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Integrated disease management for chilli wilt caused by *Fusarium oxysporum* F. Sp. *capsici*, in wilt sick pots

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Abstract
Chilli (*Capsicum annuum* L.) is an important vegetable cum spice crop grown in almost all parts of tropical and subtropical regions of the world. It belongs to the family Solanaceae. It is the most important spice crop grown all over India. The important chilli growing states are Andhra Pradesh, Maharashtra, Karnataka, Tamil Nadu, Rajasthan, Orissa, West Bangal and Madhya Pradesh having more than 70 per cent acreage of India (Anonymous, 2017).
Fusarium oxysporum f. sp. *capsici* cause chilli wilt is one of the major diseases on Chilli which is soil and seed borne. Heavy inoculum in soil and favorable environment condition results in the death of infected plant and therefore total yield loss. In this study, one antagonists, one fungicides and one botanical extract (alone and combinations) were studied against *Fusarium oxysporum* f. sp. *capsici* causing chilli wilt. Pot culture studies found that Benomyl 50% WP + *Trichoderma virens* + *Allium sativum* (95.09 %), followed by Benomyl 50% WP + *T. virens* (89.85 %), *T. virens* + *A. sativum* (87.38 %), Benomyl 50% WP + *A. sativum* (82.36 %), *T. virens* (78.39 %), Benomyl 50% WP (73.14 %) and *A. sativum* (57.24 %).

Keywords: Chilli wilt, *fusarium oxysporum* f. sp. *capsici*, fungicides, bio-agents, plant extracts

Introduction
Chilli (*Capsicum annuum* L.) is an important vegetable cum spice crop grown in almost all parts of tropical and subtropical regions of the world. It belongs to the family Solanaceae and originated from South and Central America where it was domesticated around 7000 BC. It was introduced in India by the Britishers in the 19th century in Shimla hills. Different varieties are cultivated for vegetable, pickles, spice and condiments. The genus *Capsicum* includes 30 species, five of which are cultivated: *Capsicum annuum* L., *C. frutescens* L., *C. chinense Jacq*, *C. pubescens* R. & P. and *C. baccatum* L. (Bosland and Votava, 2000; Wang and Bosland, 2006 and Ince *et al*., 2010).
Capsicum annuum is cultivated either for pungent fruited genotypes called chilli (synonyms: hot pepper, American pepper, chilli, cayenne, paprika etc.) or non-pungent fruited genotypes called sweet pepper (synonyms: Capsicum, Paprika, Bell pepper, Shimla mirch). Chilli has many culinary advantages; it comprises numerous chemicals including steam-volatile oils, fatty oils, capsaicinoids, carotenoids, vitamins, proteins, fibres and mineral elements. Capsicum fruits may serve as a source of natural bactericidal agents to be used in food and medicinal systems.
Among the various diseases, *Fusarium* wilt is very important, caused by the fungus *Fusarium oxysporum* f. sp. *capsici*. *Fusarium* is a soil borne fungus. Once a field is infected, the pathogen may survive in the soil for many years.
Fusarium wilt is characterized by wilting of the plant, upward and inward rolling of the leaves, finally turn yellow and die. Disease symptoms are characterized by an initial slight yellowing of the foliage and wilting of the upper leaves that progress in a few days into a permanent wilt with the leaves still attached. Slight vein clearing on outer portion of younger leaves, followed by epinasty (downward drooping) of the older leaves. In older stage of plants, vein clearing and epinasty were often followed by stunting, yellowing of lower leaves, wilting of leaves and young stems, defoliation and finally death of the entire plant was observed. By the time above ground symptoms are evident; the vascular system of the plant is discolored, particularly in the

lower stem and roots. Generally, the dry weather condition and excessive soil moisture enhance the disease development (Agrios, 2005).

Material and methods

Those fungicides, bioagents and phytoextracts found most effective against *Fusarium oxysporum* f. sp. *capsici* during present *in vitro* studies were selected and used (alone and in-combination) for integrated management of *Fusarium* wilt of chilli, by applying sick soil method, as detailed earlier. The test fungicides, bioagents and phytoextracts were applied (alone and in-combination) as pre-sowing seed treatment to the healthy chilli seeds / soil drenching and sown (10 seeds / bag) in the polybags, containing *Fusarium oxysporum* f. sp. *capsici* sick soil / potting mixture. For each treatment, two bags / replication were maintained. The polybags sown (10 seeds / bag) with surface sterilized healthy seed of chilli containing only *Fusarium oxysporum* f. sp. *capsici* sick soil (without any treatment) was maintained as untreated control.

Observations on seed germination, pre-emergence seed rot (PRESR) and post-emergence seedling mortality (POESM) were recorded on 7th days and 30th days after sowing and average mortality were computed. Per cent seed germination, pre-emergence seed rot (PRESR), post-emergence seedling mortality (POESM) and average mortality were calculated by following formula.

$$\text{Germination (\%)} = \frac{\text{No. of seed germinated}}{\text{Total no. of seed sown}} \times 100$$

$$\text{\% Pre-emergence mortality} = \frac{\text{No. of seed un-germinated}}{\text{Total no. of seed sown}} \times 100$$

$$\text{\% Post-emergence mortality} = \frac{\text{No. of seedlings died}}{\text{Total no. of seedling emerged}} \times 100$$

$$\text{\% Av. Mortality} = \frac{\text{\% Pre-emergence seed rot + \% Post-emergence seedling mortality}}{2}$$

Further, per cent disease reduction, over untreated control were calculated by applying following formula

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

Where,

C = per cent average mortality (pre- and post- emergence) in untreated polybags

T = per cent average mortality (pre- and post- emergence) in treated polybags

Results and discussion

1. Effect on seed germination

Result (Table 1. & Fig. 1) revealed that all the treatments significantly improved seed germination, which ranged from 58.33 to 96.66 per cent, as against 30.00 per cent in untreated control. However, significantly highest seed germination was with treatment Benomyl 50% WP + *Trichoderma virens* + *Allium sativum* (96.66 %), followed by treatment Benomyl 50% WP + *T. virens* (93.33 %), *T. virens* + *A. sativum* (88.33 %), Benomyl 50% WP + *A. sativum* (81.66 %), *T. virens* (76.66 %), Benomyl 50% WP (70.00 %) and *A. sativum* (58.33 %).

2. Effect on pre-emergence seed rot and post-emergence seedling mortality

Result (Table 1 & Fig. 1) revealed that all the treatments significantly influenced both pre-emergence seed rot (PRESR) and post-emergence seedling mortality (POESM), caused by *F. oxysporum* f. sp. *capsici*.

The pre-emergence seed rot recorded with the various treatments ranged from 3.33 to 41.66 per cent, as against 70.00 per cent in untreated control. However treatment Benomyl 50% WP + *Trichoderma virens* + *Allium sativum* was most effective with (3.33 %) pre-emergence seed rot, followed by Benomyl 50% WP + *T. virens* (6.66 %), *T. virens* + *A. sativum* (11.66 %), Benomyl 50% WP + *A. sativum* (18.33 %), *T. virens* (23.33 %), Benomyl 50% WP (30.00 %) and *A. sativum* (41.66 %), as against 70.00 per cent in untreated control.

Similar trend with post emergence seedling mortality was also observed and it ranged from 3.33 to 17.16 per cent, as against 66.02 per cent in untreated control. However, treatment Benomyl 50% WP + *Trichoderma virens* + *Allium sativum* resulted with significantly least POESM (3.33 %), followed by *T. virens* + *A. sativum* (5.66 %), Benomyl 50% WP + *A. sativum* (6.00 %), *T. virens* (6.52 %), Benomyl 50% WP + *T. virens* (7.11 %), Benomyl 50% WP (7.16 %) and *A. sativum* (17.16 %) as against comparatively highest in untreated control 66.02 per cent.

Average mortality recorded with the all treatments ranged from 3.33 to 29.41 per cent, as against 68.01 per cent in untreated control (sick soil). However, it was least with Benomyl 50% WP + *Trichoderma virens* + *Allium sativum* (3.33 %), followed by Benomyl 50% WP + *T. virens* (6.88 %), *T. virens* + *A. sativum* (8.66 %), Benomyl 50% WP + *A. sativum* (12.16 %), *T virens* (14.92 %), Benomyl 50% WP (18.58 %) and *A. sativum* (29.41 %).

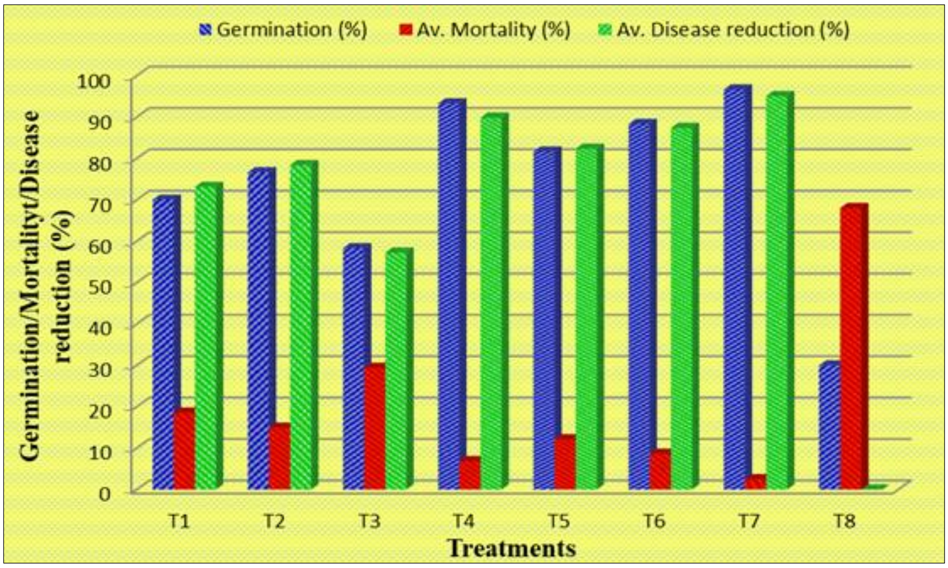
3. Effect on reduction in mortality

All of the treatments were found to reduce both pre-emergence seed rot (PRESR) and post-emergence seedling mortality (POESM) over untreated control (Table 8, PLATE XII & Fig. 8) and their reduction ranged from 95.24 (Benomyl 50% WP + *Trichoderma virens* + *Allium sativum*) to 40.48 (*A. sativum*) and 94.95 (Benomyl 50% WP + *Trichoderma virens* + *Allium sativum*) to 74.00 (*A. sativum*) per cent, respectively. However, significantly highest reduction in PRESR and POESM was recorded with Benomyl 50% WP + *Trichoderma virens* + *Allium sativum* (95.24 and 94.95 %, respectively), followed by Benomyl 50% WP + *T. virens* (90.48 and 89.23 %, respectively), *T. virens* + *A. sativum* (83.34 and 91.42 %, respectively), Benomyl 50% WP + *A. sativum* (73.81 and 90.91 %, respectively), *T. virense* (66.67 and 90.12 %, respectively), Benomyl 50% WP (57.14 and 89.15 %, respectively) and *A. sativum* (40.48 and 74.00 %, respectively).

Average mortality (PRESR + POESM) reduction recorded with the various treatments renged from 95.09 (Benomyl 50% WP + *Trichoderma virens* + *Allium sativum*) to 57.24 (*A. sativum*) per cent. However, it was highest with Benomyl 50% WP + *Trichoderma virens* + *Allium sativum* (95.09 %), followed by Benomyl 50% WP + *T. virens* (89.85 %), *T. virens* + *A. sativum* (87.38 %), Benomyl 50% WP + *A.*

sativum (82.36 %), *T. virens* (78.39 %), Benomyl 50% WP (73.14 %) and *A. sativum* (57.24 %).

These results of the present study of integrated efficacy of the test fungicides, bioagents and botanicals against *Fusarium* wilt of chilli are in agreement with the reports of many earlier workers. Subhani *et al*., (2011) reported the fungicides *viz*., Benomyl, Derosal, Ridomil as effective against *Fusarium* wilt disease of gram.



T. No.	Treatments	T. No.	Treatments
T_1	Benomyl 50% WP	T_5	Benomyl 50% WP + *Allium sativum*
T_2	*Trichoderma virens*	T_6	*T. virens* + *Allium sativum*
T_3	*Allium sativum* clove extract	T_7	Benomyl 50% WP + *T. virens* + *Allium sativum*
T_4	Benomyl 50% WP + *T. virens*	T_8	Control (Untreated)

Fig 1: Effect of various treatments on germination, mortality and disease reduction caused by *F. oxysporum* f. sp. *capsici* in chilli

Table 1: Effect of various fungicides, bioagents and botanicals on pre-emergence seed rot and post- emergence seedling mortality caused by *Fusarium oxysporum* f. sp. *capsici* in chilli

Tr. No.	Treatment	Rate	Germination (%)	Rot/mortality (%)		Average mortality (%)	Reduction over control (%)		Average reduction (%)
				PRESR	POESM		PRESR	POESM	
1	2	3	4	5	6	(5+6)	7	8	(7+8)
T_1	Benomyl 50% WP	ST @3g/kg seed	70.00 (56.78)	30.00 (33.21)	7.16 (15.52)	18.58 (25.53)	57.14 (49.19)	89.15 (70.76)	73.14 (58.78)
T_2	*Trichoderma virens*	ST @10ml/kg seed	76.66 (61.11)	23.33 (28.88)	6.52 (14.79)	14.92 (22.72)	66.67 (54.73)	90.12 (71.67)	78.39 (62.29)
T_3	*Allium sativum* clove extract (20%)	SD @20ml/kg soil	58.33 (49.79)	41.66 (40.19)	17.16 (24.47)	29.41 (32.84)	40.48 (39.51)	74.00 (59.34)	57.24 (49.16)
T_4	$T_1 + T_2$	ST+SD	93.33 (75.03)	6.66 (14.95)	7.11 (15.46)	6.88 (15.20)	90.48 (72.02)	89.23 (70.84)	89.85 (71.42)
T_5	$T_1 + T_3$	ST+SD	81.66 (64.64)	18.33 (25.34)	6.00 (14.17)	12.16 (20.40)	73.81 (59.21)	90.91 (72.45)	82.36 (65.16)
T_6	$T_2 + T_3$	ST+SD	88.33 (70.02)	11.66 (19.96)	5.66 (13.76)	8.66 (17.11)	83.34 (65.91)	91.42 (72.96)	87.38 (69.19)
T_7	$T_1 + T_2 + T_3$	ST+SD+SD	96.66 (79.46)	3.33 (10.51)	3.33 (10.51)	3.33 (9.07)	95.24 (77.39)	94.95 (77.01)	95.09 (77.19)
T_8	Control (Untreated)	-	30.00 (33.21)	70.00 (56.78)	66.02 (54.34)	68.01 (55.55)	00.00	00..00	-
S. E. m ±			0.20	0.20	0.17	-	2.59	2.34	-
C.D (P = 0.01)			0.58	0.58	0.49	-	7.56	6.83	-

* Mean of three replications PRESR- Pre emergence seed rot, POESM= Post emergence seedling mortality Figures in parentheses are Arcsine values, ST- Seed treatment, SD- Soil drenching

Conclusion

The integration of various fungicides, bioagents and botanicals (alone and in combinations) evaluated *in vitro* under pot culture were found effective in reduction of disease. All the treatments used in this were significantly increases the seed germination and reduced post emergence seedling mortality. Among all eight treatments, Benomyl 50% WP + *T. virens* + *Allium sativum* extract found most effective in reduction of disease as compare to control. also the other combination treatments viz., Benomyl 50% WP + *T. verens*, *T. virens* + *Allium sativum* extract and Benomyl 50% WP + *Allium sativum* extract were singnificantly reduced the disease as compare to control.

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