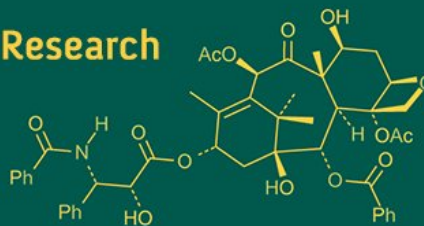


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Integrated disease management of *Fusarium* wilt (*Fusarium oxysporum* f. sp. *lini*) of linseed

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Abstract

Wilt caused by *Fusarium oxysporum* f. sp. *lini* is a severe barrier to linseed industry output and productivity. The crop loss due to linseed wilt incited by *Fusarium oxysporum* f. sp. *lini* is the most destructive disease reported to 80% under favourable conditions. Integrated disease approach the best way for management of the disease by using fungicides and bioagents. For this study four potential bioagents *Trichoderma viride*, *Trichoderma harzianum*, *Pseudomonas fluorescences*, *Bacillus Subtilis* and fungicides were selected. Eight Systemic fungicides evaluated were studied using poison food technique at different ppm concentration. Among them Carbendazim, Thiophanate methyl, Tebuconazole + Trifloxystrobin, Thiophanate methyl + Trifloxystrobin found good result inhibit mycelial growth of fungus at 500, 1000, 1500 ppm. Pooled analysis results of two years indicated that among the 15 treatments imposed on Susceptible variety PKV- NL - 260 for *Fusarium* wilt of linseed in wilt sick soil condition, the T₉ (Seed treatment with Mancozeb + Carbendazim + soil application *T. harzianum* with FYM) has recorded lower wilt incidence 15%, percent reduction over control 81.12 % with higher yield of 870.03 kg/ha, percent increase over control 60.41%, it is followed by T₁₀ (Seed treatment with Mancozeb + Carbendazim + soil application *T. viride* with FYM), T₆ (Seed treatment with Thiophanate methyl + Pyraclostrobin + soil application *T. viride* enriched FYM), T₃ (Seed treatment with *T. harzianum* + Soil application (SA) of *T. harzianum* enriched with FYM) recorded lower wilt incidence 16.93, 17.66, 21.00 respectively. F test found significant. Untreated plot T₁₅ (Control) recorded highest wilt incidence 70.78 % and less yield 344.42 kg/ha. It was concluded that the treatments T₉ and T₁₀ are considered as best treatments (though there are other good treatments available) for management of *Fusarium* wilt of linseed as they recorded lower wilt incidence and higher reduction over control, yield and increase over control.

Keywords: Integrated disease management, per cent wilt incidence, per cent inhibition, per cent reduction over control, per cent increase over control, *in-vitro*,

Introduction

Linseed (*Linum usitatissimum* L.) is one of most important species among oilseed crops. *Linum usitatissimum*, the specific name for flax within the family Linaceae, aptly describes its usefulness and versatility. In fact, the name *Linum* originated from the Celtic word lin or "thread," and the name *usitatissimum* is Latin for "most useful" (Kolodziejczyk and Fedec 1995) [6]. Linseed is one of the oldest crop cultivated for its seeds and fiber. The two products of seed are linseed oil and linseed meal. It is such a valuable crop that every part of the plant has specific economic importance. Linseed is a plant source of high nutritional value, containing 30-45% oil, omega-3 fatty acids, especially high levels of alpha-linolenic acid (ALA), 20-25% protein, and rich dietary fiber (28-30%) (Goyal *et al.*, 2022) [5]. during 2023-24, a total of 1.67 lakh tonnes of linseed was produced in India from an area of 2.39 lakh ha with an average productivity of 698 kg/ha. Madhya Pradesh, Jharkhand and Uttar Pradesh are three major linseed growing states accounting for 78% of area and 79% of production, respectively. In terms of productivity, Rajasthan stands first (1072 kg/ha) followed by Bihar (851 kg/ha) and Nagaland (771 kg/ha) (Linseed, Annual report 2023-24). The crop has been suffering from many abiotic and biotic stresses and among biotic stresses diseases are major limitations. Among the different diseases, major diseases include *Fusarium* wilt (*Fusarium oxysporum* f.sp. *lini*), rust (*Melampsora lini*), powdery mildew (*Oidium lini*), Alternaria blight (*Altenaria linicola*), foot rot (*Rhizoctonia solani*, *Pythium* spp.), and damping off of

Seedlings (*Pythium spp.*), etc. Wilt caused by *Fusarium oxysporum* f. sp. *lini* is a severe barrier to linseed industry output and productivity (Singh *et al.*, 2021) [8]. The crop loss due to linseed wilt incited by *Fusarium oxysporum* f. sp. *lini* is the most destructive disease (Sattar and Hafiz (1952) reported to 80% loss under favourable conditions. It is seed and soil borne pathogen. Management of soil borne disease by single approach is difficult, uneconomical and integrated approach is the best way. Biological control is environment friendly and most accepted method used to control *Fusarium oxysporum* (Anjajah *et al.* 2003). Fungicides were used as seed treatment for seed borne diseases, as it eradicates the seed borne inoculums. For development of an integrated disease management strategies, it is essential to use compatible bio agents and fungicides for effective disease management. Soil amendments and specific bio-control agents such as *Trichoderma*, *Pseudomonas*, and *Bacillus* etc. also incorporated in IDM which has capability to suppress soil-borne pathogens through manipulation of the physicochemical and microbiological environment. Hence, the present research was carried out to select promised and compatible bio agents for field evaluation for management of *Fusarium* wilt.

Materials and methods

This experiment was conducted at laboratory Plant Pathology Section, College of Agriculture, Nagpur. In order to find out a suitable fungicide for management of wilt of

sslinseed, eight Systemic fungicides (at the concentration of 500, 1000 and 1500 ppm) along with control were assessed by poisoned food technique under *in vitro* condition as described by (Pennycook and Corbin, 1970).

Required quantity of individual fungicide was added separately into sterilized molten and cooled PDA so as to get the desired concentrations of the fungicide. After thorough mixing twenty ml of the poisoned media was poured into sterilized Petri plates. Mycelial discs of five mm size of the test pathogen were cut with sterile cork borer from the periphery of an actively growing four day old cultures and one such disc was placed at the centre of each plate containing poisoned media. Control treatment was maintained without adding any fungicide to the medium. There were three Petriplate / replication / treatment. Then such plates were incubated at $25 \pm 20^\circ\text{C}$. Radial growth of *Fusarium oxysporum* f. sp. *lini* was measured when test fungus attained maximum growth in the control plates. The efficacy of the fungicide was expressed as per cent inhibition of mycelial growth over control which was calculated by using the formula given by Vincent (1947).

$$\text{Per cent Inhibition} = \frac{C - T}{C} \times 100$$

Where,

C = Growth of the test fungus in untreated control plates

T = Growth of the test fungus in treated plates

Table 1. List of fungicides used for *in-vitro* against *Fusarium oxysporum* f.sp. *lini*

Tr. No	Treatments	Concentrations (ppm)
T1	Carbendazim 50% WP	500, 1000, 1500
T2	Thiophanate methyl 70% WP	500, 1000, 1500
T3	Difenoconazole 25% EC	500, 1000, 1500
T4	Carbendazim 25 WP + Mancozeb 50% WP	500, 1000, 1500
T5	Metalaxyl 35% WS	500, 1000, 1500
T6	Fosetyl AL 80% WP	500, 1000, 1500
T7	Tebuconazole 25% WG + Trifloxystrobin 25% WG	500, 1000, 1500
T8	Thiophanate Methyl 450 g/l + Pyraclostrobin 50 g/l w/v FS	500, 1000, 1500
T9	Control (untreated)	--

Experimental details

Design : CRD

Treatments : Nine

Replications : Three

Integrated disease management against linseed wilt under field condition

Fifteen treatments of the experiments comprising seed treatments with bioagents, seed treatments with bioagents + soil application of bioagents with FYM, Seed treatments with Fungicides + soil application of bioagents enriched with FYM at different rates were selected for further evaluation in the field against *Fusarium oxysporum* f.sp. *lini* (as in Table 2). Susceptible linseed cultivar "PKV NL-260"

was used in the experiment. Whereas untreated seeds were used in control. Whole experiment was plotted in 3 x 3 m² plots for each of 15 treatments with three replication during year 2022-23 & 2023-24 in a Randomized Block Design (RBD) at AICRP Field, Nagpur. The observations regarding germination Percentage disease incidence at 30, 45, 60 DAS, Percent reduction over control, percent increase over control, Plot/seed yield gm, yield/ha were recorded, Treatment details are as follows

Table 2: Detail of treatments used in field studies

Sr.No.	Treatments	Rate of application (g/kg of seed)
1	Seed treatment (ST) with <i>T. harzianum</i>	4 g
2	Seed treatment with <i>T. viride</i>	4 g
3	Seed treatment with <i>T. harzianum</i> + Soil application (SA) of <i>T. harzianum</i> enriched with FYM	4 g + 4.5 g + 450 g
4	Seed treatment with <i>T. viride</i> + Soil application of <i>T. viride</i> enriched with FYM	4 g + 4.5 g + 450 g
5	Seed treatment with Thiophanate methyl + Pyraclostrobin + Soil application <i>T. harzianum</i> enriched with FYM	2 ml + 4.5 g + 450 g
6	Seed treatment with Thiophanate methyl + Pyraclostrobin + soil application <i>T. viride</i> enriched with rotten FYM	2 ml + 4.5 g + 450 g
7	Seed treatment with Tebuconazole + Trifloxystrobin + soil application <i>T. harzianum</i> enriched with FYM	1 g + 4.5 g + 450 g

8	Seed treatment with Tebuconazole + Trifloxystrobin + Soil application <i>T. viride</i> enriched with FYM	1 g + 4.5 g + 450 g
9	Seed treatment with Mancozeb + Carbendazim + soil application <i>T. harzianum</i> with FYM	1 g + 4.5 g + 450 g
10	Seed treatment with Mancozeb + Carbendazim + Soil application <i>T. viride</i> enriched with FYM	1 g + 4.5 g + 450 g
11	Seed treatment with <i>B. subtilis</i> + soil application <i>T. harzianum</i> enriched with FYM	10 g + 4.5 g + 450 g
12	Seed treatment with <i>B. subtilis</i> + Soil application <i>T. viride</i> enriched with FYM	10 g + 4.5 g + 450 g
13	Seed treatment with <i>P. fluorescence</i> + soil application <i>T. harzianum</i> enriched with FYM	10 g + 4.5 g + 450 g
14	Seed treatment with <i>P. fluorescence</i> + soil application <i>T. viride</i> enriched with FYM	10 g + 4.5 g + 300 g
15	Control	

Results and Discussions

In vitro evaluation of fungicides against *Fusarium oxysporum* f. sp. *Lini*

Mycelial growth

Results (Table 3, PLATE 1 and Fig. 1) revealed that all the treatments were significantly greater over control in terms of inhibition of pathogen growth after 7 days of inoculation, that all eight fungicides tested shown wide range of effect on radial mycelial growth of *Fusarium oxysporum* f. sp. *lini* and was decreased with increase in concentrations of the test fungicides from 500 to 1500 ppm. At 500 ppm concentration, radial mycelial at 7th day growth was ranged from 0 mm (Carbendazim) to 55.23 mm (Difenoconazole), as against 87.13 mm in untreated control. However, the Carbendazim fungicide arrested 100 per cent mycelial growth, whereas, it was significantly least mycelial growth with Thiophanate methyl + Pyraclostrobin (5.34 mm), Tebuconazole + Trifloxystrobin (8.35 mm) and Thiophanate methyl (15.57mm) followed by Fosetyl (16.00 mm), Carbendazim + Mancozeb (23.00 mm), Difenoconazole (55.23 mm) and Metalaxyl (66.66 mm). At 1000 ppm concentration, radial mycelial at 7th day growth was ranged from 0 mm (Carbendazim) to 59.00 mm (Metalaxyl), as against 87.13 mm in untreated control (Table 3 and PLATE 1 and Fig 1). However, the Carbendazim arrested 100 per cent mycelial growth. The next fungicides with significantly least mycelial growth were Tebuconazole + Trifloxystrobin (5.00 mm), Thiophanate methyl (8.47 mm), Thiophanate methyl + Pyraclostrobin (12.50 mm) Fosetyl (15.25 mm), followed by Carbendazim + mancozeb (17.33 mm), Difenoconazole (45.33 mm) and Metalaxyl (59.00 mm). At 1500 ppm concentration, radial mycelial at 7th day growth was ranged from 0 mm (Carbendazim) to 54.00 mm (Metalaxyl), as against 87.13 mm untreated control. However, the Carbendazim fungicide arrested 100 per cent mycelial growth. The fungicides with next lowest average mycelial growth were Tebuconazole + Trifloxystrobin (2.65 mm), Thiophanate methyl (3.68 mm), and Thiophanate methyl + Pyraclostrobin (6.17 mm), followed by Carbendazim + Mancozeb (11.47 mm), Fosetyl (14.68 mm) and Difenoconazole (30.57mm).

Mycelial growth inhibition

Results (Table 3, PLATE 1 and fig 1) revealed that all the systemic fungicides tested (each @ 500, 1000 and 1500 ppm) significantly inhibited mycelial growth of *Fusarium oxysporum* f.sp. *lini*, over untreated control. Further, per cent mycelial inhibition was increased with increase in concentration of the fungicides. Among all the fungicides evaluated against *Fusarium oxysporum* f. sp. *lini*, only one Carbendazim fungicide was most effective and shown per

cent inhibition of mycelial growth at 7th day i.e. 100% percent inhibition at all the concentrations tested, followed by Tebuconazole + Trifloxystrobin recorded 90.41, 94.93, 96.95 per cent inhibition at 500, 1000 and 1500 ppm concentration respectively, Thiophanate methyl + Pyraclostrobin with 85.65, 91.09 and 93.31 per cent at 500, 1000 and 1500 ppm concentration respectively, Thiophanate methyl shown 82.13, 90.27 and 96.44 per cent inhibition at 500, 1000 and 1500 ppm concentration respectively, Carbendazim + Mancozeb recorded with 73.08, 80.11 and 86.83 per cent inhibition at 500, 1000 and 1500 ppm concentration respectively and Metalaxyl 41.68, 45.00 and 67.04 per cent inhibition at 500, 1000 and 1500 ppm concentration respectively and Difenoconazole 31.61, 47.97 and 64.91 per cent inhibition at 500, 1000 and 1500 ppm. The result in the study shown that the effect of concentration level (ppm) of fungicides on growth of mycelium, it was recorded that increase in concentration level of fungicides decrease the growth of mycelium. Thus, all the fungicides evaluated were shown fungistatic reaction against test pathogen and significantly inhibited mycelial growth, over untreated control. However, the fungicides found most effective in the order of merit were Carbendazim, Tebuconazole + Trifloxystrobin, Thiophanate methyl, Thiophanate methyl + Pyraclostrobin.

Arun and Choudhary (2015) [3] tested seven fungicides *in-vitro* against *Fusarium oxysporum* f. *lini*, carbendazim 50WP and benlate 50WP were found most effective in checking the colony growth to 00 mm (completely check) Golakiya *et al.* (2018) [4] Reported that efficacy of six commonly used systemic fungicides viz., azoxystrobin, fosetyl-Al, tebuconazole, thiophanate methyl, carbendazim and flusilazole were evaluated against *F. oxysporum* f. sp. *ciceri* at different concentrations viz., 100, 250 and 500 ppm using poisoned food technique and revealed that among all the systemic fungicides at all the concentrations, that maximum mean per cent inhibition of *F. oxysporum* f. sp. *ciceri* mycelial growth was recorded in tebuconazole (99.98%) followed by carbendazim (85.03%). Saravanakumari *et al.* (2019) [7] similar results were observed by carbendazim, mancozeb (63%) + carbendazim (12%) and mancozeb gave complete growth inhibition of the fungus at 500 ppm concentration followed by trifloxystrobin (25%) + tebuconazole (50%) which showed complete mycelial growth inhibition at 1000, 1500 and 2000 ppm concentrations. Tebuconazole, hexaconazole and copper oxychloride were observed as moderate inhibitors of the mycelial growth at 500, 1000, 1500 and 2000 ppm. Minimum inhibition was recorded in benomyl, captan and zineb (64%) + hexaconazole (4%) at - 500, 1000, 1500 and 2000 ppm.

Table 3: *In-vitro* efficacy of various fungicides against mycelial growth and inhibition of *Fusarium oxysporum* f. sp. *Lin*

Tr. No.	Treatments	Colony Diameter *(mm)									Percent Inhibition @ PPM								
		500 ppm			1000 ppm			1500 ppm			500 ppm			1000 ppm			1500 ppm		
		3rd	5th	7th	3rd	5th	7th	3rd	5th	7th	3rd	5th	7th	3rd	5th	7th	3rd	5th	7th
T1	Carbendazim 50% WP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

T2	Thiophanate methyl 70% WP	11.23	13.39	15.57	4.65	6.75	8.47	1.25	2.30	3.68	68.03	77.40	82.13	86.76	88.60	90.27	95.77	96.11	96.44
T3	Difenoconazole 25 % EC	45.29	50.26	55.23	40.25	42.65	45.33	25.45	27.85	30.57	14.57	27.87	36.61	15.17	28.92	47.97	29.25	52.99	64.91
T4	Carbendazium 25 WP + Mancozeb 50%WP	18.21	20.31	23.00	13.45	15.95	17.33	7.45	9.65	11.47	48.16	61.71	73.08	65.72	73.60	80.11	78.79	83.15	86.83
T5	Metalaxyl 35 % WS	57.31	61.35	66.66	55.31	57.40	59.00	50.00	52.00	54.00	36.48	39.04	41.68	42.32	44.68	45.00	63.13	65.00	67.04
T6	Fosetyl AL80% WP	12.34	14.21	16.00	10.34	12.05	15.25	9.68	11.00	14.98	64.87	72.44	81.63	70.56	76.01	82.49	73.25	82.89	85.43
T7	Tebuconazole 50% +Trifloxystrobin 25% WG	5.35	7.05	8.35	1.95	3.00	5.00	1.31	2.00	2.65	84.77	88.10	90.41	94.26	94.44	94.93	96.27	96.62	96.95
T8	Thiophanate Methyl 450g/l + Pyraclostrobin 50g/l w/v FS	2.35	3.50	5.34	8.45	10.75	12.50	3.65	5.47	6.17	75.94	81.85	85.65	89.61	90.76	91.09	92.91	93.31	93.31
T9	Control (untreated)	35.13	59.25	87.13	35.13	59.25	87.13	35.13	9.25	87.13	0.00			0.00				0.00	
	SE (m)±	1.48	2.51	3.11	1.92	2.51	2.96	2.22	2.51	2.66									
	CD (P = 1%)	4.30	6.05	8.04	5.57	7.29	8.60	6.45	7.29	7.72									
	F test	sig	sig	sig	sig	sig	sig	sig	sig	sig									

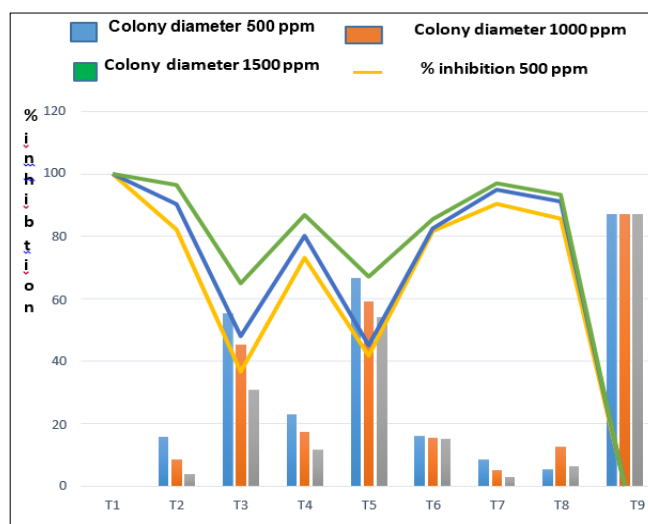


Fig. 1: In-vitro efficacy of various fungicides against mycelial growth and inhibition of *Fusarium oxysporum* f.sp. *lini*

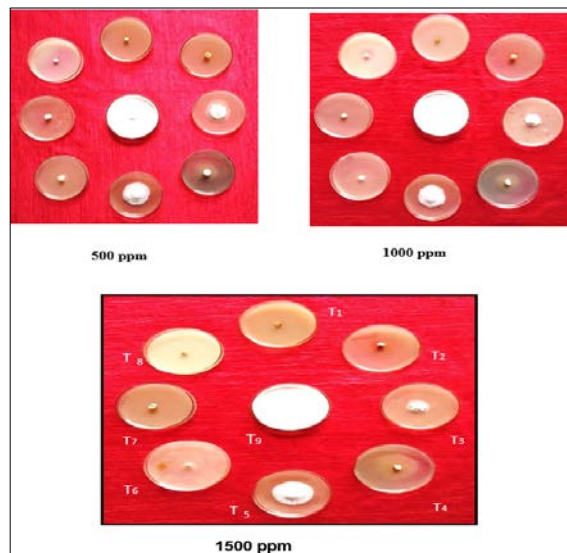


Plate 1: In-vitro efficacy of various fungicides against mycelial growth and inhibition of *Fusarium oxysporum* f. sp. *Lini*

Integrated disease management of linseed wilt under wilt sick soil condition during 2022 - 23 effect of bioagents and fungicides on linseed wilt incidence

The data presented in (Table 4, Fig. 2, Plate 2, 3, 4, 5, 6) showed that among all the fifteen treatments minimum of mean (30,45,60 DAS) per cent disease incidence in 2022-23 was recorded in (T9) Seed treatment with Mancozeb + Carbendazim + soil application *T. harzianum* enriched with FYM (12.77 %) with highest disease reduction over control of 81.68 per cent, followed by (T6) Seed treatment with Thiophanate methyl + Pyraclostrobin + soil application *T. viride* enriched with FYM (15.22 %) with disease reduction

over control 78.16 percent,(T10)Seed treatment with Mancozeb + Carbendazim + soil application *T. Viride* enriched with FYM (16.21%) with disease reduction over control 76.74 percent, (T5) Seed treatment with Thiophanate methyl + Pyraclostrobin + Soil application *T. harzianum* enriched with FYM (17.77) with reduction over control 74.70, (T3) Seed treatment with *T. harzianum* + Soil application (SA) of *T. harzianum* enriched with FYM (18.66

%) with disease reduction over control 74.17.

Effect of bioagents and fungicides on linseed yield

Data in (Table 4, Plate 2, 3, 4, 5, 6) shows that among all the treatments highest per hectare yield in 2022-23 was recorded in (T9) Seed treatment with Mancozeb + Carbendazim + soil application T. harzianum enriched with FYM (870.03 kg/ha) with highest yield percent increase over control of 63.96 followed by (T10) Seed treatment with Mancozeb + Carbendazim + Soil application T. viride

enriched with FYM (855.65 kg/ha) with percent increase over control 63.36, (T6) Seed treatment with Thiophanate methyl + Pyraclostrobin + soil application T. viride enriched with FYM (853.17 kg/ha) percent increase over control 63.25, (T5) Seed treatment with Thiophanate methyl + Pyraclostrobin + Soil application T. harzianum enriched with FYM (838.24 kg/ha) percent increase over control 62.60 which was statistically at par (T3) Seed treatment with T. harzianum + Soil application (SA) of T. harzianum enriched with FYM.

Table 4: Integration disease management in wilt sick soil against wilt incidence caused by *fusarium oxysporum* f. sp. *lini* in linseed variety pkv-nl 260 during rabi 2022-23 at aicrp, nagpur field condition

Sr. No.	Treatments	Rate of Application (g/Kg of seed)	Wilt Start (DAS)	Wilt Incidence (%)	percent Wilt Incidence 30 DAS	percent Wilt Incidence 45 DAS	percent Wilt Incidence 60 DAS	percent Wilt incidence mean 30, 45, 60 DAS	Percent Reduction Over control 2022-23	Yield mean g/plot	Yield kg/ha	Percent increase over control
1	Seed treatment (ST) with <i>T. harzianum</i>	4 g	20.00	76.50	29.00	35.00	51.00	38.33	45.01	313.33	466.26	32.76
2	Seed treatment with <i>T. viride</i>	4 g	20.00	71.50	29.92	34.14	35.61	33.22	52.71	432.33	644.84	51.38
3	Seed treatment with <i>T. harzianum</i> + Soil application (SA) of <i>T. harzianum</i> enriched with FYM	4g + 4.5 g + 450 g	20.00	70.20	16.00	18.00	20.00	18.66	74.17	550.00	838.24	62.60
4	Seed treatment with <i>T. viride</i> + Soil application of <i>T. viride</i> enriched with FYM	4g + 4.5 g + 450 g	20.00	73.65	29.65	34.41	41.86	35.30	49.46	350.00	520.83	39.80
5	Seed treatment with Thiophanate methyl + Pyraclostrobin + Soil application <i>T. harzianum</i> enriched with FYM	2 ml + 4.5 g + 450 g	23.00	75.00	15.00	18.33	20.00	17.77	74.50	563.33	838.24	62.60
6	Seed treatment with Thiophanate methyl + Pyraclostrobin + soil application <i>T. viride</i> enriched with FYM	2 ml + 4.5 g + 450 g	22.00	80.21	12.33	15.33	18.00	15.22	78.16	573.33	853.17	63.25
7	Seed treatment with Tebuconazole + Trifloxystrobin + soil application <i>T. harzianum</i> enriched with FYM	1 g + 4.5 g + 450 g	25.00	70.29	25.00	27.33	30.00	27.44	60.63	491.66	731.64	57.15
8	Seed treatment with Tebuconazole + Trifloxystrobin + Soil application <i>T. viride</i> enriched with FYM	1 g + 4.5 g + 450 g	25.00	69.63	20.00	23.33	25.00	22.77	67.33	508.33	756.44	58.55
9	Seed treatment with Mancozeb + Carbendazim + soil application <i>T. harzianum</i> enriched with FYM	1 g + 4.5 g + 450 g	20.00	80.41	10.00	13.33	15.00	12.77	81.68	584.66	870.03	63.96
10	Seed treatment with Mancozeb+Carbendazim+Soil application <i>T. viride</i> enriched with FYM	1 g + 4.5 g + 450 g	20.00	87.65	14.66	16.33	17.66	16.21	76.74	575.00	855.65	63.36
11	Seed treatment with <i>B. subtilis</i> + soil application <i>T. harzianum</i> with FYM	10 g + 4.5 g + 450 g	21.00	72.35	30.00	32.00	35.00	32.33	32.33	437.33	650.79	51.82
12	Seed treatment with <i>B. subtilis</i> + Soil application <i>T. viride</i> enriched with FYM	10 g + 4.5 g + 450 g	21.00	61.75	26.66	33.33	34.66	31.55	52.67	451.33	671.62	53.32
13	Seed treatment with <i>P. fluorescens</i> + soil application <i>T. harzianum</i> enriched with FYM	10 g + 4.5 g + 450 g	23.00	79.65	26.66	29.33	34.33	30.10	56.82	456.00	678.57	53.80
14	Seed treatment with <i>P.</i>	10 g + 4.5 g							55.37	459.66		

	fluorescence+ soil application T. viride enriched with FYM	+ 450 g	23.00	78.65	27.33	32.00	34.00	31.11			684.02	54.16
15	Control		18.00	56.75	65.82	70.00	73.33	69.71		210.66	313.49	
	SE (m)±							2.65		3.30	4.92	
	CD (P = 5%)							10.3885		9.57	14.25	
	F test							Sig		Sig	Sig	

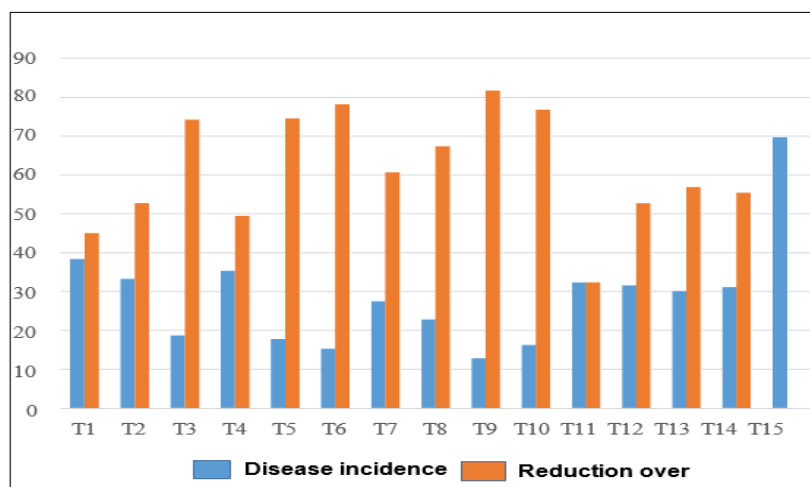


Fig 2: Effect of fungicides and bioagents on linseed wilt incidence under field condition during 2022-23



Plate 2: Field trial conducted at AIRCP, College of Agriculture, and Nagpur in wilt sick plot during 2022-23



Plate 3: T₉: Seed Treatment with Carbendazim + Mancozeb + soil application *Trichoderma harzianum* enriched with FYM during year 2022
- 23



Plate 4: T₆: Seed treatment with Thiophanate methyl + Pyraclostrobin + Soil application *Trichoderma viride* enriched with FYM during year 2022 - 23



Plate 5: T₃: Seed treatment with *Trichoderma harzianum* + Soil application of *Trichoderma harzianum* enriched with FYM during year 2022 - 23



Plate 6: T₁₅ Control plot during Year 2022 - 23

Integration disease management against linseed wilt under field condition during 2023-24

Effect of bioagents and fungicides on linseed wilt incidence

The data presented in (Table 5, Fig 3, Plate 7, 8, 9, 10, 11)) showed that among all the fifteen treatments minimum of mean (30,45,60 DAS) per cent disease incidence in 2023-24 was recorded in (T9) Seed treatment with Mancozeb + Carbendazim + soil application *T.harzianum* enriched with FYM (13.70%) with highest disease reduction over control of 80.70 per cent, followed by, (T10) Seed treatment with Mancozeb + Carbendazim + soil application *T. Viride* enriched with FYM (14.29%) with disease reduction over control 79.73 per cent, (T6) Seed treatment with Thiophanate methyl + Pyraclostrobin + soil application *T. viride* enriched with FYM (15.73%) with disease reduction over control 77.79 per cent, (T3) Seed treatment with *T.*

harzianum + Soil application (SA) of *T.harzianum* enriched with FYM (20.00%) with disease reduction over control 71.63 per cent, (T5) Seed treatment with Thiophanate methyl + Pyraclostrobin + Soil application *T. harzianum* enriched with FYM (20.32%) with disease reduction over control 71.18%.

Effect of bioagents and fungicides on linseed yield

Data in (Table 5, Plate 7, 8, 9, 10, 11) shows that among all the treatments highest per hectare yield in 2023-24 was recorded in (T9) Seed treatment with Mancozeb + Carbendazim + soil application *T.harzianum* enriched with FYM (870.03 kg/ha) with highest yield percent increase over control of 56.85 followed by (T10) Seed treatment with Mancozeb + Carbendazim + Soil application *T.viride* enriched with FYM (859.12 kg/ha) with percent increase

over control 56.30, (T6) Seed treatment with Thiophanate methyl + Pyraclostrobin + soil application *T. viride* enriched with FYM (851.18 kg/ha) per cent increase over control 55.90, (T3) Seed treatment with *T.harzianum* + Soil application (SA) of *T.harzianum* enriched with FYM (802.57 kg/ha) percent increase over control 53.23, (T5) Seed treatment with Thiophanate methyl + Pyraclostrobin + Soil application *T. harzianum* enriched with FYM (797.12 kg/ha) percent increase over control 52.91.

Linseed Annual report (2023-24) A field experiment module was conducted in order to know the the integrated effect of seed treatment, soil drenching and foliar application of fungicides and bioagent for the management of wilt disease of linseed. The experiment was conducted at Raipur, Kanke, Nagpur. At Raichur field among the six module evaluated against linseed wilt, the minimum wilt incidence was noticed with Module 5 (a. ST with carbendazim 50% WP (2 g/kg seed) b. soil application of *Trichoderma* (2.5 kg/250 kg FYM/ha) at the time of sowing) (24.14%). The maximum

yield was also recorded by Module 5 (a. ST with carbendazim 50% WP (2g/kg seed) b. Soil application of *Trichoderma* (2.5 kg/ 250 kg FYM/ha) at the time of sowing (490 kg/ha) which is significantly superior over all other treatments followed by Module 4 (a. ST with *Trichoderma* 10 g/kg seed, b. Soil application of *Trichoderma* (2.5 kg/ 250 kg FYM/ha) at the time of sowing (449 kg/ha). The maximum wilt incidence of 72.43 per cent with minimum yield (265 kg/ha) was recorded by control.

Linseed Annual report (2023-24) A field experiment was conducted at Raipur out of six module tested highest yield was obtained in module 1 (ST with Carbendazim 50% + Mancozeb 50% WP 4 kg/seed and drenching of Carbendazim 50% + Mancozeb 50% WP 4 g/ lit) at the time of disease appearance which showed maximum benefit cost ratio of 4.24. Next best treatment in terms of yield was T2 (ST with Thiophonate Methyl 45% + Pyraclostrobin 5% FS 2ml/kg seed and drenching of Thiophanate Methyl 45 % + Pyraclostrobin 5% FS 2ml/lit at time of disease appearan

Table 5: Integrated disease management in wilt sick soil against wilt incidence caused by *Fusarium oxysporum f. sp. lini* in Linseed variety PKV-NL 260 during Rabi 2023-24 at AICRP, Nagpur field condition

Sr. No.	Treatments	Rate of Application (g/Kg of seed)	Wilt Start DAS	Germination (%)	percent Wilt Incidence 30 DAS	percent Wilt Incidence 45 DAS	percent Wilt Incidence 60 DAS	Percent Wilt incidence mean 30, 45, 60 DAS	Perecent reduction over control 2023-24	Yield mean g/Plot	Yield kg/ha 2023-24	Percent Increase Over control
1	Seed treatment(ST) with <i>T. harzianum</i>	4 g	20	75.80	30.00	37.00	38.33	35.11	50.21	427.33	635.91	40.97
2	Seed treatment with <i>T. viride</i>	4 g	20	71.50	26.66	30.00	32.96	29.87	57.64	470.00	699.40	46.33
3	Seed treatment with <i>T. harzianum</i> + Soil application (SA) of <i>T. harzianum</i> enriched with FYM	4 g + 4.5 g + 450 g	20	74.80	18.00	20.00	22.00	20.00	71.63	539.33	802.57	53.23
4	Seed treatment with <i>T. viride</i> + Soil application of <i>T. viride</i> enriched with FYM	4 g + 4.5 g + 450 g	20	77.35	26.66	30.00	35.23	30.63	56.56	439.00	653.27	42.54
5	Seed treatment with Thiophanate methyl + Pyraclostrobin + Soil application <i>T. harzianum</i> enriched with FYM	2 ml + 4.5 g + 450 g	23	78.00	17.66	19.66	23.65	20.32	71.18	535.66	797.12	52.91
6	Seed treatment with Thiophanate methyl + Pyraclostrobin + soil application <i>T. viride</i> enriched with FYM	2 ml + 4.5 g + 450 g	22	82.79	14.66	15.22	17.33	15.73	77.69	571.66	851.18	55.90
7	Seed treatment with Tebuconazole + Trifloxystrobin + soil application <i>T. harzianum</i> enriched with FYM	1 g + 4.5 g + 450 g	25	72.71	21.66	25.00	27.44	24.70	64.97	530.66	620.00	39.45
8	Seed treatment with Tebuconazole + Trifloxystrobin + Soil application <i>T. viride</i>	1 g + 4.5 g + 450 g	25	67.37	22.77	23.33	26.66	24.25	65.61	453.33	674.60	44.35

	enriched with FYM											
9	Seed treatment with Mancozeb + Carbendazim + soil application <i>T. harzianum</i> enriched with FYM	1 g + 4.5 g + 450 g	20	82.59	12.77	13.33	15.00	13.70	80.57	584.66	870.03	56.85
10	Seed treatment with Mancozeb + Carbendazim + Soil application <i>T. viride</i> enriched with FYM	1 g + 4.5 g + 450 g	20	83.35	12.00	14.66	16.21	14.29	79.73	577.33	859.12	56.30
11	Seed treatment with <i>B. subtilis</i> + soil application <i>T. harzianum</i> enriched with FYM	10 g + 4.5 g + 450 g	21	70.65	28.33	30.00	32.33	30.22	57.14	477.33	710.31	47.15
12	Seed treatment with <i>B. subtilis</i> + Soil application <i>T. viride</i> enriched with FYM	10 g + 4.5 g + 450 g	21	63.25	29.66	30.00	32.99	30.88	56.21	468.33	696.92	46.14
13	Seed treatment with <i>P. fluorescence</i> + soil application <i>T. harzianum</i> enriched with FYM	10 g + 4.5 g + 450 g	23	77.35	29.33	30.10	32.00	30.47	56.79	471.66	701.88	46.52
14	Seed treatment with <i>P. fluorescence</i> + soil application <i>T. viride</i> enriched with FYM	10 g + 4.5 g + 450 g	23	74.57	25.00	30.00	31.11	28.70	28.70	485.00	721.72	47.99
15	Control		18	54.25	69.71	70.00	71.85	70.52		235.66	375.35	
	SE (m)±						1.9940			4.87	7.26	
	CD (P = 5%)						7.5919			14.13	21.03	
	F test						Sig			Sig	Sig	

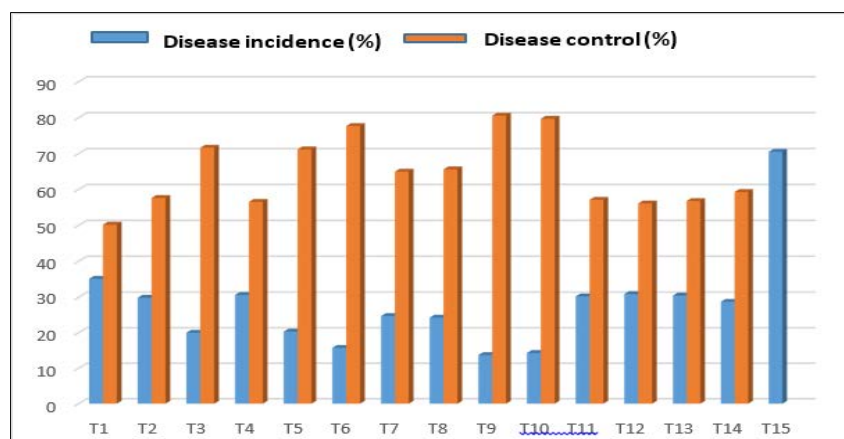


Fig 3: Effect of fungicides and bioagents on linseed wilt incidence under field condition during 2023-24



Plate 7: Field trial conducted at AIRCP, College of Agriculture, and Nagpur in wilt sick plot during 2023-24



Plate 8: T9: Seed Treatment with Carbendazim + Mancozeb + soil application *Trichoderma harzianum* enriched with FYM during year 2023 - 24



Plate 9: T6: Seed treatment with Thiophanate methyl + Pyraclostrobin + Soil application *Trichoderma viride* enriched with FYM during year 2023 - 2024



Plate 10: T3: Seed treatment with *Trichoderma harzianum* + Soil application of *Trichoderma harzianum* enriched with FYM during year 2023 - 2024



Plate 11: T₁₅: Control plot during year 2023 - 2024.

Integrated disease management of *Fusarium oxysporum* f.sp. *lini* Caused wilt of linseed under wilt sick soil field Condition (Pooled)

Per cent incidence

The pooled mean per cent incidence of linseed with all the treatments was recorded. It was ranged 15.00 to 38.54 per cent as against 70.78 per cent in untreated control (table 6 and fig 4, 5). However, the treatment observed most effective with significant minimum incidence was T9 (Seed treatment with Mancozeb + Carbendazim + soil application *T. harzianum* with FYM) 15.00% with mean reduction over control 81.12%. This was followed by the treatment viz., T10 (Seed treatment with Mancozeb + Carbendazim + Soil application *T.viride* enriched with FYM) 16.93% with mean reduction over control 78.23%, T6 (Seed treatment with Thiophanate methyl + Pyraclostrobin + soil application *T.viride* enriched FYM) 17.66% with reduction over control 77.92%, T3 (Seed treatment with *T.harzianum* + Soil application (SA) of *T.harzianum* enriched with FYM) 21.00% with reduction over control 72.90%, T5 (Seed treatment with Thiophanate methyl + Pyraclostrobin + Soil application *T.harzianum* enriched with FYM) 21.82 with reduction over control 72.84%.

Effect on seed yield

The pooled results presented shown that the seed yield (kg/ha) was significantly influenced by different treatments inflicted to control wilt disease of linseed (table 6, fig 4, 5). The yield obtained from the various treatments was ranged from 551.08 to 870.03 kg/ha, as against untreated control 344.42 kg/ha. Among the treatments, significantly highest yield of 870.03 kg/ha was recorded with the treatment T9 (Seed treatment with Mancozeb + Carbendazim + Soil application *T. harzianum* enriched with FYM) with increase

over control 59.82% followed by T10 (Seed treatment with Mancozeb + Carbendazim + Soil application *T.viride* enriched with FYM) 857.38 kg/ha with increase over control 59.82%, T6 (Seed treatment with Thiophanate methyl + Pyraclostrobin + soil application *T.viride* enriched FYM) 852.17 kg/ha with increase over control 59.58%, T3 (Seed treatment with *T.harzianum* + Soil application (SA) of *T.harzianum* enriched with FYM) 820.40 kg/ha with increase over control 58.10%, T5 (Seed treatment with Thiophanate methyl + Pyraclostrobin + Soil application *T.harzianum* enriched with FYM) 817.68 kg/ha with increase over control 57.87%.

Linseed annual report (2023-24) At Nagpur, field Module for the management linseed wilt through integrated approach, pooled results revealed that out of the five treatments the module 4 (ST with Trichoderma 10 g/kg seed and soil application of Trichoderma @ 2.5 kg/ 250 kg FYM/ha at the time of sowing and 40 DAS) was found to be the most effective in minimizing the incidence of wilt disease (8.04%) and was significantly superior to the rest of the treatments. The seed treatment with carbendazim 50% WP (2 g/kg seed) and drenching of carbendazim 50% WP (2 g/l) at the time of disease appearance was the next best treatment (9.64%), while the other treatments were on par with each other in reducing the disease incidence compared to the control 61.82%). Maximum seed yield of 625 kg/ha was obtained with ST with Trichoderma 10 g/kg seed and soil application of Trichoderma @ 2.5 kg/ 250 kg FYM/ha at the time of sowing and 40 DAS, followed by seed treatment with carbendazim 50% WP (2g/kg seed) and drenching of carbendazim 50% WP (2g/ l) at the time of disease appearance (520 kg/ha). These treatments were on par with each other and significantly superior to the rest of the treatments, including the control (312 kg/ha).

Table 6: Integration disease management in wilt sick soil against wilt incidence caused by *Fusarium oxysporum* f. sp. *lini* in Linseed variety PKV-NL 260 during at AICRP, Nagpur field condition (pooled)

Sr. No.	Treatments	Rate of application(g/kg of seed)	Wilt start DAS	Germination percentage	Percent Wilt incidence			Pooled mean Per cent reduction over control	Yield Kg/ha				Percent increase over control
					2022-23	2023-24	Pooled mean wilt incidence		2022-23	2023-24	Pooled Yield Mean g/plot	Pooled mean Kg/hec	
1	atment(ST) with <i>T. harzianum</i>	4 g	20	76.66	51.00	38.33	44.66	47.61	466.26	635.91	370.33	551.08	37.50
2	Seed treatment with <i>T. viride</i>	4 g	20	71.66	35.61	32.96	34.28	55.17	644.84	699.40	451.16	672.12	48.75
3	Seed treatment with <i>T.harzianum</i> + Soil application (SA) of <i>T.harzianum</i> enriched with FYM	4 g + 4.5 g + 450 g	20	73.33	20.00	22.00	21.00	72.90	838.24	802.57	544.66	820.40	58.10
4	Seed treatment with <i>T.viride</i> + Soil <i>viride</i> enriched with FYM	4 g + 4.5 g + 450 g	20	75.45	41.86	35.23	38.54	53.01	520.83	653.27	394.50	587.05	41.33
5	Seed treatment with Thiophanate methyl + Pyraclostrobin + Soil application <i>T.harzianum</i> enriched with FYM	2 ml + 4.5 g + 450 g	23	76.66	20.00	23.65	21.82	72.84	838.24	797.12	549.90	817.68	57.87
6	Seed treatment with	2 ml + 4.5 g	22	82.50	18.00	17.33	17.66	77.92	853.17	851.18	572.49	852.17	59.58

	Thiophanate methyl + Pyraclostrobin + soil application <i>T.viride</i> enriched FYM	+ 450 g											
7	Seed treatment with Tebuconazole +Trifloxystrobin + (SA) <i>T. harzianum</i> enriched fym	1 g + 4.5 g + 450 g	25	71.66	30.00	27.44	28.72	62.80	731.64	620.00	511.16	675.82	49.03
8	Seed treatment with Tebuconazole	1 g + 4 g +	25	68.95	25.00	26.66	25.83	66.47	756.44	674.00	480.83	715.22	51.84
	+ Trifloxystrobin + Soil application <i>T.viride</i> enriched with FYM	450 g											
9	Seed treatment with Mancozeb + Carbendazim + soil application <i>T.harzianum</i> with FYM	1 g + 4 g + 450 g	20	81.66	15.00	15.00	15.00	81.12	870.03	870.03	584.66	870.03	60.41
10	Seed treatment with Mancozeb + Carbendazim + Soil application <i>T.viride</i> enriched with FYM	1 g + 4.5 g + 450 g	20	85.98	17.66	16.21	16.93	78.23	855.65	859.12	576.16	857.38	59.82
11	Seed treatment with <i>B. subtilis</i> + soil application <i>T. harzianum</i> enriched with FYM	10 g + 4.5 g + 450 g	21	71.66	32.33	32.33	32.33	44.73	650.79	710.31	457.33	680.55	49.39
12	Seed treatment with <i>B.subtilis</i> + Soil application <i>T.viride</i> enriched with FYM	10 g + 4.5 g + 450 g	21	61.35	31.55	32.99	32.27	54.44	671.62	696.92	459.83	684.27	49.66
13	Seed treatment with <i>P. fluorescence</i> + soil application <i>T. harzianum</i> enriched with FYM	10g + 4.5 g + 450 g	23	78.33	30.10	32.00	31.05	56.80	678.57	701.88	463.83	690.22	50.10
14	Seed treatment with <i>P. fluorescence</i> + soil application <i>T. viride</i> enriched with FYM	10 g + 4.5 g + 450 g	23	76.66	31.11	31.11	31.11	57.33	684.02	721.72	472.33	702.87	50.99
15	Control		18	55.95	69.71	71.85	70.78		313.49	305.05	235.66	344.42	0.00
	SE (m)±				2.65	1.9940	1.2505		4.87	7.21	4.08	6.04	
	CD (P = 5%)				08.3885	6.9820	3.7515		14.13	21.03	11.85	17.58	
	F test				Sig	Sig	Sig		Sig	Sig	Sig	Sig	

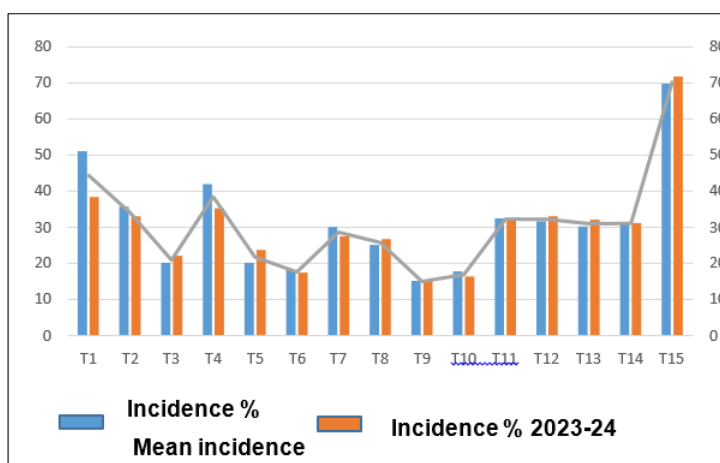


Fig 4: *In-vivo* efficacy of various treatments integration against wilt incidence caused by *Fusarium oxysporum* f. sp. *lini* (Pooled)

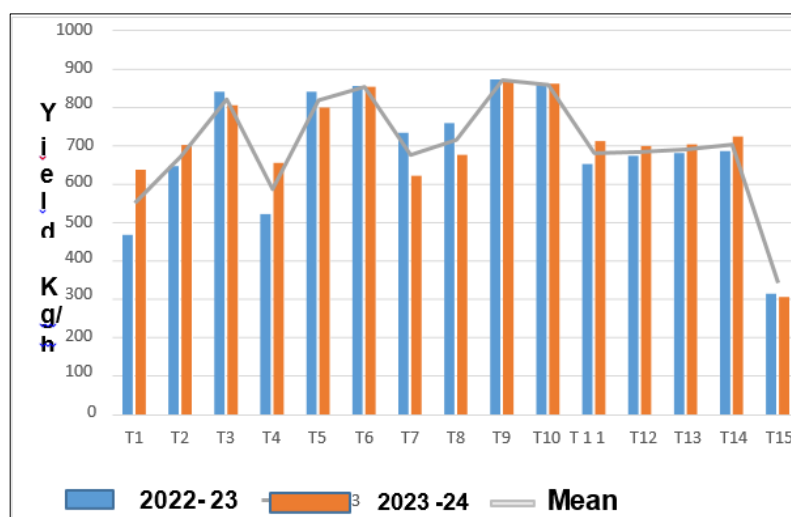


Fig 5: Effect of integrated management on linseed yield

Conclusion

In-vitro efficacy of all the fungicides, evaluated against *Fusarium oxysporum* f. sp. *lini* were found fungistatic. However, in systemic fungicide Carbendazim showed 100 per cent inhibition of growth, followed by Tebuconazole + Trifloxystrobin, Thiophanate methyl. In case of field experiment (In-vivo) on integrated disease management strategies during rabi 2022-23 and 2023-24, seed treatment with Mancozeb 25% + Carbendazim 50% WP + soil application T.harzianum with FYM could be recommended for effective management of *Fusarium oxysporum* f. sp. *lini* caused linseed wilt based on per cent reduction of disease and highest yield.

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