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Integrated Management of Stem Rot and Collar Rot Diseases of Groundnut incited by *Aspergillus niger* and *Sclerotium rolfsii*

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ABSTRACT: Stem rot and collar rot are the major soil borne diseases incited by *Sclerotium rofsii* and *Aspergillus niger* causes significant economic losses in groundnut crop. Both the pathogen are soilborne in nature and once established it will survive in the soil for many years. The present study was taken to identify the eco-friendly management of these major soilborne diseases in groundnut crop. In the present study the soil microflora was isolated from the soil collected from the major groundnut growing areas of Andhra Pradesh and Telangana states. The isolated microflora was tested against stem rot and collar rot pathogens under *in vitro* condition by using dual culture plate technique. Based on *in vitro* studies the bioagents (fungal and bacterial) which are showing highest inhibition against stem rot and collar rot pathogens were used in management of stem rot and collar rot under field conditions. Field evaluation using effective bioagents MBNRT-1 (*Trichodema harzianum*) and MBNRB-3 (*Bacillus amyloliquifaciens*) along with standard fungicide indicated that, tebuconazole as seed treatment (ST) resulted in lowest collar rot incidence (4.56%). This is followed by seed treatment + soil application (SA) of MBNRT-1 (5.96%). Pod yields were significantly higher in seed treatment + soil application of MBNRT-1 treated plots when compare to other treatments. Similarly, in stem rot management experiment, seed treatment with tebuconazole resulted lowest disease incidence (15.47%), followed by seed treatment + soil application of MBNRT-1 (16.4%). Overall, our results revealed the scope of integrating the bioagents with fungicides in managing the collar rot and stem rot diseases in groundnut.

Keywords: Collar rot, Groundnut, Management, Soilborne disease, Stem rot.

INTRODUCTION

Groundnut crop is cultivated all over the world in an area of 26.7 m ha with a total production of 40.32 m t and the average productivity is 1.6 t ha^{-1} (Shruthi *et al.*, 2017). In India, the crop is mostly grown in the states of Gujarat, Andhra Pradesh, Telangana, Tamil Nadu, Karnataka, Rajasthan and Maharashtra constituting about 80% of the total area and production of groundnut. The groundnut cultivation is often subjected to significant yield losses annually due to biotic and abiotic stresses and are the major limiting factors for attaining high productivity in India. Among various biotic stresses, soilborne and foliar diseases account for reduced pod yields (Vineela *et al*., 2018). Fungal diseases such as collar rot (*Aspergillus niger* Van Tieghem), stem rot (*Sclerotium rolfsii* Sacc.), root rot (*Rhizoctonia solani* Kuhn*)*, are causing major havoc in all crop growing areas (Jadon *et al*., 2015). Among these, collar rot and stem rot diseases are the major soil borne diseases with significant yield losses annually. Survey in Telangana and Andhra Pradesh states indicated that the disease incidence of collar rot and stem rot was high (16.82% and 10.06%) in Chittoor district of Andhra Pradesh because groundnut is grown as sole crop under irrigated conditions. However comparatively low incidence of both stem rot and collar rot in the surveyed areas of Telangana is attributable to the cropping systems in practice. In majority of the surveyed Telangana area, crop rotation of groundnut (*rabi*) with maize and rice (as a preceding crop in *kharif*) is in practice.

Collar rot disease is usually seen during the early stages of crop growth, and often results in seedling mortality at higher rates and manifested as a pre-and post-emergence damping-off of the affected seedlings. The pathogen having adaptability even under higher temperatures and causes considerable yield losses in groundnut crop (Kumari and Singh 2016). The stem rot disease is generally observed during late stages of the crop growth mostly after 45 days after sowing. Stem rot pathogen attacks the germinated groundnut seedlings and causes wilt and all the plant parts are susceptible to *S. rolfsii* but stem infection is the most common and destructive one (Wheeler, 1969). Stem rot symptoms appear initially as yellowing of leaves and wilting of the branches near the plant base, and continue to the top of the plant (Kumar *et al.,* 2013; Xu *et al.,* 2020). Mass of white mycelia develops near the soil line around the affected areas of the stem. This is followed by production of sclerotia on the infected branches, which are initially white and later turn into brown colour (Subrahmanyam *et al.,* 2012). Stem rot disease is of considerable economic significance for groundnut grown under irrigated conditions, particularly in post-rainy (*rabi*) season (Punja, 1985). Stem and pod rot causes death of the plants as well as rotting of pods resulting in direct yield losses. Stem rot is the most damaging soil borne disease In Georgia, where estimated crop losses from 2012-2016 averaged 4.6% due to stem rot; the total combined cost of damage and control measures was $47.3 million (Kemerait, 2019).

Management of soil borne diseases in groundnut is very difficult (Standish *et al*., 2019). Integrated disease management (IDM) is the conjunctive use of all the available control methods such as cultural, physical, biological, chemicals and host plant resistance etc. Sometimes, these bio agents are used in IDM their efficacy may be reduced due to harmful effects of fungicides and herbicides (Wang *et al*., 2018; Liu *et al*., 2018). There are several reports indicated that groundnut stem rot and collar rot can be managed by seed treatment with fungicides like thiram, carbendazim (Divya *et al*., 2012), bioagents like *Trichodema harzianum*, *P. fluorescens* (Adhilakshmi *et al*., 2014; John *et al.,* 2015; Ekundayo *et al.,* 2016; Sharma *et al.,* 2016; Jacob *et al*., 2016), *Bacillus* spp. (Shifa *et al.,* 2015; Ashok *et al.,* 2014; Tonelli *et al*., 2011) and soil amendments like neem seed cake + *Azadiracta indica* extract (Vishwapal *et al.,* 2013). However, for obtaining synergistic effect of bioagents when juxtaposed with chemical fungicides and herbicides, knowledge on their compatibility is mandatory. Therefore, the present study was taken up to identify potential suitable IDM package for these dreaded diseases in groundnut.

MATERIALS AND METHODS

Field trials were conducted during *kharif* season of 2013 and 2014 at ICRISAT, Patancheru to evaluate the efficacy of different biocontrol agents in managing the stem rot and collar rot diseases of groundnut. The same plots were used during both the years of experimentation. The soils are typical sandy loam in nature. Individual experiments were conducted in separate stem rot (*S. rolfsii*) and collar rot (*A. niger*) respectively. To ensure soil sickness, individual pathogens were mass multiplied on sorghum grains and applied uniformly to the soil at 150 g m^{-2} to beds prior to sowing of seeds. The experiments were laid out on beds of 2×1.5 m size in a randomized complete block design (RCBD) with eight treatments and three replications per each treatment. The popular groundnut variety, TMV 2 (bunch variety released by Oilseeds Research Station, Tindivanam) with wider adaptability and is under cultivation in Karnataka, Andhra Pradesh and Gujarat, and that is susceptible to both stem rot and collar rot diseases was used. The following are the treatments:

A. Details of the treatments used in field studies

The groundnut cultivar TMV-2 was used for field studies and is susceptible to collar rot and stem rot. Both *T. harzianum* (MBNRT-1) and *B. amyloliquifaciens* (MBNRB-3) were applied to seed @1×10^8 cfu g^{-1} and applied @ 10g kg^{-1} seed and for soil application *T. harzianum* (MBNRT-1) and *B. amyloliquifaciens* (MBNRB-3) was mixed with farm yard manure (2 kg 100 kg^{-1}) and applied to the soil prior to sowing. The fungicides azoxystrobin and tebuconazole were treated to the seed @ 1 ml kg^{-1}seed before sowing.

B. Production and delivery of biocontrol agents

One elite fungal bioagent *T. harzianum* (MBNRT-1) and one bacterial bioagent *B. amyloliquifaciens* (MBNRB-3) with superior antagonistic abilities against *S. rolfsii* and *A. niger* under laboratory conditions were selected. Talc based formulations of *T. harzianum* (MBNRT-1) and *B. amyloliquifaciens* (MBNRB-3) were used. The *T. harzianum* (MBNRT-1) formulation was prepared by inoculating a freshly grown culture on to PDB in flasks and incubated at room temperature for 10 days on a rotary shaker at 80 rpm. The fungal mass was later harvested, air-dried under aseptic conditions and mixed with talc powder at 1: 2 ratio. Carboxy methyl cellulose (CMC) was added @ 5g kg^{-1} of the formulation (Raguchander *et al.,* 1997). The formulation was later stored in sealed plastic bags for further use. The final concentration of formulation was about 1×10^8 CFU g^{-1}.

For preparing *Bacillus* formulation, the bacterium was multiplied in conical flasks by transferring a loopful of fresh culture into flasks containing nutrient broth. The flasks were incubated at room temperature on a rotary shaker at 80 rpm for 3 days. Later, talc powder was added to the bacterial broth @ 400 ml kg^{-1} of talc powder. Carboxy methyl cellulose was added at the same concentration as described previously and the formulation was stored in sealed plastic bags at room temperature for further use. The final concentration of bacterial formulation was about 1×10^8 CFU g^{-1}. TMV-2 seeds were treated with both bacterial and fungal biocontrol agents as per the treatment details @ 5g kg^{-1} seed and then shade dried prior to sowing. The biocontrol agents were amended in FYM @ 1 kg 45 kg^{-1} of FYM. The mixture was later applied to soil prior to sowing of seeds @ 225 kg ha^{-1}.

C. Experimental details

A basal dose of 20:40:50 kg ha^{-1} of NPK was added prior to preparation of experimental plots. Need based application of insecticides was taken up to control the insect pests during the crop growth period. For fungicidal applications, tebuconazole (Folicur 250 EC) was applied at the rate of 1ml kg^{-1} seed as seed treatment by soaking seeds for 30 m, then shade dried prior to sowing. For combined seed treatment with *Trichoderma harzianum* and azoxystrobin (Amistar 270 EC @1ml kg^{-1} seed), the seeds were initially soaked in fungicide for 30 m, shade dried and then treated with fungal bioagent at the same concentration as described previously. Other agronomic practices adopted during crop growth are according to the guidelines of ICRISAT, Patancheru for the *kharif* sown groundnut during both the years of experimentation.

Data collection and analysis

Observations on % seed germination, % disease incidence and pod yields were recorded for both the diseases. % disease incidence was assessed by using the formula as follows.

$$\left[\text{Percent Disease Incidence} = \frac{\text{Number of infected plants}}{\text{Total number of plants}} \times 100\right] \quad (1)$$

Pod yields were recorded at harvest. The plants were harvested individually replication-wise, pooled, dried in field and then manually harvested prior to taking pod weight and then mean weights were recorded treatment wise. The data was statistically analyzed (Gomez and Gomez 1984) using the software OPSTAT developed by CCS Haryana Agricultural University, Hisar, India and was subjected to analysis of variance (ANOVA) at two significant levels ($P< 0.05$ and $P< 0.01$) and the treatment means were compared by Critical difference (CD).

RESULTS AND DISCUSSION

A. Effect of Integrated Disease Management practices on collar rot disease in groundnut

Seed Germination (Plant stand). Based on pooled data across the years (*kharif*, 2013 and kharif, 2014) highest seed germination (plant stand) (74.75%) was observed with the treatment seed treatment+soil application *T. harzianum* (MBNRT-1). In general, except seed treatment with bioagent *B. amyloliquefaciens* (MBNRB-3) (67.79%) all other treatments have significantly improved seed germination over inoculated control (64.04%) with no significant differences among them and the % germination ranges from 71.3−74.2%. No significant improvement in plant stand was noticed when MBNRT *T. harzianum* (MBNRT-1) was juxtaposed with azoxystrobin (70.91%) over the seed treatment with *T. harzianum* (MBNRT-1) alone (71.3%). Un-inoculated plots have recorded a plant stand of 77.5%.

Disease Incidence (%). Field evaluation of biocontrol agents in groundnut during *kharif* 2013 and 2014 (Pooled mean) indicated that the seed treatment with tebuconazole was recorded the least incidence (4.56%) of collar rot followed by seed treatment + soil application of bioagent *B. amyloliquefaciens* (MBNRB-3) (5.43%), seed treatment + soil application of *T. harzianum* (MBNRT-1) (5.96), combined seed treatment with *T. harzianum* (MBNRT-1) + azoxystrobin (6.33%), seed treatment with *T. harzianum* (MBNRT-1) (7.15%) and seed treatment with bioagent *B. amyloliquefaciens* (MBNRB-3) (7.94%). No significant differences were found among all the treatments. All the treatments were more or less effective in management of collar rot in comparison with inoculated where the% incidence is 26.59. Uninoculated control plots recorded the collar rot incidence upto 2.55%.

Pod Yield. Based on pooled data (*kharif*, 2013 and *kharif*, 2014) presented in the Table 1. Significant improvement in the pod yield was noticed with seed treatment + soil application with bioagent *T. harzianum* (MBNRT-1) 1276.16 kg ha^{-1} followed by seed treatment+soil application with bioagent *B. amyloliquefaciens* (MBNRB-3) 1155.6 kg ha^{-1} and no significant differences were between these two treatments. The pod yields for other treatments were in the range of 942.4 to 1047.1 kg ha^{-1} with no significant differences among them. In uninoculated control the pod yields were up to 985.27 kg ha^{-1} whereas, in inoculated control the yields were up to 712.6 kg ha^{-1}.

B. Effect of Integrated Disease Management practices on stem rot disease in groundnut

Seed germination (Plant stand). The results from the pooled analysis (*kharif*, 2013 and *kharif*, 2014) indicated that, highest germination (77.66%) was observed with seed treatment+soil application with bioagent *T. harzianum* (MBNRT-1). Inoculated control recorded 59% seed germination. In general, all the treatments have significantly improved seed germination over inoculated control and there was no significant difference among them and the % germination ranges from 71.0−75.2%. Improvement in plant stand was noticed when bioagent MBNRT-1(*T. harzianum*) was juxtaposed with azoxystrobin (75.2%) over the seed treatment with bioagent T. *harzianum* (MBNRT-1) alone (74.08%). The per cent germination in un inoculated control plots has 75% .

Disease Incidence (%). Results on field evaluation of biocontrol agents in groundnut during *kharif* 2013 and 2014 (Pooled mean) indicated that the seed treatment with tebuconazole has recorded the lowest stem rot incidence 15.47% followed by seed treatment+soil application of *T. harzianum* (MBNRT-1) (16.40%), combined seed treatment with *T. harzianum* (MBNRT-1) + azoxystrobin (17.62%), seed treatment + soil application of *B. amyloliquefaciens* (MBNRB-3) (5.96%), seed treatment with bioagent *B. amyloliquefaciens* (MBNRB-3) (19.79%) and seed treatment with *T. harzianum* (MBNRT-1) (19.99%). The differences found among all the treatments were not significant. All the treatments were more or less effective in reducing the stem rot in comparison with inoculated control (37.33%). Uninoculated control plots recorded the stem rot incidence of 7.79%.

Pod Yield. Based on pooled data highest pod yield was noticed with seed treatment+soil application with bioagent *T. harzianum* (MBNRT-1) 918.6 kg ha^{-1} followed by seed treatment + soil application with bioagent MBNRB *B. amyloliquefaciens* (MBNRB-3) 807.6 kg ha^{-1}. No significant differences were noticed for bacterial and fungal biocontrol agents as seed treatment alone and in conjunction with soil applications. The pod yields for other treatments were in the range of 717.8−770.16 kg ha^{-1} with no significant difference among them. The pod yield in uninoculated control was 1010.5 kg ha^{-1} whereas, in inoculated control the pod yield was 573.9 kg ha^{-1}.

Successful management of collar rot using biocontrol approaches as seed treatment and soil application have been reported earlier. In groundnut, biocontrol applications have not yet taken momentum at farmer's fields in India. However, varied fungal and bacterial biocontrol agents have earlier been used against collar rot. For example, *Trichoderma* application to groundnut spermosphere has significantly contributed to collar rot resistance besides enhancing seedling stand and pod yields. Greenhouse studies specifically using *Trichoderma* spp. enhanced the rate of seed germination and seedling vigour over control (Manjula *et al*., 2004). However, different methods of field delivery of *Trichoderma* spp. have earlier been attempted for exploiting maximum biocontrol potential. For example, soil application of *Trichoderma* spp. as a fortified powder in FYM or Neem cake or vermicompost has contributed to root rot management in soybean at field level (Chakraborty *et al*., 2003). Several other reports have indicated that *Trichoderma* sp as an effective biocontrol agent against collar rot when applied to seeds. In our studies, the bioagent *T. harzianum* (MBNRT-1) when applied as both soil and seed treatment was comparatively more efficacious over seed treatment in reducing collar rot and enhancing pod yields. Seed treatment with tebuconazole @1.5 g kg^{-1} seed, mancozeb @ 3 g kg^{-1} seed and carbendazim + mancozeb @ 3 g kg^{-1} seed were very effective in management of soil borne diseases of groundnut (Jadon *et al.,* 2015).

Bacterial biocontrol agents such as PGPR have reported to be highly efficacious in reducing *A. niger* inoculum levels significantly in crop soils (Vessey, 2003). In groundnut, *Bacillus* sp. has been used as both seed treatment and soil applications individually. Reports on simultaneous application of both these methods have found to significantly reduce collar rot and other soilborne diseases effectively (Loon *et al.*, 1998). *Bacillus* is a gram positive bacterium and is effective in enhancing pod yields of groundnut through direct and indirect mechanisms (Rabindran and Vidhyasekaran 1996). Growth-promoting activities of *Bacillus* are attributed to production of siderophores, growth-hormones such as IAA, IBA, phosphate solubilizing enzymes (Ryu *et al.,* 2004). Besides, *Bacillus* sp. also produces enzymes specific to inhibition of pathogen growth and other compounds such as HCN (Dowling and Gara 1994). Our present studies indicated that bioagent *B. amyloliquefaciens* (MBNRB-3) was effective in reducing collar rot incidence as well as enhancing pod yields significantly. In our studies, bioagent *T. harzianum* (MBNRT-1) was also effective against collar rot when used conjunctively with azoxystrobin. Earlier studies by several researchers have established the efficacy of azoxystrobin under laboratory, greenhouse and field conditions against collar rot induced by *A. niger* (Gajera *et al*., 2011). Azoxystrobin is a strobilurin group of fungicide and specifically inhibits fungal pathogens by interfering with the ATP production in mitochondria of the fungus by blocking the electron transport at the site of quinol oxidation in the cytochrome (Dube, 2010). In our studies, seed treatment with tebuconazole recorded high seed germination, lower degrees of collar rot incidence and improved pod yields. Prophylactic application of tebuconazole in the present study as seed treatment might have contributed to protecting the seeds from rotting fungi such as *A. niger*, thereby reducing the subsequent collar rot incidence in the present study. Several researchers have reported the significant improvement in groundnut seedling stand by protecting the plants from collar rot fungus using tebuconazole (Raju and Naik 2006).

Since the stem rot pathogen *S. rolfsii* is soil borne in nature and it is very difficult to manage the pathogen because of its resting structures sclerotia which were produced by the pathogen during unfavourable conditions and survives for longer time in the soil in the absence of the host. Several researchers reported the effect of bioagents and fungicides under field and green house conditions in reducing the diseases incidence and increasing the pod yields. In our studies tebuconazole seed treatment was recorded lowest% stem rot incidence. Seed treatment+soil application of bioagent *T. harzianum* (MBNRT-1) not only reduced the stem rot incidence but also enhanced the pod yields. Previous reports also indicated the effect of tebuconazole in reducing the stem rot incidence in groundnut under field conditions where, seed treatment with tebuconazole @ 1.25g kg^{-1} followed by its lower dosage (1g kg^{-1} seed) was found significantly superior in the management of stem rot with least disease incidence and higher pod yield in experimental trials as well as farm and large scale demonstration trials. Similarly several other workers also reported the efficacy of tebuconazole under field conditions in reducing the stem rot incidence. Triazoles such as tebuconazole, cyperconazole and difeniconazole provide excellent control of foliar fungal diseases and some soil borne diseases including stem rot. Fungicides belonging to trialzoles group inhibit biosynthesis of ergosterol which plays an important role in structure of cell membrane of fungi (Dahmen *et al*., 1989; Waterfield and Sisler 1989). These fungicides have systemic character and can penetrate inside the seed and can be used as seed treatment and applied to green plants safely (Sundin *et al*., 1999).

Similarly seed treatment + soil application of bioagent *T. harzianum* (MBNRT-1) also showed profound effect in reducing the stem rot incidence which is more or less equal to the tebuconazole seed treatment, besides reducing the disease incidence it also improved the pod yield. Similar effects with *Trichoderma* sp. was also reported by earlier workers where they found the low incidence of stem rot in groundnut caused by *S. rolfsii* when *T. harzianum* was used as both seed treatment and soil application. Degradation of chitin in the cell walls of *S. rolfsii* by chitinases of *Trichoderma* spp., facilitates their penetration of *S. rolfsii* mycelium (Haran *et al*., 1996). Since sclerotia are the perennating bodies, which carry *S. rolfsii* from one crop growing season to the other, inhibition of sclerotial production can reduce the overall available inoculum of *S. rolfsii* in field. In our studies, the combination of azoxystrobin + bioagent *T. harzianum* (MBNRT-1) and seed treatment

+ soil application of bioagent *B. amyloliquefaciens* (MBNRB-3) also showed considerable reduction in the stem rot incidence. These results were also in agreement with the earlier studies. (Ezzahiri and Khattabi 2004) studied the effect of azoxystrobin seed treatment which decreased the root rot incidence in sugar beet. Similarly seed treatment with *Bacillus* sp reduced the incidence of seedling blight in rice caused by *S. rolfsii* (Chakraborty *et al*., 2016; Li *et al*., 2016).

Table 1: Effect of different treatments on seed germination, collar rot incidence and yield of groundnut.

Treatments	Seed germination (%)			Disease incidence (%)			Yield (Kg ha^{-1})		
	2013 *kharif*	2014 *kharif*	Pooled Mean	2013 *kharif*	2014 *kharif*	Pooled Mean	2013 *kharif*	2014 *kharif*	Pooled Mean
Seed Treatment with bioagent MBNRT-1 (*T. harzianum*)	57.5 (49.2)**	85.1 (67.3)	71.3 (58.3)	9.35 (17.5)	6.5 (14.7)	7.9 (16.1)	1242.2	846.4	1044.3
Seed Treatment with *bioagent* MBNRB-3 (*B. amyloliquefaciens*)	52.9 (46.6)	82.6 (65.4)	67.7 (56.0)	5.9 (14.0)	8.40 (16.4)	7.15 (15.2)	1079.4	914.5	996.9
Seed+Soil Treatment with bioagent MBNRT-1(*T. harzianum*)	60.8 (51.2)	88.6 (70.3)	74.7 (60.8)	6.3 (11.6)	5.6 (13.5)	5.9 (12.6)	1570.1	982.2	1276.1
Seed+Soil Treatment with bioagent MBNRB-3 (*B. amyloliquefaciens*)	58.3 (49.7)	87.0 (68.9)	72.7 (59.3)	3.9 (9.2)	6.90 (14.9)	5.43 (12.0)	1350.3	960.2	1155.2
Seed Treatment with Tebuconazole	62.5 (52.2)	85.9 (68.0)	74.2 (60.1)	5.3 (13.1)	3.80 (11.2)	4.56 (12.1)	1325.6	768.7	1047.1
Seed Treatment with bioagent MBNRT-1 (*T. harzianum*)+Azoxystrobin	52.5 (46.4)	89.3 (70.9)	70.9 (58.6)	3.4 (10.6)	9.20 (17.2)	6.3 (13.9)	1208.5	876.4	942.4
Uninoculated Control	64.2 (53.3)	90.83 (75.5)	77.5 (64.4)	1.5 (5.5)	3.67 (10.5)	2.5 (8.0)	1227.0	743.6	985.2
Inoculated Control	48.3 (44.0)	79.7 (63.2)	64.0 (53.6)	32.9 (34.7)	20.23 (26.7)	26.5 (30.7)	833.5	591.7	712.60
CD	9.6	4.8	5.61	10.9	4.4	6.15	278.2	179.5	169.7
SE(d)	4.4	2.3	2.80	5.0	2.0	3.07	128.5	82.9	84.8
SE(m)	3.1	1.6	7.94	3.5	1.4	8.70	90.8	58.6	54.0
CV (%)	9.5	3.7	9.56	22.9	15.8	27.7	12.7	12.5	12.7

**Figures in the parenthesis are angular transformed values

Table 2: Effect of different treatments on seed germination, stem rot incidence and yield of groundnut.

Treatments	Seed germination (%)			Disease incidence (%)			Yield (Kg ha^{-1})		
	2013	2014	Pooled Mean	2013	2014	Pooled Mean	2013	2014	Pooled Mean
Seed Treatment with bioagent MBNRT-1(*T. harzianum*)	62.5 (52.2)**	85.67 (67.5)	74.08 (60.0)	19.2 (25.8)	20.7 (27.0)	19.9 (26.4)	844.0	592.9	718.3
Seed Treatment with *bioagent* MBNRB-3 (*B. amyloliquefaciens*)	60.4 (51.0)	81.67 (64.6)	71.04 (57.8)	17.4 (24.6)	22.1 (28.0)	19.7 (26.3)	970.3	530.0	751.7
Seed+Soil Treatment with bioagent MBNRT-1(*T. harzianum*)	64.2 (53.2)	91.1 (72.7)	77.66 (63.0)	14.6 (22.4)	18.1 (25.1)	16.4 (23.7)	1172.0	807.9	918.6
Seed+Soil Treatment with *bioagent* MBNRB-3 (*B. amyloliquefaciens*)	60.0 (50.7)	89.1 (70.9)	74.58 (60.8)	14.9 (22.5)	20.9 (27.0)	17.9 (24.8)	1057.6	613.3	807.6
Seed Treatment with Tebuconazole	56.3 (48.6)	87.4 (69.2)	71.8 (58.9)	17.1 (24.4)	13.8 (21.8)	15.4 (23.1)	896.0	726.7	770.1
Seed Treatment with bioagent MBNRT-1 (*T. harzianum*)+Azoxystrobin	63.8 (52.9)	86.6 (68.9)	75.2 (60.9)	17.7 (24.8)	17.5 (24.6)	17.6 (24.7)	872.0	630.6	717.8
Uninoculated Control	55.0 (47.8)	95.0 (75.7)	75.0 (61.8)	6.9 (15.1)	8.6 (16.9)	7.79 (16.0)	1346.8	732.8	1010.5
Inoculated Control	38.3 (38.1)	80.5 (63.9)	59.4 (51.0)	42.5 (40.6)	32.0 (34.2)	37.3 (37.4)	667.67	479.1	573.9
CD	12.1	7.3	2.80	5.8	6.2	6.2	226.2	122.7	245.7
SE(d)	5.6	3.4	2.76	2.6	2.8	3.1	104.4	56.6	122.8
SE(m)	3.9	2.4	7.94	1.8	2.0	8.8	73.8	40.0	347.5
CV (%)	11.9	4.8	11.9	13.0	13.8	26.3	13.0	10.8	21.6

CONCLUSION

Seed treatment with tebuconazole and seed treatment + soil application of bioagent *Trichoderma harzianum* (MBNRT-1) were recorded lowest incidence of stem rot and collar rot diseases in groundnut. Whereas, highest pod yields were observed with seed treatment + soil application of bioagent *T. harzianum* (MBNRT-1). Hence it was concluded that, seed treatment + soil application of bioagent *T. harzianum* (MBNRT-1) has not only reduced the disease incidence it also improved pod yields in groundnut.

FUTURE SCOPE

Development of integrated management package for soil borne disease management in groundnut crop and evaluation of these integrated management packages in large scale under the farmers fields.

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Conflict of Interest. None.

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