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Evaluation of different Fungicides against Wilt (*Fusarium oxysporum* f.sp. *lentis*) of Lentil (*lens culinaries* medik.) in Jammu region of Jammu and Kashmir

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ABSTRACT

The present investigation evaluates the effects of various chemicals on the fungal pathogen Fusarium oxysporum f.sp. lentis, which causes wilt disease in lentil crops. Fusarium wilt is a major disease in lentils, leading to significant yield losses ranging from 50% to complete crop failure in severely affected fields, while fungicides like azoxystrobin and tebuconazole help, their environmental impact limits use. Resistant varieties struggle due to pathogen diversity and poor screening. This study aimed to manage the Fusarium wilt of lentils with chemical strategies. The disease was evaluated under field conditions, with lentil seeds treated with different chemicals to assess their efficacy against the disease. Seven chemicals namely Thiram 75 % WP, Thiophanate Methyl 70% WP, Azoxystrobin 20% + Difenconazole 12.5% WV, Propiconazole 25% EC, Tebuconazole 50% + Trifloxystrobin 25% WG, Carbendazim 50% WP and Tebuconazole 25.9 % EC, were used against the disease. Among all the chemicals evaluated, Tebuconazole 50% + Trifloxystrobin 25% WG was found most effective giving 60.34 percent disease control in the year 2023 and 63.44 per-cent disease control in 2024 under field conditions- followed by 51.31, 52.83 percent, with Tebuconazole 25.9 % EC, Propiconazole 25% EC (46.83%),(52.83%) Azoxystrobin 20% + Difenconazole (35.28%), (41.54%), thiophanate Methyl 70% WP (30.66%), (30.66%), (35.68%) Thiram (24.49%),(27.76%) and Carbendazim 50% WP (20.58%),(22.14) The seed treatment with the chemicals showed minimum disease incidence in case of Tebuconazole 50% + Trifloxystrobin 25% WG i.e.15.91 per-cent in the year 2022 and 15.12 percent in the year 2023 and the maximum disease incidence was recorded in case as untreated the control (40.12%),(41.34%) in the year 2023. The present study concluded that several new chemicals have the potential to manage the disease at lower concentrations. Chemical compounds have the potential to effectively manage the disease, even at lower concentrations.

Keywords: *chemicals, disease management, Fusarium oxysporum f.sp. lentis, chemical, pathogen*

Introduction

Lentil is a small legume seed belonging to the *Lens culinaris* species and the Leguminosae (Fabaceae or Papilionaceae) family, commonly known as Masur. It is one of the most ancient food crops that has been grown in the world and originated from South-Western Asia as early as 7000 BC. It contains 57–60% carbohydrate, 24–26% protein, 3.2% and 1.3% fiber. It is also a rich source of minerals containing calcium (69 mg per 100 g), phosphorus (300 mg per 100 g), and iron (7 mg per 100 g) of seed. India ranks first in area and second in production with 39.79% and 22.79% of world area and production respectively. Worldwide Canada ranks first in production with (41.16%) and productivity (1633 kg/ha) as compared to India (885 kg/ha). In India Lentil is grown over an area of 1.39 million ha and the production level is 1.23 million tones while the productivity is about 885 kg/ha. In Jammu and Kashmir, lentil is grown in 0.13thousand ha, and production level is 0.09 thousand tonnes, however productivity is about 696 kg/ha. It is generally grown as rainfed crop during *rabi* season.

The major lentil-growing countries of the world include Australia, Canada, China, Ethiopia, India, Nepal, Syria, Turkey, and USA [1]. Loss in lentil production is governed by several factors including poor seed quality, insects, and diseases. Among the diseases, losses caused by wilt (*Fusarium oxysporim* f.sp.*lentis*) are severe. Most of the lentil cultivated areas are reported to have this devastating disease in mild to severe form. The pathogen survives in soil as well as in seeds for several years. Pathogen infects [3] the plant in all growth stages from seedling to flowering stage. It was observed that the warm 25°C and dry conditions are the most ideal conditions for the proliferation of the disease. Wilt is a serious disease and plays a major role in reducing crop yield in India and the world [5]. It produces microconidia, macroconidia, and chlamydospores, which can persist in soil for several years. Further noted that the pathogen is also seed-borne, allowing it to spread from one location to another through seed material [4]. The management of the disease can be done through cultural, chemical, and biological methods and by the use of resistant varieties.

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In the absence of resistant tolerant varieties, it is difficult to manage the disease caused by soil-borne pathogens because of the complex edaphic environment of physical, chemical, and biological origin [14]. Management of the pathogen involves a combination of biological, cultural, and chemical practices. Various systemic and non-systemic fungicides have been tested against the pathogen, yielding diverse results. The use of synthetic chemicals plays a crucial role in managing diseases. These chemicals can protect plants from microbial infections and eradicate pathogens from the field. The systemic fungicides were found to be superior for managing pathogens through multiple studies [10]. Tebuconazole was found most effective giving 100 percent mycelium inhibition [2] in a laboratory at 500ppm followed by 88.75 percent, captan (75%), vitavax power (71%), azoxystrobin (69.5%), carbendazim (56.66%), thiram (53.75%), provax (37.5%) and control where no inhibition of mycelium was observed. eight fungicides had been evaluated against the pathogen in which [8] she found that Companion (carbendazim 12% + mancozeb 63% WP) and carbendazim were most effective at 200 ppm, while chlorothalonil was least effective. A study revealed that the soil application of propiconazole at 500 ml/ha at 15 days after sowing (DAS) resulted in the lowest disease incidence of 2.56% in pot conditions and 5.05% in field trials, compared to control [7]. Under *in-vitro* conditions carbendazim was the most effective fungicide [11] which completely inhibiting mycelial growth, followed by benomyl, topsin-M, ridomil, and vitavax (92.11- 83.46%) while the neem was the most effective plant extract. Under field conditions, carbendazim [6] seed treatment resulted in 95.5% germination, 3.65% wilt incidence, and 10.5q/ha yield, outperforming tulsi extract which showed 77.5% germination, 15.7% wilt, and 3.92 q/ha yield. Seed treatment + drenching with azoxystrobin + tebuconazole (18.2 + 18.3% SC) at 0.1% reduced lentil wilt by 69.4%, while carbendazim 50 WP reduced it by 61.5% at 45 days after sowing.

Material and Method

Isolation of pathogen

The pathogen responsible for lentil wilt was isolated from infected lentil plants collected from the field. The roots of the lentil plant were most susceptible to wilt pathogens. Small pieces of the infected plant tissue were cut using a sterile knife and then surface-sterilized by immersion in 1% sodium hypochlorite solution for 60 seconds. The tissue pieces were subsequently washed three times with sterile distilled water to remove any residual chemicals on the surface. The sterilized plant tissue was then dried by placing it on a sterile blotting paper for 1-2 minutes. The dried infected plant tissue was then transferred to Petri plates containing potato dextrose agar medium and incubated at 25±2°C for 8 days to allow the fungus to grow.

Calculation of C: B ratio

The cost-benefit ratio was calculated by using the following formula [12]

$$\text{C:B ratio} = \frac{\text{Additional income from protection}}{\text{Cost of protection}}$$

Costs

The costs of plant protection were recorded in field experiments conducted during the late planting season of 2022-23 and 2023-24. The cost of purchase of some planting, labour cost for seed treatment and drenching were calculated throughout the study, labour cost was based on the existing wage rate for unskilled labour at the locality at the time of the study which was (450 Rs) per man day. A total of 2 days of labour were used for drenching and seed treatment with the fungicides for different treatments. The totality of this cost represents the total cost of plant protection.

Field Experiment

An experiment was conducted to test the effectiveness of seven different fungicides against the wilt of lentils. The experiment was laid out at the Pulse Research Sub Station Samba, SKUAST-Jammu. (J & K) India, during the *Rabi* seasons of 2022-23 and 2023-24. The experimental site was geographically located at 32º57`N latitude and 75º11`E longitude with an altitude of 384 meters above means sea level. All the treatments were played with three replications in Randomized Block Design (RBD) with each plot measuring 3m x 1.5m. The crop was grown in the field as per the package of practices of SKUAST-J. Seeds were treated with chemicals before sowing and dried properly. The disease incidence was recorded at 30, 45, 60, and 75 days after sowing. Percent disease incidence and per cent disease control were calculated by using the following formula.

$$\textbf{Disease Incidence} = \frac{\text{No. of infected plants}}{\text{Total no. of plants assessed}} \times 100$$

$$\textbf{Per cent disease control} = \frac{(C - T)}{C} \times 100$$

Where,

C = Per cent disease incidence of control plots

T = Per cent disease incidence in treated plots

Yield parameter was also recorded to test the effect of chemicals on the crop yield per hectare.

Results

Seven different fungicides were evaluated under field conditions for their efficacy against the wilt disease of lentils at the Research farm of Pulse Research Sub-station Samba. The results presented in Table 1 and Table 2 recorded that all the treatments were found significantly superior in minimizing the disease over control. (Tebuconazole 50% + Trifloxystrobin 25% WG) was found most effective with a minimum disease incidence of 15.91 per cent and 15.12 percent respectively against 40.13 per cent and 41.35 percent in check during 2022-23 and 2023-24 followed by (Tebuconazole 25.9 % EC) 19.54 percent and 19.51 per (Propiconazole 25 % EC) 21.34 per cent and 19.87 per cent, (Azoxystrobin 20% + Difenoconazole 12.5% WV) 25.97 per cent and 24.18 per cent, (Thiophanate Methyl 70% WP) 27.82 percent and 26.60 per cent, (Thiram 75 % WP) 30.30 per cent and 29.87 per cent. The maximum disease incidence of 31.87 percent and 32.20 percent during both years was observed in (Carbendazim 50% WP). However, in the control plots the maximum disease control was recorded as 60.34 percent and 63.44 percent.

The result presented in Table 3 revealed that all treatments were statistically significant and the maximum grain yield of 1723.83 kg/ha was observed from (Tebuconazole 50% + Trifloxystrobin 25% WG) while the lowest yield of 1047.67 kg/ha was observed in control. All treatments with fungicides increase the crop yield significantly over control. The maximum yield of 71.97 per cent and 58.42 per cent during both the years was achieved in (Tebuconazole 50% + Trifloxystrobin 25% WG) followed by Propiconazole 25% EC (64.39 percent) during 2022-23 but in 2023-24 followed by (Tebuconazole 25.9 % EC) 50.17 percent.

In 2022-23 the best cost: benefit ratio of 241.8 was observed in (Tebuconazole 50% + Trifloxystrobin 25% WG) followed by 143.4 for (Carbendazim 50% WP) however the lowest 44.0 was recorded in (Azoxystrobin 20% + Difenoconazole 12.5% WV) and in 2023-24 benefit ratio of 192.8 for (Tebuconazole 50% + Trifloxystrobin 25% WG) followed by 127.5 for (Thiram 75 % WP) while the lowest was 48.4 for(Azoxystrobin 20% + Difenoconazole 12.5% WV)

Discussion

The application of different fungicides to control the wilt of lentils was found effective in controlling the disease however [13] also proved that carbendazim and carboxin effectively controlled *Fusarium oxysporum* f. sp. *lentis*, enhancing lentil seed germination, growth, and vigor, making them promising fungicides for managing lentil wilt disease. Experimentally proved that [8] Companion (Carbendazim + Mancozeb) and Carbendazim were the most effective fungicides in inhibiting the pathogen's growth in a laboratory at different conditions. Similar findings have been also recorded by [9] who also reported that the application of fungicides for the control of wilt of lentils was highly efficient.

Future scope of the study

Future research could explore the long-term efficacy and environmental impact of the identified fungicides on *Fusarium oxysporum* f.sp. *lentis*. Further research could focus on developing integrated disease management strategies that combine chemical treatments with biological controls and resistant lentil varieties. Additionally, investigating the potential of lower concentrations of effective chemicals may enhance sustainability in lentil farming, reducing reliance on high-impact fungicides while maintaining crop yields and minimizing environmental risks.

Conflict of Interest and Acknowledgements

The authors declare no conflict of interest. I am grateful to the Head of the Department of Plant Pathology at SKUAST-Jammu and the Pulse Research Sub-station in Samba for providing the necessary facilities to conduct successful experiments.

Conclusion

The studies revealed that the maximum percentage of disease control was observed with Tebuconazole 50% + Trifloxystrobin 25% WG shall be used for the management of wilt of lentil as well as to increase the yield of the crop during both years. This treatment also resulted in the maximum yield as compared to the control. Thiram 75% WP and carbendazim 50% WP were also found to be the least effective fungicides.

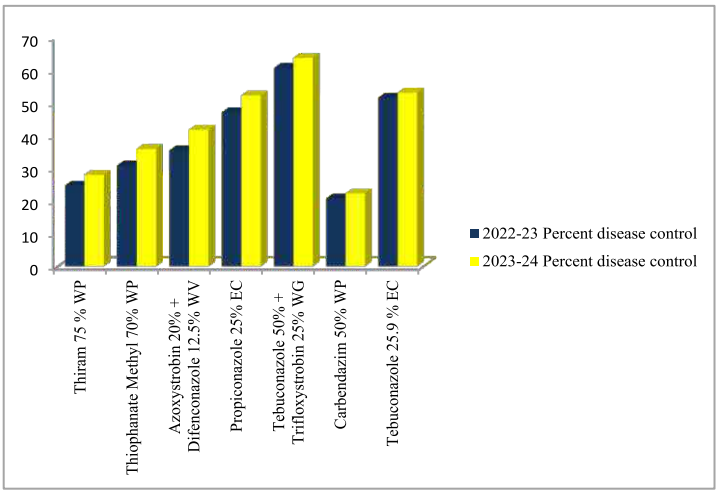

Figure 1 Percent inhibition of wilt incidence

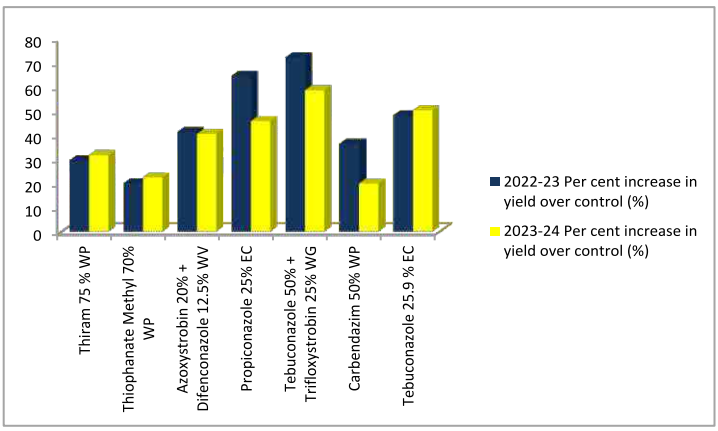

Figure 2 Effect of fungicides on percent increase of yield in lentil

Table 1 Description of fungicidal products used under in vitro and in vivo experiments during the study are discussed as under

Fungicides	Active ingredient (a.i) (%)	Formulation***	Dosage (g/ml L^{-1})	Target sites**	FRAC code*
Thiram 75 % WP	75	WP	2	MSC	M03
Thiophanate Methyl 70% WP	70	WP	1	MBC	1
Azoxystrobin 20% + Difenconazole 12.5% WV	20 +12.5	WP	1	QoI, SBI	3,11
Propiconazole 25 % EC	25	SC	1	SBI	3
Tebuconazole 50% + Trifloxystrobin 25% WG	50 +25	EC	0.75	SBI, QoI	3,11
Carbendazim 50% WP	50	WP	1	MBC	1
Tebuconazole 25.9 % EC	25.9	WW	1	SBI	3

*__frac code__ list 2024, fungicide resistance action committee
**__msc__- multi-site contact activity, __sbi__- sterol biosynthesis inhibitor, __qoi__- quinone outside inhibitors, __mbc__-methyl benzimidazole carbamates
*** __wp__: wettable powder; __ec__: emulsifiable concentrate; __sc__: soluble concentration

Table 2 Evaluation of different chemicals for the management of wilt of lentil (Fusarium oxysporum f.sp. Lentis) during 2022-23 under field conditions

S.No.	Treatments	Dosage (g/ml L-1)	Disease incidence (%)					
			2022-23					
			30 DAS	45 DAS	60 DAS	75 DAS	Mean	Percent disease control
1	Thiram 75 % WP	2	22.81 (28.51)	28.78 (32.42)	32.40 (32.67)	37.20 (37.57)	30.30	24.49
2	Thiophanate Methyl 70% WP	1	20.30 (26.76	26.27 (30.81)	29.79 (33.05)	34.93 (36.19)	27.82	30.66
3	Azoxystrobin 20% + Difenconazole 12.5% WV	1	19.14 (25.92)	24.66 (29.75)	27.29 (31.47)	32.78 (34.91)	25.97	35.28
4	Propiconazole 25% EC	1	15.84 (23.42)	19.25 (26.00)	22.33 (28.18)	27.92 (31.88)	21.34	46.83
5	Tebuconazole 50% + Trifloxystrobin 25% WG	0.75	11.62 (19.92)	13.65 (21.64)	17.04 (26.36)	21.34 (27.49)	15.91	60.34
6	Carbendazim 50% WP	1	25.11 (30.05)	29.33 (32.77)	34.00 (35.63)	39.03 (38.63)	31.87	20.58
7	Tebuconazole 25.9 % EC	1	16.21 (23.72)	18.21 (25.25)	20.65 (27.00)	23.08 (28.69)	19.54	51.31
8	Control		34.89 (36.19)	37.40 (37.68)	40.31 (39.39)	47.90 (43.77)	40.12	-
	S.Em+-		0.44	0.46	0.54	0.58		
	C.D. at 5%		1.37	1.41	1.67	1.78		
	C.V. %		2.89	2.70	2.98	2.89		

Table 3 Evaluation of different chemicals for the management of lentil wilt pathogen (Fusarium oxysporum f.sp. Lentis) during 2023-24 under field conditions

S.No.	Treatments	Dosage (g/ml L-1)	Disease incidence (%)					
			2023-24					
			30 DAS	45 DAS	60 DAS	75 DAS	Mean	Percent disease control
1	Thiram 75 % WP	2	23.47 (28.95)	27.89 (31.85)	31.44 (34.09)	36.68 (37.26)	29.87	27.76
2	Thiophanate Methyl 70% WP	1	21.22 (27.40)	24.74 (29.80)	28.23 (32.06)	32.19 (34.54)	26.60	35.68
3	Azoxystrobin 20% + Difenconazole 12.5% WV	1	18.65 (25.56)	22.51 (28.30)	25.24 (30.14)	30.30 (33.37)	24.18	41.54
4	Propiconazole 25% EC	1	14.77 (22.57)	16.75 (24.14)	21.58 (27.65)	26.36 (30.86)	19.87	51.96
5	Tebuconazole 50% + Trifloxystrobin 25% WG	0.75	10.14 (18.54)	13.60 (21.61)	17.20 (24.46)	19.53 (26.19)	15.12	63.44
6	Carbendazim 50% WP	1	26.62 (31.05)	29.61 (32.95)	33.48 (35.33)	39.07 (38.67)	32.20	22.14
7	Tebuconazole 25.9 % EC	1	14.53 (22.39)	17.85 (24.97)	20.74 (27.07)	24.90 (29.91)	19.51	52.83
8	Control		36.57 (37.19)	38.14 (38.12)	42.81 (40.84)	47.86 (40.84)	41.34	-
	S.Em+-		0.68	0.59	0.66	0.72		
	C.D. at 5%		1.86	1.82	2.03	2.22		
	C.V. %		3.96	3.56	3.66	3.69		

Table 4 Impact of Seed Treatment with Fungicides on Lentil Wilt Yield (per ha) under Field Conditions during 2022-23 and 2023-24

Treatments	Yield (Kg/ha) 2022-23	Per cent increase in yield over control (%)	BCR	Yield (Kg/ha) 2023-24	Per cent increase in yield over control (%)	BCR	Pooled Yield Kg/ha
Thiram 75 % WP	1320.00	29.37	105.8	1413.66	31.50	127.5	1366.83
Thiophanate Methyl 70% WP	1223.66	19.93	67.8	1315.33	22.36	85.5	1269.50
Azoxystrobin 20% + Difenconazole 12.5% WV	1440.33	41.16	44.0	1508.66	40.34	48.4	1474.50
Propiconazole 25% EC	1677.33	64.39	241.8	1566.00	45.67	192.8	1621.67
Tebuconazole 50% + Trifloxystrobin 25% WG	1754.66	71.97	94.1	1703.00	58.42	85.9	1728.83
Carbendazim 50% WP	1390.66	36.30	143.4	1288.00	19.81	87.9	1339.33
Tebuconazole 25.9 % EC	1511.00	48.09	44.5	1614.33	50.17	52.1	1562.67
Control	1020.33	-	-	1075.00	-	-	1047.67
S.Em+-	1.97			2.67			
C.D. at 5%	6.08			8.20			
C.V. %	0.24			0.32			

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