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# Integrated Management of Stem Rot of Groundnut Caused by *Sclerotium rolfsii* Sacc. Through Fungicides, Bioagents and Organic Manures

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## ABSTRACT

**Background:** The groundnut crop faces various biotic and abiotic stresses that reduce yield and quality, leading to significant economic losses. Stem rot, caused by *Sclerotium rolfsii*, is a major root disease, causing 40-55% yield loss. Hence effective management strategies for stem rot are essential.

**Methods:** A field trial was conducted in a randomized complete block design with three replications at the Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, during *rabi* 2023-24 and *kharif* 2024-25. The trial evaluated the efficacy of cost-effective fungicides, bioagents and organic manures against groundnut stem rot. Disease incidence (%) and yield per hectare were analyzed statistically.

**Result:** Laboratory experiments revealed that seed dressing fungicides Carboxin 37.5% + Thiram 37.5% DS and Propiconazole 25% EC were highly effective against *Sclerotium rolfsii*. Among bioagents, *Trichoderma harzianum* (IOF, UAS, Dharwad strain) showed the highest efficacy, followed by *T. harzianum* (NBAIM, Mau, Uttar Pradesh strain) and *T. harzianum* (NBAIR, Bengaluru strain). A two-year evaluation of ten integrated treatment modules during *rabi* seasons demonstrated that seed treatment with a consortia of *T. harzianum* (NBAIM, Mau, UP) + *T. harzianum* (NBAIR, Bengaluru) at 10 g $kg^{-1}$ seeds, combined with soil application of vermicompost enriched with *T. harzianum* (NBAIM, Mau, UP) + *T. harzianum* (NBAIR, Bengaluru) (1 kg each + 100 kg vermicompost) at 250 kg/acre in seed furrows at sowing, resulted in the lowest disease incidence and highest pod yield, chlorophyll content, haulm yield and benefit-cost ratio.


**Key words:** Bioagents, Groundnut, Management, Stem rot.

## INTRODUCTION

Groundnut (*Arachis hypogaea* L.), a key legume and oilseed crop, is predominantly cultivated across tropical and subtropical regions, playing a crucial role for both smallholder and commercial farmers. As of 2023, groundnut is grown over an area of 5.70 million hectares in India, with an annual production of 10.13 million tonnes and an average productivity of 1,777 kg/ha (Source: Ministry of Agriculture and Farmers Welfare, Government of India). The leading groundnut-producing states in India Gujarat, Andhra Pradesh, Karnataka, Tamil Nadu and Rajasthan each contribute over 1 million tonnes annually. In Karnataka alone, groundnut is cultivated on 0.57 million hectares, yielding a total production of 1.01 million tonnes and an average productivity of 846 kg/ha. However, groundnut yields are often constrained by various abiotic and biotic stresses, including poor soil fertility, water scarcity, viral infections, collar rot and stem rot.

Stem rot also known as Sclerotium blight, Sclerotium rot, southern blight, southern stem rot, Sclerotium wilt, root rot, pod rot, or white mold caused by *Sclerotium rolfsii* Sacc. is a major constraint in groundnut cultivation due to its detrimental impact on both yield and quality. This necrotrophic, soil-borne fungus has a broad host range, affecting numerous agricultural and horticultural crops and is widely distributed across tropical, subtropical and warm temperate regions worldwide. In India, the pathogen is

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present in all groundnut-growing states, with the most severe outbreaks reported in Karnataka, Andhra Pradesh, Maharashtra, Gujarat, Madhya Pradesh, Odisha and Tamil Nadu (Kumar *et al.,* 2013).

The primary symptoms of stem rot in groundnut include rapid wilting and death of young plants, while older plants typically exhibit yellowing and wilting before dying. Infected stem bases often show a white mass of mycelium (Wheeler, 1969). Siddaramaiah *et al.* (1979) observed root rot in young groundnut plants, characterized by girdling at the base, eventually leading to plant death. In older plants, infections were noted on the roots, pegs and pods. During harvest, decayed pegs frequently broke off, leaving pods behind in the soil, resulting in substantial yield losses. Sclerotia were also observed on the soil surface and infected stems (Baruah *et al.,* 1980). According to Adiver, (2003), younger plants are particularly more susceptible and cause 15-70% yield losses and in epidemic conditions especially under wet weather during the pod-filling stage losses can soar up to 80%. *Sclerotium rolfsii* Sacc. (teleomorph: *Athelia rolfsii* Tu and Kimbrough) is a highly destructive pathogen, capable of infecting nearly 500 plant species, including groundnut, across warm temperate and tropical regions worldwide.

Management of soil borne diseases in groundnut is very difficult (Standish *et al.,* 2019). There are several reports indicated that groundnut stem rot can be managed by seed treatment with fungicides like thiram, carbendazim (Divya *et al.,* 2012) and soil amendments like neem seed cake + Azadiracta indica extract (Vishwapal *et al.,* 2013). However, a review of existing literature reveals limited information on effective management approaches by using bioagents for this disease and increasing incidence of stem rot and the associated economic losses, the present study was undertaken to develop suitable and effective management practices for its control.

## MATERIALS AND METHODS

### Preparation of giant culture of *Sclerotium rolfsii*

The pathogen *Sclerotium rolfsii* was isolated from groundnut plants exhibiting stem and root rot symptoms, collected from the experimental plots of the All India Coordinated Research Project on Groundnut at the main agricultural research station (MARS), University of Agricultural Sciences (UAS), Dharwad, Karnataka. Isolation was performed using the tissue segment method on potato dextrose agar (PDA) medium. For giant culture preparation, crushed sorghum seeds were used as a substrate. The substrate was prepared by mixing 200 g of crushed sorghum seeds with 50 ml of distilled water in a 500 ml conical flask and sterilized at 15 psi for one hour on two consecutive days. The sterilized flasks were then inoculated with 4-5 discs from a seven day old culture of *S. rolfsii* and incubated at 28±1°C for 20 days (Choudhary *et al.,* 2011). During incubation, the contents were mixed regularly to ensure uniform fungal growth.

### *In vitro* evaluation of fungicides

The efficacy of various seed dressing fungicides Carbendazim 50% WP, Carbendazim 12% + Mancozeb 63% WP, Thiophanate Methyl 45% + Pyraclostrobin 5% FS, Carboxin 37.5% + Thiram 37.5% DS, Penflufen 240 FS, Propiconazole 25% EC, Tebuconazole 5.36% FS and Tebuconazole 50% + Trifloxystrobin 25% WG (Nativo 75 WG) were evaluated under *in vitro* conditions using the poisoned food technique as described by Nene and Thapliyal, (1973). Each fungicide was tested at concentrations of 0.025%, 0.05% and 0.1%. A control treatment was maintained by placing a mycelial disc of the pathogen at the center of a Petri plate containing PDA medium without any fungicide. The per centage inhibition of mycelial growth was calculated using the formula proposed by Vincent, (1947).

The diameter of the fungal colony was measured for each treatment once the pathogen had fully covered the medium in the control plates. The reduction in colony diameter in fungicide-treated plates, relative to the control, was considered an indicator of fungitoxicity. The per centage inhibition of mycelial growth over the control was calculated using the formula provided by Vincent, (1947).

$$I = \frac{C - T}{T} \times 100$$

Where,

I= Per cent inhibition.

C= Colony diameter in control (mm),

T= Colony diameter in treatment (mm).

### *In vitro* evaluation of biocontrol agents

The efficacy of various fungal and bacterial biocontrol agents were evaluated under *in vitro* conditions against the mycelial growth of *Sclerotium rolfsii* using the dual culture technique (Dennis and Webster, 1971). The biocontrol agents tested included *Trichoderma harzianum*, AUUB 209 (*Streptomyces enissocaesilis*) and AUDT 626 (*Streptomyces racemochromogenes*) obtained from the Institute of organic farming (IOF), University of Agricultural Sciences, Dharwad. Additional *T. harzianum* isolates were sourced from the Indian Institute of Oilseed Research, Hyderabad (cellulose-based formulation), Kerala Agricultural University, Kerala; the National Bureau of Agriculturally Important Microorganisms, Mau, Uttar Pradesh and the National Bureau of Agricultural Insect Resources, Bengaluru. Control plates were maintained by placing a mycelial disc of *S. rolfsii* at the center of a Petri plate containing PDA medium without any biocontrol agents. The per centage inhibition of mycelial growth was calculated using the formula provided by Vincent, (1947).

Observations on colony diameter were recorded once the pathogen had completely covered the medium in the control plates. The per centage inhibition of mycelial growth was then calculated using the formula provided by Vincent, (1947), as previously mentioned.

**Integrated disease management**

A field experiment on the integrated management of stem rot in groundnut was conducted at the sick plot of All India Coordinated Research Project (AICRP) on Groundnut, the main agricultural research station (MARS), University of Agricultural Sciences, Dharwad, during the *rabi* 2023-24 and *kharif* 2024-25 seasons. The experiment utilized *in vitro*-effective fungicides and biocontrol agents, in combination with organic manures. It was laid out in a randomized complete block design (RCBD) with ten treatment schedules, including an untreated control and three replications. Groundnut variety GPBD 4 was sown at a spacing of 30 cm × 10 cm, with a plot size of 4 m × 3 m. All recommended agricultural practices were followed to cultivate the crop, except for disease management. Details of the treatments are provided in Table 1.

Stem rot disease incidence was recorded at 30, 60 and 75 days after sowing (DAS) by counting the total number of plants and the number of infected plants. The per centage disease incidence at each growth stage was calculated using the following formula:

Per cent disease incidence (PDI) =

$$\frac{\text{Number of plants infected}}{\text{Total number of plants}} \times 100$$

The plots were harvested separately and the pod yield was recorded, then converted to quintals per hectare (q/ha). The pods from each treatment were collected separately and the haulm yield was measured using a digital electronic balance. Additionally, the chlorophyll content in the leaves was measured using a spadometer and the readings were recorded in SPAD units.

The cost of production was analyzed to identify the most economical treatment among the different management practices. Cost and return analysis were conducted following the procedures outlined by Kushwah *et al.* (2017) and Bhupender *et al.* (2020). The benefit-cost ratio (BCR) was calculated as follows:

$$\text{Benefit cost ratio} = \frac{\text{Gross return per ha}}{\text{Total cost of production per ha}}$$

**Data analysis**

Data was analysed as per the procedures given by Panse and Sukhatme, (1978). Data in per centage was converted to angular transformed values and $\sqrt{(X + 1)}$ values, before analysis (Walter, 1967). Analysis of variance and least significance difference (LSD) were determined at 5 and 1 per cent probability. Treatment means were compared using LSD to determine efficacy of different treatments.

**Table 1:** Details of different treatments used under field trials for identifying effective integrated management strategy.

| Treatment | Detail |
|---|---|
| $T_1$ | Seed treatment with *Trichoderma harzianum* (NBAIM, Mau, UP) at the rate of 10 g $kg^{-1}$ seeds followed by soil application of vermicompost enriched *Trichoderma harzianum* (NBAIM, Mau, UP) 1 kg + 100 kg vermicompost @ 250 kg/acre at the time of sowing to the seed furrows. |
| $T_2$ | Seed treatment with *Trichoderma harzianum* (NBAIR, Bengaluru) at the rate of 10 g $kg^{-1}$ seeds followed by soil application of vermicompost enriched *Trichoderma harzianum* (NBAIR, Begaluru) 1 kg + 100 kg vermicompost @ 250 kg/acre at the time of sowing to the seed furrows. |
| $T_3$ | Seed treatment with consortia (*Trichoderma harzianum* (NBAIM, Mau, UP) + *Trichoderma harzianum* (NBAIR, Bengaluru)) at the rate of 10 g $kg^{-1}$ seeds followed by soil application of vermicompost enriched *Trichoderma harzianum* (NBAIM, Mau, UP) 1kg + *Trichoderma harzianum* (NBAIR, Bengaluru) 1 kg + 100 kg vermicompost @ 250 kg/acre at the time of sowing to the seed furrows. |
| $T_4$ | Seed treatment with *T. harzianum* (IOF strain) at the rate of 10 g $kg^{-1}$ seeds followed by soil application of vermicompost enriched *T. harzianum* 1 kg + 100 kg Vermicompost @ 250 kg/acre at the time of sowing to the seed furrows. |
| $T_5$ | Seed treatment with *P. fluorescens* (IOF strain) at the rate of 10 g $kg^{-1}$ seeds followed by soil application of vermicompost enriched *P. fluorescens* 1 kg + 100 kg vermicompost @ 250 kg/acre at the time of sowing to the seed furrows. |
| $T_6$ | Seed treatment with *T. harzianum* (IOF strain) at the rate of 10 g $kg^{-1}$ seeds followed by soil application of vermicompost + UASD *Mycorrhizal* consortium (UASD *Mycorrhizal* consortium 8 kg + 100 kg vermicompost) @ 250 kg/acre at the time of sowing to the seed furrows. |
| $T_7$ | Soil application of vermicompost + UASD *Mycorrhizal* consortium (UASD *Mycorrhizal* consortium 8 kg + 100 kg vermicompost) @ 250 kg/acre at the time of sowing to the seed furrows. |
| $T_8$ | Seed treatment with Carboxin 37.5% + Thiram 37.5% WP at the rate of 3 g $kg^{-1}$ seeds. |
| $T_9$ | Seed treatment with Carboxin 37.5% + Thiram 37.5% WP at the rate of 3 g $kg^{-1}$ seeds followed by soil application of vermicompost enriched *T. harzianum* (IOF strain) 1 kg + 100 kg vermicompost @ 250 kg/acre at 35-40 DAS. |
| $T_{10}$ | Untreated control. |

## RESULTS AND DISCUSSION

### *In vitro* assay of seed dressing fungicides against *Sclerotium rolfsii*

The highest mean inhibition of mycelial growth of *S. rolfsii* was observed with Carboxin 37.5% + Thiram 37.5% DS (100.00%), which was statistically comparable to Penflufen 240 FS (100.00%) and Propiconazole 25% EC (100.00%). These were followed by Tebuconazole 50% + Trifloxystrobin 25% WG (96.08%) and Tebuconazole 5.36% FS (87.45%). The lowest mycelial inhibition of 8.24% was recorded with Carbendazim 50% WP. Among the different concentrations tested, the maximum mycelial inhibition of 100.00% was observed at the 0.1% concentration, which was significantly higher than the 0.05% and 0.025% concentrations (Table 2).

The findings are in agreement with previous studies by Nitharwal, (2019), Pathak *et al.* (2019) and Kumari *et al.* (2022). Maruti *et al.* (2017) reported that carbendazim 12% + mancozeb 63% WP and carboxin 37.5% + thiram 37.5% WP exhibited complete inhibition of *Rhizoctonia bataticola* at all tested concentrations. Similarly, Sangappa and Mallesh (2016) observed total inhibition of mycelial growth with carbendazim 12% + mancozeb 63% at various concentrations (0.05%, 0.10% and 0.20%). These consistent results underscore the effectiveness of such fungicidal combinations against the disease-causing pathogen.

### *In vitro* assay of bioagents against *Sclerotium rolfsii*

*In vitro* evaluation of bioagents using the dual culture technique showed a significant difference in the per centage of mycelial growth inhibition of *S. rolfsii* by the various bioagents tested. The highest mycelial growth inhibition of 88.89% was observed with *Trichoderma harzianum* NBAIM, Mau, Uttar Pradesh strain, followed by the *T. harzianum* IOF, UAS, Dharwad strain (86.67%) and *T. harzianum* NBAIR, Bengaluru strain (77.85%). The lowest mycelial growth inhibition of 9.79% was recorded with AUUB 209 (*Streptomyces enissocaesilis*) (Table 3).

The results are consistent with those of Kumar and Kelaiya, (2021) and Gajera *et al.* (2012), who evaluated the *in vitro* potential of *Trichoderma* species against *M. phaseolina*. The highest growth inhibition of the test pathogen was observed with the antagonist *T. koningi* (74.3%), followed by *T. harzianum* (61.4%). Microscopic examination revealed that these two antagonists were able

**Table 2.** *In-vitro* evaluation of fungicides against *S. rolfsii* causing stem rot of groundnut using poisoned food technique.

| Fungicides | Per cent mycelial growth inhibition Concentration (%) | | | Mean |
|---|---|---|---|---|
| | 0.025 | 0.05 | 0.1 | |
| Carbendazim 50% WP (Bavistin 50 WP) | 1.57(5.69)* | 4.71(12.46) | 8.24(16.57) | 4.84 |
| Carbendazim 12% + Mancozeb 63% WP (SAAF) | 7.84(16.25) | 11.76(20.04) | 15.29(23.01) | 11.63 |
| Thiophanate Methyl 45% + Pyraclostrobin 5% FS (Xelora) | 10.20(18.61) | 12.94(21.07) | 16.47(23.94) | 13.20 |
| Carboxin 37.5% + Thiram 37.5% DS (Vitavax power) | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) | 100.00 |
| Penflufen 240 FS | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) | 100.00 |
| Propiconazole 25% EC (Tilt 25 EC) | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) | 100.00 |
| Tebuconazole 5.36% FS (Raxil 5.36 FS) | 74.51(59.69) | 78.82(62.61) | 87.45(69.29) | 80.26 |
| Tebuconazole 50%+ Trifloxystrobin 25% WG (Nativo 75 WG) | 93.73(75.59) | 94.51(76.66) | 96.08(78.77) | 94.77 |
| | F | C | F*C | |
| S.Em. ± | 0.793 | 0.485 | 1.373 | |
| C.D. @ 1% | 1.594 | 0.976 | 2.762 | |

Note: * arc sine transformed values, F- Fungicide, C- concentration, F*C- interaction.

**Table 3:** *In-vitro* evaluation of bio-control agents against *S. rolfsii* causing stem rot of groundnut using dual culture technique.

| Biocontrol agents | Mycelial growth inhibition(%) |
|---|---|
| AUUB 209 (*Streptomyces enissocaesilis*) | 9.79 (18.22)* |
| AUDT 626 (*Streptomyces racemochromogenes)* | 59.33(50.38) |
| Cellulose based *Trichoderma harzianum* (IIOR, Hyderabad) | 26.52(30.94) |
| *Trichoderma harzianum* (KAU, Kerala) | 64.44(53.40) |
| *Trichoderma harzianum* (NBAIM, Mau, Uttar Pradesh) | 88.89(70.78) |
| *Trichoderma harzianum* (NBAIR, Begaluru) | 77.85(61.94) |
| *Trichoderma harzianum* (IOF, UAS, Dharwad) | 86.67(68.63) |
| S.Em. ± | 1.27 |
| C.D. at 1% | 5.39 |
| CV (%) | 4.36 |

***** arc sine transformed values.

**Table 4:** Integrated management of stem rot of groundnut.

| Treatments | Per cent disease incidence | | | Per cent disease incidence reduction over control | Relative chlorophyll content at 60 DAS (SPAD reading) | Per cent relative chlorophyll content increase over control | Pod yield (q/ha) | Per cent pod yield increase over control | Haulm yield (q/ha) | Per cent haulm yield increase over control | B:C ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Rabi* 2023 | *Kharif* 2024 | Pooled | | | | | | | | |
| $T_1$ | 17.01(24.37) | 18.45(25.45) | 17.73(24.88) | 62.92 | 42.67 | 50.39 | 18.68 | 39.60 | 22.84 | 18.96 | 1.84 |
| $T_2$ | 15.89(23.51) | 17.31(24.6) | 16.60(24.03) | 65.28 | 43.17 | 52.17 | 20.57 | 53.75 | 25.17 | 31.09 | 2.03 |
| $T_3$ | 9.51(17.97) | 10.04(18.48) | 9.78(17.89) | 79.54 | 53.19 | 87.49 | 22.71 | 69.69 | 29.02 | 51.16 | 2.24 |
| $T_4$ | 13.68(21.72) | 14.61(22.48) | 14.15(21.91) | 70.40 | 44.50 | 56.86 | 21.75 | 62.58 | 26.75 | 39.34 | 2.15 |
| $T_5$ | 18.21(25.27) | 21.36(27.54) | 19.79(26.28) | 58.61 | 39.62 | 39.64 | 17.75 | 32.62 | 21.16 | 10.18 | 1.75 |
| $T_6$ | 13.47(21.55) | 13.41(21.49) | 13.44(21.50) | 71.89 | 46.62 | 64.33 | 22.34 | 66.94 | 28.05 | 46.11 | 2.15 |
| $T_7$ | 21.23(27.45) | 26.00(30.68) | 23.62(28.99) | 50.60 | 37.45 | 32.01 | 18.39 | 37.41 | 19.58 | 1.98 | 1.79 |
| $T_8$ | 22.06(28.03) | 23.54(29.04) | 22.80(28.53) | 52.32 | 37.50 | 32.16 | 17.57 | 31.34 | 20.09 | 4.65 | 1.71 |
| $T_9$ | 10.25(18.68) | 12.35(20.58) | 11.30(19.53) | 76.36 | 49.04 | 72.86 | 22.40 | 67.43 | 28.84 | 50.22 | 2.16 |
| $T_{10}$ | 44.77(42.02) | 50.87(45.52) | 47.82(43.77) | - | 28.37 | - | 13.38 | - | 19.20 | - | 1.34 |
| S.Em. ± | 1.329 | 1.005 | 1.120 | - | 1.348 | - | 0.674 | - | 1.815 | - | - |
| C.D. at 5% | 3.948 | 2.985 | 3.338 | - | 4.004 | - | 2.001 | - | 5.392 | - | - |
| CV (%) | 9.218 | 6.568 | 7.564 | - | 5.769 | - | 5.488 | - | 10.748 | - | - |

Cost of seeds @ Rs. 5600/q, Price of Vitavax power- 1800/kg, *Trichoderma harzianum* (IOF, UAS, Dharwad)-130/kg, *Trichoderma harzianum* (NBAIM, Mau, UP)-150/kg, *Trichoderma harzianum* (NBAIR, Bengaluru)-150/kg, *Trichoderma harzianum* (KAU, Kerala)-150/kg, *Trichoderma harzianum* (IIOR, Hyderabad)-150/kg *Angular transformed values.

to overgrow and degrade the mycelium of *M. phaseolina*, coiling around the hyphae with appressoria and hook-like structures. Additionally, specific activities of cell wall-degrading enzymes, including chitinase, β-1,3 glucanase, protease and cellulase, were recorded (Silva *et al.,* 2004; Mukherjee *et al.,* 2003). Rathore *et al*. (2020) and Lakhran and Ahir, (2022) also reported the effectiveness of *T. viride*, *Bacillus subtilis* and *Pseudomonas fluorescens* in inhibiting the radial growth of *M. phaseolina*.

**Integrated management of stem and root rot of cowpea**

Among the ten integrated treatment modules evaluated during *rabi* 2023-24 and *kharif* 2024-25, seed treatment with a consortia of *Trichoderma harzianum* (NBAIM, Mau, UP) + *T. harzianum* (NBAIR, Bengaluru) at 10 g $kg^{-1}$ of seeds, followed by soil application of vermicompost enriched with *T. harzianum* (NBAIM, Mau, UP) 1 kg + *T. harzianum* (NBAIR, Bengaluru) 1 kg + 100 kg vermicompost @ 250 kg/acre at sowing ($T_3$), resulted in the lowest disease incidence (9.78%, a 79.54% reduction over control), along with the highest pod yield (22.71 q/ha), haulm yield (29.02 q/ha) and relative chlorophyll content (53.19 SPAD reading). Treatment $T_3$ was comparable to treatment $T_9$, which involved seed treatment with Carboxin 37.5% + Thiram 37.5% WP at 3 g/kg seeds, showing 94.83% seed germination, 11.30% disease incidence (a 79.54% reduction), 22.40 q/ha pod yield, 28.84 q/ha haulm yield and 49.04 SPAD reading. The highest disease incidence (47.82%), lowest pod yield (13.38 q/ha) and haulm yield (19.20 q/ha) were observed in the untreated control ($T_{10}$) (Table 4). Regarding cost-benefit analysis, the highest benefit-cost ratio (BCR) of 2.24 was achieved with seed treatment using the consortia of *T. harzianum* (NBAIM, Mau, UP) + *T. harzianum* (NBAIR, Bengaluru), followed by soil application of vermicompost enriched with the same. The BCR for $T_9$, involving Carboxin 37.5% + Thiram 37.5% WP, was 2.16, while the untreated control ($T_{10}$) had the lowest BCR of 1.34.

The results align with findings by Jambhulkar *et al.* (2015), Nagamani *et al.* (2011) and Kullalli (2019). Sunkad *et al.* (2018) reported that seed treatment with Mancozeb 50% + Carbendazim 25% WS at 3.5 g/kg, followed by soil drenching with the same fungicide (3 g/L), resulted in the highest reduction of dry root rot in chickpea, along with the maximum seed yield and test weight. In a field study on the integrated management of dry root rot in cowpea caused by *Rhizoctonia bataticola*, dry seed dressing with carbendazim proved most effective, followed by seed treatment and soil application of *T. viride* mixed with *P. fluorescens* and supplemented with FYM (Koli, 2019). Under field conditions, the highest control of root rot (*M. phaseolina*) (83.76%) was achieved with seed treatment using tebuconazole 50% + trifloxystrobin 25% WG at 1.5 g/kg, along with soil application of *T. harzianum* at 10 kg/ha, which resulted in the highest pod yield (19.5 q/ha) and net return (Rs. 39,826/ha) (Malagi *et al.,* 2023). Additionally, seed treatment with *P. fluorescens* (10 g/kg) and neem cake soil application (2.5 kg/ha) minimized root rot (*M. phaseolina*) infection in cowpea (Vengadeshkumar *et al.,* 2019).

## CONCLUSION

Among the seed dressing fungicides tested against *S. rolfsii*, Carboxin 37.5% + Thiram 37.5% DS and Penflufen 240 FS proved most effective. Among the bio-agents tested, *Trichoderma harzianum* NBAIM, Mau, Uttar Pradesh strain was followed by *T. harzianum* IOF, UAS, Dharwad strain which was most efficient in suppressing the mycelia growth of *S. rolfsii*. Out of the ten integrated treatment modules tested during *rabi* 2023-24 and *kharif* 2024-25 came out that, seed treatment with consortia [*T. harzianum* (NBAIM, Mau, UP) + *T. harzianum* (NBAIR, Bengaluru)] at 10 g $kg^{-1}$ seeds followed by soil application of vermicompost enriched *T. harzianum* (NBAIM, Mau, UP) 1 kg + *T. harzianum* (NBAIR, Bengaluru) 1 kg + 100 kg vermicompost @ 250 kg/acre at sowing to the seed furrows ($T_3$) exhibited significantly least per cent disease incidence (9.78) with highest pod yield (22.71 q/ha), haulm yield (29.02 q/ha) and chlorophyll content (53.19 SPAD reading) with B:C ratio of 2.24.

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**Disclaimers**

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions.

**Conflict of interest**

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