



RESEARCH ARTICLE

Green management techniques for the fusarium wilt of lentil (*Lens culinaris* Medik.) with an economic analysis of treatment effects

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Abstract

Lentil (*Lens culinaris* Medik.) is an important pulse crop increasingly affected by fusarium wilt in major lentil-growing regions of India, resulting in significant yield losses. This study aimed to develop an eco-friendly management approach for fusarium wilt using biological and organic treatments. Field trials were carried out consecutively during rabi 2022 and 2023 crop seasons in randomised block design (RBD) with 3 replications, using local variety. Results of the 2-year experiment revealed that, among the different treatments, soil application of farmyard manure (FYM) enriched with *Trichoderma harzianum* (100 : 1) at 500 kg/ha followed by seed treatment with *T. harzianum* at 10 g/kg of seed was the most effective in managing fusarium wilt. This treatment recorded the lowest mean disease incidence of 8.71 % and elevated yield of 7.61 q/ha. In contrast, the untreated check recorded a high mean disease incidence of 33.82 % with a very low yield of 3.27 q/ha. These findings demonstrate the potential of biological and organic treatments as effective eco-friendly strategies for managing fusarium wilt of lentil.

Keywords: eco-friendly, farmyard manure, fusarium wilt, *Lens culinaris*, *Trichoderma harzianum*

Introduction

Lentil (*Lens culinaris* L.) is the third-most important cool-season grain legume in the world after chickpea and pea. The seeds are highly rich in protein, dietary fibre, vitamin B, iron and phosphorus. The seeds are used chiefly in soups and stews and the herbage is used as fodder in some places (1). Lentil is one of the oldest cultivated pulses and is widely grown in countries such as India, Pakistan, Bangladesh and Italy. This pulse is rich source of protein and some other amino acids like lysine and tryptophane. It provides balanced nutrition to humans and its straw is also used as animal feed (2, 3). Its less cooking time compared to other pulses made lentil more popular in the fuel-deficient developing countries like India. Lentil also plays an important role in crop diversification and intensification programmes and contributes to soil health improvement and sustainable agricultural production systems at both national and international levels.

Fusarium wilt is one of the major diseases affecting lentil all over the world and globally considered as the most harmful soil borne

disease of lentil (4, 5). In India, the disease is a major limiting factor affecting lentil cultivation in states such as Madhya Pradesh, Uttar Pradesh, West Bengal, Bihar, Assam, Rajasthan, Haryana, Punjab and Himachal Pradesh, with disease incidence observed from the seedling stage onwards (6–8). Identification of molecular variability was performed by sequence analysis of rDNA-ITS region of each isolate and sequencing of rDNA-ITS region supported the morphological study and confirmed the associated fungi at species level (9, 10).

Fusarium wilt-infected lentil plants exhibit symptoms such as stunting, wilting, chlorosis, necrosis, defoliation and eventual plant death. Initial symptoms often include yellowing of individual leaflets or slight drooping of lower leaves on a single stem, which gradually progresses to complete wilting (11). It is reported that when sensitive lentil varieties grow in short-season rotation, root diseases are usually the most serious because when environmental conditions are conducive to disease development, pathogen inoculants can rapidly accumulate (12).

Considering the substantial yield losses caused by fusarium wilt, effective management of this disease is imperative. Although use of different chemicals have so far been advocated for control of different plant diseases including wilt. Further, unscrupulous use of fungicides will certainly lead to impose hazardous effect on soil health and ultimately to human health (13). In this context, the use of biological agents such as *Trichoderma* offers a promising, eco-friendly approach for the sustainable management of fusarium wilt in lentil (14–16). The present investigation aimed to develop an eco-friendly management approach for fusarium wilt using biological and organic treatments.

Materials and Methods

The present investigation on *Lens culinaris* Medik. was carried out at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad (Karnataka). Field trials were carried out consecutively during rabi 2022 and 2023 crop seasons in randomised block design (RBD) with 3 replications, using tadmok local variety with each plot measuring 4 x 3 m². The crop was grown in the field to follow all agronomical packages of practices. Treatments consisted of farmyard manure and selected bioagents, along with fungicidal checks, for the management of fusarium wilt as detailed in Table 1.

Observations on fusarium wilt disease incidence (%) were recorded using a standard formula (17). Grain yield (q/ha) was recorded at harvest and economic parameters such as gross returns, net returns and benefit–cost ratio were calculated. The relationship between disease incidence and yield was analysed using correlation analysis in R software. Yield distribution across treatments was visualised using violin plots generated with the ggplot2 and ggpubr packages.

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

Results and Discussion

Results pooled over 2 years indicated significant differences among treatments in managing fusarium wilt and improving yield. Treatment T₄, comprising of soil application of farm yard manure (FYM) enriched with *Trichoderma harzianum* (100 : 1) at 500 kg/ha along with seed treatment of *T. harzianum* at 10 g/kg seed, recorded the lowest mean disease incidence (8.71 %) among biological treatments and produced the highest yield (7.61 q/ha). This was followed by T₁ (seed treatment with *T. harzianum* at 10 g/kg seed), which registered a disease incidence of 9.17 % and yield of 7.31 q/ha (Table 2). In contrast, the untreated control exhibited a significantly higher mean disease incidence (33.82 %) with a markedly lower yield of 3.27 q/ha (Fig. 1).

Table 1. Treatment details for management of lentil wilt

Treatment No.	Treatment details
T1	Seed treatment with <i>Trichoderma harzianum</i> at 10 g/kg of seeds
T2	Seed treatment with <i>Pseudomonas fluorescens</i> at 10 g/kg of seeds
T3	Seed treatment with <i>Bacillus subtilis</i> at 10 g/kg of seeds
T4	FYM enrichment with <i>Trichoderma harzianum</i> at 1 : 100 and at 500 kg/ha followed by seed treatment with <i>T. harzianum</i> at 10 g/kg of seeds
T5	FYM enrichment with <i>Pseudomonas fluorescens</i> at 1 : 100 and at 500 kg/ha followed by seed treatment with <i>P. fluorescens</i> at 10 g/kg of seeds
T6	FYM enrichment with <i>Bacillus subtilis</i> at 1 : 100 and at 500 kg/ha followed by seed treatment with <i>B. subtilis</i> at 10 g/kg of seeds
T7	Seed treatment with carbendazim 50 % WP at 2 g/kg of seeds (Fungicide check)
T8	Seed treatment with (Carboxin 37.5 % + Thiram 37.5 %) DS at 2 g/kg of seeds (Fungicide check)
T9	Untreated check

FYM : Farmyard manure

Table 2. Disease incidence and economics of different management practices during 2022 and 2023 rabi season

Sl. No.	Treatment details	Disease incidence (%)			Yield (q/ha)			Cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B : C ratio
		2022	2023	Pooled	2022	2023	Pooled				
1	ST with <i>Trichoderma</i> at 10 g/kg of seeds	9.26 (17.72*)	9.08 (17.55)	9.17 (17.64)	7.48 (15.88)	7.14 (15.51)	7.31 (15.69)	20902	49714	28812	2.38
2	ST with <i>Pseudomonas</i> at 10 g/kg of seeds	16.46 (23.95)	16.80 (24.21)	16.63 (24.08)	6.46 (14.73)	6.13 (14.34)	6.30 (14.54)	20902	42811	21909	2.05
3	ST with <i>Bacillus</i> at 10 g/kg of seeds	22.54 (28.36)	20.94 (27.25)	21.74 (27.81)	5.21 (13.2)	4.94 (12.85)	5.08 (13.03)	20902	34514	13612	1.65
4	Soil application of FYM enriched with <i>Trichoderma</i> + T1	8.85 (17.31)	8.57 (17.03)	8.71 (17.17)	7.81 (16.24)	7.42 (15.81)	7.61 (16.03)	21322	51777	30455	2.43
5	Soil application of FYM enriched with <i>Pseudomonas</i> + T2	14.11 (22.08)	15.61 (23.29)	14.86 (22.69)	6.58 (14.87)	6.28 (14.52)	6.43 (14.69)	21322	43718	22396	2.05
6	Soil application of FYM enriched with <i>Bacillus</i> + T3	20.38 (26.85)	19.75 (26.4)	20.06 (26.62)	5.32 (13.34)	5.08 (13.03)	5.20 (13.19)	21322	35364	14042	1.66
7	ST with carbendazim 50 % WP at 2 g/kg of seeds (Fungicide check)	5.37 (13.41)	5.09 (13.04)	5.23 (13.22)	8.50 (16.96)	8.34 (16.8)	8.42 (16.88)	20922	57286	36364	2.74
8	ST with (Carboxin 37.5 % + Thiram 37.5 %) DS at 2 g/kg of seeds (Fungicide check)	5.19 (13.18)	4.63 (12.43)	4.91 (12.81)	8.86 (17.32)	8.73 (17.19)	8.79 (17.26)	20972	59791	38819	2.85
9	Untreated check	35.81 (36.78)	31.82 (34.35)	33.82 (35.57)	3.37 (10.58)	3.18 (10.27)	3.27 (10.43)	20872	22250	1378	1.07
	S.Em. ±	0.92	0.73	0.66	0.50	0.58	0.51				
	CD (5 %)	2.75	2.19	1.99	1.50	1.75	1.52				
	CV	7.19	5.83	5.26	5.89	6.99	6.03				

*Arcsine transformed values



Untreated check

Soil application of FYM enriched with
Trichoderma harzianum (100 : 1) at 500 kg/ha followed
by seed treatment with *T. harzianum* at 10 g/ kg of seeds

Fig. 1. Differential wilt incidence in untreated check and the effective treatment.

Among the fungicide checks, treatment T₈, comprising seed treatment with Carboxin 37.5 % + Thiram 37.5 % DS at 2 g/kg of seed, was found to be the most effective. It recorded the highest mean seed yield of 8.79 q/ha, the lowest disease incidence of 4.91 % and the maximum benefit (B) ratio of 2.85. This was followed by treatment T₇, involving seed treatment with Carbendazim 50 % WP at 2 g/kg of seed, which recorded a slightly higher disease incidence of 5.23 % along with a mean yield of 8.42 q/ha and a B: C ratio of 2.74.

The violin plot illustrated that among all treatments, *Trichoderma* enriched FYM recorded one of the highest seed yields, closely followed by *Trichoderma* seed treatment. These treatments performed comparably to fungicidal checks and significantly outperformed other bioagents and the untreated control, highlighting the potential of *Trichoderma*-based approaches in improving yield under fusarium wilt conditions (Fig. 2).

The scatter plots showed a strong negative correlation ($R^2 = 0.99$) between disease incidence and yield in both 2022 and 2023, indicating that higher fusarium wilt incidence leads to substantial yield reduction. The relationship is statistically significant ($p < 0.001$), emphasising the need for effective disease management to sustain yields (Fig. 3).

The findings of the present study emphasise the importance of integrating biological control agents with organic amendments for the sustainable management of fusarium wilt. The combined use of *T. harzianum* with enriched FYM proved to be an effective strategy in reducing disease incidence, which can be attributed to the enhanced antagonistic activity of the bioagent in the rhizosphere. Enriched FYM likely served as a suitable substrate for the establishment and multiplication of *T. harzianum*, thereby improving its persistence and efficacy against the soil-borne pathogen. In addition to disease suppression, the integration of

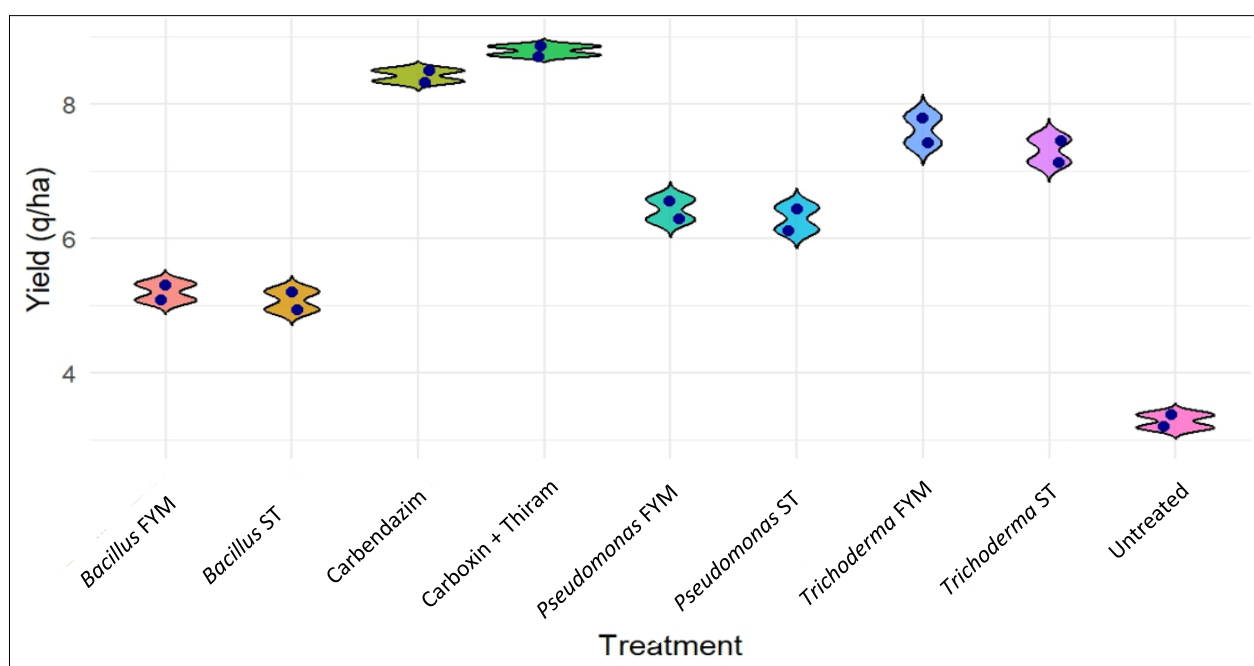


Fig. 2. Yield distribution in each treatment over years.

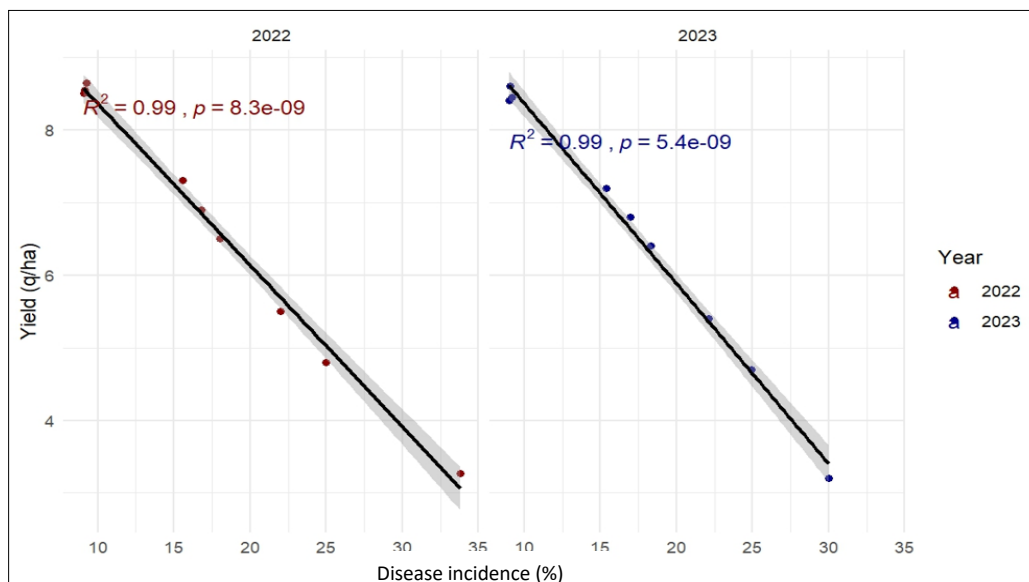


Fig. 3. Correlation between disease incidence and yield over 2 years.

bioagents with organic amendments may have contributed to improved soil health and increased plant vigour. Organic amendments are known to enhance soil structure, nutrient availability and microbial diversity, which collectively create a suppressive soil environment unfavourable for pathogen development. The improved plant growth observed under these treatments could also be linked to the growth-promoting effects of *T. harzianum*, including enhanced nutrient uptake and induction of systemic resistance in plants.

Integrated disease management strategies using alum, zinc and bio-control agents in the glasshouse studies revealed that the maximum increase in seed germination and disease control was recorded in *T. harzianum* + zinc + alum as well as *P. fluorescens* + alum + zinc (18). The present findings are also consistent with earlier reports indicating the effectiveness of soil application of *Trichoderma viride* in the eco-friendly management of chickpea wilt (19–22).

Conclusion

Although chemical fungicides offer high efficacy against fusarium wilt, their repeated use is associated with risks such as the development of resistant pathogen populations, environmental contamination and adverse effects on non-target organisms. Hence the use of bioagents is an effective ecofriendly approach which not only reduces disease incidence and improves yield but also contributes to soil health and ecological balance. Adoption of integrated disease management practices emphasising biological and organic inputs is essential for achieving long-term sustainability, crop protection and soil health in lentil production systems.

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Authors' contributions

GB involved in planning and implementation of the trail, drafting,

editing of the manuscript. KNV carried out isolation, characterisation of the pathogen editing of the manuscript. AB assisted in multiplication of pathogen and draft writing of manuscript. SM involved in planning and implementation of the trail. GM, BHP, MDP involved in implementation of trail. BK drafted the manuscript. SVH assisted in proof reading of the manuscript and BY helped in statistical analysis of data. All authors read and approved the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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