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Evaluation of rhizospheric antagonistic microorganisms and fungicides against pod rot associated pathogens of groundnut *(Arachis hypogaea* L.)

P Ramanjineyulu, K Viswanath, P Nagamani and N Kiran Kumar

Abstract
Pod rot is a serious disease of groundnut crop affecting the quality and yield potentiality to a large extent, it poses a great threat to the groundnut farming community. In the evaluation of the efficacy of four isolates of *Trichoderma* spp, and four isolates of rhizospheric bacteria against all the isolates of *Fusarium* spp, *Rhizoctonia bataticola, Sclerotium rolfsii,* TT4 isolate of *Trichoderma* has shown 41.3 per cent and TB3 isolate of rhizospheric bacteria has shown 66.0 per cent highest mean inhibition. Among the fungicides tested against pathogen isolates which exhibited the lowest mean per cent inhibition in dual culture studies *viz., Fusarium sp* (TF1), *Rhizoctonia bataticola* (TRb8), *Sclerotium rolfsii* (TSr6), tebuconazole and tebuconazole + trifloxystrobin has shown cent per cent inhibition at all the three concentrations. In *in vivo* evaluation of integrated management components against the three isolates of pathogens, the treatment T6 i.e. seed treatment with tebuconazole @ 1g/kg of seed, soil application of potential fungal and bacterial bio agents accompanied by soil application of gypsum at 45 DAS has recorded the lowest pod rot incidence of 11.4, 20.7 and 6.0 per cent respectively. Management of the disease itself is difficult due to the complex of pathogen association, for which there is a need for the integration of cultural, biological and chemical methods in disease management.

Keywords: Groundnut, pod rot, rhizospheric antagonistic microorganisms, fungicides

Introduction
Groundnut (*Arachis hypogaea* L.) is a major oilseed, feed and food crop widely cultivated in tropical and subtropical regions of the world. It is the fourth important source of edible oil and third most source of vegetable protein. The kernels contain 44-56 per cent high quality edible oil, 22-30 per cent easily digestible protein, 10-20 per cent carbohydrates, vitamins (E, K and B complex), minerals (Ca, P, Mg, Zn and Fe) and digestible fiber (Bell, 2008) [4]. Anantapur, Chittoor, Kurnool and Kadapa are the major groundnut growing districts, occupying 97 per cent of total groundnut growing area of the state (IOPEPC Report, 2017) [15].

Productivity levels of groundnut in most of the developing countries are low due to several production constraints which include biotic and abiotic stresses, lack of seed dispersal systems, technological knowhow, market accessibility, low input use etc.

Among soil borne diseases of groundnut, pod rot is a complex and economically important disease widespread in the Semi-Arid Tropics causing severe damage to groundnut production in a number of countries including India (Abdou and Khadr, 1974; Frank, 1972; Mercer, 1977; Porter *et al*., 1975) [1, 11, 23, 28]. Depending upon the geographic location, the losses in yield due to pre-harvest pod rot may vary in the range of 5-50 per cent (Subrahmanyam *et al.*, 1980) [32]. In Andhra Pradesh the mean disease incidence was varied from 11.4 to 28.6 per cent and 8.5 to 30.0 per cent in Chittoor and Anantapuramu districts respectively (Ramanjineyulu *et al*., 2018) [30]. Pod rot of groundnut is emerging as a serious disease in different agro-climatic zones of Andhra Pradesh due to change in soil moisture, pH, soil temperature and crop sequence facilitating rapid multiplication of different microflora in crop rhizosphere

Management of pod rot has been difficult in part because of the wide host range of the pathogens (Melouk and Backman, 1995) [22] and limited cultivar resistance (Besler *et al*., 2003; Lewis and Filonow, 1990; Walker and Csinos, 1980) [5, 19, 35]. Hence, in the present study an attempt was made to manage this soil borne disease with some bio agents and chemicals.

Material and Methods

Isolation and maintenance of pod rot associated pathogens and rhizospheric antagonistic microorganisms

Pod rot associated pathogens which were isolated during the previous study (Ramanjineyulu *et al*., 2018) [30] *viz*., *Fusarium* spp., *Rhizoctonia bataticola* and *Sclerotium rolfsii* were used in the present investigation. Native rhizospheric soil samples collected during the survey (Ramanjineyulu *et al*., 2018) [30] were used for isolation of rhizospheric antagonistic mycoflora. Rhizosphere antagonistic fungi were isolated on *Trichoderma* selective medium and rhizosphere antagonistic bacteria were isolated on Kings B medium by following serial dilution technique (Johnson and Curl, 1977) [16].

In vitro evaluation of bio-control agents against pod rot associated pathogens

Dual culture technique was used to identify the potential rhizospheric antagonists of groundnut (Dennis and Webster, 1971) [8]. Per cent inhibition of growth of the fungus over the control was calculated (Vincent, 1927) [34].

$$Per\ cent\ inhibition\ (PI)\ (\%) = \frac{C - T}{C} \times 100$$

Where, PI = Per cent inhibition in growth of test pathogen, C = Radial growth (mm) of test pathogen in control, T = Radial growth (mm) of test pathogen in treatment

Among all the rhizosphere antagonistic mycoflora and bacteria tested against pod rot pathogens, one of each potential fungus, bacteria and each one virulent pathogen were selected and used for further studies.

In vitro evaluation of the efficacy of fungicides against pod rot associated pathogens

Five fungicides *viz*., Hexaconazole 5% EC, Tebuconazole 25.9% EC, Mancozeb + Carbendazim 63%) + (12%) WP, Metiram + Pyraclostrobin (55%) + (5%) WG and Tebuconazole + Trifloxystrobin (50%) + (25%) WG were evaluated *In vitro* efficacy of fungicides against the pathogens was evaluated by poisoned food technique (Nene and Thapliyal, 1993) [24]. Per cent inhibition of the growth of the fungus over the control was calculated. (Vincent, 1927) [34].

$$Per\ cent\ inhibition\ (PI)\ (\%) = \frac{C - T}{C} \times 100$$

Where, PI = Per cent inhibition in growth of test pathogen, C = Radial growth (mm) of test pathogen in control, T = Radial growth (mm) of test pathogen in treatment.

Evaluation of effective fungicide and bio-control agents against dominant pod rot fungi *in vivo*

This experiment was conducted under glasshouse conditions by randomized block design (RBD) on Dharani cultivar and maintained three replications of each treatment. In this experiment the effective fungicide and bio-control agents were evaluated against dominant pod rot associated fungi as per the treatments given below:

Treatment. No	Treatment
T1	Seed treatment with Tebuconazole 2% DS @ 1 g/kg of seed
T2	T1+ Soil application with potential rhizospheric fungal bio-agent (RFx) at 45 DAS
T3	T1+ Soil application with potential rhizospheric bacterial bio-agent (RBx) at 45 DAS
T4	T1 + Foliar spray of effective fungicide at 60 and 75 DAS
T5	T1+ Soil application of Gypsum @ 500 kg/ha at 45 DAS
T6	T1+ Soil application of potential fungal and potential bacterial bio-agent + soil application of Gypsum at 45 DAS
T7	T1 + Soil application of Gypsum at 45 DAS + foliar spray of effective fungicide at 60 and 75 DAS
T8	Control

Mass multiplication of pod rot associated fungi and preparation of talc based formulation of potential fungal and bacterial bio control agent

Mass multiplication of pod rot associated fungi was carried out on substrate sorghum grains as per the method suggested by Patil *et. al*. (2017) [25]. Potential fungal biocontrol agent was mass multiplied on PDB and formulations prepared as per method suggested by Raguchander *et al*., 1997 [29]. Antagonistic bacterium was mass multiplied on nutrient broth and talc formulations are prepared by the method suggested by Vidhyasekaran and Muthamilan 1995 [33]. Seed treatment was done with Tebuconazole 2% DS (Raxil) @ 1 g kg $^{-1}$ of seed. Seeds are properly mixed with the required quantity of fungicide and shade dried. Earthen pots (30 cm in diameter) were filled with sterilized soil and pathogen inoculum was mixed at a proportion of 30 g kg^{-1} to the soil then the seeds were sowed, later the treatments were imposed. Control pots were also maintained. The disease reduction percentage of pod rot diseases was calculated as follow:

$$Per\ cent\ reduction\ over\ control = \frac{\text{disease reduction in control}}{\text{disease reduction in treatment}} \times 100$$

Results and Discussion

Isolation of bio-control agents from rhizosphere of groundnut

From the rhizosphere soil samples two isolates each of *Trichoderma* spp. and bacteria were isolated from Madibaka village (TT1; TB1) of Yerpedu mandal and TMV Kandriga (TT2; TB2) of Srikalahasti Mandal of Chittoor district. Similarly from the Anantapur district two isolates each of *Trichoderma* spp and bacteria from Siddampeta (TT3; TB3) of Bukkarayasamudram mandal and Jonnalakothapalle (TT4; TB4) of Mudigubba mandal were isolated (Plate 1, 2.

In vitro evaluation of the antagonistic activity of bio-control agents against pod rot associated pathogens

In vitro evaluation of the efficacy of *Trichoderma* spp. against *Fusarium* spp.

The efficacy of four isolates of *Trichoderma* spp. was evaluated by dual culture against all the ten isolates of *Fusarium* spp. (Table 1). In the dual culture of the ten isolates of *Fusarium* spp. with TT1 *Trichoderma sp.*, the highest per cent inhibition (35.8%) was recorded on TF2 *Fusarium sp*. which was at par with TF7 (34.4%), TF8 (33.6%), TF1

(32.3%), TF9 (31.9%) isolates and significantly differed with the remaining isolates. Whereas with TT2 isolate of *Trichoderma sp*. the highest per cent inhibition of 34.5 per cent was recorded on TF5 isolate of *Fusarium sp.*, which significantly differed with rest of the isolates. Similarly with TT3 isolate of *Trichoderma sp.*, the highest per cent inhibition of 67.6 per cent was recorded on TF2 *Fusarium* isolate which significantly differed with rest of the isolates. With TT4 isolate of *Trichoderma sp.* the highest per cent inhibition of 41.0 per cent recorded on TF8 isolate of *Fusarium sp* which significantly differed with the remaining isolates.

***In vitro* evaluation of the efficacy of *Trichoderma* spp. against *Rhizoctonia bataticola* isolates**

In the dual culture of TT1 isolate of *Trichoderma sp* against all the ten isolates of *R. bataticola*, the highest inhibition of 67.7 per cent was recorded with TRb5 isolate which significantly differed with other isolates. While with TT2 isolate of *Trichoderma sp*., the highest per cent inhibition of 60.0 per cent was observed with TRb3 which significantly differed in inhibition with other isolates. Similarly, with TT3 isolate of *Trichoderma sp*., the highest inhibition of 47.1 per cent was recorded with TRb4 which significantly differed with rest of the isolates. Finally with TT4 isolate of *Trichoderma sp*., the highest inhibition (74.9%) was observed on TRb3 which significantly differed with rest of the *R. bataticola* isolates (Table 1).

***In vitro* evaluation of the efficacy of *Trichoderma* spp. against *Sclerotium rolfsii* isolates**

Interaction effects between ten isolates of *S. rolfsii* and TT1 isolate of *Trichoderma* sp. in dual culture revealed that the highest inhibition (57.2%) was observed on TSr5 which was on par with TSr4 (54.3%) and significantly differed with rest of the isolates (Table 1). While with TT2 isolate of *Trichoderma sp*., the highest inhibition (50.3%) was observed on TSr5 which differed significantly with rest of the isolates. Similarly with TT3 isolate of *Trichoderma sp*., the highest inhibition (45.5%) was observed on TSr7 which was on par with TSr5 (45.2%) and significantly differed with rest of the isolates. Finally with TT4 isolate of *Trichoderma sp.*, the highest inhibition (51.3%) was observed on TSr9 which was on par with TSr10 (50.0%) and differed significantly with rest of the isolates.

***In vitro* evaluation of the efficacy of rhizospheric bacteria against *Fusarium* spp.**

Interaction effects between ten isolates of *Fusarium* spp**.** and TB1 isolate of bacteria in dual culture revealed that the TB1 isolate of bacteria exhibited the highest inhibition (56.6%) on TF3 isolate of *Fusarium sp.* which was on par with TF9 (53.9%) and differed significantly with the rest (Table 1). With TB2 bacterial isolate, the highest inhibition of 55.5 per cent was observed on TF4 and TF6 which differed significantly with rest of the isolates. Similarly with TB3 bacterial isolate, the highest inhibition (62.2%) was observed on TF4 which differed significantly with rest of the isolates. Finally with TB4 bacterial isolate, the highest inhibition (69.8%) was observed on TF4 isolate of *Fusarium sp.* which differed significantly with other isolates.

***In vitro* evaluation of the efficacy of rhizospheric bacteria against *Rhizoctonia bataticola* isolates**

Interaction effects between ten isolates of *R. bataticola* and TB1 isolate of rhizospheric bacteria in dual culture revealed that TB1 isolate of bacteria showed, the highest inhibition (64.4%) on TRb10 which was on par with TRb5 (62.2%) and significantly differed with remaining isolates (Table 1). With TB2 isolate of bacteria, the highest inhibition (63.5%) was recorded on TRb9 which was on par with TRb4 (58.4%) and significantly differed with remaining isolates. Similarly with TB3 isolate of bacteria, the highest inhibition (78.9%) was observed on TRb10 which was on par with TRb2 (73.3%) and differed significantly with remaining isolates. Finally with TB4 bacterial isolate, the highest inhibition (56.9%) was observed on TRb10 which was on par with TRb1 (55.0%), TRb6 (52.2%), TRb5 (51.2%) and significantly differed with remaining isolates of *R. bataticola.*

***In vitro* evaluation of the efficacy of rhizospheric bacteria against *Sclerotium rolfsii* isolates**

Interaction effects between the ten isolates of *S. rolfsii* and TB1 rhizospheric bacteria in dual culture revealed that the TB1 bacterial isolate showed the highest inhibition of 69.1 per cent on TSr2, which was on par with TSr10 (67.1%), TSr1 (65.4%), TSr5 (65.4%) and TSr7 (64.5%) and significantly differed with the remaining isolates of *S. rolfsii* (Table 1). While, with TB2 isolate of bacteria, the highest inhibition of 89.9 per cent was observed on TSr8 which was on par with TSr4 (88.5%), TSr2 (87.4%), TSr5 (86.3%) and TSr3 (85.6%) and differed significantly with remaining isolates. Similarly with TB3 bacterial isolate the highest inhibition (92.4%) was observed against TSr7 which was on par with TSr10 (92.3%), TSr4 (90.6%), TSr1 (89.2%), TSr5 (88.2%) and TSr8 (87.8%) and significantly different with rest of the isolates. Finally with TB4 isolate of bacteria, the highest inhibition was observed on TSr5 (81.9%) which differed significantly with remaining isolates of *S. rolfsii*.

There were significant differences in average responses to antagonism by the four isolates each of *Trichoderma* spp and rhizospheric bacteria between the different genera of pathogens *viz., Fusarium, Rhizoctonia and Sclerotium.* Also there were significant differences in average antagonistic abilities of the isolates of *Trichoderma* and rhizospheric bacteria when averaged over pathogens. On comparing the overall per cent inhibition of the isolates of *Trichoderma* and rhizospheric bacteria on the isolates of *Fusarium* spp, *R. bataticola* and *S. rolfsii*, TT4 isolate of *Trichoderma*, TB3 isolate of rhizospheric bacteria has shown the highest mean per cent inhibition. Whereas, TF1 isolate of *Fusarium sp*, TRb8 isolate of *R. bataticola* and TSr6 isolate of *S. rolfsii* has exhibited the lowest mean per cent inhibition as shown in table 1.

***In vitro* evaluation of the efficacy of fungicides against pod rot associated pathogens**

Five fungicides were evaluated under *in vitro* for their overall efficacy on the isolates with the lowest degree of growth inhibition in dual culture *viz., Fusarium sp*. (TF1), *R. bataticola* (TRb8), *S. rolfsii* (TSr6). Among the fungicides tested against TF1 isolate of *Fusarium sp*.; tebuconazole, mancozeb + carbendazim and tebuconazole + trifloxystrobin have shown cent per cent inhibition of the mycelial growth at all the three concentrations. The mycelial growth inhibition increased with increase in the concentrations of hexaconazole (51.1 to 67.7%) and metiram + pyraclostrobin (61.9 to 64.4%) from 1500 to 2500 ppm (Table 2).

In case of fungicides tested against TRb8 isolate of *R.*

bataticola, tebuconazole, mancozeb + carbendazim, metiram + pyraclostrobin and tebuconazole + trifloxystrobin showed cent per cent inhibition at all the three concentrations. Whereas, hexaconazole showed increased inhibition from 78.3 to 88.3 per cent with the increase in concentration from 1500 ppm to 2500 ppm. In case of fungicides tested against TSr6 isolate of *S. rolfsii*, hexaconazole, tebuconazole, metiram + pyraclostrobin and tebuconazole + trifloxystrobin showed cent per cent inhibition at all the three concentrations. Whereas, the combination product of mancozeb + carbendazim showed increased inhibition from 59.1 to 100 per cent with the increase in concentration from 2500 ppm to 3500 ppm (Table 2). The data revealed that all the fungicides at all the three concentrations reduced the mycelial growth of pathogens when compared to control.

Table 1: Summarized per cent inhibition of pod rot associated pathogens by the fungal and bacterial antagonists

Name of the pathogens	Name of the isolate	*Trichoderma* spp.				Rhizospheric bacteria				Mean per cent inhibition
		TT1	TT2	TT3	TT4	TB1	TB2	TB3	TB4	
Fusarium spp	TF1	32.3	16.4	19.9	31.6	46.3	34.1	42.0	44.4	33.4
	TF2	35.8	12.8	62.6	33.7	42.5	44.0	46.0	43.0	40.0
	TF3	30.5	24.2	38.0	31.7	56.6	45.8	45.8	51.5	40.5
	TF4	24.6	23.0	21.5	24.9	45.6	55.5	62.2	69.8	40.9
	TF5	23.7	30.2	34.4	23.1	46.3	42.1	45.5	41.5	35.8
	TF6	25.0	14.4	26.8	14.8	43.2	55.5	55.6	55.5	36.4
	TF7	34.4	22.8	47.2	33.3	45.1	47.0	55.0	53.0	42.2
	TF8	31.2	21.1	19.4	34.3	41.6	47.0	41.6	45.2	35.2
	TF9	31.9	13.6	28.1	27.6	53.8	35.6	47.7	47.8	35.8
	TF10	24.4	10.3	26.0	32.0	39.1	47.6	46.7	45.7	34.0
Rhizoctonia bataticola	TRb1	57.6	49.0	34.8	53.7	57.5	38.1	48.9	55.0	49.3
	TRb2	48.1	44.0	30.0	70.2	51.9	49.6	73.3	34.3	50.2
	TRb3	49.2	60.0	25.4	74.9	51.9	38.1	50.8	40.0	48.8
	TRb4	25.0	42.1	47.1	62.4	59.3	58.4	55.2	37.1	48.3
	TRb5	67.6	45.0	26.1	33.1	62.2	52.9	71.1	51.2	51.2
	TRb6	38.1	45.5	28.1	51.7	59.6	50.0	68.2	52.2	49.2
	TRb7	48.4	36.0	38.5	47.7	55.6	50.6	65.4	40.8	47.9
	TRb8	34.4	46.9	27.9	48.3	55.6	45.2	62.6	47.0	46.0
	TRb9	23.1	47.6	31.6	57.4	54.2	63.5	60.6	34.4	46.6
	TRb10	37.3	47.8	25.9	56.3	64.4	50.4	78.9	56.9	52.2
Sclerotium rolfsii	TSr1	50.5	34.3	34.3	42.2	65.4	65.2	89.2	66.3	55.9
	TSr2	49.5	38.6	37.0	41.1	69.1	87.4	75.8	54.8	56.7
	TSr3	50.0	42.0	29.3	38.0	55.5	85.6	82.2	61.7	55.5
	TSr4	54.3	34.7	26.8	31.7	58.8	88.5	90.6	67.0	56.5
	TSr5	57.2	50.3	45.2	36.5	65.4	86.3	88.5	81.9	63.9
	TSr6	31.9	29.1	24.1	22.1	37.1	65.9	73.9	17.7	37.7
	TSr7	49.0	37.5	45.5	46.7	64.5	78.8	92.4	54.3	58.6
	TSr8	51.6	34.0	30.1	36.8	63.1	89.9	87.8	71.9	58.2
	TSr9	52.4	34.4	30.4	51.3	51.6	78.4	85.1	69.6	56.6
	TSr10	50.7	31.7	31.5	50.0	67.1	75.6	92.3	73.3	59.0
Mean per cent inhibition		40.7	34.0	32.4	41.3	54.3	58.4	66.0	52.2	

Table 2: *In vitro* evaluation of fungicides on the mycelial growth of virulent isolates of *Fusarium* spp. Rhizoctonia bataticola and *Scleortium rolfsii*

		Fusarium spp.			*Rhizoctonia bataticola*		*Sclerotium rolfsii*	
S. No	Fungicides	concentration (ppm)	Mycelial growth (cm)	Per cent inhibition over control	Mycelial growth (cm)	Per cent inhibition over control	Mycelial growth (cm)	Per cent inhibition over control
1	Hexaconazole (5% EC)	1500	4.4	51.1 (45.6)	2.0	78.3 (62.2)	0.0	100.0 (90.0)
		2000	4.2	53.1 (46.7)	1.8	80.6 (63.8)	0.0	100.0 (90.0)
		2500	2.9	67.8 (55.4)	1.1	88.3 (70.0)	0.0	100.0 (90.0)
2	Tebuconazole (25.9% EC)	500	0.0	100.0 (90.0)	0.0	100.0 (90.0)	0.0	100.0 (90.0)
		1000	0.0	100.0 (90.0)	0.0	100.0 (90.0)	0.0	100.0 (90.0)
		1500	0.0	100.0 (90.0)	0.0	100.0 (90.0)	0.0	100.0 (90.0)
3	Mancozeb (63%) + Carbendazim (12%) WP	2500	0.0	100.0 (90.0)	0.0	100.0 (90.0)	3.68	59.2 (50.2)
		3000	0.0	100.0 (90.0)	0.0	100.0 (90.0)	1.63	81.9 (64.8)
		3500	0.0	100.0 (90.0)	0.0	100.0 (90.0)	0.00	100.0 (90.0)
4	Metiram (55%) + Pyraclostrobin (5%) WG	1500	3.4	61.9 (51.9)	0.0	100.0 (90.0)	0.0	100.0 (90.0)
		2000	3.2	64.4 (53.4)	0.0	100.0 (90.0)	0.0	100.0 (90.0)
		2500	3.4	62.8 (52.4)	0.0	100.0 (90.0)	0.0	100.0 (90.0)
5	Tebuconazole (50%) + Trifloxystrobin (25%) WG	660	0.0	100.0 (90.0)	0.0	100.0 (90.0)	0.0	100.0 (90.0)
		1320	0.0	100.0 (90.0)	0.	100.0 (90.0)	0.0	100.0 (90.0)
		1980	0.0	100.0 (90.0)	0.0	100.0 (90.0)	0.0	100.0 (90.0)
6	Control	-	9.0	-	9.0	-	9.0	
	C.D		0.14	1.68	0.06	1.05	0.06	0.51

	S.Em		0.05	0.59	0.02	0.37	0.02	0.18
	C.V		5.24	1.58	5.00	0.86	4.98	0.42

Evaluation of effective fungicide and potential bio-control agents against pod rot associated pathogens under pot culture conditions

In the present study, TF1 isolate of *Fusarium sp*, TRb8 isolate of *R. bataticola*, TSr6 isolate of *S. rolfsii* recorded the lowest degree of growth inhibition when compared to other isolates of the respective fungi in dual culture with each of the four fungal and bacterial antagonists. The fungicide tebuconazole, TT4 isolate of *Trichoderma sp* and TB3 isolate of bacteria showed significant efficacy under *in vitro* against all the isolates of *Fusarium sp., R. bataticola* and *S. rolfsii.* Hence, in order to evaluate the same under *in vivo*, the treatments were designed by integrating effective antagonists, fungicide, and isolates of the pathogen

Results observed from the table 3 revealed that, against the three isolates of pathogen *viz.*, TF1 isolate of *Fusarium sp*, TRb8 isolate of *R. bataticola*, TSr6 isolate of *S. rolfsii*, treatment T6 i.e. seed treatment with tebuconazole @ 1g/kg of seed + soil application of potential fungal and bacterial bio agents + soil application of gypsum at 45 DAS has recorded the lowest pod rot incidence of 11.4, 20.7 and 6.0 per cent respectively with 73.3, 64.4, 87.6 per cent reduction over untreated control in the pot culture studies. The dry weight of the plants in pots inoculated with *Fusarium sp* (31.1 and 30.3 g), *R. bataticola* (31.8 and 29.8 g) and *S. rolfsii* (33.2 and 32.5 g) was found to be on par in T6 and T7 treatments.

The *in vitro* screening with arbitrary rating system for biological antagonists effective against soil borne plant pathogens is a simplistic approach to understanding a small sector of biological systems in disease control (Bell *et al.*, 1982) [3]. *Trichoderma* spp. are effective in control of soil/seed borne fungal diseases in several crop plants (Kubicek *et al*., 2001) [18], including groundnut (Podile and Kishore, 2002). Antagonists like *T. harzianum* and *T. viride* could inhibit the pathogens *A. niger, F. solani, Rhizopus sp, M. phaseolina* causing pod rot disease of groundnut (Elad *et al.*, 1982; Meher, 1997) [9, 21]. The evaluation of the antagonistic activities of *T. harzianum* strain T100, *T. viride* and *T. haematum* against *F. oxysporum* and *F. proliferatum*, showed that *T. harzianum* T100 strain lysed the confronting mycelia and produced volatile metabolites exhibiting the highest inhibition (Perveen and Bokhari, 2012; Ghanbarzadeh *et al.*, 2014) [26, 12].

Table 3: Evaluation of effective fungicide and potential bio control agents against virulent isolate of *Fusarium* spp. under pot culture conditions

Treatment	*Fusarium* spp			*Rhizoctonia bataticola*			*Sclerotium rolfsii*		
	Plant dry wt/pot (g)	Pod rot incidence (%)	% reduction over control	Plant dry wt/pot (g)	Pod rot incidence (%)	% reduction over control	Plant dry wt/pot (g)	Pod rot incidence (%)	% reduction over control
T1	22.1	36.5 (37.1)	14.7 (22.49)	22.1	36.5 (37.1)	14.7 (22.49)	22.1	36.5 (37.1)	14.7 (22.49)
T2	27.8	27.0 (31.3)	36.9 (37.39)	27.8	27.0 (31.3)	36.9 (37.39)	27.8	27.0 (31.3)	36.9 (37.39)
T3	28.1	27.0 (31.3)	36.9 (37.38)	28.1	27.0 (31.3)	36.9 (37.38)	28.1	27.0 (31.3)	36.9 (37.38)
T4	29.0	18.2 (25.2)	57.4 (49.26)	29.0	18.2 (25.2)	57.4(49.26)	29.0	18.2 (25.2)	57.4 (49.26)
T5	28.0	26.8 (31.1)	37.3 (37.46)	28.0	26.8 (31.1)	37.3 (37.46)	28.0	26.8 (31.1)	37.3 (37.46)
T6	31.1	11.4 (19.7)	73.3 (58.87)	31.1	11.4 (19.7)	73.3 (58.87)	31.1	11.4 (19.7)	73.3 (58.87)
T7	30.3	14.6 (22.3)	65.8 (54.21)	30.3	14.6 (22.3)	65.8 (54.21)	30.3	14.6 (22.3)	65.8 (54.21)
T8	20.6	42.8 (40.8)		20.6	42.8 (40.8)		20.6	42.8 (40.8)	
CD	3.62	2.69	1.72	3.62	2.69	1.72	3.62	2.69	1.72
S.Em	1.20	0.89	0.56	1.20	0.89	0.56	1.20	0.89	0.56
CV	7.60	5.16	2.29	7.60	5.16	2.29	7.60	5.16	2.29

The results from experimentation shows that tebuconazole, a triazole fungicide having broad spectrum activity; might have inhibited the sterol demethylation in the cell wall of *Fusarium sp, R. bataticola and S. rolfsii* when tested alone (Baird *et al.*, 1991; Brenneman *et al.*, 1994) [2, 6] and also in combination with trifloxystrobin. Being an ubiquinol oxidase inhibitor molecule, trifloxystrobin intereferes with mitochondrial respiration pathway thereby, inhibits the growth of fungi (Kodandaram *et al.*, 2013) [17]. Similar results were obtained in controlling *R. bataticola* (Maruti *et al.*, 2017) [20]. Significant reduction in the *Rhizoctonia* pod rot of groundnut was observed on spraying with tebuconazole and azoxystrobin (Grichar *et al.*, 2000; Besler *et al.*, 2003) [14, 5].

In addition, increased calcium levels in plant tissues following applications of calcium nitrate or calcium sulfate provide some disease control, especially under low inoculum pressure conditions. High levels of calcium in plant tissues perfectly offset the action of oxalic acid and the cell wall degrading enzymes of the pathogen (Grichar and Boswell, 1990). Soil application of gypsum reduces the severity of stem and pod rot of groundnut with the increase in the rate of gypsum application (Csinos and Gaines, 1986; Grichar and Boswell, 1990) [7, 13]. In the present study, the lowest per cent disease incidence was recorded in treatments consisting of gypsum application in combination with soil application of potential fungal and bacterial antagonists and also with foliar spray of tebuconazole. However, the disease incidence was found to be high in gypsum alone applied pots which may be attributed to the high inoculum potential in the soil as proposed by Filonow and Jackson, 1989 [10].

From the present study it can be concluded that the groundnut pod rot disease is complex in nature due to the association of more than one soil borne pathogens for the control of which there is a need for the integration of cultural, biological and chemical methods in disease management.

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