Integrated Disease Management Strategies for Fusarium Wilt in Lentil (*Lens culinaris*)

Abstract

Given the critical importance of lentils in Indian agriculture and nutrition, and the widespread impact of Fusarium wilt, there is an urgent need for in-depth research to understand the pathogen's epidemiology, resistance breeding, and integrated management practices. Addressing this challenge is essential for improving lentil productivity and ensuring sustainable pulse production in India and beyond. One of the major constraints in achieving higher lentil productivity is the prevalence of biotic stresses, particularly fungal diseases. The present research was undertaken to develop effective control measures against the disease. Both laboratory and field experiments were conducted at the Department of Plant Pathology, Institute of Agricultural Sciences, Bundelkhand University, Jhansi, Uttar Pradesh, India. Pure cultures of *Fusarium oxysporum* f. sp. *lentis* were multiplied on sorghum seeds that had been soaked overnight in 50% sucrose and 0.0003% streptomycin. A set of media with different pH levels (5.0, 6.0, 7.0, 8.0, and 8.5) was prepared by adjusting the pH of potato dextrose agar (PDA) using N/10 HCl or N/10 NaOH solutions, measured with a pH meter. A pathogenicity test was conducted under net-house conditions using a susceptible lentil cultivar, PDL-1, to fulfil Koch's postulates. The highest germination was observed with Carbendazim + Mancozeb (97.98%), followed by Metalaxyl and Mancozeb + *Trichoderma asperellum*. All treatments improved germination over the control, indicating their effectiveness in managing seed or soil-borne pathogens. Among tested treatments, carbendazim 12% + mancozeb 13% demonstrated the highest mycelial inhibition in vitro and was most effective in field trials, significantly reducing wilt incidence and improving yield. These findings can be applied globally to improve lentil production, particularly in regions with similar agro-climatic conditions, enhancing food security and sustainability in pulse production worldwide.

Keywords: Soil-borne pathogens; pathogenicity; fusarium wilt; potato dextrose agar.

1. Introduction

Pulses, ranking second only to cereals in global agricultural importance, are integral to the vegetarian diet due to their high protein content and substantial role in promoting soil fertility. Among these, lentil (*Lens culinaris* Medik) stands out as a vital Rabi crop, particularly suited to rainfed farming systems in India. As a legume, lentil not only enriches diets but also enhances soil health through biological nitrogen fixation, contributing approximately 101 kg of nitrogen per hectare annually (Aryee & Boye, 2017; Dhull et al., 2023; Romano et al., 2021; Li et al., 2024). India holds a distinguished position as the world's leading producer, consumer, and exporter of pulses. The states of Madhya Pradesh, Maharashtra, Rajasthan, Uttar Pradesh, Karnataka, and Andhra Pradesh contribute nearly 80% of the country's total pulse production, underscoring their pivotal role in national food security (Malik et al., 2022; Varghese et al., 2019).

Lentil, an ancient crop domesticated around 8000 BC in the Near East and Mediterranean region, belongs to the Fabaceae family and Papilionaceae sub-family. It is a diploid, short, self-pollinating plant that has remained a staple in many cuisines, especially in the Middle East and Indian subcontinent (Dhull et al., 2023; Li et al., 2024). Commonly referred to as the "poor man's meat", lentils are nutritionally rich, with protein content ranging from 22% to 34.6%, alongside high levels of carbohydrates (63.1%), dietary fiber (4.6%), and essential minerals such as calcium (68 mg/100 g), phosphorus (300 mg/100 g), and iron (7 mg/100 g) (Aryee & Boye, 2017; Li et al., 2024).

Globally, lentils are cultivated across 2.5 million hectares, with India, Pakistan, and Bangladesh accounting for nearly 38% of total global production. In India, lentils are predominantly grown in the northern plains and central-eastern regions, with Madhya Pradesh and Uttar Pradesh being the top producers. Madhya Pradesh leads with 5.92 lakh hectares under cultivation and a production of 7.17 lakh tonnes, while Uttar Pradesh follows with 4.97 lakh hectares and 4.90 lakh tonnes. However, productivity remains low, averaging only 764 kg/ha nationally and 715.46 kg/ha in Uttar Pradesh. Despite India's leadership in pulse production, it ranks 23rd globally in lentil productivity, reflecting significant yield gaps that must be addressed (Malik et al., 2022; Varghese et al., 2019; Singh & Singh, 2014).

One of the major constraints in achieving higher lentil productivity is the prevalence of biotic stresses, particularly fungal diseases. Lentil crops are susceptible to several fungal pathogens, including *Fusarium oxysporum* f. sp. *lentis* (Fol), the causal agent of Fusarium wilt. This soilborne disease is recognised as one of the most destructive threats to lentil cultivation worldwide, impacting plants from seedling to maturity stages, resulting in seed rot, stem rot, damping-off, wilting, and root decay. First documented in Hungary in 1937, Fusarium wilt has since been reported across numerous countries, including India, the USA, the former USSR, Syria, and Turkey. In India, Fusarium wilt is particularly prevalent in lentil-growing regions such as Uttar Pradesh, Madhya Pradesh, Bihar, Rajasthan, Punjab, and West Bengal (Malik et al., 2022; Eujayl et al., 1998). The disease thrives in warm, dry climates, especially at temperatures exceeding 25°C. A nationwide survey across 116 districts found reproductive-stage plant mortality due to this disease ranging from 0.7% to 9.3%, with *Fusarium oxysporum* f. sp. *lentis (Fol)* accounting for 62% of the mean mortality (Jiskani et al., 2021; Singh et al., 2017). "Disease management is required to ensure stable lentil production. Application of fungicide is one of the solutions to overcome this problem but field applications is not feasible due to the expense required and technical difficulty in infusing chemicals into the soil. The most sustainable and effective solution to this problem is the development of resistant cultivars" (Meena et al., 2017). "Wild lentil species have been identified as a potential source of resistance that can be tailored for resistance breeding (Singh et al., 2020). Multi-location screening of germplasms identifies germplasms that are resistant to multiple races present in a geographic region" (Nishmitha et al., 2023). Given the critical importance of lentils in Indian agriculture and nutrition, and the widespread impact of Fusarium wilt, there is an urgent need for in-depth research to understand the pathogen's epidemiology, resistance breeding, and integrated management practices. Addressing this challenge is essential for improving lentil productivity and ensuring sustainable pulse production in India and beyond.

2. Material and Method

The present research was undertaken to develop effective control measures against the disease. Both laboratory and field experiments were conducted at the Department of Plant Pathology, Institute of Agricultural Sciences, Bundelkhand University, Jhansi, Uttar Pradesh, with 25.4539 latitude and 78.6086 longitude. Lentil cultivar, $PDL^{-1,}$ was used as the test cultivar. Test Pathogen *Fusarium oxysporum* f. sp. *lentis* (*Fol*) was isolated from wilt-affected lentil plants. The test pathogen culture was maintained on Potato Dextrose Agar (PDA) medium and stored at 4 ± 1 °C in a refrigerator. All experiments were conducted using PDA as the growth medium.

2.1 Collection of Disease Sample

Infected plants that showed typical wilting symptoms were collected during the Rabi season (2024-25) from the Chemical research farm, Narayan Bagh, Jhansi. Samples were brought to the Department of Plant Pathology, Bundelkhand University, Jhansi, Uttar Pradesh, for isolation and further studies.

2.2 Isolation of the Pathogen

Diseased lentil plants exhibiting wilt symptoms were thoroughly washed with tap water. Small sections were cut from infected roots using a sterilised blade. These pieces were surface sterilised by immersion in 0.1% $HgCl_2$ solution for one minute, followed by three thorough rinses in sterile distilled water to eliminate traces of the sterilising agent. The sterilised root segments were then aseptically transferred to sterilised potato dextrose agar (PDA) plates. The Petri plates were incubated at 25 ± 1°C for three days to allow fungal growth. Emerging fungal colonies were subcultured by transferring small bits of growth onto fresh PDA plates. Pure cultures of the fungus were obtained by further sub-culturing using the hyphal tip method under aseptic conditions. The fungus *Fusarium oxysporum* f. sp. *lentis* (Fol) was sub-cultured on potato dextrose agar (PDA) slants and incubated at 25 ± 1°C for ten days to allow adequate fungal growth. The resulting cultures were stored in a refrigerator at 4°C for preservation and were sub-cultured monthly to maintain viability.

2.3 Mass Culture of the Wilt Fungus and Pathogenicity Test

Pure cultures of *Fusarium oxysporum* f. sp. *lentis* were multiplied on sorghum seeds that had been soaked overnight in 50% sucrose and 0.0003% streptomycin. Treated seeds were placed in 500 ml conical flasks, which were autoclaved twice (30 minutes at 121.6 °C (1.05 kg/cm²) with a 24-hour interval between cycles). After cooling, each flask was inoculated with the pure *Fol* culture and incubated at 25 ± 1 °C for 8–10 days, with daily manual shaking to ensure uniform colonisation. The fully colonised seeds (20 g per pot) were thoroughly mixed into sterilized soil in pots, with three replicates per treatment. Healthy lentil seeds (*cv*. PDL-1) were surface-sterilised in 0.1% $HgCl_2$, rinsed three times in sterile water, and sown in both inoculated and uninoculated (control) pots. All pots were watered regularly to maintain adequate moisture, and disease symptoms were recorded up to 60 days after sowing. To confirm Koch's postulates, the pathogen was re-isolated from the roots and stems of symptomatic plants.

2.4 Media Study

To determine a suitable medium for the growth of the pathogen, various plant-based, synthetic, and semi-synthetic media were prepared and evaluated. Mycelial growth was recorded for each medium to assess its effectiveness in supporting fungal growth.

2.5 Experimental Details

The experiment was conducted using a Completely Randomised Design (CRD) with 3 replications and 8 treatments, evaluating the sporulation of the pathogen on the following media: Potato dextrose agar (Natural), V-8 juice agar (Hi-Media), C-zepak's agar (Hi-Media), Potato dextrose agar (Hi-Media), Oat meal agar (Hi-Media), Corn meal agar, Lentil leaf extract agar, and Lentil Root extract Agar.

2.6 Effect of Temperature on Growth and Sporulation of *Fusarium oxysporum f. sp. Lentis*

In this experiment, 20 ml of sterilised potato dextrose agar (PDA) was poured into sterilised 90 mm diameter Petri plates, with each treatment repeated four times. After the medium solidified, the Petri plates were inoculated aseptically by placing a 6 mm diameter mycelial disc, cut from a 5-day-old pure culture of *Fusarium oxysporum f. sp. lentis* (Fol), in the centre of each plate. The inoculated plates were then incubated at various temperatures (10, 15, 20, 25, 30, and 35±1°C) in a B.O.D. incubator. Observations on the radial growth and sporulation of the fungus were recorded. Radial growth was measured on the 7th day after inoculation, while sporulation density was observed under a microscope on the 15th day. The data were statistically analysed to assess the impact of temperature on fungal growth and sporulation.

2.7 Effect of pH on Growth and Sporulation of *Fusarium oxysporum f. sp. Lentis*

A set of media with different pH levels (5.0, 6.0, 7.0, 8.0, and 8.5) was prepared by adjusting the pH of potato dextrose agar (PDA) using N/10 HCl or N/10 NaOH solutions, measured with a pH meter. Once the pH was adjusted, the medium was sterilised in an autoclave. After sterilisation, the medium was cooled to 45°C, and 20 ml of the medium was poured aseptically into sterilised Petri plates. After solidification, a 6 mm disc of *Fusarium oxysporum f. sp. lentis* (Fol) fungus was cut aseptically using a sterilised cork borer and placed in the centre of each Petri plate. The plates were incubated at 30±1°C in an incubator, with four replications for each pH value.

Observations on radial growth and sporulation were recorded. Radial growth was measured on the 7th day, and sporulation density was observed under a microscope on the 15th day after inoculation. The data obtained were analysed statistically.

2.8 Estimation of Sporulation

To estimate sporulation, after 15 days of incubation, a 5 mm disc was cut from the colony and suspended in 10 ml of distilled water. The suspension was shaken well to release the spores. The number of spores was then counted using a haemocytometer under a microscope. The results were categorised based on the following scale suggested by Singh et al. (2017): Excellent, Good, Fair, Poor, and No Sporulation, depending on the density and visibility of the spores observed (Singh et al., 2017).

2.9 Efficacy of Different Treatments against Fusarium Wilt in *In-vitro* as well as Field Conditions

In the *in-vitro* evaluation of different treatments against *Fusarium oxysporum* f. sp. *lentis*, the poisoned food technique was employed. For this, 100 ml of potato dextrose agar (PDA) medium was sterilised in 150 ml conical flasks. The required amount of each treatment was aseptically incorporated into the molten PDA, and to prevent bacterial contamination, streptomycin was added to each flask before pouring the medium. The amended medium was then poured into sterilised Petri plates, with an untreated medium serving as the control (Jiskani et al., 2021; Singh et al., 2017).

List 1. Details of expression sporulation

Sporulation Level	Symbol	Number of Spores / Microscopic Field
Excellent	++++	61 and above
Good	+++	41 – 60
Fair	++	21 – 40
Poor	+	Less than 20
No Sporulation	–	Nil

A 6 mm mycelial disc was cut from the margin of a 5-day-old *Fusarium* culture using a sterilised cork borer and placed centrally on the medium in an inverted position to ensure contact with the medium. Three replications were maintained for each treatment. The inoculated Petri plates were incubated in a B.O.D. incubator at 30±1°C, and after 7 days, the colony diameter of the pathogen was measured using a scale in millimetres. The percentage growth inhibition due to the treatments was calculated, and the percentage inhibition of mycelial growth over the control was computed. The data obtained were analysed statistically.

Treatment Details:

T1: Water
T2: *Pseudomonas fleurosence*
T3: Carbindazim + menozeb 12%, 13%
T4: Neem leaf extract
T5: *Trichoderma viridae*
T6: Metalyxl 8%
T7: Mencozeb + *Trichoderma viridae*

Observation to be Recorded:

1. Germination (%) = $No.\ of\ seed\ germinated/\ Total\ no.\ of\ seed\ sown\ X100$
2. Per cent wilt disease incidence (PDI) = $No.\ of\ seed\ germinated/\ Total\ no.\ of\ seed\ sown\ X100$
3. $I = C-T/C\ X100$

Where, I = Per cent inhibition, C = Growth in control, T = growth in treatment

3. Result and Discussion

"Biotic stresses such as Fusarium wilt (*Fusarium oxysporum* f. sp. l*entis* [Fol]), Ascochyta blight (*Ascochyta lentis*), Stemphylium blight (*Stemphylium botryosum*), anthracnose (*Colletotrichum truncatum*), root rot (*Rhizoctonia solani*), rust (*Uromyces viciae-fabae*), white mould (*Sclerotinia sclerotiorum*), and collar rot (*Sclerotium rolfsii*) have been reported to cause significant yield losses" (Jiskani et al., 2021; Singh et al., 2017; Meena et al., 2020). These pathogens affect various plant parts, leaves, stems, roots, and pods, resulting not only in reduced productivity but also in diminished seed

quality due to discolouration, thereby impacting marketability.

Among these, Fusarium wilt caused by *Fusarium oxysporum* f. sp. *lentis* (Fol) stands out as a major constraint in lentil production across India. It causes substantial economic losses by severely affecting plant vigour and survival.

3.1 Pathogenicity Test, Suitable Media, Favourable Temperature and pH for Pathogen Growth

3.1.1 Symptoms

The disease can manifest at either the early seedling stage or during the reproductive (adult) stage of crop development. The wilt pathogen, *Fusarium oxysporum* f. sp. *lentis*, survives in the soil as chlamydospores, which can remain viable for several years (Ayub et al., 2024; Jadhav et al., 2024). These resilient structures allow the pathogen to persist in the absence of a host and colonise crop residues and roots of many plants commonly used in crop rotation with lentil. As a result, the incidence of wilt disease is on the rise, posing a significant threat to lentil production and leading to substantial yield losses. The first symptom of wilt appears in the field as isolated patches, often with a more or less circular outline, which gradually enlarge as the season progresses. The initial symptoms include yellowing and curling of the leaves, starting from the lower part of the plant and progressing upwards. This is followed by drooping of the crown, eventually leading to the death of the plant. The root system is poorly developed and exhibits brown discolouration, which may be partial or complete. In early infections, the taproot is often destroyed at the tip and appears abnormally short. Similar disease symptoms have also been reported by Ayub et al. (2024), who observed that lentil wilt appears in patches in the field during both the seedling and adult stages of crop growth. Jadhav et al. (2024) also described comparable symptoms and noted that the pathogen is typically confined to the cortical tissues in the early stages of infection, while in advanced stages, it invades the vascular elements.

3.1.2 Isolation

The fungus was isolated from infected roots of lentil plants exhibiting characteristic wilt symptoms. These included stunted plant growth, initial yellowing or pale discoloration of the leaves, followed by progressive drying and eventual death of the plant. Discoloration of the vascular system was observed, indicating the entry and colonization of the pathogen through the roots. The finding are supported by similar findings as reported elsewhere (Choudhury et al., 2025; Chaurasiya, 2023).

3.1.3 Pathogenicity Test

A pathogenicity test was conducted under net-house conditions using a susceptible lentil cultivar, PDL-1, to fulfil Koch's postulates. Wilt incidence of 60.00% was observed in pathogen-inoculated pots. The wilted plants exhibited symptoms identical to those observed in naturally infected plants. The fungus was successfully re-isolated from the wilted plants, and its cultural characteristics were found to be identical to the original isolate, thereby confirming pathogenicity. These results are in agreement with findings by Kharte et al., (2025). Among the methods tested, soil inoculation and spore suspension in pot culture were most effective in creating high disease pressure under artificial conditions. In the present study, the pathogen *Fusarium oxysporum* f. sp. *lentis* (Fol) was mass-multiplied on sterilised sorghum grain medium, which supported profuse mycelial growth and conidial production.

3.2 Mass Multiplication of Pathogens on Different Media

Similar approaches for mass multiplication of the pathogen were also reported by Kharte et al. (2025) Nigam & Singh, (2022). Colonies of *Fusarium oxysporum* f. sp. *lentis* (Fol) grown on potato dextrose agar (PDA) appeared white and cottony, exhibiting moderate aerial mycelial growth. Within 3-4 days of incubation, the medium turned pinkish due to pigmentation. The fungal mycelium was septate and produced three distinct types of spores. Macroconidia were sickle-shaped, typically 3 to 5- septate, with both ends pointed. Microconidia were mostly single-celled, although a few were two-celled, and were ellipsoid to ovate in shape. These findings are in accordance with earlier reports by Nigam & Singh (2022).

Among the media tested, the maximum colony diameter (90.00 mm) of *Fusarium oxysporum* f. sp. *lentis* was recorded on oatmeal agar (Hi-Media), which was statistically at par with potato dextrose agar (Hi-Media) that yielded a colony diameter of 88.57 mm. Both were significantly

superior to potato dextrose agar (Natural) (86.67 mm), V-8 juice agar (Hi-Media) (84.00 mm), lentil root extract agar (78.40 mm), Czapek's agar (Hi-Media) (69.40 mm), and corn meal agar (37.57 mm). Potato dextrose agar (Hi-Media) was also found to be at par with potato dextrose agar (Natural) in terms of colony diameter. The least colony diameter (19.73 mm) was observed on lentil leaf extract agar.

The pathogen sporulated on all media tested, except lentil leaf extract agar and corn meal agar, indicating that these two media did not support sporulation or extensive mycelial growth. Excellent sporulation was recorded on oatmeal agar (Hi-Media), potato dextrose agar (Hi-Media), and potato dextrose agar (Natural). Good sporulation was observed on V-8 juice agar (Hi-Media), while fair sporulation was noted on lentil root extract agar and Czapek's agar (Hi-Media). These findings are in agreement with previous studies. Kharte et al., (2022). Previous studies also found PDA to be an excellent medium for fungal growth and sporulation, followed by Richard's agar. Some previous studies also reported similar observations (Chaurasiya et al., 2023; Kharte et al., 2022; Choudhury et al., 2025; Chaurasiya, 2023).

Table 1. *In-vitro* effect of different culture media on mycelial growth and sporulation of *F. oxysporum* f. sp. *lentis*

Sr. No.	Media name	Colony diameter in mm (7 DAI)*	Sporulation**
1	Potato dextrose agar (Natural)	85.00	++++
2	V-8 juice agar	83.40	+++
3	C-zepak's agar	67.00	++
4	Potato dextrose agar (Hi media)	87.67	++++
5	Oat meal agar	89.57	++++
6	Corn meal agar	35.00	-
7	Lentil leaf extract agar	20.67	-
8	Lentil root extract agar	77.73	++
SEm= 1.193		**CD at 5%= 3.576**	

**average of three replications: DAI= Days after inoculation*

*** Categories of sporulation: Excellent (++++) = 61 & above, Good (+++) = 41-60,Fair (++) = 21-40, Poor (+) = Less than 20, No (-) = Nil*

3.3 Effect of Temperature and pH on Pathogen Sporulation

The effect of different temperature levels (10°C, 15°C, 20°C, 25°C, 30°C, and 35°C) on radial growth and sporulation of *Fusarium oxysporum* f. sp. *lentis* was studied after 168 hours of incubation, as per the data present in Table 2. Significantly higher mycelial growth (90.00 mm) was observed at 30°C, followed by 25°C, which produced a colony diameter of 87.00 mm. A marked reduction in mycelia growth was observed at both lower and higher temperature extremes. Microscopic examination revealed excellent sporulation density at 30°C and 25°C. Good sporulation was recorded at 20°C, while fair sporulation was noted at 35°C. Poor sporulation was observed at 15°C and 10°C.

Similarly, the effect of different pH levels (5.0, 6.0, 7.0, 8.0, and 8.5) on radial growth and sporulation was also assessed. The pathogen was able to grow at all pH levels tested; however, significantly higher mycelial growth (90.00 mm) was recorded at pH 6.0 after 168 hours of incubation. This was followed by pH 5.0 (86.50 mm) and pH 7.0 (82.50 mm), which were also found favorable for mycelial growth. Growth declined with both increasing and decreasing pH away from 6.0, with the minimum colony diameter (57.50 mm) observed at pH 8.5. Excellent sporulation was observed at pH 6.0, good sporulation at pH 5.0 and 7.0, fair sporulation at pH 8.0, and poor sporulation at pH 8.5. These results are in line with earlier findings (Ayub et al., 2024; Jadhav et al., 2024; Choudhury et al., 2025; Chaurasiya, 2023).

3.4 Efficacy of Different Treatments against *Fusarium* Wilt in *In-vitro* and Field Conditions

3.4.1 *In-vitro* Condition

The efficacy of various treatments was evaluated in-vitro against *Fusarium oxysporum f. sp. lentis* on PDA. The data recorded in Table 3 and Fig. 1 revealed that all treatments caused significantly more per cent inhibition of mycelial growth of fungus over the control. Among the treatments,

the maximum per cent inhibition of mycelium growth was reported in Carbindazim 12% + mencozeb 13% (79.116%), followed by Metalyxl, Mencozeb + *Trichoderma viridae*, neem leaf extract and P*seudomonas fleurosenc*e with 75.894%, 64.797%, 63.842% and 62.291%, respectively. The least per cent inhibition was observed in *Trichoderma viride* (51.670%).

Table 2. *In-vitro* effect of different temperatures on mycelial growth and sporulation of *F. oxysporum f. sp. Lentis*

Sr. No.	Temperature (°C)	Colony diameter in mm (7 DAI)*	Sporulation**
1	10 °C	20	+
2	15 °C	37	+
3	20 °C	65	+++
4	25 °C	88	++++
5	30 °C	91	++++
6	35 °C	59	++
SEm= 0.601		**CD at 5%= 1.785**	

**average of four replications: DAI= Days after inoculation*

*** Categories of sporulation: Excellent (++++) = 61 & above, Good (+++) = 41-60, Fair (++) = 21-40, Poor (+) = Less than 20, No (-) = Nil*

Table 3. *In-vitro* efficacy of different treatments on mycelial growth inhibition of *Fusarium oxysporum* f. sp. *lentis* (Fol)

Sr. No.	Treatments	Mycelial Growth (mm)	Per cent Inhibition
T1	Water (Control)	83.800	0.00
T2	*Pseudomonas fluorescens* (Seed treatment)	31.600	62.291
T3	Carbendazim 12% + Mancozeb 13% (Seed treatment)	17.500	79.116
T4	Neem leaf extract (Foliar spray)	30.300	63.842
T5	*Trichoderma asperellum* (Seed treatment)	40.500	51.670
T6	Metalaxyl (Foliar spray)	20.200	75.894
T7	Mancozeb + *Trichoderma asperellum* (Seed treatment)	29.500	64.797

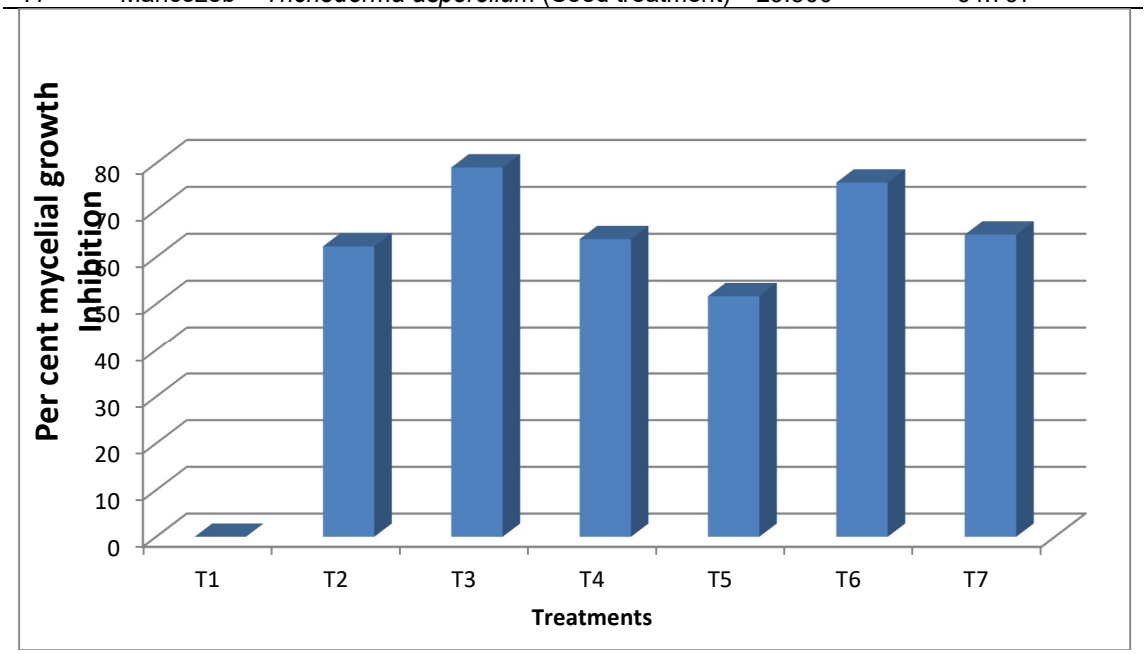

Fig. 1. *In-vitro* Efficacy of different treatments on radial mycelial growth inhibition of *Fusarium oxysporum* f. sp. *lentis* (Fol)

3.5 Effect of Different Treatments on Germination, Disease Severity and Yield

Seven different treatments were evaluated under field conditions for their comparative efficacy in reducing wilt disease incidence caused by *Fusarium oxysporum* f. sp. *lentis*. The results, presented in Table 4 and Fig. 2, show that the highest germination was observed with Carbendazim + Mancozeb (97.98%), followed by Metalaxyl and Mancozeb + Trichoderma asperellum. All treatments improved germination over the control, indicating their effectiveness in managing seed or soil-borne pathogens. All treatments significantly reduced the wilt disease incidence when compared to the untreated control. The per cent disease incidence across different treatments ranged from 14.25% to 58.23%. Among these treatments, the combination of carbendazim 12% + mancozeb 13% resulted in the lowest disease incidence (14.25%) and the highest yield (11.503 q/ha), followed by metalaxyl. Other treatments,

Table 4. Effect of different treatments on disease severity and incidence of Fusarium wilt in lentil

Sr. No.	Treatments	Germination % (Arc Sine Transformed)	Disease Incidence % (Arc Sine Transformed)	% Disease Control over Control	Yield (q/ha)
T1	Water (Control)	83.24 (65.884)	58.23 (49.718)	0.00	3.553
T2	*Pseudomonas fluorescens* (Seed treatment)	92.24 (73.939)	38.34 (38.240)	19.89	6.850
T3	Carbendazim 12% + Mancozeb 13% (Seed treatment)	97.98 (81.801)	14.25 (22.166)	43.98	11.503
T4	Neem leaf extract (Foliar spray)	93.34 (75.014)	36.42 (37.103)	21.81	8.820
T5	*Trichoderma asperellum* (Seed treatment)	90.52 (72.277)	41.56 (40.121)	16.67	5.170
T6	Metalaxyl (Foliar spray)	97.21 (80.359)	34.91 (36.202)	23.32	10.500
T7	Mancozeb + *Trichoderma asperellum* (Seed treatment)	94.84 (77.187)	35.23 (36.392)	23.00	10.070

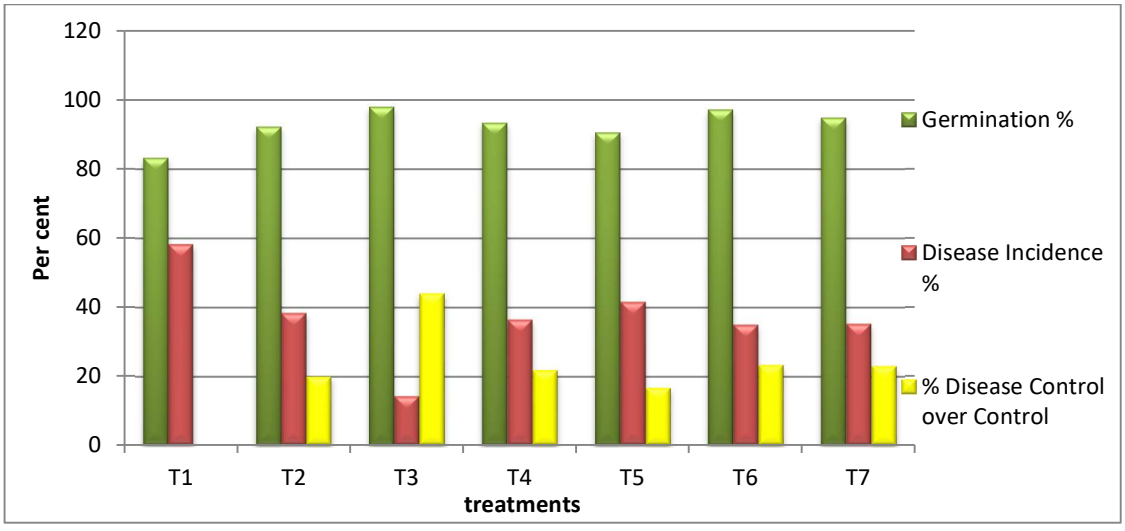

Fig. 2. Graph showing the effect of different treatments on disease severity and incidence of Fusarium wilt in lentil

such as mancozeb + *Trichoderma viride*, neem leaf extract, *Pseudomonas fluorescens*, and *Trichoderma viride*, also showed significantly better results compared to the untreated control. The lowest per cent disease incidence over the control (19.89%) and the highest yield (6.85

q/ha) were recorded with *Pseudomonas fluorescens*. Thus, carbendazim 12% + mancozeb 13% and metalaxyl were found to be the most effective chemicals in reducing wilt incidence and enhancing lentil grain yield in this investigation. The findings of this study are supported by similar observations by some other publications (Jiskani et al., 2021; Singh et al., 2017; Eujayl et al., 1998; Choudhury et al., 2025; Chaurasiya, 2023).

4. Conclusion

Lentil (*Lens culinaris*) is a vital pulse crop in India, valued for its high protein content and role in food security, especially in states like Uttar Pradesh, Madhya Pradesh, and Bihar. Lentil wilt disease, caused by *Fusarium oxysporum* f. sp. *lentis*, poses a major threat to lentil cultivation in the Bundelkhand region of Uttar Pradesh. Symptoms observed in infected plants included gradual wilting and drying, beginning from the seedling stage and progressing through flowering to the late pod-filling stage. The causal organism was successfully isolated from infected plants collected from the fields of the Chemical Research Farm, Bundelkhand University, Jhansi, Uttar Pradesh, and confirmed to be responsible for the disease. *Fusarium oxysporum* f. sp. *lentis* was successfully isolated and confirmed as the causal agent of lentil wilt, exhibiting typical symptoms and fulfilling Koch's postulates. The fungus showed optimal growth and sporulation on oatmeal agar and PDA at 25–30°C and pH 6.0. Among tested treatments, carbendazim 12% + mancozeb 13% demonstrated the highest mycelial inhibition in vitro and was most effective in field trials, significantly reducing wilt incidence and improving yield. Metalaxyl and biocontrol agents like *Pseudomonas fluorescens* and *Trichoderma viride* also provided notable disease suppression, supporting integrated disease management approaches for lentil wilt.

Competing Interests

Authors have declared that no competing interests exist.

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