CHEMICAL AND BIOLOGICAL MANAGEMENT OF WILT DISEASE OF SAFFLOWER

Abstract

An experiment was carried out to evaluate the efficacy of different bio-agents and chemicals against wilt disease of safflower .The field experiment was conducted in a Randomised Block Design at Agricultural Research Station, Annigeri during *rabi* 2021 and 2022, using crop variety, Annigeri-1 in a plot size of 2.25m × 4m and 12 treatments in 3 replications of fungicides and biocontrol agents in an integrated approach and observations such as per cent seedling emergence, wilt incidence at 30, 60 and 90 days after sowing and seed yield per plot were recorded. Among the fungicides examined under field conditions, the combi-product Carboxin 37.5 % + thiram 37.5 % showed the least per cent disease incidence at 30 days after sowing (4.62 %), 60 days after sowing (11.74 %) and 90 days after sowing (15.16 %), followed by Penflufen 13.28 % w/w + trifloxystrobin 13.28 % w/w FS (11.94 %) with less per cent disease incidence at 30 days after sowing (5.83 %), 60 days after sowing (11.96 %) and 90 days after sowing (15.72 %) over untreated control, which has shown the highest per cent disease incidence at 30 days after sowing (27.00 %), 60 days after sowing (37.60 %) and 90 days after sowing (40.88 %). Significantly, the least mean per cent disease incidence (10.67 %) was observed in case of combi-product Carboxin 37.5 % + thiram 37.5 % which was on par with Penflufen 13.28 % w/w + trifloxystrobin 13.28 % w/w FS (11.14 %) and found to be superior over Thiophanate methyl 45 % + pyraclostrobin 5 % FS (12.48 %) and Carbendazim 25 % + mancozeb 50 % (14.11 %) over untreated control (35.16 %). Among the biocontrol agents, the least per cent disease incidence was recorded in case of *Trichoderma harzianum* at 30 days after sowing (8.63 %), 60 days after sowing (14.48 %) and 90 days after sowing (19.18 %) and the least mean per cent disease incidence (14.10 %) followed by *Neofusicoccum parvum* (15.92 %) and *Pseudomonas fluorescens* (18.595 %). The highest mean per cent disease incidence (20.76 %) was noticed in case of *Bacillus subtilis* as compared to untreated control (35.16 %).

Introduction

Safflower (*Carthamus tinctorius* L.) is an oilseed crop of the post rainy season mainly cultivated in Vertisol in the Deccan region of India. In the world, India is the largest producer of safflower occupying 0.56 lakh hectares and average yield of 640 kg ha^{-1}(2). Safflower is a rabi crop and it is tolerant to drought, salt and saline water. In India, safflower is grown for its vegetable oil and fodder purpose and also the orange-red dye (carthamin) is derived from its florets. In India safflower is mainly cultivated for cooking purpose as the seed contains 24-36 per cent oil with linoleic acid of 78 per cent, which is helpful in reducing blood cholesterol level.

Safflower is known to suffer from many fungal (leaf spot/blight (*Alternaria carthami*), wilt (*Fusarium oxysporum* f.sp.*carthami*), root rot (*Rhizoctonia bataticola*), powdery mildew (*Erysiphe cichoracearum* DC), anthracnose (*Colletotrichum capsici*) and charcoal rot (*Macrophomina phaseolina* (Tassi) Goid)), bacterial (leaf blight/spot (*Pseudomonas syringae* van Hall)) and viral diseases (mosaic (cucumber mosaic virus), necrosis (tobacco streak virus)) at different stages of crop growth (Bhale *et al*., 1998). Seed/soil borne pathogen particularly fungal pathogens affects directly and indirectly the quality and quantity of the oilseed crops in terms of deterioration and reduction in oil content, reduction in germination, viability of seed and potential losses in yields. As primary importance, it is the fact that seed borne plant pathogens introduce diseases into new areas previously free from such pathogens. In safflower, *Fusarium* wilt, *Macrophomina* root rot, *Alternaria* blight are known and reported as externally or internally seed borne fungi which are causing heavy losses to this crop.

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Wilt of safflower caused by *Fusarium oxysporum* f. sp. *carthami* Klisiewicz and Houston is an important soil borne disease occurring mainly in poor drained areas of Karnataka and Maharashtra leading to yield losses as high as 80% (Kalpana Sastry *et al*., 1993). The disease is reported to be seed transmitted upto 10-40% and the fungus perpetuates as mycelium and spores on the seed and seed coat or as chlamydospores in plant debris in soil (Chakrabarti, 1980). Wilt of safflower is a soil and seed borne disease and therefore, efforts were made to control the disease and to reduce the yield losses. The present studies were carried out to evaluate the efficacy of fungicides and biocontrol agents against *Fusarium oxysporum* f. sp. *carthami* causing wilt of safflower under *in vivo* conditions.

Material and methods

The field experiment was conducted in a Randomised Block Design at Agricultural Research Station, Annigeri during *rabi* 2021-22 and 2022-23, using crop variety, Annigeri-1 in a plot size of 2.25m × 4m and 12 treatments in 3 replications of fungicides and bio control agents in an integrated approach and observations such as per cent seedling emergence, wilt incidence at 30, 60 and 90 days after sowing and seed yield per plot were recorded. The treatments are as follows,

Treatment	Fungicides and biocontrol agents
T_1	Seed treatment with Captan 50 WP at 3 g/ kg of seeds
T_2	Seed treatment with Carbendazim 50 WP at 2 g/ kg of seeds
T_3	Seed treatment with Tebuconazole 2 % DS at 2 g/ kg of seeds
T_4	Seed treatment with Carboxin 37.5 % + thiram 37.5 % WP at 3 g/ kg of seeds
T_5	Seed treatment with Carbendazim 25 % + mancozeb 50 % WS at 3 g/ kg of seeds
T_6	Seed treatment with Thiophanate methyl 45 % + pyraclostrobin 5 % FS at 2 g/ kg of seeds
T_7	Seed treatment with Penflufen 13.28 % w/w + trifloxystrobin 13.28 % w/w FS at 2 g/ kg of seeds
T_8	Seed treatment with *Pseudomonas fluorescens* WP at 10 g/ kg of seeds + soil application of *P. fluorescens* enriched with FYM (1 kg *P. fluorescens*+ 20 kg neem powder +100 kg FYM per acre) applied to seed furrows at the time of sowing.
T_9	Seed treatment with *Trichoderma harzianum* at 10 g/ kg of seeds + soil application of *T. harzianum* enriched with FYM (1 kg *T. harzianum*+ 20 kg neem powder + 100 kg FYM per acre) applied to seed furrows at the time of sowing.
T_{10}	Seed treatment with *Bacillus subtilis* at 10 g/kg of seeds + soil application of *B. subtilis* enriched with FYM (1 kg *B. subtilis* + 20 kg neem powder + 100 kg FYM per acre) applied to seed furrows at the time of sowing.
T_{11}	Seed treatment with *Neofusicoccum parvum* at 10 g/ kg of seeds + soil application of *N. parvum* enriched with FYM (1 kg *N. parvum* + 20 kg neem powder + 100 kg FYM per acre) applied to seed furrows at the time of sowing.
T_{12}	Untreated control

List 1 – treatment details

Statistical analyses: The field experimental data collected during the study was analysed statistically for its significance of difference by the normal statistical procedure adopted for randomized complete block design

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(RCBD) and interpretation of data was carried out. Fischer's method of analysis of variance was used for analysis and interpretation of the data as outlined. The level of significance used in 'F' tests was p = 0.05 for the study and for *in vitro* studies Complete Randomized Design (CRD) was used and the level of significance in 'F' tests was p = 0.01.

Result and discussion

Under field conditions Carboxin 37.5% + thiram 37.5% has shown the least per cent disease incidence (5.12%) on 30 days after sowing and it was increased during 60 and 90 days after sowing in all the fungicide treatments. The highest per cent disease incidence (23.62%) was observed on 90 days after sowing in case of Captan 50 WP. The least mean per cent disease incidence (11.21%) was observed in Carboxin 37.5% + thiram 37.5% treated plots which is found to be on par with Penflufen 13.28% w/w + trifloxystrobin 13.28% w/w FS (11.94%) followed by Thiophanate methyl 45% + pyraclostrobin 5% FS (13.63%) and Carbendazin 25% + mancozeb 50% (14.67%) (Table 1, Fig. 1 and Plate 1).

Among all the biocntrol agents, the least per cent disease incidence (9.42%) has been shown by *Trichoderma harzianum* treated plots on 30 days after sowing and highest per cent disease incidence (26.34%) by *Bacillus subtilis* on 90 days after sowing. *Trichoderma harzianum* has shown the least mean per cent disease incidence (14.86%) followed by *Neofusicoccum parvum* (16.83%) and the highest mean per cent disease incidence (21.22%) by *Bacillus subtilis.* The untreated plot has shown the mean per cent disease incidence of 36.18 per cent (Table 2, Fig. 1 and Plate 1).

It was found that among all the fungicide treatments Carboxin 37.5% + thiram 37.5% has shown the highest per cent disease reduction over control (70.43%) followed by Penflufen 13.28% w/w + trifloxystrobin 13.28% w/w FS (68.23%) and among bioagents *Trichoderma harzianum* showed the highest Per cent disease reduction over control (59.78%) and lowest in case of Captan 50 WP (49.40%) and *Bacillus subtilis* (41.62%) (Table 2).

The highest per cent seedling emergence of 95.71 per cent and seed yield of 12.8 (q/ha) has been seen in Carboxin 37.5% + thiram 37.5% treated plots followed by Penflufen 13.28% w/w + trifloxystrobin 13.28% w/w FS and lowest in case of Captan 50 WP. With regard to bioagents *Trichoderma harzianum* has shown the highest per cent seedling emergence (80.00%) and seed yield (10.8 q/ha) and lowest by *Bacillus subtilis.* Based on these observations the results of economic analysis revealed that the Carboxin 37.5% + thiram 37.5% seed tratment was economically benefited with highest B: C ratio of 1(Table 3).

The pooled data of the field experiments conducted during *Rabi* 2021 and 2022 revealed that, among the fungicides examined under field conditions, the combi-product Carboxin 37.5 % + thiram 37.5 % showed the least per cent disease incidence at 30 days after sowing (4.62 %), 60 days after sowing (11.74 %) and 90 days after sowing (15.16 %), followed by Penflufen 13.28 % w/w + trifloxystrobin 13.28 % w/w FS (11.94 %) with less per cent disease incidence at 30 days after sowing (5.83 %), 60 days after sowing (11.96 %) and 90 days after sowing (15.72 %) over untreated control, which has shown the highest per cent disease incidence at 30 days after sowing (27.00 %), 60 days after sowing (37.60 %) and 90 days after sowing (40.88 %). Significantly, the least mean per cent disease incidence (10.67 %) was observed in case of combi-product Carboxin 37.5 % + thiram 37.5 % which was on par with Penflufen 13.28 % w/w + trifloxystrobin 13.28 % w/w FS (11.14 %) and found to be superior over Thiophanate methyl 45 % + pyraclostrobin 5 % FS (12.48 %) and Carbendazim 25 % + mancozeb 50 % (14.11 %) over untreated control (35.16 %). Among the biocontrol agents, the least per cent disease incidence was recorded in case of *Trichoderma harzianum* at 30 days after sowing (8.63 %), 60 days after sowing (14.48 %) and 90 days after sowing (19.18 %) and the least mean per cent disease incidence (14.10 %) followed by *Neofusicoccum parvum* (15.92 %) and *Pseudomonas fluorescens* (18.595 %). The highest mean per cent disease incidence (20.76 %) was noticed in case of *Bacillus subtilis* as compared to untreated control (35.16 %).

It was found that among the fungicide treatments, the combi-product Carboxin 37.5 % + thiram 37.5 % has shown the highest per cent disease reduction over control (70.36 %) followed by Penflufen 13.28 % w/w +

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trifloxystrobin 13.28 % w/w FS (68.96 %) and among the bioagents *Trichoderma harzianum* showed the highest Per cent disease reduction over control (60.35 %). The highest per cent seedling emergence (95.91 %) and seed yield (12.9 q/ha) were seen in case of Carboxin 37.5 % + thiram 37.5 % treated plots followed by Penflufen 13.28 % w/w + trifloxystrobin 13.28 % w/w FS. With regard to bioagents, *Trichoderma harzianum* has shown the highest per cent seedling emergence (81.27 %) and seed yield (11.01 q/ha) as compared to control, which has recorded the lowest per cent seedling emergence (54.98) and lowest seed yield (7.05 kg/ha) (Table 4).

Based on these observations the results of economic analysis revealed that, the Carboxin 37.5 % + thiram 37.5 % seed treatment was economically beneficial with highest B:C ratio of 1.81 followed by Penflufen 13.28 % w/w + trifloxystrobin 13.28 % w/w FS (1.63), Thiophanate methyl 45 % + pyraclostrobin 5 % FS (1.58) and Carbendazim 25 % + mancozeb 50 % (1.51) as compared to control (1.02) (Table 2).

The above results were Similar with the reports of De and Chaudhary (1999) are also in confirmation with the present findings, who observed the minimization of wilt disease due to Bavistin, Mancozeb M-45 and Vitavax. Bhatti *et al*. (1985), Pedgoanker and Mayee (1989) and Cicero *et al*. (1992) have reported the effectiveness of Thiram, Cabendazim against safflower wilt pathogen F. oxysporum f.sp. carthami. All the fungicidal seed treatments increased germination, plant height which correlated with the findings of Pathak *et al*. (2001). Similarly, Deshmukh and Raut (1992) reported that *Trichoderma harzianum* Rifai and *T. viride.* Pers. overgrew colonies of *Colletotrichum gloeosporioides* and *T. harzianum* was more aggressive than *T. viride*. Santha Kumari (2002) observed that the isolates of T1.

This can be attributed to higher competitive ability of this *Trichoderma* spp. The antagonism of *Trichoderma* spp. against many fungi is mainly due to production of acetaldehyde compound (Dennis and Webster, 1971). This may also be the reason for its antagonistic effect on seed/soil borne pathogens. Godtfredsen and Vagedal (1965) reported trichodermin, Pyke and Dictz (1960) found dermadin as major volatile antibiotic produced by *Trichoderma* spp., which suppress several plant pathogens.

The above results were supported by the findings of Indi *et al.* (2016), Suresh *et al.* (2016) and Rajendraprasad *et al.* (2021) on efficacy of different fungicides and bioagents as seed dressers for management of seed and soil borne diseases of safflower.

Conclusion

Seed treatment with Carboxin 37.5 % + thiram 37.5 % WP at 3 g/ kg of seeds and *Trichoderma harzianum* at 10 g/ kg of seeds + soil application of *T. harzianum* enriched with FYM (1 kg *T. harzianum*+ 20 kg neem powder + 100 kg FYM per acre) applied to seed furrows at the time of sowing in an integrated approach will be an effective method controlling *Fusarium* wilt disease of safflower. Based on these observations the results of economic analysis revealed that, the Carboxin 37.5 % + thiram 37.5 % seed treatment was economically beneficial with highest B:C ratio of 1.81.

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Table 1: Effect of different fungicides/ bio agents treatments on wilt incidence and yield of safflower under field conditions

Seed treatments		Dosage (g/kg seeds)	Per cent seedling emergence	Per cent disease incidence			Mean PDI	Mean PDR over control	Seed yield (q/ha)
				30DAS	60DAS	90DAS			
Fungicides									
T_1	Captan 50 WP	3	72.86	13.12 (21.24)	18.72 (25.64)	23.62 (29.08)	18.49 (25.47)	49.40 (44.66)	9.0
T_2	Carbendazim 50 WP	2	78.57	10.32 (18.74)	17.85 (24.99)	21.86 (27.88)	16.68 (24.10)	54.91 (47.82)	9.6
T_3	Tebuconazole 2% DS	2	82.86	10.14 (18.57)	15.34 (23.06)	19.43 (26.15)	14.97 (22.76)	59.21 (50.31)	10.2
T_4	Carboxin 37.5% + thiram 37.5%	3	95.71	5.12 (13.08)	12.28 (20.51)	16.23 (23.76)	11.21 (19.56)	70.43 (57.06)	12.8
T_5	Carbendazim 25% + mancozeb 50%	3	84.29	9.64 (18.09)	15.23 (22.97)	19.15 (25.95)	14.67 (22.52)	60.13 (50.85)	10.7
T_6	Thiophanate methyl 45% + pyaraclostrobin 5% FS	2	88.57	8.13 (16.57)	14.54 (22.42)	18.21 (25.26)	13.63 (21.66)	63.29 (52.71)	11.2
T_7	Penflufen 13.28% w/w+ trifloxystrobin 13.28% w/w FS	2	92.86	6.23 (14.45)	12.46 (20.67)	17.13 (24.45)	11.94 (20.21)	68.23 (55.69)	11.6
	Bio agents								
T_8	*Pseudomonas fluorescens*	10	67.14	14.36 (22.27)	19.14 (25.94)	24.16 (29.44)	19.22 (26.00)	47.12 (43.35)	8.7
T_9	*Trichoderma harzianum*	10	80.00	9.42 (17.87)	15.42 (23.12)	19.73 (26.37)	14.86 (22.67)	59.78 (50.64)	10.8

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T_{10}	*Bacillus subtilis*	10	61.43	15.78 (23.41)	21.54 (27.65)	26.34 (30.88)	21.22 (27.43)	41.62 (40.17)	8.1
T_{11}	*Neofusicoccum parvum*	10	72.86	11.74 (20.04)	17.83 (24.98)	20.92 (27.22)	16.83 (24.22)	53.96 (47.27)	10.3
T_{12}	Control	54.29	27.67	38.63 (38.43)	42.24 (40.54)	36.18 (36.98)	-	7.2	
Mean	77.62	11.81	18.25	22.42 (28.26)	17.49 (24.72)	52.34 (46.34)	10.02		
S. Em. ±	2.44	0.78	1.02	1.21			0.52		
C. D. at 5%	7.21	2.31	3.02	3.57			1.53		
C. V. (%)	5.45	6.90	7.10	7.48			8.15		

PDI: Per cent Disease Incidence PDR: Percent Disease Reduction over contro

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Table 2: Economic analysis for management of *Fusarium* wilt of safflower in response to different seed treatments

Seed treatments		Seed yield (q/ha)	Cost of cultivation (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	B:C Ratio
Fungicides						
T_1	Captan 50 WP	9.0	32489	41400	8911	1.27
T_2	Carbendazim 50 WP	9.6	32503	44160	11657	1.36
T_3	Tebuconazole 2% DS (2% w/w)	10.2	32811	46920	14109	1.43
T_4	Carboxin 37.5% + thiram 37.5%	12.8	32524	58880	26356	1.81
T_5	Carbendazim 25% + mancozeb 50%	10.7	32507	49220	16713	1.51
T_6	Thiophanate methyl 45% + pyaraclostrobin 5% FS	11.2	32567	51520	18953	1.58
T_7	Penflufen 13.28% w/w + trifloxystrobin 13.28% w/w FS	11.6	32669	53360	20691	1.63
Bioagents						
T_8	*Pseudomonas fluorescens*	8.7	34078	40020	5942	1.17
T_9	*Trichoderma harzianum*	10.8	34055	49680	15625	1.46
T_{10}	*Bacillus subtilis*	8.1	34156	37260	3104	1.09
T_{11}	*Neofusicoccum parvum*	10.3	33919	47380	13461	1.40
T_{12}	Control	7.2	32459	33120	661	1.02

Note: Selling rate of seeds: 4600 Rs./

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Table 3: Management of safflower wilt by different fungicides/ biocontrol agents under field conditions for the year 2021 and 2022

Fungicides														
	Per cent seedling emergence		Per cent disease incidence						Mean PDI		Mean PDR over control		Seed yield (q/ha)	
			30DAS		60DAS		90DAS							
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
T_1	72.86	73.81	13.12	11.21	18.72	16.72	23.62	22.13	18.49	16.69	49.40	51.13	9	9.6
T_2	78.57	79.26	10.32	10.2	17.85	15.53	21.86	18.93	16.68	14.89	54.91	56.40	9.6	10.1
T_3	82.86	84.2	10.14	9.84	15.34	13.24	19.43	14.2	14.97	12.43	59.21	63.60	10.2	11.4
T_4	95.71	96.12	5.12	4.12	12.28	11.2	16.23	15.42	11.21	10.25	70.43	69.99	12.8	13.1
T_5	84.29	86.32	9.64	9.23	15.23	13.23	19.15	18.23	14.67	13.56	60.13	60.28	10.7	11.6
T_6	88.57	90.57	8.13	7.25	14.54	11.54	18.21	15.21	13.63	11.33	63.29	66.80	11.2	12.4
T_7	92.86	94.86	6.23	5.44	12.46	11.46	17.31	14.13	11.94	10.34	68.23	69.70	11.6	12.8
	67.14	69.84	14.36	13.23	19.14	17.56	24.16	23.12	19.22	17.97	47.12	47.37	8.7	9.2
T_9	80	82.54	9.42	7.85	15.42	13.54	19.73	18.63	14.86	13.34	59.78	60.93	10.8	11.23
T_{10}	61.43	64.34	15.78	14.37	21.54	20.85	26.34	25.69	21.22	20.30	41.62	40.53	8.1	8.9
T_{11}	72.86	73.45	11.74	10.92	17.83	15.42	20.92	18.69	16.83	15.01	53.96	56.04	10.3	11.02
T_{12}	54.29	55.67	27.67	26.34	38.63	36.57	42.24	39.52	36.18	34.14	-		7.2	7.8
S. Em. ±	2.44	2.43	0.78	0.82	1.02	1.45	1.21	1.45					0.52	0.56

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C. D. at 5%	7.21	7.26	2.31	2.63	3.02	3.41	3.57	3.78					1.53	1.58
C. V. (%)	5.45	6.23	6.9	7.21	7.1	7.48	7.4	7.92					8.15	9.4

Table 4: Economic analysis for management of *Fusarium*wilt of safflower in response to different seed treatments (Pooled for the year 2021 and 2022)

Seed treatments		Seed yield (q/ha)	Cost of cultivation (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	B:C Ratio
Fungicides						
T_1	Captan 50 WP	9.0	32489	41400	8911	1.27
T_2	Carbendazim 50 WP	9.6	32503	44160	11657	1.36
T_3	Tebuconazole 2 % DS (2 % w/w)	10.2	32811	46920	14109	1.43
T_4	Carboxin 37.5 % + thiram 37.5 %	12.8	32524	58880	26356	1.81
T_5	Carbendazim 25 % + mancozeb 50 %	10.7	32507	49220	16713	1.51
T_6	Thiophanate methyl 45 % + pyraclostrobin 5 % FS	11.2	32567	51520	18953	1.58
T_7	Penflufen 13.28 % w/w + trifloxystrobin 13.28 % w/w FS	11.6	32669	53360	20691	1.63
Biocontrol agents						
T_8	*Pseudomonas fluorescens*	8.7	34078	40020	5942	1.17
T_9	*Trichodermaharzianum*	10.8	34055	49680	15625	1.46
T_{10}	*Bacillus subtilis*	8.1	34156	37260	3104	1.09
T_{11}	*Neofusicoccumparvum*	10.3	33919	47380	13461	1.40
T_{12}	Control	7.2	32459	33120	661	1.02

Note: Selling rate of seeds: 4600 Rs./q

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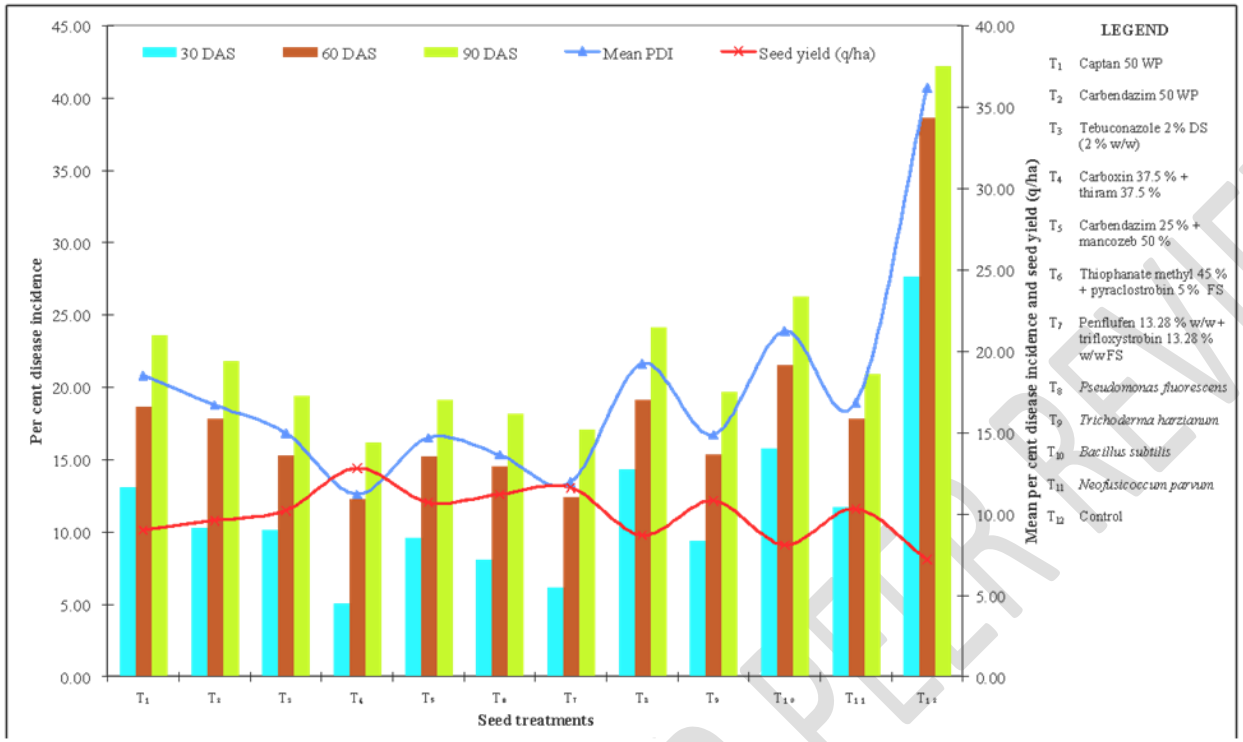

Fig 1.: Effect of various fungicides and bioagents treatments on Fusarium wilt incidence at different growth stages of safflower and seed yield

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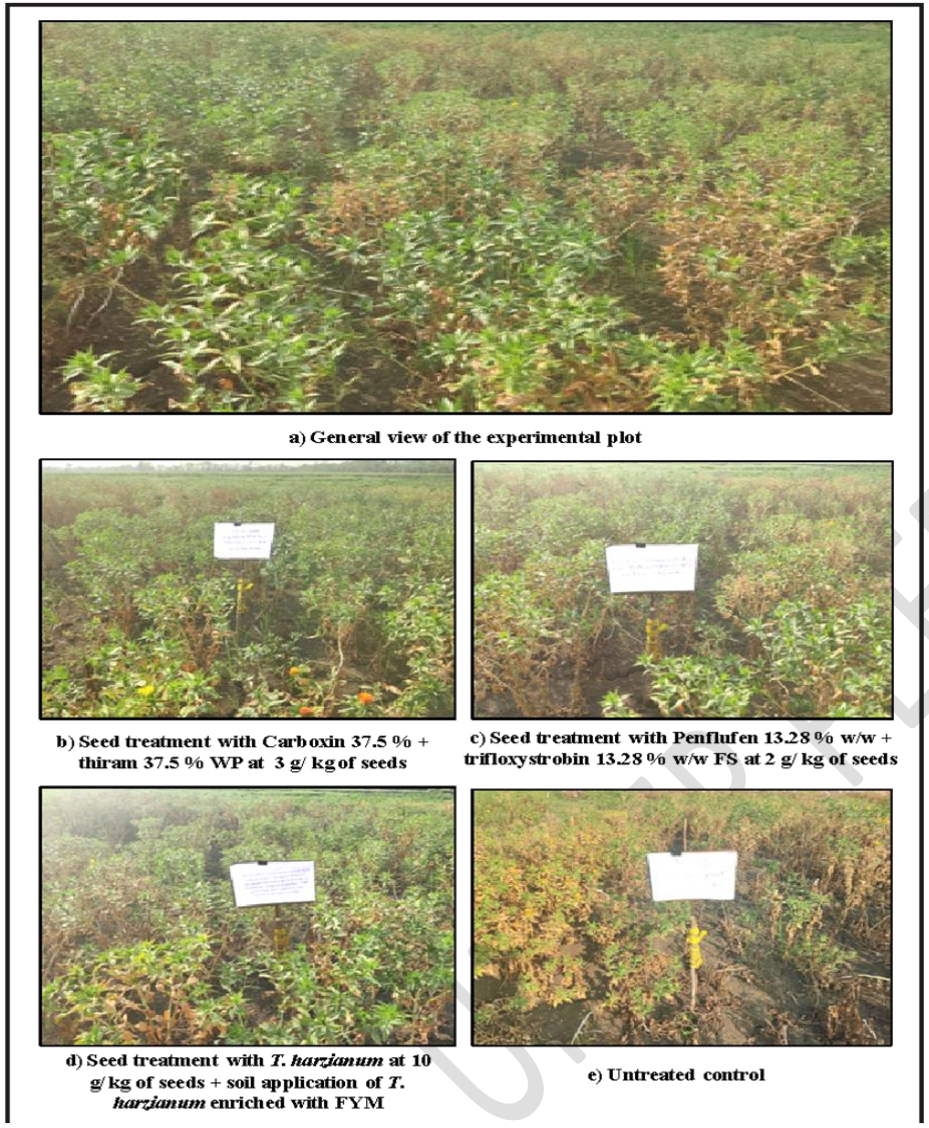

Plate 1: Integrated management of *Fusarium* wilt of safflower under field conditions during the years of 2021 and 2022

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