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Integrated Management of Turmeric Rhizome Rot Caused by *Pythium aphanidermatum*

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A B S T R A C T

Turmeric (*Curcuma longa* L) rhizome rot caused by *Pythium aphanidermatum* was one of the divesting disease and causes accountable losses. All fungicides, bioagents, botanicals and soil amendments (alone and in combination) tested *in vitro* for management of turmeric rhizome rot was found effective against *P. aphanidermatum.* However, significantly highest reduction in average mortality was recorded with Metalaxyl (RT) + its drenching (85.37 %), followed by T4 + T5 (RT) + T1 (SA) (74.54 %), Carbendazim 12 % WP + Mancozeb 63 % WP (RT) + its drenching (73.30 %), T4 + T5 (RT) + T3 (SA) (71.87 %), Bioagent consortia (RT) + Its Drenching 71.20 %), Copper oxychloride (RT) + its drenching (68.79 %), T4 + T5 (RT) + T2 (SA) (68.40 %), T4 + T5 (RT) + Bioagent consortia (SA) (68.07 %), Metalaxyl (RT) (68.80 %), Carbendazim 12 % WP + Mancozeb 63 % WP (RT) (62.60 %), Copper oxychloride (RT) (61.31 %), *Trichoderma viride* (RT) (54.86 %), Neem leaf extract (RT) (51.22 %) and NSKE (SA) (48.09 %).

Introduction

Turmeric e belongs to family Zingiberaceae. This is also called as 'hidden Lilly' or 'golden spice' or 'turmeric of commerce' or 'Indian saffron' or 'Haldi'. It is originated from Tropical South Asia. Turmeric is the third largest spice produced in the country and it accounts for about 14 % of total spices produced in India. India is the world's largest producer of turmeric and apparently accounts for more than 80 per cent of the world's production, followed by China, Indonesia, Bangladesh, and Thailand (Selvan *et al.*, 2002). The area, production and productivity of turmeric in India has been reported to be 175.73 and 185.58 thousand hectares, 959.35 and 943.33 thousand tones and 5459 and 5083 kg/ha, respectively, during year 2014-15 and 2015-16 (Anonymous, 2016). The total area in Maharashtra under turmeric was 11.0 thousand hectares, with production 11.0 thousand tones and productivity of 1000 kg/ha, respectively (Anonymous, 2015).

Turmeric is prone to many fungal, bacterial, viral and nematode diseases. Among all diseases rhizome rot caused by *P. aphanidermatum* is most destructive and widespread disease causes very high crop loss under favorable conditions (Rathaiah, 1982). The disease has been reported to causes more than 60 per cent mortality of seedlings both in nursery and field condition and about 50-80 per cent losses during storage (Nirmal, 1992); rhizome rot resulted in yield loss of 50% (Rajalakshmi *et al*., 2016).

Materials and Methods

On the basis of results obtained in *in vitro* (plate and pot culture) the fungicides, bioagents, botanicals and soil amendments found effective were selected for integrated management of turmeric rhizome rot (pot culture). The earthen pots (30 cm dia.) disinfected with 5 per cent of Copper sulphate solution were filled with the autoclaved potting mixture of soil: sand: FYM (2:1:1). The mass multiplied (sand: maize medium) inoculum of *P. aphanidermatum* was inoculated (@ 50 g / kg potting mixture) separately to the potting mixture in pots, mixed thoroughly, watered adequately and incubated for two weeks in the screen house, to proliferate the pathogen and make the soil / potting mixture sick. The pot culture experiment comprised of 15 treatments as described under treatment details.

The test fungicides, talc based formulations of the bioagents and consortia, aqueous extract of botanicals and soil amendments were applied (alone and in combination) as pre-sowing rhizome treatment to the healthy rhizomes of turmeric Cv. Selum and post sowing soil application. After 96 hrs treated healthy rhizomes of turmeric Cv. Selum were sown (1 rhizome / pot), in the earthen pots containing *P. aphanidermatum* sick soil and maintained in the screen house. The earthen pots containing *P. aphanidermatum* sick soil sown with surface sterilized healthy rhizomes of turmeric Cv. Selum and without application of any treatment were maintained as untreated control. For each treatment, six pots / treatment / replication were maintained and all treatments replicated thrice. All these pots were watered regularly and maintained in the screen house for further studies.

Observations on rhizome germination and pre emergence rhizome rot (PERR) will be recorded at 30 days after sowing and that of post emergence seedling mortality (PESM) at 60, 90, 120 and 150 DAS. The per cent of rhizome germination, pre emergence rhizome rot (PERR) and post emergence seedling mortality (PESM) will be calculated by following formulae.

$$\text{Germination (\%)} = \frac{\text{No. of rhizomes germinated}}{\text{Total no. of rhizomes sown}} \times 100$$

$$\text{PERR (\%)} = \frac{\text{No. of rhizomes ungerminated}}{\text{Total no. of rhizomes sown}} \times 100$$

$$\text{PESM (\%)} = \frac{\text{No. of seedlings died}}{\text{Total no. of seedlings}} \times 100$$

Results and Discussion

Effect on rhizome germination

Results (Table 1 and Fig. 1) revealed that all the test treatments improved rhizome germination, over untreated control and it was ranged from 65.14 [NSKE (SA)] to 90.17 (Metalaxyl (RT) + its drenching) per cent, as against 40.06 per cent in untreated control.

However it was significantly highest with Metalaxyl (RT) + its drenching (90.17 %), followed by Metalaxyl (RT) (83.71 %), T4 + T5 (RT) + T1 (SA) (80.41 %), Carbendazim 12 % WP + Mancozeb 63 % WP (RT) + its drenching (80.12 %), T4 + T5 (RT) + T3 (SA) (79.86 %), Bioagent consortia (RT) + its drenching (79.52 %), Copper oxychloride (RT) + its drenching (77.94 %), T4 + T5 (RT) + T2 (SA) (77.68 %), T4 + T5 (RT) + Bioagent consortia (SA) (77.54 %), Carbendazim 12 % WP + Mancozeb 63 % WP (RT) (77.48 %), Copper oxychloride

(RT) (76.14 %) and *Trichoderma viride* (RT) (70.92 %). Whereas, NSKE (SA) and Neem leaf extract (RT) were found least effective with comparatively minimum rhizome germination of 65.14 and 67.56 per cent, respectively. Further, all the test treatments recorded significantly increase in rhizome germination, over untreated control and it was ranged from 38.50 [NSKE (SA)] to 55.57 (Metalaxyl (RT) + its drenching) per cent. However, highest increase in rhizome germination was recorded with Metalaxyl (RT) + its drenching (55.57 %), followed by Metalaxyl (RT) (52.14 %), T4 + T5 (RT) + T1 (SA) (50.18 %), Carbendazim 12 % WP + Mancozeb 63 % WP (RT) + its drenching (50.00 %), T4 + T5 (RT) + T3 (SA) (49.84 %), Bioagent consortia (RT) + its drenching (49.62 %), Copper oxychloride (RT) + its drenching (48.60 %), T4 + T5 (RT) + T2 (SA) (48.43 %), T4 + T5 (RT) + Bioagent consortia (SA) (48.34 %), Carbendazim 12 % WP + Mancozeb 63 % WP (RT) (48.30 %), Copper oxychloride (RT) (47.39 %) and *Trichoderma viride* (RT) (43.51 %). Whereas, NSKE (SA) and Neem leaf extract (RT) were found less effective with 38.50 and 40.70 per cent increase in rhizome germination, respectively.

Effect on pre and post emergence mortalities

It is evident from Table 1 and Figure 1 all the treatments significantly influenced the both pre emergence rhizome rot (PERR) and post emergence seedling mortality (PESM), caused by *P. aphanidermatum* in turmeric Cv. Selum.

The pre emergence rhizome rot (PERR) recorded with all the treatments was ranged from 9.83 (Metalaxyl (RT) + its drenching) to 34.86 [NSKE (SA)] per cent, as against 59.94 per cent in untreated control. However it was significantly least with Metalaxyl (RT) + its drenching (9.83 %), followed by Metalaxyl (RT) (16.29 %), T4 + T5 (RT) + T1 (SA) (19.59 %), Carbendazim 12 % WP + Mancozeb 63 % WP (RT) + its drenching (19.88 %), T4 + T5 (RT) + T3 (SA) (20.14 %), Bioagent consortia (RT) + its drenching (20.48 %), Copper oxychloride (RT) + its drenching (22.06 %), T4 + T5 (RT) + T2 (SA) (22.32 %), T4 + T5 (RT) + Bioagent consortia (SA) (22.46 %), Carbendazim 12 % WP + Mancozeb 63 % WP (RT) (22.52 %), Copper oxychloride (RT) (23.86 %) and *Trichoderma viride* (RT) (29.08 %). Whereas, NSKE (SA) and Neem leaf extract (RT) were found least effective with comparatively maximum pre emergence rhizome rot of 34.86 and 32.44 per cent, respectively.

The post emergence seedling mortality (PESM) recorded with all the treatments was ranged from 12.85 (Metalaxyl (RT) + its drenching) to 35.23 [NSKE (SA)] per cent, as against 100 per cent in untreated control. However it was significantly least with Metalaxyl (RT) + its drenching (12.85 %), followed by T4 + T5 (RT) + T1 (SA) (18.23 %), Carbendazim 12 % WP + Mancozeb 63 % WP (RT) + its drenching (20.24 %), T4 + T5 (RT) + T3 (SA) (22.65 %), Bioagent consortia (RT) + its drenching (23.43 %), Copper oxychloride (RT) + its drenching (25.61 %), T4 + T5 (RT) + T2 (SA) (25.97 %), T4 + T5 (RT) + Bioagent consortia (SA) (26.38 %), Metalaxyl (RT) (35.23 %), Carbendazim 12 % WP + Mancozeb 63 % WP (RT) (37.22 %), Copper oxychloride (RT) (37.58 %) and *Trichoderma viride* (RT) (41.76 %). Whereas, NSKE (SA) and Neem leaf extract (RT) were found least effective with comparatively maximum post emergence seedling mortality of 45.67 and 43.44 per cent, respectively.

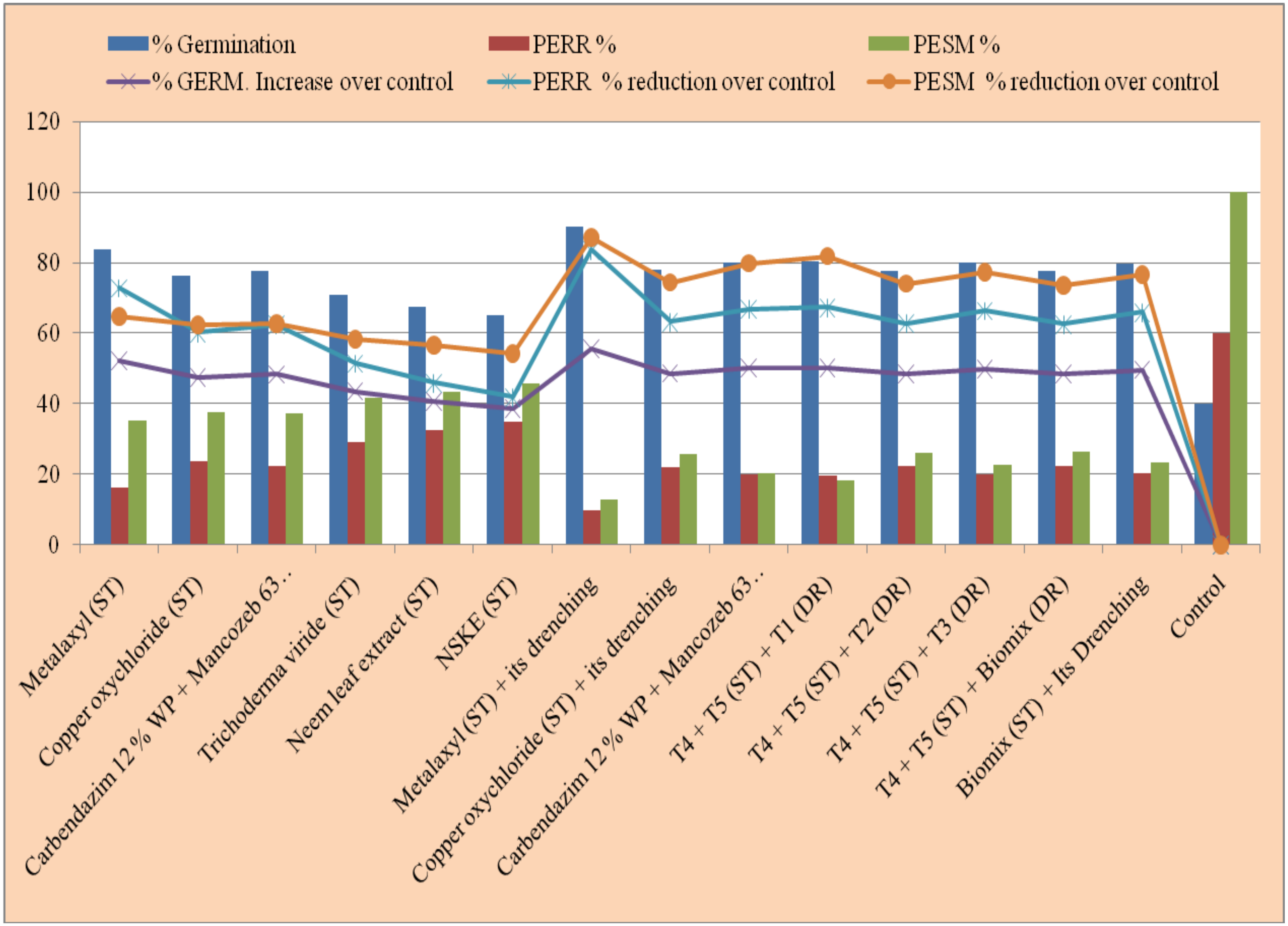
The average mortality recorded with all the treatments was ranged from 11.34 (Metalaxyl (RT) + its drenching) to 40.27 [NSKE (SA)] per cent, as against 79.97 per cent in untreated control.

Table.1 Integrated disease management against turmeric rhizome rot Cv. Selum (Pot culture)

Tr. No.	Treatments	Dose (g/kg of rhizome or t/ha of soil)	Germination * (%)	% Incr. over contr.	Incidence (%) *		Av. Mor. (%)	Red. (%) over control		Av. Red. (%)
					PERR	PESM		PERR	PESM	
T_1	Metalaxyl (RT)	1.0 g/kg	83.71 (66.20)	52.14 (46.23)	16.29 (23.80)	35.23 (36.41)	25.76 (30.50)	72.82 (58.58)	64.77 (53.59)	68.80 (56.04)
T_2	Copper oxychloride (RT)	2.5 g/kg	76.14 (60.76)	47.39 (43.50)	23.86 (29.24)	37.58 (37.81)	30.72 (33.66)	60.19 (50.88)	62.42 (52.19)	61.31 (51.53)
T_3	Carbendazim 12 % WP + Mancozeb 63 % WP (RT)	2.0 g/kg	77.48 (61.67)	48.30 (44.02)	22.52 (28.33)	37.22 (37.60)	29.87 (33.13)	62.43 (52.20)	62.78 (52.40)	62.60 (52.30)
T_4	*Trichoderma viride* (RT)	10 g/kg	70.92 (57.37)	43.51 (41.27)	29.08 (32.63)	41.76 (40.26)	35.42 (36.52)	51.48 (45.85)	58.24 (49.74)	54.86 (47.79)
T_5	Neem leaf extract (RT)	10 ml/kg	67.56 (55.28)	40.70 (39.64)	32.44 (34.72)	43.44 (41.23)	37.94 (38.02)	45.88 (42.64)	56.56 (48.77)	51.22 (45.70)
T_6	NSKE (SA)	50 g / Kg of potting mixture	65.14 (53.81)	38.50 (38.35)	34.86 (36.19)	45.67 (42.52)	40.27 (39.39)	41.84 (40.30)	54.33 (47.48)	48.09 (43.90)
T_7	Metalaxyl (RT) + its drenching	1.0 g/kg + 1.0 %	90.17 (71.73)	55.57 (48.20)	9.83 (18.28)	12.85 (21.01)	11.34 (19.68)	83.59 (66.11)	87.15 (68.99)	85.37 (67.51)
T_8	Copper oxychloride (RT) + its drenching	2.5 g/kg + 2.5 %	77.94 (61.99)	48.60 (44.20)	22.06 (28.01)	25.61 (30.40)	23.84 (29.22)	63.20 (52.65)	74.39 (59.60)	68.79 (56.04)
T_9	Carbendazim 12 % WP + Mancozeb 63 % WP (RT) + its drenching	2.0 g/kg + 2.0 %	80.12 (63.52)	50.00 (45.00)	19.88 (26.48)	20.24 (26.74)	20.06 (26.61)	66.83 (54.84)	79.76 (63.26)	73.30 (58.89)
T_{10}	T4 + T5 (RT) + T1 (SA)	10 g/kg + 10 ml/kg + 1.0 %	80.41 (63.73)	50.18 (45.10)	19.59 (26.27)	18.23 (25.28)	18.91 (25.78)	67.32 (55.13)	81.77 (64.72)	74.54 (59.70)
T_{11}	T4 + T5 (RT) + T2 (SA)	10 g/kg + 10 ml/kg + 2.5 %	77.68 (61.81)	48.43 (44.10)	22.32 (28.19)	25.97 (30.64)	24.15 (29.43)	62.76 (52.39)	74.03 (59.36)	68.40 (55.79)
T_{12}	T4 + T5 (RT) + T3 (SA)	10 g/kg + 10 ml/kg + 2.0 %	79.86 (63.33)	49.84 (44.91)	20.14 (26.67)	22.65 (28.42)	21.40 (27.55)	66.40 (54.57)	77.35 (61.58)	71.87 (57.97)
T_{13}	T4 + T5 (RT) + Bioagent consortia (SA)	10 g/kg + 10 ml/kg + 4 kg/ha	77.54 (61.71)	48.34 (44.05)	22.46 (28.29)	26.38 (30.90)	24.42 (29.61)	62.53 (52.26)	73.62 (59.10)	68.07 (55.60)
T_{14}	Bioagent consortia (RT) + its drenching	10 g/kg + 4 kg/ha	79.52 (63.09)	49.62 (44.78)	20.48 (26.91)	23.43 (28.95)	21.96 (27.94)	65.83 (54.23)	76.57 (61.05)	71.20 (57.54)
T_{15}	Control		40.06 (39.27)	00.00 (00.00)	59.94 (50.73)	100.00 (90.00)	79.97 (63.41)	00.00 (00.00)	00.00 (00.00)	00.00 (00.00)
	SE ±		**0.26**	**0.24**	**0.31**	**0.30**	**0.31**	**0.38**	**0.30**	**0.34**
	CD (P=0.01)		**0.74**	**0.70**	**0.90**	**0.86**	**0.88**	**1.02**	**0.86**	**0.94**

*-Mean of three replications, Av.: Average, Mor.: Concentration, Incr.: Increase Red.: Reduction, PERR: Pre emergence rhizome rot, PESM: Post Emergence Seedling Mortality, RT: Rhizome Treatment, SA: Soil Application, Figures in parentheses are angular transformed values

Fig.1 Integrated efficacy of various treatments against turmeric rhizome rot (Pot Culture)



However, it was significantly least with Metalaxyl (RT) + its drenching (11.34 %), followed by T4 + T5 (RT) + T1 (SA) (18.91 %), Carbendazim 12 % WP + Mancozeb 63 % WP (RT) + its drenching (20.06 %), T4 + T5 (RT) + T3 (SA) (21.40 %), Bioagent consortia (RT) + its drenching (21.96 %), Copper oxychloride (RT) + its drenching (23.84 %), T4 + T5 (RT) + T2 (SA) (24.15 %), T4 + T5 (RT) + Bioagent consortia (SA) (24.42 %), Metalaxyl (RT) (25.76 %), Carbendazim 12 % WP + Mancozeb 63 % WP (RT) (29.87 %), Copper oxychloride (RT) (30.72 %) and *Trichoderma viride* (RT) (35.42 %). Whereas, NSKE (SA) and Neem leaf extract (RT) were found least effective with comparatively maximum average mortality of 40.27 and 37.94 per cent, respectively.

Reduction in mortality

All the test treatments were found to reduce both PERR and PESM over untreated control (Table 1).

The reduction in pre emergence rhizome rot (PERR) was ranged from 41.84 [NSKE (SA)] to 83.59 (Metalaxyl (RT) + its drenching) per cent. However, it was significantly highest with Metalaxyl (RT) + its drenching (83.59 %), followed by Metalaxyl (RT) (72.82 %), T4 + T5 (RT) + T1 (SA) (67.32 %), Carbendazim 12 % WP + Mancozeb 63 % WP (RT) + its drenching (66.83 %), T4 + T5 (RT) + T3 (SA) (66.40 %), Bioagent consortia (RT) + its drenching (65.83 %), Copper oxychloride (RT) + its drenching (63.20 %), T4 + T5 (RT) + T2 (SA) (62.76 %), T4 + T5 (RT) + Bioagent consortia (SA) (62.53 %), Carbendazim 12 % WP + Mancozeb 63 % WP (RT) (62.43 %), Copper oxychloride (RT) (60.19 %) and *Trichoderma viride* (RT) (51.48 %). Whereas, NSKE (SA) and Neem leaf extract (RT) were recorded comparatively least reduction in pre emergence rhizome rot of 41.84 and 45.88 per cent, respectively.

The reduction in post emergence seedling mortality (PESM) was ranged from 54.33 [NSKE (SA)] to 87.15 (Metalaxyl (RT) + its drenching) per cent. However, it was significantly highest with Metalaxyl (RT) + its drenching (87.15 %), followed by T4 + T5 (RT) + T1 (SA) (81.77 %), Carbendazim 12 % WP + Mancozeb 63 % WP (RT) + its drenching (79.76 %), T4 + T5 (RT) + T3 (SA) (77.35 %), Bioagent consortia (RT) + its drenching (76.57 %), Copper oxychloride (RT) + its drenching (74.39 %), T4 + T5 (RT) + T2 (SA) (74.03 %), T4 + T5 (RT) + Bioagent consortia (SA) (73.62 %), Metalaxyl (RT) (64.77 %), Carbendazim 12 % WP + Mancozeb 63 % WP (RT) (62.78 %), Copper oxychloride (RT) (62.42 %) and *Trichoderma viride* (RT) (58.24 %). Whereas, NSKE (SA) and Neem leaf extract (RT) were recorded comparatively least reduction in post emergence seedling mortality of 54.33 and 56.56 per cent, respectively.

The reduction in average mortality was ranged from 48.09 [NSKE (SA)] to 85.37 (Metalaxyl (RT) + its drenching) per cent. However, it was significantly highest with Metalaxyl (RT) + its drenching (85.37 %), followed by T4 + T5 (RT) + T1 (SA) (74.54 %), Carbendazim 12 % WP + Mancozeb 63 % WP (RT) + its drenching (73.30 %), T4 + T5 (RT) + T3 (SA) (71.87 %), Bioagent consortia (RT) + its drenching 71.20 %), Copper oxychloride (RT) + its drenching (68.79 %), T4 + T5 (RT) + T2 (SA) (68.40 %), T4 + T5 (RT) + Bioagent consortia (SA) (68.07 %), Metalaxyl (RT) (68.80 %), Carbendazim 12 % WP + Mancozeb 63 % WP (RT) (62.60 %), Copper oxychloride (RT) (61.31 %) and *Trichoderma viride* (RT) (54.86 %). Whereas, NSKE (SA) and Neem leaf extract (RT) were recorded comparatively least reduction in average mortality of 48.09 and 51.22 per cent, respectively. These results are in conformity with the findings of those reported earlier by several workers against, *Pythium aphanidermatum* infecting turmeric (Sagar, 2006; Bharathi and Sudhakar, 2011;

Shanmugam *et al.*, 2015), *P. aphanidermatum* infecting ginger (Jayasekhar *et al.*, 2000; Balakrishnan, 2005; Anonymous, 2006; Sagar, 2006; Kulkarni *et al.*, 2007; Kulkarni, 2011; Kadam, 2014, Basistha and Homan, 2015; Dhroo *et al.*, 2015).

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