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Management of foot rot of finger millet (*Eleusine coracana* (L.) Gaertan) caused by *Sclerotium rolfsii*

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Abstract
Seed treatment with *T. harzianum* @ 5 g kg^{-1} seed followed by root dipping in *T. harzianum* solution plus application of Neem cake @ 50 g hill^{-1} at transplanting recorded the lowest mean per cent disease incidence (3.69) and the maximum average yield for 2 years was 34.54 q ha^{-1}. Seed treatment with thiram @ 3 g kg^{-1} of seed plus seedling root dipping in solution of *T. harzianum* at transplanting plus application of neem cake @ 50 g hill^{-1} at transplanting was at par at 15 DAT, 30 DAT and 60 DAT respectively.

Keywords: Finger millet, foot rot, *Sclerotium rolfsii*, seed treatment, thiram, neem cake powder, root diping, trichoderma harzianum, percent disease incidence (PDI)

Introduction
Finger millet (*Eleusine coracana* (L.) Gaertan) is one of the important cereal millet crops grown under rain fed condition by small and marginal farmers and tribal population for both grain and forage. It is commonly called as 'nutritious millet' providing fair amount of proteins, minerals, calcium, fibres and vitamins in abundance to people. It is good source for growing infants and aged people who need calcium supplement. The higher fiber content of finger millet helps in many ways as it prevents constipation, high cholesterol formation and intestinal cancer. People suffering from diabetes are advised to eat finger millet and other small millets instead of rice (Malleshi and Haddimani 1993) [8].

S. rolfsi is predominantly distributed in tropical and sub-tropical countries. It is cultivated in more than 25 countries in Africa and Asia, because of its adaptability to different agro climatic conditions. In India major finger millet growing states are Karnataka, Tamil Nadu, Andhra Pradesh, Odisha, Maharashtra, Uttar Pradesh, Bihar and Gujrat accounting for more than 95.00 per cent of the total finger millet production (Sonnad, 2005) [15]. It is grown on 1268 thousand hectares with a production of 1888.5 thousand ton. In Maharashtra, finger millet occupies an area of about 927 hundred ha with an annual grain production of 1111 hundred ton with productivity 1198 kg ha^{-1}. The largest acreage of ragi is in Konkan region. In Konkan region, finger millet plays an important role in agriculture with an area of 326 hundred ha with an annual production 411 hundred ton (Anonymous, 2016) [2].

Foot rot of finger millet caused by *S. Rolfsi* Sacc. is common in rainy season when warm temperature and high relative humidity exists. Weber (1931) [16] and Garret (1956) [6] reported that fungus survived in the soil for many years by producing sclerotial bodies and causing the disease either in the form of stem rot or foot rot or root rot in addition to leaf blight on several of its hosts. *S.rolfsii* can over winter as mycelium in infected tissues or plant debris. Sclerotia serves as the principal over wintering structure and primary inoculum for disease persisting near the soil surface.

Foot rot which has been reported to cause more than 50 per cent yield loss. As the disease was minor and sporadic in nature, extensive systematic studies have not been carried out, but it is increasing in the recent past; particularly under in high rainfall situations (Nagaraja and Reddy, 2009) [11]. The present research work was conducted to investigate the combinations of various treatments including chemicals, bio-agents and organic amemdments to manage the disease to minimum level and to obtain the maximum yield.

Materials and Methods

Preparation of nursery (Raising of seedlings) and preparation of experimental plot

Nursery for raising seedlings was prepared as per treatments T_1 (Seed treatment with Thiram @ 3g kg^{-1} of seed), T_2 (Seed treatment with *Trichoderma harzianum*@ 5g kg^{-1} of seed) and T_3 (Control) by using standard practices. Preparation of experimental plot was also done by employing all standard agronomic techniques.

Treatment details for the management of foot rot of finger millet.

Tr. No.	Treatment	Time of application
T_1	Seed treatment with thiram @ 3g kg^{-1} of seed.	Sowing
T_2	Seed treatment with *Trichoderma harzianum*@ 5g kg^{-1} of seed.	sowing
T_3	Seed treatment with thiram@ 3g kg^{-1} of seed. + seedling root dipping in water solution of *T.harzianum* 0.5 % before transplanting.	Sowing and transplanting
T_4	Seed treatment with *T.harzianum* @ 5g kg^{-1} of seed + seedling root dipping in *T.harzianum* before transplanting.	Sowing and transplanting
T_5	Seed treatment with thiram @ 3g kg^{-1} of seed + application of Neem cake @ 50 g hill^{-1} during transplanting.	Sowing and transplanting
T_6	Seed treatment with *T.harzianum* @ 5g kg^{-1}of seed + application of Neem cake @ 50 g hill^{-1} during transplanting.	Sowing and transplanting
T_7	Seed treatment with thiram @ 3g kg^{-1} of seed + seedling root dipping in *T.harzianum* before transplanting + application of Neem cake @ 50 g hill^{-1} during transplanting.	Sowing and transplanting
T_8	Seed treatment with *T.harzianum*@ 5g kg^{-1} of seed + seedling root dipping in *T.harzianum* before transplanting + application of Neem cake @ 50 g hill^{-1} during transplanting.	Sowing and transplanting
T_9	Control	-----

Methods of recording observations

Data were recorded visually by observing the symptoms. The observations were recorded at fortnight interval from the day of transplanting. The number of foot rot infected plants were counted from each treatment plot and the percent disease incidence was worked out by the formula

$$\text{Percent Disease Incidence (PDI)} = \frac{\text{Number of foot rot infected plants}}{\text{Total no of plants observed}} \text{X } 100$$

Percent Disease Control (PDC) against untreated was calculated by the formula

$$\text{\% Disease Control (PDC)} = \frac{\text{PDI in control-PDI in treatment}}{\text{PDI in control}} \text{ X } 100$$

Yield

Fingers were harvested at maturity and yields of net plot were recorded in kg per plot and later expressed in quintols per hectare.

Percent yield increase over control

$$\text{Yield increase over control (\%)} = \frac{\text{Yield in treatment plot-Yield in control plot}}{\text{Yield in control plot}} \text{X} 100$$

Results and Discussion

Percent disease incidence

The pooled analysis of data depicted in Table 1 and Fig.1 revealed that the per cent disease incidence (PDI) ranged from 0.19 to 5.05 at 15 DAT, 0.85 to 7.45 at 30 DAT, 2.18 to 12.13 at 45 DAT and 3.69 to 13.41 at 60 DAT respectively. Seed treatment with *T. harzianum* @ 5 g kg^{-1} seed plus root dipping in *T. harzianum* solution plus application of neem cake @ 50 g hill^{-1} at transplanting (T_8) recorded the lowest per cent disease incidence 0.19, 0.85, 2.18 and 3.69 at 15 DAT, 30DAT, 45 DAT and 60 DAT respectively. and the highest per cent disease incidence 5.05, 7.45, 12.13 and 13.41 was recorded in T_9 (Control) at 15 DAT, 30DAT, 45 DAT and 60 DAT respectively.

Seed treatment with *T. harzianum* @ 5 g kg^{-1} seed plus seedling root dipping in *T. harzianum* solution plus application of Neem cake @ 50 g hill^{-1} at transplanting (T_8) and Seed treatment with thiram @ 3 g kg^{-1} of seed plus seedling root dipping in solution of *T. harzianum* at transplanting plus application of neem cake @ 50 g hill^{-1} at transplanting (T_7) were at par at 15 DAT, 30 DAT and 60 DAT. Seed treatment with *T. harzianum* @ 5 g kg^{-1} of seed + application of neem cake @ 50 g hill^{-1} at transplanting (T_6) and seed treatment with thiram @ 3 g kg^{-1} of seed plus application of neem cake @ 50 g hill^{-1} at transplanting (T_5) were at par at 15 DAT and 30 DAT. Seed treatment with *T. harzianum* @ 5 g kg^{-1} of seed plus seedling root dipping in solution of *T. harzianum* at transplanting (T_4) and seed treatment with thiram @ 3g kg^{-1} of seed plus seedling root dipping in solution of *T. harzianum* at transplanting (T_3) were at par at 30 DAT and seed treatment with thiram @ 3 g kg^{-1} of seed plus application of neem cake @ 50 g hill^{-1} at transplanting (T_5) and Seed treatment with *T. harzianum* @ 5 g kg^{-1} of seed + Seedling root dipping in solution of *T. harzianum* at transplanting (T_4) and Seed treatment with Thiram @ 3g kg^{-1} of seed + Seedling root dipping in solution of *T. harzianum* at transplanting (T_3) were at par at 45 DAT.

In respect of terminal disease incidence at 60 DAT, seed treatment with *T. harzianum* @ 5 gm kg^{-1} seed plus seedling root dipping in *T. harzianum* solution plus application of Neem cake @ 50 g hill^{-1} at transplanting (T_8) and Seed treatment with Thiram @ 3g kg^{-1} of seed + Seedling root dipping in solution of *T. harzianum* at transplanting + Application of Neem cake @ 50 g hill^{-1} at transplanting (T_7) were at par. So also treatments Seed treatment with Thiram @ 3g kg^{-1} of seed + Seedling root dipping in solution of *T. harzianum* at transplanting (T_3) and seed treatment with *T. harzianum* @ 5g kg^{-1} of seed (T_2) were at par.

Per cent disease reduction

The comparison of all the treatments comprising use of bio-agents, organic and fungicides with control revealed that seed treatment with *T. harzianum* @ 5 g kg^{-1} seed plus root dipping in *T. harzianum* solution plus application of neem cake @ 50 g hill^{-1} at transplanting (T_8) recorded the highest (72.46 %) reduction in disease incidence which was followed by seed treatment with thiram @ 3g kg^{-1} of seed + seedling root dipping in solution of *T. harzianum* at transplanting + application of neem cake @ 50 g hill^{-1} at transplanting (T_7), Seed treatment with *T. harzianum* @ 5 g kg^{-1} of seed +

application of neem cake @ 50 g hill^{-1} at transplanting (T_6). More than 50 per cent reduction in disease was recorded in seed treatment with *T. harzianum* @ 5 g kg^{-1} seed plus seedling root dipping in *T. harzianum* solution plus application of neem cake @ 50 g hill^{-1} at transplanting (T_8) (72.46%) and seed treatment with thiram @ 3g kg^{-1} of seed + Seedling root dipping in solution of *T. harzianum* at transplanting + application of neem cake @ 50 g hill^{-1} at transplanting (T_7) (67.42).

Mundhe (2005) [9] tested ten antagonists against *S. rolfsi*, the causal agent of finger millet foot rot. They found that maximum inhibition of *S. rolfsi* was accomplished due to *T. harzianum* (strain P) (73.77%) followed by *T. harzianum* (strain JCR) (73.00%) *T. viride* (JCR) (72.66%) and *P. fluorescens* (71.55%). The result of thiarm applications are in agreement with the results of Dabre (2000) who found the total inhibition of *S. rolfsii* causing collar rot of gerbera due to Thiram (0.25%). The results of application of *T. harzianum* to the root zone of tomatoes controlled *Sclerotium rolfsii* infection in naturally infested soil and further on transplanting the treated plants showed reduced disease incidence to the tune of 93 per cent (Elad *et al.*, 1980) [5]. Furrow application of talc based *T. harzianum* (106 cfu g^{-1}) @1.5 kg mixed with 300 kg of either farm yard manure or castor cake ha^{-1} just before sowing to control stem rot disease of groundnut was recommended for Saurashtra farmers (Anon., 2001) [1]. The findings of application of combination of bio-agent and fungicides are in tune with research work of Dutta and Das (2002) [4] who tested the efficacy of *T. harzianum, T. viride, a*nd *T. koningii* and two seed dressing fungicides *viz.* thiram (0.10%) and mancozeb (0.10%) for the management of collar rot of tomato, caused by *S. rolfsii*. Soil application of *Trichoderma* at the time of transplanting or application of farmyard manure with *T. harzianum* resulted in minimum disease incidence and increased dry mass of roots, shoots and yield. Results of using different *Trichoderma* antagonists for complete growth inhibition of *S. rolfsii* causing stem rot of groundnut (Sahu and Senapati, 2003 and Rao and Kulkarni, 2003) [14, 13] also justified the present findings. The results obtained by use of soil organic amendment like neem cake tally with findings of Johnson *et al.* (2003) [7] who conducted a field experiment for four years using different soil amendments (neem cake, gypsum, single super phosphate, pongamia cake, castor cake and farmyard manure) in management of *S. rolfsii* inciting stem rot of groundnut. Among the different amendments, basal application of gypsum at 500 kg ha^{-1}followed by neem cake at 150 kg ha^{-1} reduced the stem rot incidence by 39 and 31% respectively resulting in additional pod yield of 260 and 200 kg ha^{-1}, respectively. Pawar (2013) [12] conducted integrated management study on the foot rot disease of finger millet in field condition with 7 different treatments. Among these, seed treatment with *P. flourescens* and *T. viride* each @ 5 g/kg showed least per cent disease incidence (12.38%).

Effect on yield

The maximum average yield of 2 years was 34.54 q ha^{-1} in the treatment seed treatment with *T.harzianum* @ 5 g kg^{-1}seed plus seedling root dipping in *T. harzianum* solution plus application of Neem cake @ 50g hill^{-1} at transplanting (T_8). It was followed by Seed treatment with Thiram @ 3g kg^{-1}of seed + Seedling root dipping in solution of *T. harzianum* at transplanting + Application of Neem cake @ 50 g hill^{-1}at transplanting (T_7) which recorded yield of 31.46 q ha^{-1}. Average yield of treatment of Seed treatment with *Trichoderma harzianum* @ 5g kg^{-1} of seed + Application of Neem cake @ 50 g hill^{-1} at transplanting (T_6) and Seed treatment with Thiram @ 3g kg^{-1} of seed + Application of Neem cake @ 50 g hill^{-1} at transplanting (T_5) for 2 consecutive *Kharif* seasons was 30.52 q ha^{-1} and 30.08 q ha^{-1}and were statistically at par. Maximum average per cent increase in yield (37.42%) as compared to control was recorded in treatment of Seed treatment with *T. harzianum* @ 5 g kg^{-1} seed plus seedling root dipping in *T. harzianum* solution plus application of Neem cake @ 50 g hill^{-1} at transplanting (T_8).

Table 1: Management of foot rot of finger millet

Tr. No.	Treatment	Per cent Disease Incidence*				Per cent disease reduction compared to untreated
		15 DAT	30 DAT	45 DAT	60 DAT	
T_1	Seed treatment with Thiram @ 3g kg^{-1} of seed.	3.23 (10.35)	4.54 (12.30)	8.00 (16.42)	9.90 (18.33)	26.14
T_2	Seed treatment with *Trichoderma harzianum* @5g kg^{-1} of seed	2.46 (9.02)	3.95 (11.46)	7.31 (15.68)	9.23 (17.68)	31.13
T_3	Seed treatment with Thiram @ 3g kg^{-1} of seed.+Seedling root dipping in solution of *T. harzianum* at transplanting	2.00 (8.13)	3.21 (10.32)	6.64 (14.93)	8.82 (17.27)	34.19
T_4	Seed treatment with *T. harzianum* @5g kg^{-1} of seed + Seedling root dipping in solution of *T. harzianum* at transplanting	1.28 (6.49)	3.15 (10.22)	6.49 (14.75)	8.23 (16.67)	38.64
T_5	Seed treatment with Thiram @ 3g kg^{-1} of seed + application of Neem cake @ 50 g hill^{-1} at transplanting	0.89 (5.41)	2.00 (8.13)	6.29 (14.52)	7.59 (15.99)	43.38
T_6	Seed treatment with *T. harzianum* @5g kg^{-1} of seed + Application of Neem cake @ 50 g hill^{-1} at transplanting	0.81 (5.16)	1.69 (7.46)	4.57 (12.34)	7.05 (15.39)	47.41
T_7	Seed treatment with Thiram @ 3g kg^{-1} of seed + Seedling root dipping in solution of *T. harzianum* + Application of Neem cake @ 50 g hill^{-1} at transplanting	0.39 (3.58)	1.28 (6.49)	3.06 (10.07)	4.12 (11.71)	67.42
T_8	Seed treatment with *T. harzianum* @5g kg^{-1} of seed + Seedling root dipping in solution of *T. harzianum* + Application of Neem cake @ 50 g hill^{-1} at transplanting at transplanting	0.19 (2.49)	0.85 (5.28)	2.18 (8.49)	3.69 (11.07)	72.46
T_9	Control	5.05 (12.98)	7.45 (15.83)	12.13 (20.38)	13.41 (21.48)	-
	S. Em±	0.09	0.16	0.20	0.16	-
	C. D (at 5%)	0.28	0.50	0.61	0.48	-

Table 2: Effect of management of foot rot on yield of finger millet C v- Dapoli 2

Tr. No.	Treatment	*Yield (kg/ha)	% increase Over control
T_1	Seed treatment with Thiram @ 3g kg^{-1} of seed.	2779.33	10.56
T_2	Seed treatment with *T. harzianum* @5g kg^{-1} of seed	2829.33	12.55
T_3	Seed treatment with Thiram @ 3g kg^{-1} of seed.+ Seedling root dipping in solution of *T. harzianum* at transplanting	2900.33	15.38
T_4	Seed treatment with *T. harzianum* @5g kg^{-1} of seed + Seedling root dipping in solution of *T. harzianum* at transplanting	2952.16	17.44
T_5	Seed treatment with Thiram @ 3g kg^{-1} of seed + application of Neem cake @ 50 g $hill^{-1}$ at transplanting	3008.50	19.68
T_6	Seed treatment with *T. harzianum* @5g kg^{-1} of seed + Application of Neem cake @ 50 g $hill^{-1}$ at transplanting	3052.33	21.42
T_7	Seed treatment with Thiram @ 3g kg^{-1} of seed + Seedling root dipping in solution of *T. harzianum* + Application of Neem cake @ 50 g $hill^{-1}$ at transplanting	3146	25.15
T_8	Seed treatment with *T. harzianum* @5g kg^{-1} of seed + Seedling root dipping in solution of *T. harzianum* + Application of Neem cake @ 50 g $hill^{-1}$ at transplanting	3454.33	37.42
T_9	Control	2513.66	-
	S.Em±	14.87	-
	C.D (P=0.05)	44.59	-

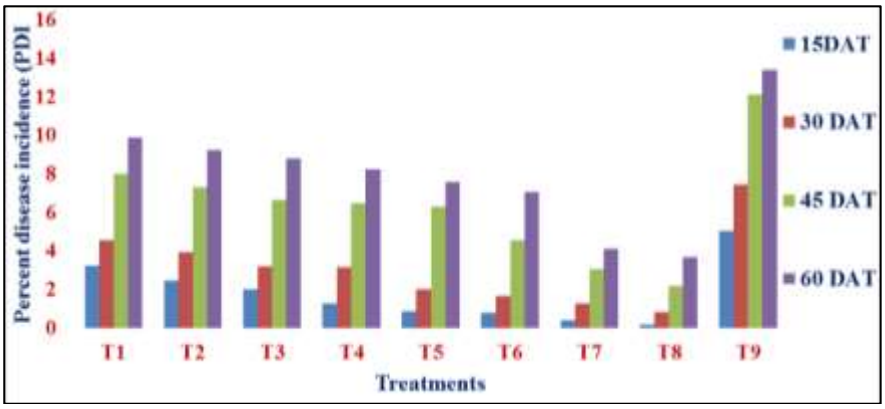

Fig 1: Percent disease incidence of finger millet foot rot

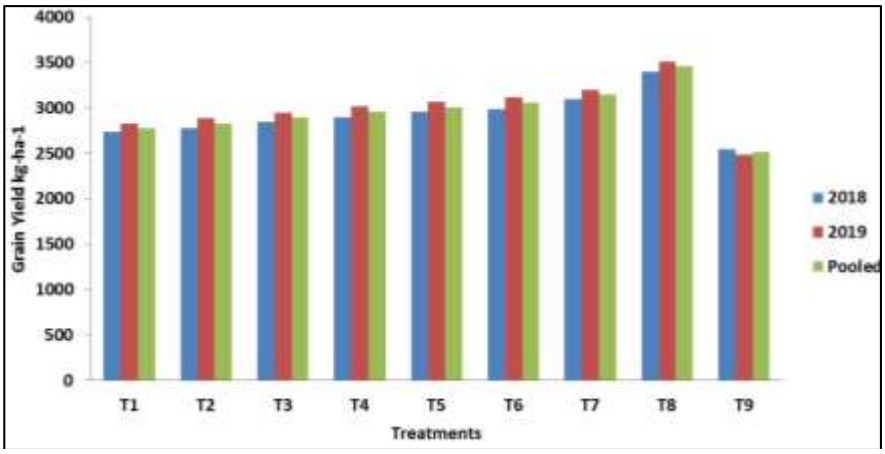

Fig 2: Effect of management on grain yield of Finger Millet Kharif 2018, Kharif 2019 and Pooled

Conclusion

On the basis of this study it is concluded that the Seed treatment with *T. harzianum* @ 5 gm kg^{-1} seed plus root dipping in *T. harzianum* solution plus application of Neem cake @ 50 g $hill^{-1}$ at transplanting recorded minimum foot rot severity (3.69) with the highest (72.46 %) reduction in disease incidence. Maximum average yield (34.54 q ha^{-1}) was also recorded in the same treatment.

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