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Integrated management of vascular wilt of lentil caused by *Fusarium oxysporum* f. sp. *Lentis*

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Abstract
An extensive study was undertaken to manage the most vigorous, polyphagous pathogen *Fusarium oxysporum* causing wilt disease in lentil. A field experiment was conducted during 2017-18 cropping season to evaluate different management options (seed treatment with thirum, *Trichoderma harzianum* and soil drenching alone with propiconazole and in combination with organic manures) on wilt of lentil caused by *Fusarium oxysporum* f. sp. *Lentis* under artificial inoculation condition in pots and field. It was observed that the minimum 2.56% disease incidence was recorded in soil application of Propiconazole @ 500 ml/ha 15 DAS as compared to control (66.66%) in pot condition. At field level the lowest percent disease incidence (5.05%) was recorded in soil application of Propiconazole (@ 500 ml/ha after 15 DAS, whereas 7.07 percent disease incidence was observed in soil application of Neem cake @0.1 kg $^{m-2}$ + *Trichoderma harzianum* @1 g m $^{-2}$ and soil Application of *Trichoderma harzianum* @1 g m $^{-2}$ + Press mud @ 2.5 kg m^{-2} compared to control (14.14%) in field condition.

Keywords: *Fusarium oxysporum*, propiconazole, vascular wilt, lentil

Introduction
Lentil wilt is one of the most widespread and destructive diseases caused by *Fusarium oxysporum* Schechet. Emend. Snyder and Hansen f. sp. *lentis* Vasudeva and Srinivasan (Fol). The disease may cause complete crop failure under favourable conditions for disease development and can be the major limiting factor for lentil cultivation in certain areas. At global level India ranked first in the area and second in the production with 43% and 37% of world area and production respectively [1]. Fusarium wilt causes yield losses upto 50% in India. The disease appears in either early stage of crop growth (seedling) or during the reproductive stage (adult stage) [5, 9]. The wilt pathogen survives in the soil as chlamydospores that can remain viable for several years [4] and is capable of colonizing residues and roots of most crops grown in rotation with lentil. The incidence of the wilt disease is increasing, causing substantial lentil yield losses. Plant diseases are mostly controlled by chemical pesticides and in some cases by cultural practices. However, the widespread use of chemicals in agriculture has been a subject of public concern and scrutiny due to the potential harmful effects on the environment, their undesirable effects on non-target organisms and possible carcinogenicity of some chemicals [3]. Environmental concerns of pesticides use and development of fungicidal resistance have necessitated use of eco-friendly tools for disease management. Use of bio-agents, fungicides alone and combination with organic amendments against lentil wilt is the best alternative to chemical control measures. Field studies were therefore conducted in year 2017-18 to evolve the individual use and best combination for controlling lentil wilt. However, the present investigation deals with the integrated management of lentil wilt by integrating chemical, bio-agents and organic amendments.

Materials and Methods
A pot and field experiment was conducted in the *Rabi* season of the year 2017-2018 at the Department of Plant Pathology and Crop Research Centre, S.V.P. University of Agriculture and Technology, Meerut.
In the experimental plot, the wilt causing fungal pathogens (*F. oxysporum* f. sp. lentis) were added to the soil to make the soil wilt sick. Eight treatments were laid out in randomized block

design (RBD) with plot size of 4.0 m x 3.0 m (gross size). Three replications were maintained for each treatment. In each treatment, sowing of lentil seeds was done at a spacing of 30x10 cm row to row and plant to plant respectively. Fertilizers were applied @ 20 kg N, 40 kg P_2O_5 and 20-40 kg K_2O/ha. Treatments of fungicides were imposed by as a seed treatment and in form of soil drenching with their appropriate doses and bio-control agents were imposed by as a seed treatment and as a soil application with organic amendments with their suitable doses. The organic amendments (FYM, press mud, neem cake, mustard cake and vermin-compost) were thoroughly mixed as per recommended dose in 4×3 m2 plots. Appling of *T. harzianum* as soil application, @ 2.5 kg/ha pre incorporated on100 kg well decomposed organic manure for fifteen days and apply in soil 15 days prior to seeds sowing. Surface sterilized seed sown without any treatment in inoculated plot served a control. The following treatments were imposed in randomized block design (RBD).

Treatments details in pot experiment

T_1 = Soil Application of Vermicompost (@ 50 g kg^{-1} soil) + *Trichoderma harzianum* (@ 5 g kg^{-1}soil)
T_2 = Soil Application of *Trichoderma harzianum* (@5 g kg^{-1}soil) + Press mud (@ 50 g kg^{-1} soil)
T_3 = Soil Application of Neem cake (@25 g kg^{-1}soil)
T_4 = Soil Application of Neem cake (@25 g kg^{-1}soil) + *Trichoderma harzianum* (@5 g kg^{-1}soil)
T_5 = Soil Application of Mustard cake (@25 g kg^{-1}soil)
T_6 = Soil Application of Vermicompost (@ 50 g kg^{-1} soil) + *Pseudomonas fluorescens* (@ 5 g kg^{-1}soil)
T_7 = Seed treatment with thiram (@ 3 g kg^{-1} seed)
T_8 = Soil Application of Propiconazole (@ 0.1% concentration) 15 DAS
T_9= Untreated control.

Treatments details of IDM in field condition

T_1 = Seed treatment with *Trichoderma harzianum* (@ 1 g kg^{-1} seed) + *Pseudomonas fluorescens* (@ 5 g kg^{-1}soil)
T_2 = Soil Application of *Trichoderma harzianum* (@1 g m^{-2}) + FYM (@ 2.5 kg m^{-2})
T_3 = Soil Application of *Trichoderma harzianum* (@1 g m^{-2}) + Press mud(@ 2.5 kg m^{-2})
T_4 = Soil Application of Mustard cake(@ 0.2 kg m^{-2})
T_5 = Soil Application of Mustard cake(@0.2 kg m^{-2}) + *Trichoderma harzianum*(@1 g m^{-2})
T_6 = Soil Application of Neem cake(@0.1 kg m^2)
T_7 = Soil Application of Neem cake(@0.1 kg $^{m-2}$) + *Trichoderma harzianum* (@1 g m^{-2})
T_8 = Soil Application of Propiconazole (@ 500 ml/ha) 15 DAS
T_9 = Untreated control.

Observations recorded

Percent disease incidence: The percent disease incidence disease was calculated by the following formula:

$$\text{Disease incidence } \% = \frac{\text{Number of infected plant}}{\text{Total number of plant}} \times 100$$

Test weight (g)

After threshing a random sample of grains drawn from grain yield of each plot from this, 1000-grains were counted, and their weight will be recorded as test weight (g).

Grain yield (q ha^{-1})

Produce of each net plot were threshed and grains thus obtained will be winnowed, cleaned and weighed. The yield were recorded in kg/plot and then converted into q ha^{-1}.

Statistical analysis: The data on experiments conducted in the pots were subjected to statistical analysis. The data were transformed whenever required. The critical difference was worked out at 5.0 per cent probability level to find out the difference between treatments.

Results and Discussion

Integrated management of wilt of lentil in pot condition: Eight different combinations A combination of management practices such as soil application of organic amendments *viz.* Vermicompost (50 g/kg soil), Pressmud (50 g/kg soil), Neem cake (25 g/kg soil) and Mustard cake(25 g/kg soil) with biocontrol agents i.e., *Trichoderma harzianum* (5 g/kg soil), *Pseudomonas fluorescens* (5 g/kg soil) and seed treatment with Thiram (3 g/kg seed) and Soil application of Propiconazole @ 0.1% were applied against wilt of lentil.

It is evident from Table-1 all the treatments significantly reduced the percent disease incidence and increased the yield and test weight. The minimum percent disease incidence (2.56%) and maximum yield per pot (14.66g) and test weight (19.00g) was recorded in (T8) Soil application of Propiconazole @ 0.1% 15 DAS, where in case of (T_2) soil application of *Trichoderma harzianum* @5 g kg^{-1}soil + Press mud @ 50 g kg^{-1} soil i.e. 5.12% disease incidence was recorded compared to control (66.66%) disease incidence (4.66g) yield per pot and (13.06g) test weight. Similarly many researchers worked [8] observed that soil application of *T. viride*-1 reduced wilt incidence by 31.1 percent while a combination of *T. viride*-1 and Neem product, Amritguard (@ 200 ppm) Soil application of *T. viride*-1 reduced wilt incidence by 31.1 percent while a combination of *T.viride*-1 and Amritguard provided 28.4 percent control at 60 days after sowing in pots Amritguard provided 28.4 percent control at 60 days after sowing in pots.

Table 1: Integrated disease management under artificial inoculation condition (pot)

Treatment	Disease Incidence %	Yield (pot/ gram)	Test weight
T1	9.70	13.86	17.00
T2	5.12	14.13	17.80
T3	10.07	13.51	17.33
T4	9.52	13.78	17.56
T5	11.91	12.80	17.23
T6	10.25	13.83	16.90
T7	4.94	14.16	17.20
T8	2.56	14.66	19.00
Untreated control	66.66	4.66	13.06
C.D	7.078	1.453	1.156

Integrated management of wilt of lentil in field condition

Similarly in field conditions data from the table 2 the lowest percent disease incidence (5.05%) and maximum yield (16.29 Q ha^{-1}) was recorded in (T8) Soil application of Propiconazole (@ 500 ml/ha after 15 DAS followed by (7.07%) in both (T3) Soil Application of *Trichoderma harzianum* (@1 g m^{-2}) + Press mud(@ 2.5 kg m^{-2}) and (T7) Soil Application of Neem cake(@0.1 kg $^{m-2}$) + *Trichoderma harzianum* (@1 g m^{-2}) while, The highest percent disease incidence (11.11%) was recorded in (T5) Soil application of Mustard cake @ 0.2 kg m^{-2} + *Trichoderma harzianum* @1 g m^{-2} followed compared to control (14.14%). Similarly [6] reported that chemical seed treatment of chickpea with Thiram (0.15 percent) + Carbendazim (0.1 percent) is proved to be the most effective against *Fusarium oxysporum* f. sp. *ciceri*. [2] reported that the Integrated disease management strategies using alum, zinc and bio-control agents in the glasshouse studies revealed that the maximum increase in seed germination, disease control was recorded in T. harzianum +zinc + alum as well as P. fluorescens+ alum+zinc also similar findings with [7]. Thus, chickpea wilt incited by *F. oxysporum* f. sp. *ciceri* being soil borne disease could be managed by the integration of various practices like using resistant varieties, seed treatment with chemicals, seed and soil application with bioagents and amendment of soils with oilseed cakes.

Table 2: Integrated disease management under field condition

Treatment	Diseases Incidence (%)	Yield (q/ ha)	Test weight (gm)
T1	8.08	15.74	17.2
T2	10.1	15.36	18.56
T3	7.07	15.92	17.83
T4	9.09	14.07	17.70
T5	11.11	13.7	18.13
T6	8.08	15.36	17.20
T7	7.07	15.55	18.46
T8	5.05	16.29	17.78
Control	14.14	12.59	16.73
SE(m)	0.982	0.578	0.299
CD	2.968	1.749	0.903

Conclusion

For integrated disease management of disease, soil application of Propiconazole @0.1% 15 DAS and Soil application of *Trichoderma harzianum* @1 g m^{-2} + Press mud@ 2.5 kg m^{-2} and Soil application of Neem cake (@0.1 g kg m^{-2}) + *Trichoderma harzianum* (@1 g m^{-2}). Was found most effective in reducing the disease incidence of wilt of lentil and increase the yield of lentil.

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Conflicts of Interest

The authors declare no conflict of interest. The granting agencies have no role in study design, data collection, interpretation and analysis of data or decision to publish.

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