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Integrated management of vascular wilt of lentil (*Lens culinaris* M) incited by *Fusarium oxysporum* f. sp. *Lentis*

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Abstract
Lentil (*Lens culinaris* M) has gained importance in various parts of Rajasthan as potential pulses crop. This crop suffers from many diseases among which vascular wilt of lentil caused by *Fusarium oxysporum* f. sp. *lentis*, has become a thoughtful trouble in recent years in Rajasthan and in other lentil growing parts of India, resulting heavy yield losses. Field experiments were conducted during 2016-17 and 2017-18 cropping season to evaluate the effect of different control options (seed treatment with Carbendazim, Trichoderma harzianum and soil drenching alone with chemicals and in combination with organic manures) on lentil wilt caused by Fusarium oxysporum f. sp. lentis. The results indicated that Maximum mean germination per cent (98.71), maximum per cent mean disease control (85.49), mean mortality percentage (8.27) and maximum pooled yield (918.44 kg/ha) of two years 2016-17 & 2017-18 was recorded in soil application with FYM 6t/ha + 2.5 kg/ha *Trichoderma harzianum* + seed treatment with Carbendazim @ 2g/kg seeds and Maximum 40.71 per cent mean wilt incidence, minimum per cent mean germination (90.82), minimum per cent mean disease control (34.21) and minimum pooled yield (630.35 kg/ha) of two years was reported in treatment soil drenching of Carbendazim + Mancozeb @0.1%/hac.

Keywords: vascular wilt, lentil (*Lens culinaris* M), *Fusarium oxysporum* f. sp. *Lentis*

Introduction
Lentil (*Lens culinaris* Medik.) is one of the major grain legume crops and play very important role in the supply of the protein to under nourished vegetarian population of the country. In India total coverage area under this crop is about 1.27 million hectare and production 0.97 million tonnes and average productivity 765 kg/hectare (Anonymous, 2018-19) [1]. The cultivation of lentil is well adapted to the conditions prevailing in Rajasthan and is cultivated in about 75677 hectares with annual production 75877 tonnes and productivity 1003 kg/hectare (Anonymous, 2018-19) [1]. Lentil seeds are rich in protein, the mean level being at about 28.5% (Stoilova and Pereira, 1999) [9]. It suffers from a number of diseases. Wilt of lentil caused by Fusarium oxysporum f. sp. lentis is one of the widest spread and destructive disease where ever crop is grown. The yield losses due to this disease as much as 50 percent have been reported in India (Anonymous, 1999) [2]. Many attempts have been made to control this disease using chemical, biological, varietal and cultural methods (Ram and Pandey, 2011; Sinha and Sinha, 2004; Khan and Mehnaz, 2003; Srivastava *et al*., 2000) [5, 7, 4, 8]. None of the control measures found to be effective individually at field level. Management with cultural practices and fungicides is not potential because of it have mainly soil born nature. 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 (2016-17 to 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, bioagents and organic amendments.

Materials and Methods
Integrated Disease Management of lentil wilt using different bio-control agents, organic amendments and chemicals
A field trial was undertaken for two years, i.e. during *Rabi* 2016-17 and *Rabi* 2017-18 at Research Farm of Rajasthan Agricultural Research institute, Durgapura, Jaipur.

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. Nine treatments were laid out in randomized block design (RBD) with plot size of 3.0 m x 3.0 m (gross size). Four 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, neem cake, poultry manure and vermin-compost) were thoroughly mixed as per recommended dose in 3×3 m^2 plots. Appling of *T. harzianum* as soil application, @ 2.5 kg/ha pre-incubated 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).

Treatment Details

T1= SA of FYM @ 6 t/ha + *T. harzianum* @ 2.5 Kg/ha
T2= SA of neem cake @ 1 t/ha + *T. harzianum* @ 2.5 Kg/ha
T3= SA of vermi-compost @ 2 t/ha + *T. harzianum* @ 2.5 Kg/ha
T4= SA of poultry manure @ 4 t/ha + *T. harzianum* @ 2.5 Kg/ha
T5= ST with Carbendazim @ 2 gm/kg seed + *T. harzianum* @ 6 gm/kg seed
T6= Soil drenching of carboxin+ thiram @ 0.1%
T7= Soil drenching of carbendazim + mancozeb @ 0.1%
T8= SA of FYM @ 6 t/ha + SA of *T. harzianum* @ 2.5 Kg/ha + ST with Carbendazim @ 2 gm/kg seed
T9= Untreated control

Following observations were recorded at periodic intervals after germination of seeds.

1. Germination of seed after 10 and 20 days after of sowing. 2. Disease incidence at 10, 30 and 60 days after sowing. 3. Plants stand at harvest. 4. Observation of Grain Yield (kg/ha) and Results were analyzed statistically.

Result and discussion

Integrated management of lentil wilt disease in field condition

Eight different combinations of various bio-agents, fungicides and organic manure were evaluated under field conditions for their comparative efficacy against seed germination and wilt disease incidence, disease control against wilt disease of lentil by seed treatment, soil application and soil drenching methods. Different bio agents, fungicides and organic manure were used at their different doses and lentil grain yield was also recorded.

It is evident from Table-1 & Fig-1 that the maximum mean germination per cent (98.71), maximum per cent mean disease control (85.49), mortality percentage (8.72) and maximum pooled yield (918.44 kg/ha) of two years 2016-17 & 2017-18 was recorded in soil application with FYM 6t/ha + 2.5 kg/ha *Trichoderma harzianum* + seed treatment with Carbendazim @ 2g/kg seeds Followed by seed treatment with Carbendazim + *Trichoderma harzianum*. Per cent wilt incidence was found at par in Soil application with FYM + *T. harzianum* (33.12), soil application with neem cake + *T. harzianum* (34.72), soli application with Vermicompost + *T. harzianum* (36.52), soil application with poultry manure + *T. harzianum* (33.98). Maximum 40.71 per cent mean wilt incidence, minimum per cent mean germination (90.82), minimum percent mean disease control (34.21) and minimum pooled yield (630.35) of two years was reported in treatment soil drenching of Carbendazim + Mancozeb. So, all treatments were found highly significant over control.

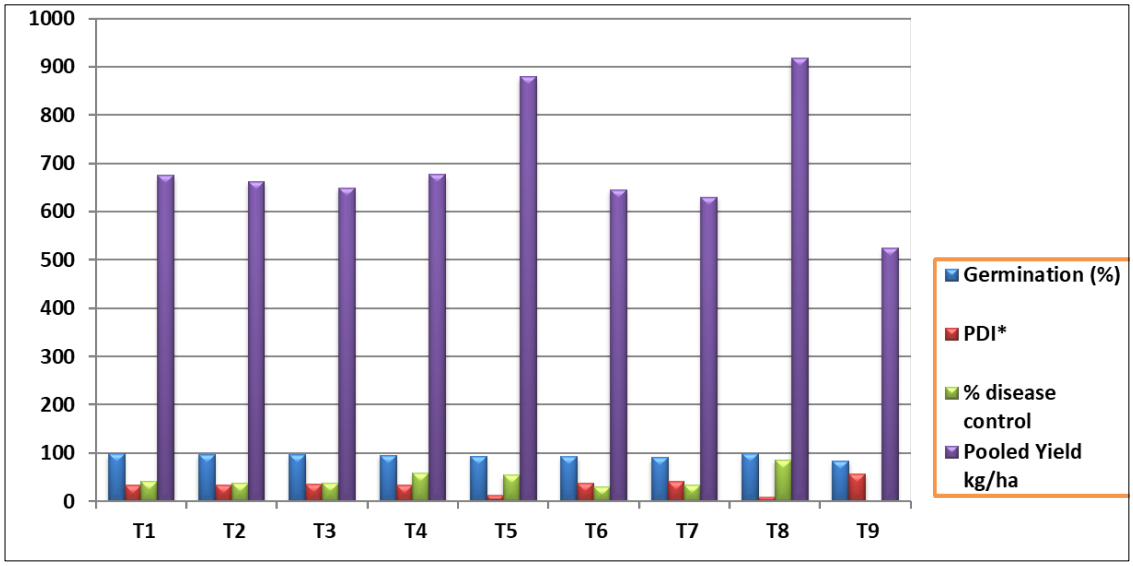
Integration of biological and chemical methods seems to be a very promising way of controlling plant pathogens with a minimal interference with biological equilibrium. For the integration, the two systems must be compatible. In the present investigation, effect of different combinations of various bio-agents, fungicides and organic manure were evaluated under field conditions for their comparative efficacy against seed germination and wilt disease incidence, disease control against wilt disease of lentil by seed treatment, soil application and soil drenching methods. Maximum mean germination per cent, maximum per cent mean disease control, mean mortality percentage and maximum pooled yield of two years 2016-17 & 2017-18 was recorded in soil application with FYM 6t/ha + 2.5 kg/ha *Trichoderma harzianum* + seed treatment with Carbendazim @ 2g/kg seeds and Maximum mean wilt incidence, minimum per cent mean germination, minimum per cent mean disease control and minimum pooled yield of two years was reported in treatment soil drenching of Carbendazim + Mancozeb @0.1%/hac So, that among these treatments, all treatments were found highly significant in all observations over control. These findings agreed with the Ansari, (2003) [3] who 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 Singh *et al*. 2017.

Table 1: Integrated management of lentil wilt disease in field condition

S. No.	Treatment	Dose	2016-17				2017-18				**Mean			
			Germination (%)	PDI*	% disease control	Yield kg/ha	Germination (%)	PDI*	% disease control	Yield kg/ha	Germination (%)	PDI*	% disease control	Pooled Yield kg/ha
1.	SA with FYM + *T. harzianum*	6t/ha+2.5kg/ ha	97.97	33.91	38.51	667.78	98.05	32.34	43.11	682.91	98.01	33.13	40.81	675.35
2.	SA with neem cake + *T. harzianum*	1t/ha+ 2.5kg/ ha	97.11	35.07	34.81	659.44	97.26	34.37	39.54	665.72	97.19	34.72	37.18	662.58
3.	SA with Vermicompost + *T. harzianum*	2t/ha+2.5kg/ha	95.93	37.18	40.01	643.33	96.17	35.85	36.94	655.23	96.05	36.52	38.48	649.28
4.	SA with poultry manure + *T. harzianum*	4 t/ha+ 2.5kg/ha	94.92	34.21	75.89	675.28	95.31	33.75	40.63	678.33	95.12	33.98	58.26	676.81
5.	ST with Carbendazim + *T. harzianum*	2+6gm/kg seed	93.02	13.75	30.83	872.10	93.79	12.18	78.58	885.76	93.41	12.97	54.71	878.93

6.	Soil drenching of Carboxin+ Thiram	0.1%/hac	92.01	39.45	27.13	637.02	92.34	37.50	34.04	653.73	92.18	38.48	30.59	645.38
7.	Soil drenching of Carbendazim + Mancozeb	0.1%/hac	90.47	41.56	84.71	624.01	91.17	39.85	29.90	636.69	90.82	40.71	34.21	630.35
8.	SA with FYM+*T. harzianum* + ST with Carbendazim	6 t/ha+2.5 Kg/ha+2 gm/kg seed	98.28	8.72	38.51	914.30	99.13	7.81	86.26	922.58	98.71	8.27	85.49	918.44
9.	Control	-	83.04	57.03	0.00	526.42	84.21	56.85	0.00	521.27	83.63	56.94	0.00	523.85
	S.Em. ±		0.36	1.72		18.53	0.28	1.93		23.50				21.01
	C.D.at 5 %		1.05	5.02		57.09	0.81	5.63		72.39				64.74
	C.V. %		0.77	10.29		4.64	0.59	11.98		5.81				5.23

*Average of four replications, Figures in parentheses are angular transformed values, PDI = Percent disease incidence, **mean of two years (2016-17 & 2017-18)



T1=SA with FYM + *T. harzianum*, T2=SA with neem cake + *T. harzianum*, T3=SA with Vermicompost + *T. harzianum*
T4=SA with poultry manure + *T. harzianum*, T5=ST with Carbendazim + *T. harzianum*, T6=Soil drenching of Carboxin+ Thiram
T7=Soil drenching of Carbendazim + Mancozeb, T8=SA with FYM+*T. harzianum* + ST with Carbendazim
T9=Control

Fig 1: Integrated management of lentil wilt disease in field condition

Conclusion

Integrated disease management strategies were studies using various combinations of bio-control gents, soil amendments and fungicides in the field conditions. Studies revealed that the maximum seed germination, minimum disease incidence, highest grain yield was observed in SA with FYM +*T. harzianum* + ST with Carbendazim and least effective was found soil drenching with Carboxin + Thiram @ 0.1%/hac.

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