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RESEARCH ARTICLE

# Effect of consortia of biocontrol agents and organic amendments in confronting collar rot (*Sclerotium rolfsii* Sacc.) disease in brinjal (*Solanum melongena* L.) for sustainable cultivation

**K Kalpana[1*], M Ayyandurai[2], M Theradimani[3] & J Rajangam[4]**

[1]Department of Plant Protection, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Periyakulam 625 604, Tamil Nadu, India

[2]Department of Plant Pathology, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai 625 104, Tamil Nadu, India

[3]Department of Plant Pathology, VOC Agricultural College and Research Institute Killikulam, Thoothukudi District, Tamil Nadu Agricultural University, Vallanad 628 252, Tamil Nadu, India

[4]Department of Plant Pathology, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Periyakulam 625 604, Tamil Nadu, India

*Correspondence email - kalpssri73@gmail.com

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## Abstract

Collar rot, caused by *S. rolfsii*, is a significant threat to brinjal cultivation in Tamil Nadu. The most virulent isolate of *S. rolfsii*, identified as IS (VIL)-9, exhibited the highest disease incidence (42.4 %) in field surveys and 92.56 % in pathogenicity tests of our previous studies. The *Bacillus* spp. and *Trichoderma* spp. exhibited antagonistic activity against *S. rolfsii*. Aqueous extracts of various oil cakes including neem, pungam, mahua, castor and cotton were prepared and tested for their antifungal efficacy against *S. rolfsii*. Among the oil cake extracts, neem oil cake (10 %) exhibited the highest inhibition of *S. rolfsii* growth (81.11 %), followed by mahua oil cake (76.66 %), pungam oil cake (57.77 %), castor oil cake (34.44 %) and cotton oil cake (18.88 %). In addition, a pot culture experiment was conducted to evaluate the effectiveness of combined applications of biocontrol agents and organic amendments against collar rot disease. Ten treatments were tested, including combinations of *Bacillus* sp., *Trichoderma* sp. and neem cake. *Bacillus* sp., *Trichoderma* sp. and neem oil cake are compatible with one another in the *in vitro* assay. Among the various integrated treatments, the combined application of both biocontrol agents, *Bacillus* sp. and *Trichoderma* sp., with neem cake ($T_8$) reduced the disease incidence to 14.59 %. The control pots with only *S. rolfsii* inoculation showed a disease incidence of 80.60 %. This study demonstrated that the integrated use of biocontrol agents and organic amendments such as neem cake and oil cake extracts significantly reduces the incidence of collar rot caused by *S. rolfsii* in brinjal cultivation providing an eco-friendly alternative to chemical control.

**Keywords:** *Bacillus* spp.; biocontrol agents; oil cake extracts; *S. rolfsii*; sustainable disease management; *Trichoderma* spp.

## Introduction

Brinjal is a widely popular vegetable crop grown in India and other parts of the world. It is cultivated over an area of 728.00 kha, yielding 12660.00 kt annually, with a productivity of 17.7 t/ha (1). Brinjal is affected by numerous plant pathogens at various stages of its development. Among them, *S. rolfsii*, the causal agent of collar rot has emerged as a significant threat negatively impacting its production worldwide. Collar/foot rot can cause a 60-100 % mortality in eggplants (2). In recent years, biological control has gained importance in disease management. Biological agents and medicinal plant extracts have demonstrated strong inhibitory effects against *S. rolfsii*, making them eco-friendly and valuable for both the environment and farmers (3). *Trichoderma harzianum* and *Trichoderma viride* exhibited strong antagonistic activity against *S. rolfsii* in sugar beet under both *in vitro* and *in vivo* conditions, with inhibition rates of 86 % and 88 % respectively. Similarly, *Trichoderma hamatum* effectively suppressed *S. rolfsii* by 79 % (4, 5). Moreover, the highest levels of glucanase, chitinase and peroxidase activities were observed in bulbs and roots of onion plants co-inoculated with *Trichoderma asperellum* and *S. rolfsii* (6). *Bacillus subtilis* controlled *S. rolfsii* in greenhouse-grown peanuts by 92 % (7). The antifungal compounds produced by *B. subtilis* exhibit strong antagonistic activity against *S. rolfsii* (8). *Bacillus megaterium* exhibited the highest mycelial growth inhibition against *S. rolfsii*; showed inhibition rates reaching 87.85 % (9). Seed treatment and soil drenching with antagonistic cultures like *B. subtilis* significantly reduced seedling mortality in wheat by suppressing *S. rolfsii* (10). *Bacillus* isolates effectively inhibited the *S. rolfsii* through antibiosis (11). The exudation of extracellular compounds into the rhizosphere, production of antimicrobial substances and secretion of plant hormone helped to suppress plant diseases, promote growth and enhance nutrient absorption from the soil (12). *B. subtilis* strain G-1 successfully controls stem rot caused by *S. rolfsii* in groundnut through antibiotic production (13).

Among the organic amendments, mahua cake was found to be the most effective in reducing the incidence of sclerotium wilt in jasmine, followed by neem cake (14). An integrated management strategy against sclerotial wilt disease in bell pepper, demonstrating that the combined application of *T. viride*, chetu compound and neem cake was effective in controlling the disease (15). Neem cake as a soil amendment reduced stem rot disease in groundnut, showing the lowest incidence of disease (16). In the present study, an attempt was made to explore the antifungal activity of different oil cake extracts against the devastating pathogen *S. rolfsii* under *in vitro* conditions. Additionally, the combined application of biocontrol agents and oil cakes was tested against the pathogen under pot culture conditions.

## Materials and Methods

### Pathogen and effect of biocontrol agents

Different isolates of *S. rolfsii* from various brinjal-growing regions of Tamil Nadu were previously documented (17). Among them, IS(VIL)-9 exhibited the highest disease incidence in Vilangudi village [9.9498 °N, 78.0879 °E] in Madurai district of Tamil Nadu, recording 42.4 % during the survey and 92.56 % in pathogenicity tests. Additionally, we have studied the effect of *Bacillus* spp. and *Trichoderma* spp. on the growth of the collar rot pathogen *S. rolfsii* [Acc. No MT065836] under *in vitro* conditions. The *in vitro* efficacy tests revealed that the mycelial growth of *S. rolfsii* was significantly inhibited by the *Trichoderma* isolate T-AG, with an 84.44 % growth reduction, followed by the *Bacillus* isolate B-VI, which showed a 55.55 % growth reduction (17).

### Preparation of aqueous extracts of oil cakes

An adequate quantity of each oil cake was powdered separately and soaked in sterile distilled water at a concentration of 1 g/mL water separately and left undisturbed overnight. The soaked substance was homogenized using pestle and mortar, which was then filtered with a muslin cloth. The collected filtrate was centrifuged at 10000 rpm for 15 min. The supernatant obtained was used as the standard oil cake extract solution (100 %) (18).

### Effect of different oil cake extract against *S. rolfsii* through poisoned food technique

Five disparate organic amendments *viz.*, neem cake, mahua cake, cotton cake, pungam cake and castor cake were assessed for the antifungal property against the virulent isolate IS (VIL)-9 of *S. rolfsii* use of poisoned food technique (19). The newly prepared PDA medium was poured into several conical flasks with a quantity of 40 mL for each conical flask. Aqueous extracts of each organic amendment were mixed at 10 mL with 40 mL of PDA medium to get 10 %, following sterilization of the medium in an autoclave. 15 mL of each sterilized PDA medium amended with extracts of organic amendments was poured into sterilized Petri plates separately and then it was allowed to solidify. A 9 mm mycelial disc of *S. rolfsii* was taken from an actively growing culture and placed at the centre of each Petri plate., It was thenmaintained at room temperature. The PDA medium without extracts of organic amendments was kept as control. Each treatment was replicated thrice.The mycelial growth of *S. rolfsii* was assessed after the full growth in the control plate (20).

$$PI = \frac{D_c - D_t}{D_c} \times 100 \quad \text{Eqn. 1}$$

$D_c$ = average diameter of fungal growth (cm) in control

$D_t$ = average diameter of fungal growth (cm) in treatment

### Multiplication of inoculum in sand maize media

The inculum of the unalike isolates of *S. rolfsii* was proliferated on sand maize medium separately. The medium constitutes 1900 g of sieved sand and 100 g of maize powder (19:1). The above two ingredients were blended and soaked in 400 mL of sterile distilled water per kg and put in glucose bottles. The bottles were sterilized at 121 °C with 15 psi pressure for 2 hr and for two alternate days, which then inoculated with two 9 mm mycelial disc of vibrantly growing *S. rolfsii* and observed after for 15 days at room temperature (28 ± 2 °C), until the production of brown coloured sclerotia which otherwise signal the maturity. The bottled compounds were mixed thoroughly ahead of applying to soil.

### *In vitro* effect of combined application of antagonists and organic amendments

A pot culture experiment consisting of ten treatments was executed in the glasshouse at Department of Plant Pathology, Agricultural College and Research Institute, Madurai [9.9699 °N, 78.2040 °E] using two biocontrol agents viz., *Trichoderma* sp. and *Bacillus* sp., along with an organic amendment i.e., neem cake to evaluate the efficacy of application of biocontrol agents, organic amendment and their combinations against brinjal collar rot disease caused by *S. rolfsii*. These treatments were replicated thrice in completely randomized block design. Earthen pots were filled with sterilized potting medium (red soil:sand:FYM at 1:1:1 w/w/w) along with the inoculum of *S. rolfsii* at 5 g/pot. The antagonists and organic amendments were applied in four ways named, seed treatment, seedling root dip, soil drenching and soil application. The control pots were inoculated with pathogen alone. The effect of each treatment on the disease incidence was estimated individually.

### Treatment details

The most promising isolates of antagonistic organism *viz., Bacillus* sp. B (VI)-9, *Trichoderma* sp. T (VT)-3 and organic amendment (neem cake) were administered in different interlude and combinations to fight the collar rot of brinjal in pot culture experiment. The study evaluated the various treatments for managing collar rot in brinjal *viz.,* $T_1$- Seed treatment (ST) with *Bacillus* sp. @ 10 g/kg of seed + Seedling root dipping (SRD) of 30 - 35 days old brinjal seedlings with *Bacillus* sp. @ 10 g/L for 30 min; $T_2$- ST with *Trichoderma* sp. @ 4 g/kg of seed + SRD of 30 - 35 days old brinjal seedlings with *Trichoderma* sp. @ 4 g/L for 30 min; $T_3$ - ST + SRD with *Bacillus* sp. + Soil application (SA) of neem cake @ 100 g/kg of soil; $T_4$ - ST + SRD with *Trichoderma* sp. + SA of neem cake @ 100 g/kg of soil; $T_5$ - $T_3$ + Soil drenching (SD) with *Bacillus* sp. @ 10 g/L at 30, 45 & 60 DAT( Days After Transplanting); $T_6$ - $T_4$ + SD with *Trichoderma* sp. @ 10 g/L at 30, 45 & 60 DAT; $T_7$ - ST (14 g/kg seed) + SRD @ 14 g/L + SA ( 15 g/kg of soil) with mixture of *Bacillus* sp. & *Trichoderma* sp. + SA of neem cake @ 100 g/kg of soil; $T_7$ + SD with mixture of *Bacillus* sp. & *Trichoderma* sp. @ 20 g/ L at 30, 45 & 60 DAT; $T_9$ - ST + SRD for 30 min + SD with carbendazim @ 0.2 % (positive check); $T_{10}$ - Untreated control. Each treatment was three times replicated.

## Statistical analysis

The data were statistically analysed using the AGRIS version 92 (21). The data were subjected to analysis of variance (ANOVA), the percentage values of the Disease Reduction Over Control and arcsine transformed values. Data were subjected to analysis of variance (ANOVA) at two significant levels ($p<0.05$ and $p<0.01$) and means were compared by Least significant difference (LSD).

## Results and Discussion

The minimal mycelial growth of the pathogen was spotted in the neem cake amended plate with 1.70 cm and accounting to 81.11 % growth reduction over control (Table 1 & Fig. 1). The second least mycelia growth was noted in mahua cake with 2.10 cm recording growth reduction of 76.66 % over control. Cotton cake was found least effective in inhibiting the mycelial growth to 7.30 cm leading to 18.88 % growth reduction over control. Under *in vitro* conditions, groundnut oil cake and neem cake exhibited a suppression of 79.62 % and 76.29 % respectively, against collar rot and web blight of cowpea (25). Neem extract (*Azadirachta indica)* caused maximum inhibition of mycelial growth, sclerotial production, as well as sclerotial size and viability (26). Similarly, neem cake (10 %) extract treatment significantly reduced the oxalic acid content in the culture filtrate to 0.87 mg/mL, compared to 4.23 mg/mL in the untreated control, indicating its strong inhibitory effect on oxalic acid production by *S. rolfsii* (27).

**Table 1.** Efficacy of organic amendments against the mycelial growth of *S. rolfsii in vitro*

| Sl. No. | Organic amendments | Concentration (10 %) | |
|---|---|---|---|
| | | Mycelial growth (cm)* | Per cent growth reduction over control(%) |
| 1. | Neem cake | 1.70 | 81.11 (64.24) |
| 2. | Mahua cake | 2.10 | 76.66 (61.14) |
| 3. | Pungam cake | 3.80 | 57.77 (49.46) |
| 4. | Castor cake | 5.90 | 34.44 (35.93) |
| 5. | Cotton cake | 7.30 | 18.88 (25.75) |
| C | Control | 9.00 | 00.00 (0.00) |
| CD (P=0.05) | | 0.24 | 1.87 |

*Mean of three replications

Values in the parentheses are arc sine transformed values

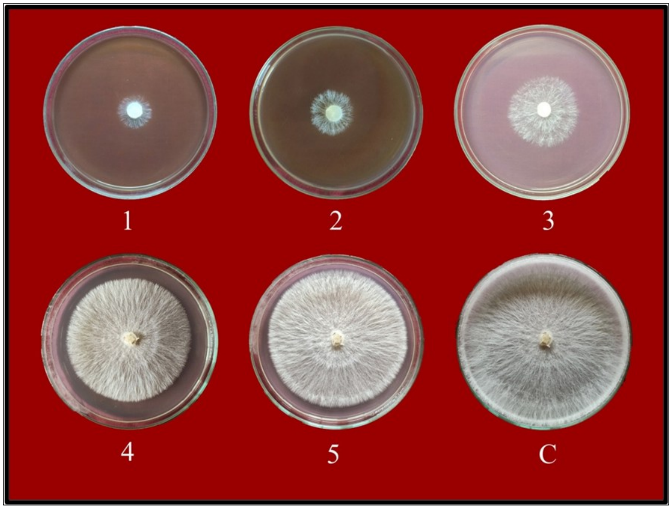


**Fig. 1.** Efficacy of extracts of organic amendments (10 %) on the mycelial growth of *S. rolfsii* (IS (VIL)-9) under *in vitro*. 1. Neem cake; 2. Mahua cake; 3. Pungam cake; 4. Castor cake; 5. Cotton cake; C. Control.

The *Trichoderma* spp. and *Bacillus* spp. antagonist isolated from native of brinjal showed that the mycelial growth of the *S. rolfsii* was significantly inhibited by the *Trichoderma* isolate T-AG with 84.44 % growth reduction followed by the *Bacillus* isolate B-VI with 55.55 % growth reduction. Similarly, *T. virens* NBAII Tvs12 antagonist showed buttressing mycoparasitism against *S. rolfsii* of groundnut by ceasing the growth to 87.91 % (22). *Trichoderma* completely overgrew the pathogen *S. rolfsii* with percentage inhibition rate of 81.36 % (23). Mycelium of *S. rolfsii* was decisively halted by five isolates of *Trichoderma* spp. (UD4-8, UD14-4, UD12-10, UD12-102 and KL10-12) with percentages of inhibition from 80-90 % (24). *Bacillus* strain LHSB1 was very beefy in clamping down on the radial growth of *S. rolfsii* hyphae to 93.8 % and20 mm width inhibition zone. Strain LHSB1 formidably fettered sclerotia formation and germination, caused abnormalities and membrane integrity detriment to hyphae (28). Three antifungal lipopeptides *viz.,* bacillomycin A, surfactin A and fengycin A, which were spotted in LHSB1 strain would be in responsible for the biocontrol activity of LHSB1 against *S. rolfsii* (28).

## Effect of antagonists and organic amendments on collar rot of brinjal in pot culture

The experimental results revealed that the treatment $T_8$ resulted in the least disease incidence of 14.59 % over 75.23 % of untreated control which makes up for the highest disease reduction of 80.60 % (Table 2 & Fig. 2). The treatment $T_7$ was found to be second in controlling collar rot in pot culture. The treatment $T_7$ recorded 17.72 % disease incidence with 76.44 % growth reduction over control. The positive check $T_9$ (ST + SRD for 30 min + SD with carbendazim @ 0.2 %) was recorded 12.10 % disease incidence resulting in 84.03 % growth reduction over control. The treatment $T_1$ underperformed among all other treatments with the PDI (Per cent Disease Incidence) of 34.20 % and accounting to 54.33 % over control (Fig. 3). The treatment $T_8$ showed significant mean difference thus, outperforming all other treatments in this experiment. A similar observation was recorded with the soil application of *Trichoderma viride* Tv-Ve1 (5 g/pot) combined with neem cake (20 g/pot), which resulted in the lowest root rot disease incidence (5.09 %) and the highest disease reduction (93.53 %) over the control in coleus(29).

**Table 2.** Effect of antagonists and organic amendment against collar rot disease in brinjal plants under pot culture

| T. No. | Treatments | Percent disease incidence(PDI)* | Disease reduction over control (%) |
|---|---|---|---|
| $T_1$ | ST with *Bacillus* sp. @ 10 g/kg of seed + SRD of 30 - 35 days old brinjal seedlings with *Bacillus* sp. @ 10 g/L for 30 min | 34.20 | 54.53 (41.49) |
| $T_2$ | ST with *Trichoderma* sp. @ 4 g/kg of seed + SRD of 30 - 35 days old brinjal seedlings with *Trichoderma* sp. @ 4 g/L for 30 min | 32.53 | 56.75 (42.77) |
| $T_3$ | ST + SRD with *Bacillus* sp. + SA of neem cake @ 100 g/kg of soil | 30.50 | 59.45 (45.08) |
| $T_4$ | ST+ SRD with *Trichoderma* sp. + SA of neem cake @ 100 g/kg of soil | 27.52 | 63.41 (47.35) |
| $T_5$ | $T_3$ + SD with *Bacillus* sp. @ 10 g/L at 30, 45 & 60 DAT | 23.88 | 68.25 (50.15) |
| $T_6$ | $T_4$ + SD with *Trichoderma* sp. @ 10 g/ L at 30, 45 & 60 DAT | 20.01 | 73.40 (53.97) |
| $T_7$ | ST (14 g/kg seed) + SRD @ 14 g/L + SA (15 g/kg of soil) with mixture of *Bacillus* sp. & *Trichoderma* sp. + SA of neem cake @ 100 g/kg of soil | 17.72 | 76.44 (55.84) |
| $T_8$ | $T_7$ + SD with mixture of *Bacillus* sp. & *Trichoderma* sp. @ 20 g/ L at 30, 45 & 60 DAT | 14.59 | 80.60 (60.76) |
| $T_9$ | ST + SRD for 30 min + SD with carbendazim @ 0.2 % (positive check) | 12.10 | 84.03 (65.49) |
| $T_{10}$ | Untreated control | 75.23 | 00.00 (0.00) |
| CD (P=0.05) | | 1.30 | 2.52 |

Mean of three replications

Values in the parentheses are arc sine transformed values

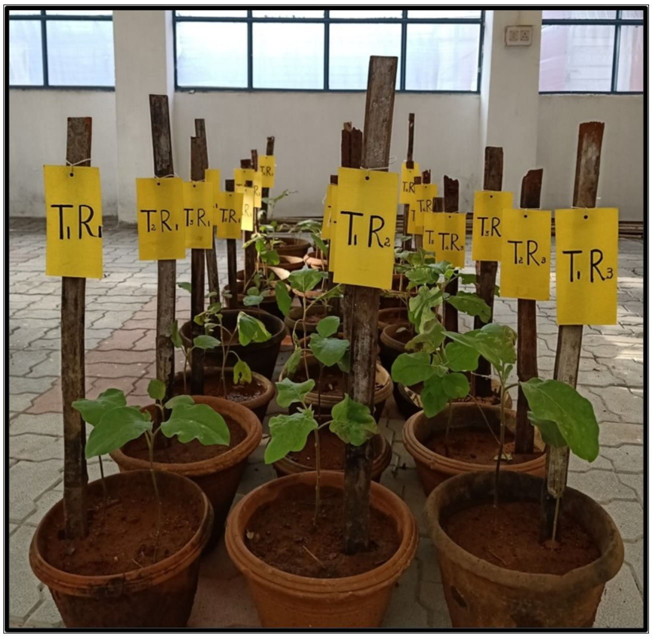

**Fig. 2.** Pot culture experiment on the effect of antagonists and organic amendment on the collar rot disease of brinjal.

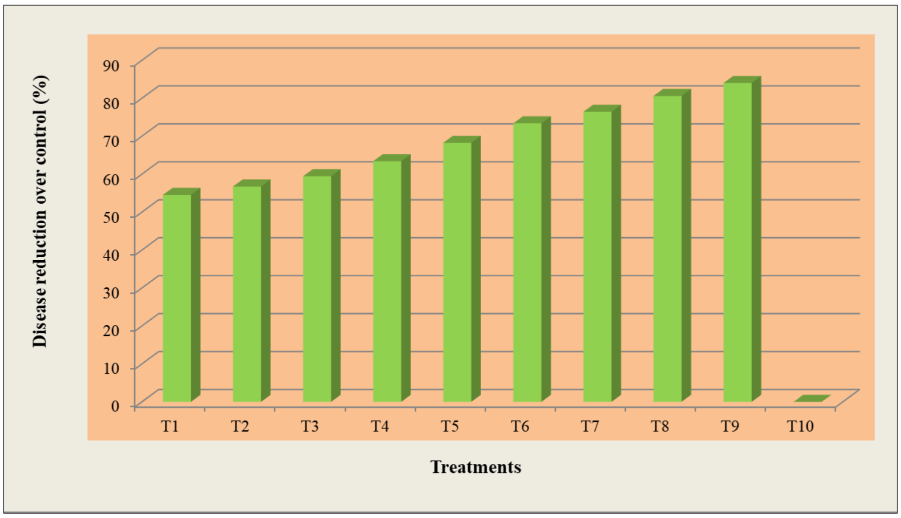


**Fig. 3.** Effect of antagonists, organic amendment and their combination on the management of collar rot of brinjal under pot culture condition.

Application of *T. harzianum* inoculum to soil and seed dressing in the pots exhibited per cent disease reduction of 33-50 % and 72-83 % respectively (30). The application of FYM with seed treatment of *T. harzianum* at 4 g/kg seed + phosphate solubilizing bacteria at 25 g/kg seed resulted in a 26.0 % reduction in root rot of green gram caused by *Macrophomina phaseolina* (31). *S. rolfsii* is highly soil persistent; in this context, the different modes of application are very important for reducing the inoculum load of soil.

The seedling dip application of carboxin + thiram + *T. harzianum* + soil application of neem seed cake against collar rot of chilli resulted in the least mortality as well as the highest yield (32). A supportive result with the application of *Trichoderma* spp. and *Bacillus subtilis* as seed treatments and soil sprinkle with *Trichoderma* spp. had significantly higher effect on a disease incidence than *Bacillus* in cramping cowpea damping-off and stem rot (33The tuber treatment of carboxin + *T. harzianum* along with soil application of FYM (Farm Yard Mannure) and neem cake, has reduced the wilt incidence provoked by *S. rolfsii* and increased the yield of potato (34). Previous study reported similar results by the application of *Pseudomonas fluorescens* (Pf1) + *T. viride* Tv1 + *B. subtilis* Bs16 + neem cake + FYM + zinc sulfate, which hindered the collar and root rot disease incidence in physic nut (35). The soil application of *P. fluorescens* @ 20 g/pot and *B. subtilis* @ 25 g/pot had effectively reduced the wilt incidence of jasmine in pot culture experiment (36). Seeds pre-treated with *B. subtilis* subsp. *spizizenii*, *B. subtilis* subsp. *subtilis*, *Bacillus atrophaeus*, *Bacillus tequilensis* and *Streptomyces cyaneofuscatus* resulted in 50-58.5 % reduction in severity of root-rot of bean (37). In addition significant disease reduction of 56.67 %, 46.67 % and 26.67 % by *Bacillus* sp. 2PR9b, *Bacillus* sp. 1PR7a and *Bacillus* sp. 2P2, respectively, compared to the control (93.33 %) against the collar rot pathogen in tomato (38).

Neem seed cake, *Trichoderma* sp. *and Bacillus* sp. attributed the synergistic and additive growth effects that enhanced the plant vigour as well as substantial antagonistic activity of bio antagonist against collar rot pathogen. The addition of the oil cake into the soil increases the cation exchange capacity, water holding capacity as well as creates a good soil structure for plant growth and effectively reduces the harmful soil-borne pathogens. In the plant protection aspect, oil cake produces high antifungal principles against soil-borne pathogens like bacteria, fungi and nematodes.

Soil-borne diseases are effectively managed by organic amendments through various mechanisms. Mahua cake and neem cake demonstrated significant antimicrobial properties and effectively inhibited diseases. Notably, oil cakes rich in secondary metabolites, such as phenolic and flavonoid compounds, exhibited strong antimicrobial activity. Application of organic amendments alters the soil suppressiveness, stimulates the activities of beneficial microbiota such as *Rhizobacteria*, *Trichoderma* and *Pseudomonas* species, which create competition for nutrients with the infectious agents during decomposition and enhances the production of phenols or tannins with induced resistance in the plant system (39). Addition of neem cake into the soil enhances the population of *Trichoderma* spp.

## Conclusion

The study demonstrated the effectiveness of *Trichoderma* spp. and *Bacillus* spp. in suppressing *S. rolfsii*, accentuated their potential as biocontrol agents. Among the oil cake extracts tested, some exhibited strong antifungal activity, further supporting their use in disease management. The combined application of biocontrol agents and organic amendments significantly reduced disease incidence in pot trials. These findings suggested that integrating biocontrol agents with organic amendments could serve as an eco-friendly and sustainable strategy for managing collar rot in brinjal.

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## Authors' contributions

KK contributed to the writing of the original draft and conceptualization of the study AA, MA, MT and JR were involved in revising the draft, including the incorporation of tables and figures and proofreading. All authors have read and approved the final version of the manuscript.

## Compliance with ethical standards

**Conflict of interest:** Authors do not have any conflict of interests to declare.

**Ethical issues:** None

## References

1. Indiastat. 2019. Available at: https://www.indiastat.com.
2. Siddique MAB, Meah MB, Siddiqua MK, Rahim MA, Haque MM. Response of ten brinjal varieties to foot rot caused by *Sclerotium rolfsii*. Bangladesh J Plant Pathol. 2002;18(1/2):77-81.
3. Dwivedi SK, Prasad G. Integrated management of *Sclerotium rolfsii*: an overview. Eur J Biomed Pharm Sci. 2016;3(11):137-46.
4. Mathur SB, Sarbhoy AK. Biological control of sclerotium root rot of sugarbeet. Indian Phytopathol. 1978;31(3):365-7.
5. Barakat RM, Al-Mahareeq F, Al-Masri MI. Biological control of *Sclerotium rolfsii* by using indigenous *Trichoderma* spp. isolates from Palestine. Hebron Univ Res J. 2006;2(2):27-47.
6. Guzmán-Valle P, Bravo-Luna L, Montes-Belmont R, Guigón-López C, Sepúlveda-Jiménez G. Induction of resistance to *Sclerotium rolfsii* in different varieties of onion by inoculation with *Trichoderma asperellum*. Eur J Plant Pathol. 2014;138:223-9. https://doi.org/10.1007/s10658-013-0336-y
7. Abd-Allah EF. Effect of a Bacillus subtilis isolate on southern blight (Sclerotium rolfsii) and lipid composition of peanut seeds. Phytoparasitica. 2005;33(5):460-6. https://doi.org/10.1007/BF02981395
8. Nalisha I, Muskhazli M, Nor Farizan T. Production of bioactive compounds by *Bacillus subtilis* against *Sclerotium rolfsii*. Malays J Microbiol. 2006;2(2):19-23. https://doi.org/10.21161/mjm.220604

9. Suryawanshi AP, Borgaonkar AS, Kuldhar DP, Dey U. Integrated management of collar rot (*Sclerotium rolfsii*) of brinjal (*Solanum melongena*). Indian Phytopathol. 2015;68(2):189-95.

10. Harlapur SI. Studies on some aspects of foot rot of wheat caused by *Sclerotium rolfsii* Sacc. [MSc thesis]. Dharwad: University of Agricultural Sciences; 1988.

11. De Curtis F, Lima G, Vitullo D, De Cicco V. Biocontrol of *Rhizoctonia solani* and *Sclerotium rolfsii* on tomato by delivering antagonistic bacteria through a drip irrigation system. Crop Prot. 2010;29(7):663-70. https://doi.org/10.1016/j.cropro.2010.01.012

12. Suneeta P, Aiyanathan K, Arutkani E, Nakkeeran S. Efficacy of *Bacillus* spp. in the management of collar rot of *Gerbera* under protected cultivation. Res Crops. 2016;17(4):745–52. https://doi.org/10.5958/2348-7542.2016.00126.1

13. Shifa H, Gopalakrishnan C, Velazhahan R. Characterization of antifungal antibiotics produced by *Bacillus subtilis* G1 antagonistic to *Sclerotium rolfsii*. Biochem Cell Arch. 2015;15(1):99–104.

14. Ramamoorthy V, Alice D, Meena B, Muthusamy M, Seetharaman K. Biological management of sclerotium wilt of jasmine. Indian J Plant Prot. 2000;28(1):102–4.

15. Anitha CK, Rajaram RD, Chandrasekhara RK, Bhupal RT, Prabhakar RI. Integrated management of sclerotial wilt disease of bell pepper (*Capsicum annuum* L.). Indian J Plant Prot. 2000;28(1):15–8.

16. Johnson M, Subramanyam K, Balaguravaiah D, John SM. Management of stem rot in groundnut through soil amendments. Ann Plant Prot Sci. 2003;11(1):83–5.

17. Abinaya A, Kalpana K, Ebenezar EG, Thiruvudainambi S, Theradimani M, Arunkumar R. Evaluation of antagonistic potential of *Bacillus* spp. and *Trichoderma* spp. against *Sclerotium rolfsii* Sacc. causing collar rot disease in *Solanum melongena* L. Int J Curr Mic robiol App Sci. 2020;9(12):694–703. https://doi.org/10.20546/ijcmas.2020.912.083

18. Jha AK, Dubey SC, Jha DK. Evaluation of different leaf extracts and oil cakes against *Macrophomina phaseolina* causing collar rot of okra. J Res Birsa Agric Univ. 2000;12(2):225–8.

19. Schmitz H. *Poisoned food technique*. *Industrial & Engineering Chemistry Analytical Edition* 1930;2(4):361–363.

20. Dennis C, Webster J. Antagonistic properties of species-groups of *Trichoderma*: I. Production of non-volatile antibiotics. Trans Br Mycol Soc. 1971;57(1):25–39. https://doi.org/10.1016/S0007-1536(71)80077-3

21. Gomez KA, Gomez AA. Statistical procedures for agricultural research. 2nd ed. New York: John Wiley and Sons. 1984;680.

22. Hirpara DG, Gajera HP, Hirpara HZ, Golakiya BA. Antipathy of *Trichoderma* against *Sclerotium rolfsii* Sacc.: evaluation of cell wall-degrading enzymatic activities and molecular diversity analysis of antagonists. J Mol Microbiol Biotechnol. 2017;27(1):22–8. https://doi.org/10.1159/000452997

23. Bosah O, Igeleke CA, Omorusi VI. *In vitro* microbial control of pathogenic *Sclerotium rolfsii*. Int J Agric Biol. 2010;12(3):474-6.

24. Suriyagamon S, Phonkerd N, Bunyatratchata W, Riddech N, Mongkolthanaruk W. Compost seed of *Trichoderma harzianum* UD12-102 in controlling collar and stem rot of tomato caused by *Sclerotium rolfsii*. Environ Nat Resour J. 2018;16(2):20–8.

25. Aparna KP, Girija VK. Efficacy of plant oils and oil cakes against *Rhizoctonia solani* Kuhn causing collar rot and web blight of cowpea under in-vitro conditions. Int J Curr Microbiol Appl Sci. 2018;7(1):2091–8. https://doi.org/10.20546/ijcmas.2018.701.252

26. Singh SR, Prajapati RK, Srivastava SSL, Pandey RK, Gupta PK. Evaluation of different botanicals and non-target pesticides against *Sclerotium rolfsii* causing collar rot of lentil. Indian Phytopathol. 2007;60(4):499–501.

27. Paramasivan M, Mohan S, Muthukrishnan N, Chandrasekaran A. Degradation of oxalic acid (OA) producing *Sclerotium rolfsii* (Sacc.) by organic biocides. Arch Phytopathol Plant Protect. 2013;46(3):357–63. https://doi.org/10.1080/03235408.2012.740983

28. Chen L, Wu YD, Chong XY, Xin QH, Wang DX, Bian K. Seed-borne endophytic *Bacillus velezensis* LHSB1 mediate the biocontrol of peanut stem rot caused by *Sclerotium rolfsii*. J Appl Microbiol. 2020;128(3):803–13. https://doi.org/10.1111/jam.14508

29. Gnanaprakash S, Raja IY, Manonmani K, Balasubramanian P. Integrated strategies for the management of root rot disease of medicinal coleus (*Coleus forskohlii* Briq.) incited by *Macrophomina phaseolina* (Tassi.) Goid. Acta Hortic. 2019;1241:507–14. https://doi.org/10.17660/ActaHortic.2019.1241.75

30. Biswas KK, Sen C. Management of stem rot of groundnut caused by *Sclerotium rolfsii* through *Trichoderma harzianum*. Indian Phytopathol. 2000;53(3):290–5.

31. Deshmukh MA, Gade RM, Belkar YK, Koche MD. Efficacy of bioagents, biofertilizers and soil amendments to manage root rot in greengram. Legume Res. 2016;39(1):140–4. https://doi.org/10.18805/lr.v0iOF.6772

32. Daunde AT. Integrated management of collar rot of chilli caused by *Sclerotium rolfsii* Sacc. [PhD thesis]. Parbhani: Vasantrao Naik Marathwada Krishi Vidyapeeth; 2018..

33. Adandonon A, Aveling TAS, Labuschagne N, Tamo M. Biocontrol agents in combination with *Moringa oleifera* extract for integrated control of Sclerotium-caused cowpea damping-off and stem rot. Eur J Plant Pathol. 2006;115409–18. https://doi.org/10.1007/s10658-006-9031-6

34. Basamma M. Integrated management of sclerotium wilt of potato caused by *Sclerotium rolfsii* Sacc. [MSc (Ag) thesis]. Dharwad: University of Agricultural Sciences. 2008.

35. Latha P, Anand T, Prakasam V, Jonathan EI, Paramathma M, Samiyappan R. Combining *Pseudomonas*, *Bacillus* and *Trichoderma* strains with organic amendments and micronutrient to enhance suppression of collar and root rot disease in physic nut. Appl Soil Ecol. 2011;49:215–23. https://doi.org/10.1016/j.apsoil.2011.05.003

36. Maheswari MPU, Muthusamy M, Alice D. Evaluation of antagonists against jasmine wilt caused by *Sclerotium rolfsii* Sacc. J Biol Control. 2002;16(2):135–40.

37. Gholami M, Khakvar R, Niknam G. Introduction of some new endophytic bacteria from *Bacillus* and *Streptomyces* genera as successful biocontrol agents against *Sclerotium rolfsii*. Arch Phytopathol Plant Protect. 2013;47(1):122–30. https://doi.org/10.1080/03235408.2013.805043

38. Sahu PK, Singh S, Gupta A, Singh UB, Brahmaprakash GP, Saxena A. Antagonistic potential of bacterial endophytes and induction of systemic resistance against collar rot pathogen *Sclerotium rolfsii* in tomato. Biol Control. 2019;137:104014. https://doi.org/10.1016/j.biocontrol.2019.104014

39. Panth M, Hassler SC, Baysal-Gurel F. Methods for management of soilborne diseases in crop production. Agriculture. 2020;10(1):16. https://doi.org/10.3390/agriculture10010016


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