RESEARCH ARTICLE Legume Research- An International Journal, Volume 47 Issue 10: 1751-1757 (October 2024)

# Revolutionizing Garden Pea Yield: A Synergistic Strategy with Plant Extracts, Bio-control Agents and Fungicides for Root Rot Disease Management and Optimal Productivity

Yogita Nain[1], Nitin Chawla[1], Priyanka Kumari Meena[1], Ridhi Shankar Sharma[1], Kiran Choudhary[1], Jyoti Rani[2]

10.18805/LR-5311

## ABSTRACT

**Background:** Pea, a vegetable crop cultivated in cooler regions globally, holds substantial economic significance in India. Unfortunately, root rot poses a significant challenge, especially during the early stages of plant growth, with *Fusarium solani* f. sp. *pisi* identified as the causative agent. To address this issue, a comprehensive study was conducted over two consecutive years, evaluating the efficacy of various plant extracts, bioagents and fungicides, both in field and laboratory settings, to control root rot in pea.

**Methods:** A field experiment was conducted at Rajasthan Agricultural Research Institute, Jaipur in the *Rabi* seasons of 2021-22 and 2022-23 aimed to develop a sustainable strategy to gather valuable insights and observations throughout the growing seasons to combat root rot in pea crops, specifically using the susceptible variety Arkel.

**Result:** Among all fungicides, plant extracts and bio-control agents that demonstrated efficacy in laboratory settings were subsequently evaluated in real-field conditions. In field condition seed treatment with tebuconazole 50%+ trifloxystrobin 25% at 0.1% along with soil application of neem cake at 5 q/ha was found best with minimum disease incidence and maximum pod yield (75.80 q/ha). Among these treatments, neem cake was the most effective in reducing the incidence of root rot in peas compared to the application of mustard cake.

**Key words:** Bio-agents, Fungicides, *Fusarium solani*, Organic amendments, Plant extract, Root rot.

## INTRODUCTION

Pea, a prominent vegetable crop mainly grow in cooler regions globally, holds a substantial place in Indian economiy, In India, the menace of root rot disease poses a grave threat to pea cultivation, especially in the III[rd] A zone of Rajasthan, causing detrimental effects on the initial plant growth. This perilous disease is primarily caused by *Fusarium solani* (Mart.) Appel and Wolleweber f. sp. *pisi* (E. R. John) Snyder and Hansen and it remains a pervasive issue for pea (*Pisum sativum* L.) cultivation on a global scale. *Fusarium* root rot tends to be most devastating when the soil temperatures range between 26° to 27°C. Additionally, a scarcity of water exacerbates the severity of root rot (Riley *et al.,* 2016). Notzably, the disease manifests in field in patches (Sinha *et al.,* 2018).

The impact of this disease on pea crops is severe, affecting all stages of growth and resulting in staggering yield losses of up to 97 per cent due to this devastating disease El-Saadony *et al.* (2021). Moreover, the disease has made its presence felt in the Kashmir Valley, with incidence rates ranging from 14.8 to 64.7 per cent (Nazir *et al.,* 2022). *Fusarium* species, particularly *F. solani* and *F. oxysporum*, are the primary causal organism behind this damaging disease (Chatterton *et al.,* 2019).

Among fungal infections, *Fusarium solani* f. sp. *pisi* induced root rot poses a significant challenge, particularly due to its soil-borne nature. Therefore, this study has been initiated, aiming to design a more feasible and enduring strategy to combat *Fusarium solani* f. sp. *pisi* induced root rot, finally extenuating the losses endured by pea cultivators. This study aspires to offer practical insights into disease management, striving to enhance pea crop resilience and minimize the detrimental effects of root rot. By aligning with the study's fundamental goal, the research activities to contribute substantially to agricultural practices, ensuring a sustainable and prosperous future for pea cultivation while combatting the persistent challenge of *Fusarium solani* f. sp. *pisi* induced root rot.

[1]Department of Plant Pathology, Rajasthan Agricultural Research Institute, Durgapura-302 018, Rajasthan, India.
[2]Chaudhary Devi Lal University, Sirsa-125 055, Haryana, India.

**Corresponding Author:** Yogita Nain, Department of Plant Pathology, Rajasthan Agricultural Research Institute, Durgapura-302 018, Rajasthan, India. Email: nainyogita9@gmail.com

**How to cite this article:** Nain, Y., Chawla, N., Meena, P.K., Sharma, R.S., Choudhary, K. and Rani, J. (2024). Revolutionizing Garden Pea Yield: A Synergistic Strategy with Plant Extracts, Bio-Control Agents and Fungicides for Root Rot Disease Management and Optimal Productivity. Legume Research. 47(10): 1751-1757. doi: 10.18805/LR-5311.

**Submitted:** 29-02-2024 **Accepted:** 08-08-2024 **Online:** 23-09-2024

## MATERIALS AND METHODS

### Source of isolates

The isolates were taken from Rajasthan Agricultural Research Institute, Durgapura, Jaipur. A field experiment

conducted at Rajasthan Agricultural Research Institute, Jaipur, Rajasthan, in the *Rabi* seasons of 2021-22 and 2022-23.

**Efficacy of plant extract against *F. solani* f. sp. *pisi***

In this experiment, 9×12 inch sterilized clay pots were filled with autoclaved soil and each pot was inoculated with the pathogen. To do this, we mixed the top 5 cm of soil in each pot with the pathogen's inoculum, which was previously multiplied on cereal grains (sorghum) at 25 g per pot.

Healthy plant parts (leaves, stems, cloves, rhizomes) were collected, washed and crushed with distilled water (100 g in 100 ml, w/v). The resulting extract was filtered through muslin cloth, yielding 100% concentration. This was further diluted 10% using distill water. Seeds soaked individually in a 10% plant extract solution (neem, giloy, turmeric, tulsi, clove and eucalyptus) for 30 minutes and sown at 10 seeds per pot. The experiments was conducted in CRD with three repetitions.

**Efficacy of bio-agents against *F. solani* f. sp. *pisi* under greenhouse conditions**

In this test, seeds were individually treated with bio-agents (namely *Trichoderma harzianum*, *Trichoderma viride*, *Pseudomonas fluorescens* and *Bacillus subtilis*) at a rate of 10 g/kg of seeds and then sown separately in pots. The experiment followed a completely randomized design. A Control was also maintained which contained surface sterilized seeds without bio-agents. Pots were watered as needed, kept under steady conditions and root rot observations were recorded up to 60 days after sowing (DAS).

**Efficacy of fungicide against *F. solani* f. sp. *pisi***

In this experiment, seeds received individual treatment with a fungicide (tebuconazole, azoxystrobin, hexaconazole, carboxin + thiram, tebuconazole + trifloxystrobin and carbendazim + mancozeb) at a rate of 2 gm/kg and 0.2%/kg of seeds and were then sown separately in pots at a rate of 10 seeds per pot. The study utilized a completely randomized design (CRD) with three repetitions. Root rot incidence was carefully noted for 60 days after sowing (DAS).

**Details of field experiment**

A field experiment conducted at Rajasthan Agricultural Research Institute, Jaipur, Rajasthan, in the *Rabi* seasons of 2021-22 and 2022-23 aimed to develop a sustainable strategy to gather valuable insights and observations throughout the growing seasons to combat root rot in pea crops, specifically using the susceptible variety Arkel. Field experiments used a randomized block design with three replicate plots of 3 m × 2 m measurements and plants spaced 30 cm × 10 cm apart. Organic soil amendments, were mixed into the soil two weeks prior to seed sowing. Following this, the soil was deliberately inoculated with a 25g inoculum /square meter at a depth of 5-8 cm to increase disease pressure. For seed treatment, bio-control agents (*T. harzianum* and *T. viride*) were individually cultured on Potato Dextrose Agar (PDA) followed by harvesting the sporulating colonies by suspending them in 20 ml of water in each Petri plate. This suspension was then mixed with 10 g of sterilized talc powder to form a slurry. This slurry was applied to the seeds at a rate of 10 g/kg. The treated seeds were placed in a moist chamber overnight to facilitate the establishment of the antagonists on them. For fungicide (tebuconazole, tebuconazole+trifloxystrobin) and plant extract (clove and neem) seed treatments, 0.2% and 10% concentration employed respectively. The seeds were soaked separately in these solutions for 30 minutes, air-dried in the shade and then sown. Observations were meticulously recorded for root rot incidence and green pod yield and detailed data is available in Table 1.

The per cent disease incidence was calculated by using the following formula:

$$\text{Disease incidence (\%)} = \frac{\text{Number of disease plant}}{\text{Total number of plants}} \times 100$$

**Table 1:** Details of neem cake, plant extract, bio- agent and fungicide treatment against *Fusarium solani* f. sp. *pisi.*

| S. no | Treatment combinations |
|---|---|
| T1 | ST with clove extract @ 10% + SA of neem cake @ 5q/ha |
| T2 | ST with neem extract @ 10% + SA of neem cake @ 5q/ha |
| T3 | ST with *Trichoderma harzianum* @10 g/kg seed + SA of neem cake @ 5 q/ha |
| T4 | ST with *Trichoderma viride* @ 10 g/kg seed + SA of neem cake @ 5 q/ha |
| T5 | ST with tebuconazole 50% EC @ 0.1% + SA of neem cake @ 5 q/ha |
| T6 | ST with tebuconazole 50% @ 0.1% + trifloxystrobin 25 % WG + SA of Neem cake @ 5 q/ha |
| T7 | ST with clove extract @ 10% + SA of mustard cake @ 5 q/ha |
| T8 | ST with neem extract @ 10% + SA of mustard cake @ 5 q/ha |
| T9 | ST with *Trichoderma harzianum* @10 g/kg seed + SA of mustard cake @ 5 q/ha |
| T10 | ST with *Trichoderma viride* @ 10 g/kg seed + SA of mustard cake @ 5 q/ha |
| T11 | ST with tebuconazole 50% EC @ 0.1%+ SA of mustard cake @ 5 q/ha |
| T12 | ST with tebuconazole 50%+ trifloxystrobin 25% WG @ 0.1% + SA of mustard cake @ 5 q/ha |

Where, ST= Seed treatment, SA= Soil application.

**Table 2:** Effect of different plant extracts against root rot disease under greenhouse conditions.

| Treatments | Concentration used | Disease incidence (%) | Disease reduction (%) |
|---|---|---|---|
| Tulsi | 10% | 47.84 (43.74) | 28.08 |
| Turmeric | 10% | 43.42 (41.20) | 34.72 |
| Giloy | 10% | 50.51 (45.27) | 24.06 |
| Neem | 10% | 30.84 (33.71) | 53.64 |
| Clove | 10% | 29.31 (32.75) | 55.94 |
| Eucalyptus | 10% | 56.18 (48.53) | 15.54 |
| Control | | 66.51 (54.62) | 0.00 |
| S.Em ± | | 1.15 | |
| C.D. (p= 0.05) | | 3.53 | |
| C.V. | | 4.31 | |

Figures in parentheses are angular transformed value.

**Table 3:** Effect of different bio-agents against root rot disease under greenhouse conditions.

| Treatments (bio-agents) | Disease incidence (%) | Disease reduction (%) |
|---|---|---|
| *T. harzianum* | 19.27 (26.02) | 69.41 |
| *T. viride* | 21.38 (27.53) | 66.06 |
| *P. florescens* | 25.67 (30.43) | 59.25 |
| *Bacillus subtillis* | 31.88 (34.37) | 49.40 |
| Control | 63.00 (52.53) | 0.00 |
| S.Em ± | 1.86 | |
| C.D. (p= 0.05) | 2.76 | |
| C.V. | 4.65 | |

Figures in parentheses are angular transformed values.

**Table 4:** Effect of different fungicides against root rot disease under greenhouse conditions.

| Fungicides | Disease incidence (%) | Disease reduction(%) |
|---|---|---|
| Tebuconazole 25% EC | 10.91 (19.26) | 83.36 |
| Azoxystrobin 23% SC | 19.93 (26.49) | 69.60 |
| Hexaconazole 5% WP | 23.18 (28.76) | 64.64 |
| Tebuconazole 25%+ Trifloxystrobin 50% WG | 7.57 (15.93) | 88.45 |
| Carboxin 37.5%+ Thiram 37.5% DS | 40.29 (39.38) | 38.53 |
| Carbendazim 12%+ Mancozeb 63% WP | 16.75 (24.14) | 74.45 |
| Control | 65.54 (54.03) | 0 |
| S.Em ± | 0.69 | |
| C.D. (p= 0.05) | 2.12 | |
| C.V. | 4.56 | |

Figures in parentheses are angular transformed values.

## RESULTS AND DISCUSSION

### Effect of different plant extracts against root rot disease

In green house condition, all plant extracts, demonstrated significant superiority over the control. The data revealed that treating the seeds with clove extract at a concentration of 10% resulted in the lowest disease incidence (29.31%), followed by neem extract (30.84%) (Table 2).

This superior effect of clove aqueous extract can be due to the presence of mainly phenolic compounds and their derivatives reported by Shan *et al.* (2005). Eugenol is the main bioactive compound of clove, Neveu *et al.* (2010) known for its ability to inhibit fungal growth and spore production. The aqueous extract of *Azadirachta indica* inhibits the growth of soil borne pathogens, indicating the presence of antifungal substances in the plant material Mondall *et al.* (2009). A similar conclusion, highlighting the *in vitro* effectiveness of various plant extracts, including *Azadirachta indica*, in controlling brinjal wilt fungal pathogens (Babu Joseph *et al.* 2008). seed treatment with extracts of neem at 10% concentration were most effective against *F. oxysporum* (Khanna *et al.* 2021).

### Effect of different bio-agents against root rot disease

The minimum disease incidence percentage (19.27%) was recorded in the case of *T. harzianum*, closely followed by *T. viride* (21.38%). Additional details can be found in Table 3. *Trichoderma harzianum* demonstrated significant interactions with the activities of the pathogen's phenol oxidizing enzymes (Chakraborty *et al.* 2007). Notably, a reduction in the activities of phenol oxidizing enzymes was observed after 21 days of incubation when plants were treated with both the pathogen and the antagonist. The potential of *Trichoderma harzianum* in managing diseases caused by *R. solani* has been demonstrated in mothbean cultivation (Godara and Singh 2021).

### Effect of different fungicides against root rot disease

The data highlighted that seed treatment with tebuconazole + trifloxystrobin resulted in the lowest percentage of disease incidence (7.57%). Our findings of green house and field experiment are consistent with the results of Attri *et al.* (2019) *Fusarium* wilt of bell pepper was also managed by using fungicides and mycelial growth of pathogen was significantly inhibited by all tested fungicide. Carbendazim and tebuconazole + trifloxystrobin effectively control root rot of pea reported by Anita and Ratnoo (2015) (Table 4).

**Table 5:** Effect of neem cake, plant extract, bio-agent and fungicide against root rot of pea under field conditions.

| Treatments | PDI at 60 days | | Pooled data | PDI at 90 days | | Pooled data | Per cent disease reduction | | Yield q/ha | | Pooled data | Increased yield over control (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2021 | 2022 | | 2021 | 2022 | | 60 Days | 90 Days | 2021 | 2022 | | |
| T1- ST with Clove extract @ 10% + SA of Neem cake @ 5 q/ha | 20.65 (26.99) | 24.93 (29.91) | 22.79 (28.45) | 22.05 (27.98) | 27.68 (27.83) | 24.87 (27.68) | 45.23 | 53.39 | 62.35 | 64.35 | 63.35 | 61.93 |
| T2- ST with Neem extract @ 10% + SA of Neem cake @ 5 q/ha | 22.75 (28.42) | 26.11 (30.69) | 24.43 (29.55) | 25.38 (30.23) | 28.39 (28.39) | 26.89 (29.31) | 41.29 | 49.60 | 62.05 | 59.38 | 60.71 | 55.20 |
| T3- ST with *Trichoderma harzianum* @ 10 g/kg seed+ SA of Neem cake @ 5 q/ha | 10.75 (19.11) | 14.68 (22.49) | 12.72 (20.80) | 13.28 (21.33) | 18.34 (18.34) | 15.81 (19.83) | 69.44 | 70.36 | 69.13 | 67.79 | 68.46 | 75.00 |
| T4- ST with *Trichoderma viride* @10 g/kg seed + SA of Neem cake @ 5 q/ha | 13.04 (21.11) | 17.46 (24.68) | 15.25 (22.90) | 15.34 (23.04) | 19.80 (19.80) | 17.57 (21.42) | 63.36 | 67.06 | 67.38 | 66.04 | 66.71 | 70.53 |
| T5- ST with Tebuconazole 50% @ 0.1% + SA of Neem cake @ 5 q/ha | 7.50 (15.77) | 12.76 (20.91) | 10.13 (18.34) | 8.76 (17.12) | 14.17 (14.17) | 11.47 (15.65) | 75.65 | 78.51 | 75.26 | 74.93 | 75.09 | 91.95 |
| T6- ST with Tebuconazole 50%+ Trifloxystrobin 25% WG @ 0.1%+SA of Neem cake @ 5 q/ha | 6.74 (14.97) | 9.32 (17.71) | 8.03 (16.34) | 7.68 (16.07) | 10.41 (10.41) | 9.04 (13.24) | 80.71 | 83.06 | 76.21 | 75.39 | 75.80 | 93.77 |
| T7- Control | 40.39 (39.43) | 42.83 (40.85) | 41.61 (40.14) | 52.83 (46.60) | 53.86 (53.85) | 53.34 (50.23) | 0.00 | 0.00 | 40.12 | 38.12 | 39.12 | |

**Table 5: Continue ...**

**Table 5: Continue...**

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T1- ST with Clove extract @ 20%+SA of Mustard cake @ 5 q/h | 27.32 (31.42) | 31.07 (33.79) | 29.20 (32.61) | 29.67 (32.93) | 34.12 (34.31) | 31.89 (35.68) | 34.08 | 41.72 | 49.20 | 47.53 | 48.37 | 52.19 |
| T2- ST with Neem extract @ 10%+SA of Mustard cake @ 5 q/h | 23.17 (28.74) | 37.83 (37.89) | 30.50 (33.32) | 27.55 (31.62) | 40.98 (39.74) | 34.26 (35.68) | 31.14 | 37.39 | 48.83 | 46.83 | 47.83 | 50.50 |
| T3- ST with *Trichoderma harzianum* @ 10 g/kg seed+ SA ofMustard cake @ 5 q/h | 18.32 (25.31) | 21.68 (27.69) | 20.00 (26.49) | 20.72 (27.04) | 23.19 (28.75) | 21.96 (27.90) | 54.85 | 59.88 | 53.47 | 52.14 | 52.80 | 66.15 |
| T4- ST with *Trichoderma viride* @ 10 g/kg seed+ SA of Mustard cake @ 5 q/h | 19.42 (26.11) | 23.13 (28.69) | 21.28 (27.41) | 20.06 (26.57) | 25.61 (30.37) | 22.84 (28.48) | 51.97 | 58.27 | 52.17 | 50.84 | 51.50 | 62.06 |
| T5- ST with Tebuconazole % @ 0.1%+SA of Mustard cake@ 5 q/h | 11.70 (19.97) | 14.73 (22.54) | 13.22 (21.26) | 12.94 (21.05) | 15.34 (23.03) | 14.14 (22.05) | 70.17 | 74.16 | 59.58 | 58.54 | 59.06 | 85.85 |
| T6- ST with Tebuconazole 50%+ Trifloxystrobin 25% @ 0.1%+SA of Mustard cake 5 q/h | 11.39 (19.70) | 12.89 (21.01) | 12.14 (20.36) | 13.00 (21.11) | 14.34 (22.22) | 13.67 (21.67) | 72.59 | 75.02 | 60.17 | 59.17 | 59.67 | 87.76 |
| T7- Control | 44.12 (41.59) | 44.46 (41.79) | 44.29 (41.70) | 55.31 (48.04) | 54.13 (47.36) | 54.72 (47.70) | 0.00 | 0.00 | 32.78 | 30.78 | 31.78 | 52.19 |
| S.Em± | 1.24 | 1.28 | 0.47 | 1.17 | 1.51 | 0.52 | | | 2.21 | 1.58 | 0.72 | |
| C.D (P=0.05) | 3.81 | 3.94 | 1.39 | 3.61 | 4.66 | 1.49 | | | 6.82 | 4.86 | 2.12 | |
| C.V | 9.66 | 8.33 | 8.94 | 7.93 | 8.82 | 8.48 | | | 7.53 | 5.53 | 6.64 | |

Figures in parentheses are angular transformed value.

**Field experiment under *in vivo* conditions**

The application of plant extracts, bio-agents and fungicides combined with neem cake resulted in a significant reduction in root rot incidence across all years, as depicted in Table 5. The findings at 60 days after sowing indicated the lowest disease incidence, with 6.74% and 9.32% root rot incidence during 2022 and 2023, respectively, observed in seed treatment with tebuconazole + trifloxystrobin, along with soil application of Neem cake. Leading to an impressive 80.71% reduction in root rot incidence compared to untreated control plots. Following closely, seed treatment with tebuconazole, coupled with soil application of neem cake, was identified as the next best option, reducing root rot incidence by 75.65% compared to the untreated control plots.

The results at 90 days after sowing clearly indicate that the lowest disease incidence, at 7.68% and 10.41% root rot incidence during 2022 and 2023, respectively, was observed in seed treatment involving tebuconazole + trifloxystrobin, along with soil application of Neem cake. Following closely, seed treatment with tebuconazole, combined with soil application of neem cake, proved to be the next best option, reducing root rot incidence by 78.51% compared to the untreated control plots.

It was evident that the maximum pod yield of 75.80 q/ha was observed in seed treatment involving tebuconazole + trifloxystrobin, combined with soil application of neem cake. Following closely, seed treatment with tebuconazole, coupled with soil application of neem cake, yielded 75.09 q/ha of pods.

Further analyzing the pod yield data, the maximum increase in green pod yield was observed with seed treatment involving tebuconazole 25%+ trifloxystrobin 50% WG at 0.1% concentration, combined with soil application of neem cake at 5q/ha, resulting in a 93.77% increase. Tebuconazole is categorized as triazole fungicides which fungicides operate as inhibitors of demethylase (DMI) Amoghavarsha *et al.* (2021). It disrupt the fungal cell wall formation process, ultimately impeding the fungus's ability to reproduce and grow. The recently introduced trifloxystrobin, has been shown to inhibit broad spectrum fungi Margot *et al.* (1998). The evaluated fungicides showed high activity against *Fusarium in vitro* and demonstrated great efficacy for reducing the disease in the greenhouse trial Ezrari *et al.* (2022). Trifloxystrobin belongs to the strobilurin class of fungicides which possess improved safety and environmental characteristics Neem cake was highly effective in controlling crown rot of cucumber under *in-vivo* conditions, further validating our result Nehra *et al.* (2020). Neem cake proved to be the most effective treatment, achieving the highest disease reduction rates of 79.15% and 70.07% against root rot of clusterbean (Shivran *et al.* 2023).

## CONCLUSION

In recent years, the cultivation of peas has witnessed a decline primarily due to the significant constraint of root rot disease caused by *Fusarium solani* f. sp. *pisi*. Our study highlighted the high effectiveness of *T. harzianum* as bio-agents, as well as clove extracts and tebuconazole + trifloxystrobin in inhibiting disease incidence under greenhouse conditions. All the promising treatments incorporating an organic amendment demonstrated superiority in reducing disease incidence and promoting higher pod yield. Notably, neem cake applied at 5 q/ha emerged as the most effective, showcasing minimal disease incidence and significantly enhancing pod yield compared to treatments involving mustard cake at 5 q/ha.

**Conflict of interest**

On behalf of all authors of this manuscript, I, [Yogita Nain], declare that none of the authors have any conflicts of interest that could have influenced the work reported in this manuscript. All authors have agreed to this submission and have approved the final manuscript. There are no financial, personal, or professional relationships that could be perceived as potential conflicts of interest.

## REFERENCES

Amoghavarsha, C., Pramesh, D., Chidanandappa, E., Sharanabasav, H., Raghunandana, A. Prasanna, M.K., Rajashekara, H. and Saddamhusen, A. (2021). Chemicals for the management of paddy blast disease. Blast disease of cereal crops: Evolution and Adaptation in Context of Climate Change. pp. 59-81.

Anita, S. and Ratnoo, S.R. (2015). Integrated management of root rot of pea (*Pisum sativum* L.) caused by *Fusarium solani* (Mart). Department of Plant Pathology, MPUAT, Udaipur. Ph.D. Thesis. pp 135.

Attri, K, Sharma, A. and Sharma, M. (2019). Management of fusarium wilt of bell pepper through fungicides. Journal of Pharmacognosy and Phytochemistry. 8(5): 1444-1447.

Babu Joseph, M.A.D. and Kumar, V. (2008). Bioefficacy of plant extracts to control *Fusarium solani* f. sp. *melongenae* incitant of brinjal wilt. Global Journal of Biotechnology and Biochemistry. 3(2): 56-59.

Chakraborty, M.R. and Chatterjee, N.C. (2007). Interaction of *Trichoderma harzianum* with *Fusarium solani* during its pathogenesis and the associated resistance of the host. Asian Journal of Experiance Science. 21(2): 353-357.

Chatterton, S., Harding, M.W., Bowness, R., Mclaren, D.L., Banniza, S. and Gossen, B.D. (2019). Importance and causal agents of root rot on field pea and lentil on the Canadian prairies, 2014-2017. Canadian Journal of Plant Pathology. 41(1): 98-114.

El-Saadony, M.T., Saad, A.M., Najjar, A.A., Alzahrani, S.O., Alkhatib, F.M., Shafi, M.E. and Hassan, M.A. (2021). The use of biological selenium nanoparticles to suppress *Triticum aestivum* L. crown and root rot diseases induced by Fusarium species and improve yield under drought and heat stress. Saudi Journal of Biological Sciences. 28(8): 4461-4471.

Ezrari, S., Lazraq, A., El Housni, Z., Radouane, N., Belabess, Z., Mokrini, F. and Lahlali, R. (2022). Evaluating the sensitivity and efficacy of fungicides with different modes of action against *Neocosmospora solani* and *Fusarium species*, causing agents of citrus dry root rot. Archives of Phytopathology and Plant Protection. 55(9): 1117-1135.

Godara, S.L. and Singh, N. (2021). Management of root rot (*Rhizoctonia solani*) of mothbean through Bio-Agents. Legume Research-An International Journal. 44(11): 1392-1397. doi: 10.18805/LR-4242.

Khanna, A., Raj, K. and Kumar, P. (2021). Construing the role of plant extracts, fungicides and bio-agents in ameliorating Fusarium wilt management in chickpea. Legume Research-An International Journal. 47(7): 1228-1234. doi: 10.18805/LR-4637.

Margot, P., Huggenberger, F., Amrein, J. and Weiss, B. (1998). A New Broad-spectrum Strobilurin Fungicide. In: Brighton Crop Protection Conference on Pests and Diseases. pp. 375-382.

Mondall, N.K., Mojumdar, A., Chatterje, S.K., Banerjee, A., Datta, J.K. and Gupta, S. (2009). Antifungal activities and chemical characterization of neem leaf extracts on the growth of some selected fungal species *in vitro* culture medium. J. Appl. Sci. Environ. Manage. 13(1): 49-53.

Nazir, N., Badri, Z.A., Bhat, N.A., Bhat, F.A., Sultan, P., Bhat, T.A. and Sakina, A. (2022). Effect of the combination of biological, chemical control and agronomic technique in integrated management pea root rot and its productivity. Scientific Reports. 12(1): 11348. doi: 10.1038/s41598-022-15580-1.

Nehra, D., Ahir, R.R. and Lakhran, L. (2020). Management of crown rot of cucumber (*Fusarium solani*) through integrated practices and organic amendments. International Journal of Current Microbiology Applied Sciences. 9(7): 2373-2378.

Neveu, V., Perez-Jiménez, J., Vos, F., Crespy, V., du Chaffaut, L., Mennen, L. and Scalbert, A. (2010). Phenol-Explorer: An online comprehensive database on polyphenol contents in foods. Database. bap024. doi: 10.1093/database/bap024.

Riley, M.B., Williamson, M.R. and Maloy, O. (2016). Plant disease diagnosis. The Plant Health Instructor. doi: 10.1094. PHI-I-2002-1021-01.

Shan, B., Cai, Y.Z., Sun, M. and Corke, H. (2005). Antioxidant capacity of 26 spice extracts and characterization of their phenolic constituents. Journal of Agricultural and Food Chemistry. 53(20): 7749-7759.

Sinha, P., Rizvi, G. and Parashar, R. (2018). Management of wilt disease of pulses: A review. International Journal Pure Applied Bioscience. 6: 696-708.

Shivran, M., Ghasolia, R.P. and Bajaya, T., (2023). Evaluation of bio-control agents and organic amendments for managing root rot (*Rhizoctonia solani*) of clusterbean (*Cyamopsis tetragonoloba*). Indian Journal of Agricultural Research. 57(5): 691-696. doi: 10.18805/IJARe.A-5626.