therefore, the present experiment on integrated management of tomato root rot, which is caused by *R. solani* was conducted.

MATERIALS AND METHODS

The present studies (*in vitro* and *in vivo*) were conducted in the Department of Plant Pathology, Nagaland University, Medziphema campus. *In vitro* evaluation was conducted in the laboratory of Plant Pathology

and *in vivo* experiments carried out at the instructional-cum-research farm.

The site of the experiment is situated in the lower elevation of Chumoukedima district of Nagaland at latitude of 25°45' 43" N, longitude of 93°53' 04" E and altitude of 310 m above mean sea level.-The experimental site at Medziphema is sub-tropic and high humid in climatic condition. The average temperature during the study period was between 21°C-32°C. The meteorological data recorded from ICAR-NEH Region, Nagaland Centre, Jharnapani, Nagaland during the period of study (Table 1).

Based on *in vitro* evaluation, the promising bio-agent and chemical were selected for field experiment. The trial was laid down in randomized block design (RBD) at instructional-cum-research farm, Medziphema with three replications each in integrated manner, viz. T₁: un-inoculated control (Neither pathogen nor treatment was applied. This represents the natural/background condition), T₂: inoculated control (Pathogen is applied, but no treatment was given. This represents the maximum disease pressure and serves as a benchmark for evaluating treatment effectiveness), T₃: 4 weeks soil solarization, T₄: soil application with *T. harzianum*-14, T₅: soil drenching at collar region with mancozeb, T₆: 4 weeks soil solarization + drenching of mancozeb at collar region, T₇: 4 weeks soil solarization with collar drenching with mancozeb, T₈: soil application with *T. harzianum*-14 (Mixing the inoculum (*T. harzianum*-14) with compost, farmyard manure, or fertilizer and incorporating it into the soil before sowing/transplanting) + collar drenching with mancozeb and T₉: 4 weeks soil solarization + soil application with *T. harzianum*-14 + collar drenching with mancozeb. The pure culture of *R. solani* was obtained from Plant Pathology department, School of Agricultural Sciences, Nagaland University, Medziphema Campus. The pure culture of *Trichoderma asperellum*, *T. harzianum*-14, *T. harzianum* and *T. virens*

and the chemical fungicides namely azoxystrobin (23% SC) @ 0.1%, mancozeb (75% WP) @ 0.25%; COC (50% WP) @ 0.3% and chlorothalonil (75% WP) @ 0.2%, were obtained from Plant Pathology department, SAS, Nagaland University.

Efficacy of bio-agents against *R. solani*

In vitro test of selected bio-agents were carried out against the pathogen by confrontation dual culture technique to select the most promising bio-agent for field experiment. The mycelial discs of the test pathogen and bio-agents of 5 mm each were placed opposite to each other in three replicated petri plates containing PDA medium. A set of three plates having the test pathogen alone was maintained as control for comparison. Petri plates were incubated after sealing with parafilm at $25 \pm 2^\circ\text{C}$ till full growth of the pathogen was obtained in control plates. The *in vitro* experiment, poisoned food technique was used to evaluate the effect of test fungicides against *R. solani* (Nene and Thapliyal, 1982). The percentage inhibition of mycelial growth of the pathogen by different fungicides was calculated using the formula described by Vincent (1947).

Compatibility test of the potential bio-agent with fungicides

Compatibility test between the bio-agent, *T. harzianum*-14 and the fungicides was carried out by poisoned food technique. The bio-agent was allowed to grow on the poisoned medium mixed with the appropriate dose of the test fungicides. Control plates containing non-poisoned PDA medium and the most effective bio-agent plates were maintained for comparison. The plates after sealing with parafilm were placed at $25 \pm 2^\circ\text{C}$ till complete growth of effective bio-agent was obtained in the control plates.

RESULTS AND DISCUSSION

In vitro* test of the antagonistic impact of bio-agents on *R. solani

Among four *Trichoderma* spp. tested in the present experiment for their antagonistic effect against *R. solani*, *T. harzianum*-14 was found the most potent bio-agent with 58.96% inhibition as compared to control with zero inhibition. This was followed by *T. harzianum* with 51.97% inhibition against the pathogen (Table 2). The above results are in line with earlier researchers (Karima *et al.*, 2012), who observed maximum antagonistic effect against *R. solani* under *in vitro* test was *T. harzianum*. An eco-friendly method to manage isabgol wilt caused by *Rhizoctonia* with the use of *T. harzianum* and *T. virens* which resulted in resistance in plants and significantly reduce wilt incidence (Ashraf *et al.*, 2013). The bioagent, *T. harzianum* stopped the development of *R. solani* after application with 47.68% of the fungus (Sonakar *et al.*, 2014). The yield and management were highest with *T. harzianum* when evaluated against *R. solani* (Khan *et al.*, 2014). Among four *Trichoderma* species tested, *T. harzianum* was found the best with 65.13% of inhibition against *R. solani* (Rajput *et al.*, 2016).

In vitro* test of fungicides against *R. solani

Among four chemical fungicides tested, mancozeb and copper oxychloride gave 100% mycelial growth inhibition of the pathogen, followed by chlorothalonil 68.69% inhibition and azoxystrobin 39.25% as compared to control with zero per cent inhibition against the pathogen (Table 3). The present experimental finding is in conformity with the reports of Mishra and Sinha (1999), who reported that mancozeb (0.25%) and chlorothalonil (0.20%) were highly effective in reducing post-emergence French bean root rot caused by the pathogen, *R. solani* under greenhouse condition. The effect of different fungicides on web blight of urd bean caused by the pathogen, *R. solani* and reported that carbendazim (0.1%) and mancozeb (0.25%)

were the best fungicides in minimizing disease severity and enhanced grain yield (Shailbala and Tripathi, 2004). Under *in vitro* condition, the combination of carbendazim and mancozeb showed most effective result in inhibiting growth of *R. solani* (Sharma et al., 2017).

Compatibility test of potent bio-agent with fungicides

The results of *in vitro* test between *T. harzianum*-14 with fungicides showed that the bio-agent was significantly compatible to mancozeb with the mean inhibition of 13.21% (Table 4). This finding is in conformity with earlier researcher (Bagwan, 2010), who observed that thiram (0.2%) and mancozeb (0.2%) had least growth inhibition of *T. harzianum*, growth inhibition of bio-agents below 35% were considered compatible. It was also reported that Ridomil gold (metalaxyl + mancozeb) and mancozeb were observed to have least inhibitory impact on *Trichoderma* sp. (Kumar et al., 2017). The compatibility test of *T. harzianum* with mancozeb and found least inhibitory effect on *Trichoderma* (Shashikumar et al., 2019).

Integrated management of tomato root rot

The findings of the present experiments indicated that minimum root rot disease incidence was observed in un-inoculated control (T₁) with 19.44%, followed by T₉ (with treatment combinations of soil solarization cum *T. harzianum*-4 soil inoculation + drenching at the collar region with mancozeb) with 22.22%. The highest disease incidence being recorded in pathogen inoculated control (T₂) with 70.51% at 90 days after sowing (Table 5). The uninoculated control (T₁) recorded the lowest disease incidence (19.44%), whereas all other treatments exhibited comparatively higher incidence. This observation suggests that the tested inoculation treatments did not confer the expected level of disease suppression under the prevailing experimental conditi

Several factors may have contributed to this response, including variation in microbial establishment and colonization, possible antagonistic interactions among introduced microorganisms and native microflora, environmental conditions influencing microbial activity, or host physiological responses to inoculation. Similar inconsistencies in biological treatment performance have been reported in the literature, where efficacy is strongly dependent on environmental and edaphic factors. Therefore, the present findings highlight the complexity of plant–microbe–pathogen interactions and emphasize that successful inoculation cannot be assumed across all conditions. The novelty of this study lies not in demonstrating superior disease control, but in identifying circumstances under which the tested inoculants failed to outperform the control, thereby providing valuable information for optimizing inoculation strategies and improving our understanding of factors governing treatment efficacy.

The findings are in line with the observation of Pinkerton et al. (2002), who stated *Trichoderma* application minimizes the incidence of leather rot by 76.6% compared to the untreated control. Whereas, soil solarization and *Trichoderma* inoculation in combination or alone, minimized leather rot incidence by 36.9% relative to the untreated control in the consecutive year. The combined treatment of soil solarization and *T. harzianum* reduced disease by 60%, 95% and 90% for bean, strawberry and cucumber respectively (Levy et al., 2004). Combining of soil solarization and bio-control agents reduced disease incidence by >83% (Jayaraj and Radhakrishnan, 2008). Lesser plant infection with 19.6% was recorded in combined application of *Trichoderma* isolate, plant extract and Ridomil compared to control where maximum infection of 85.2% was observed (Handiso and Alemu, 2017).

CONCLUSION

It may be concluded from the present experimental findings that tomato root rot management by integrating soil solarization with *T. harzianum*-14 and drenching with mancozeb at the collar region, is considered an effective management practice for tomato root rot reduction. The treatments are eco-friendly and has no ill effect on the environment and the consumers.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Table 1: Meteorological data during the experiment (August, 2019 to January, 2020).

Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)
	Max.	Min.	Max.	Min.	
August, 2019	33.9	24.8	91.8	73.2	57.9
September, 2019	31.9	23.2	94.0	71.8	42.6
October, 2019	30.2	21.1	95.5	71.0	74.2
November, 2019	28.4	15.7	97.5	64.0	26.5
December, 2019	25.8	8.7	97.3	55.0	9.4
January, 2020	25.4	7.3	97.0	54.0	6.7

Table 2: *In vitro* antagonistic test of bio-agents on *R. solani*

Treatment	Per cent inhibition (%)			Mean
	24 hrs.	48 hrs.	72 hrs.	
T ₀ : <i>R. solani</i>	0.00 (0.25)*	0.00 (0.25)	0.00 (0.25)	0.00
T ₁ : <i>T. asperellum</i>	31.55 (34.13)	33.99 (35.66)	57.32 (49.21)	40.95
T ₂ : <i>T. harzianum</i> -14	54.76 (47.74)	54.68 (47.70)	67.43 (55.21)	58.96
T ₃ : <i>T. harzianum</i>	45.24 (42.26)	47.17 (43.37)	62.95 (52.51)	51.97
T ₄ : <i>T. virens</i>	17.86 (24.81)	24.51 (29.65)	50.57 (45.33)	30.98
SEm±	1.66	1.09	0.52	-
CD (p=0.05)	5.15	3.43	1.65	

*Figures in parenthesis are angular transformed values

Table 3: *In vitro* evaluation of fungicides on mycelial growth of *R. solani*

Treatment	Per cent inhibition (%)			Mean (hrs.)
	24 hrs.	48 hrs.	72 hrs.	
T ₀ : <i>R. solani</i>	0.00 (0.25)	0.00 (0.25)	0.00 (0.25)	0.00
T ₁ : Azoxystrobin (0.10%)	20.83 (26.90)	32.75 (34.91)	64.16 (53.23)	39.25
T ₂ : Mancozeb (0.25%)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00
T ₃ : Copper oxychloride (0.30%)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00
T ₄ : Chlorothalonil (0.20%)	29.17 (32.59)	83.63 (66.13)	93.28 (74.98)	68.69
SEm±	1.65	0.17	0.38	-
CD (p=0.05)	5.08	0.53	1.16	

Table 4: Compatibility of *T. harzianum*-14 with the fungicides

Treatments	Mycelial growth mean (mm)	Per cent inhibition (%)	Compatible / non-compatible
T ₁ : <i>T. harzianum</i> -14 + azoxystrobin (0.10%)	8.33	71.64	Incompatible
T ₂ : <i>T. harzianum</i> -14 + mancozeb (0.25%)	26.67	13.21	Compatible
T ₃ : <i>T. harzianum</i> -14 + copper oxychloride (0.30%)	9.83	68.47	Incompatible
T ₄ : <i>T. harzianum</i> -14 + chlorothalonil (0.30%)	3.11	87.99	Incompatible
T ₀ : <i>T. harzianum</i> -14 (control)	29.44	0.00	Control
SEm±	0.38	1.50	
CD (p=0.05)	1.17	4.7	-

Table 5: Effect of integrated treatments on tomato root rot incidence

Treatments	Disease incidence (%)					
	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
T ₁ : Un-inoculated control	2.78 (9.42)* *	5.55 (13.63)	8.33 (16.78)	11.11 (19.21)	16.66 (23.91)	19.44 (25.76)
T ₂ : Inoculated control	27.66 (31.68)	33.33 (35.26)	36.11 (36.89)	41.66 (40.17)	60.89 (51.28)	70.51 (57.10)
T ₃ : 4 weeks soil Solarization	19.44 (26.06)	22.22 (28.03)	30.55 (33.51)	33.33 (35.25)	36.11 (36.85)	38.89 (38.57)
T ₄ : Soil treatment with <i>T. harzianum</i> -14	11.11 (19.45)	13.88 (21.86)	25.00 (29.94)	30.55 (33.51)	33.33 (35.02)	36.11 (36.91)
T ₅ : Drenching at the collar region with mancozeb	13.88 (21.65)	16.66 (24.08)	27.78 (31.75)	33.33 (35.25)	36.11 (36.82)	38.89 (38.57)
T ₆ : 4 weeks soil solarization + Soil treatment with <i>T. harzianum</i> -14	11.11 (19.21)	11.11 (19.21)	19.44 (26.13)	27.78 (31.75)	30.55 (33.51)	33.33 (35.15)
T ₇ : 4 weeks soil solarization + Drenching at the collar region with mancozeb	8.33 (16.78)	13.88 (21.65)	16.66 (24.02)	22.22 (28.03)	27.77 (31.43)	33.33 (35.15)
T ₈ : Soil treatment with <i>T. harzianum</i> -14 + Drenching at the collar region with mancozeb	5.55 (13.63)	11.11 (19.21)	16.66 (24.02)	19.44 (26.11)	22.22 (27.69)	24.99 (29.46)
T ₉ : 4 weeks soil solarization + Soil treatment with <i>T. harzianum</i> -14 + Drenching at the collar region with mancozeb	5.55 (13.63)	8.33 (16.78)	13.89 (21.18)	16.66 (24.02)	19.44 (25.76)	22.22 (27.81)
SEm±	1.55	1.50	1.97	1.58	3.18	2.71
CD (p=0.05)	4.64	4.49	5.90	4.74	9.54	8.14

*Figures in parenthesis are angular transformed values