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In vitro efficacy of fungicides against *Fusarium solani* incited by dry root rot of sweet orange

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Abstract
Fusarium is a large genus of filamentous fungi widely dispersed in soil and huge yield losses in crop plants. In present study eight different fungicides were evaluated *in vitro* at different concentrations *viz.*, 500, 1000, 2000 and 2500 ppm against *Fusarium solani* by applying poisoned food technique. However, highest average mycelial growth inhibition was recorded with Carbendazim and SAFF (each 100 %). These were followed by the fungicides viz., Propiconazole (79.09 %), Hexaconazole % (72.15 %), Chlorothalonil (61.63 %), Mancozeb (49.15 %), Captan (40.86 %). The fungicide Benomyl was found comparatively less effective with minimum mycelial inhibition of 34.39 per cent.

Keywords: fungicides, dry root rot, *Fusarium solani*, inhibition

Introduction
Fusarium is largest genus of filamentous fungi widely distributed in agricultural soils. It contains large number of destructive plant pathogens such as *F. avenaceum*, *F. eumartii*, *F. oxysporum* and particularly *F. solani*, which is potential cause of vascular wilt, root rot, dry root rot and fruit rot as well as influence seed germination in different host plants. This can be seed-borne both internal and external, survive more than 1-2 years in seed (Watt, 2006) [17]. Crop plants are highly susceptible to attack of *F. solani* during the pre- and post-emergence stages (Nawar, 2007) [7]. It easily develops in several types of soil, especially on light sandy soils and can cause dry root rot disease in different crops in various parts of the world (Celar, 2000) [1]. Under drought stress, the losses could reach 95% of production in some fields (Rojo *et al*., 2007) [10].
Although currently a variety of techniques and methods have been known to control plant pathogens, in which few has been proved to satisfactory. The use of chemical based fungicides is most effective and reliable method to control the pathogens. However, chemicals are highly toxic to targeted pathogen, plants, products, human beings and other form of life. Therefore, the present study was carried out to compare the efficacy of different fungicides against *F. solani*.

Materials and methods
In vitro evaluation of fungicides
Efficacies of eight different fungicides were evaluated *in vitro* at different concentrations (each @ 500, 1000, 2000 and 2500 ppm) against *F. solani* by applying Poisoned food technique (Nene and Thapliyal, 1993) [9] and using potato dextrose agar (PDA) as basal culture medium. Based on active ingredient, the requisite quantity of each test fungicide was calculated and mixed thoroughly with autoclaved and cooled (40^0C) PDA medium separately in conical flasks (250 ml / cap) to obtain desired concentrations of 500, 1000, 2000 and 2500 ppm. Fungicide amended PDA medium was then poured (20 ml / plate) aseptically in glass Petri plates (90 mm dia.) and allowed to solidify at room temperature. For each of the test fungicide and its test concentrations, a triplicate set of petri plates / treatment / replication were maintained. After solidification of the medium, all the plates were inoculated aseptically with a 5 mm culture disc obtained from a week old actively growing pure culture of *F. solani* separately. The culture disc was placed on PDA in inverted position in the centre of the Petri plate and plates were incubated at 28 $\pm$ 2^0C. Petri plates filled with plain PDA (without any fungicide) and inoculated separately with the culture disc of *F. solani* were maintained as untreated control.

Treatment details
Design	:	CRD
Replications	:	Three
Treatments	:	9

Observations on radial mycelial growth / colony diameter of the test pathogens were recorded at an interval of 24 hours and continued till untreated control plates were fully covered with mycelial growth of the test pathogen, Per cent mycelial growth inhibition of the test pathogens with the test fungicides over untreated control were calculated by applying following formula (Vincent, 1927) [13]:

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

Where,
C= growth of the test fungus in untreated control plates.
T= growth of the test fungus in treated plates.

Results and Discussion

***In vitro* efficacy of fungicides**

Radial mycelial growth

Result revealed that (Fig) all the fungicides tested exhibited a wide range of radial mycelial growth of the *Fusarium solani* and was found to be decreased drastically with increase in the concentration of the fungicides tested.

At 500 ppm, radial mycelial growth of *F. solani* was ranged from 0.00 mm (Carbendazim and SAFF) to 68.13 mm (Benomyl) as against 90 mm in untreated control. However, significantly least mycelial growth was recorded with the fungicide viz. (Carbendazim and SAFF nill (00.00 mm). These was followed by the fungicides viz, Propiconazole (26.45), Hexaconazole (34.00 mm) Chlorothalonil (43.11mm), Mancozeb (54.79 mm), Captan (61.77 mm) and Benomyl (68.13 mm). Fungicide Benomyl recorded comparatively less effective with maximum mycelial growth 56.16 mm.

At 1000 ppm, all the fungicides tested exhibited similar trend as that of 500 ppm and it was ranged from 0.00 mm (Carbendazim and SAFF) to 62.12 mm (Benomyl), as against 90.00 mm in untreated control. However, significantly least mycelial growth was recorded with the fungicides *viz*., Carbendazim and SAFF (0.00 mm). This was followed by the fungicides *viz.* Propiconazole (21.46 mm), Hexaconazole (28.61 mm), Chlorothalonil (38.06 mm), Mancozeb (49.74 mm), Captan (56.71 mm) and Benomyl (62.12 mm), less effective with the fungicide Benomyl recorded comparatively maximum mycelial growth 62.12 mm

At 2000 ppm, all the fungicides tested exhibited similar trend of radial mycelial growth of the *F. solani* it was ranged from 0.00 mm (Carbendazim and SAFF) to 56.16 mm (Benomyl), as against 90 mm in untreated control. However, significantly least mycelial growth was recorded with the fungicides *viz* Carbendazim and SAFF (0.00 mm). These was followed by the fungicides *viz.*, Propiconazole (15.36 mm), Hexaconazole (21.58 mm), Chlorothalonil (31.15 mm), Mancozeb (42.76 mm), Captan (49.79 mm) and Benomyl (56.16mm). Fungicide was reported least effect 56.16 mm.

At 2500 ppm, concentrations all the fungicides evaluated exhibited similar tread as that of 500,100, 2000 ppm and were found to be decreased further as compared to that 500, 1000 and 2000 ppm and it was ranged from 0.00 mm (Carbendazim and SAFF) to 49.79 mm (Benomyl), as against 90 mm in untreated control. However, significantly least mycelial growth was recorded with the fungicides *viz.*, Carbendazim and SAFF (0.00 mm). These was followed by the fungicides *viz.*, Propiconazole (10.22 mm), Hexaconazole (16.41mm), Chlorothalonil (25.81 mm), Mancozeb (35.78 mm) and Captan (44.62 mm) and Benomyl (49.79 mm). Fungicide Benomyl was found comparatively less effective with maximum mycelial growth of 49.79 mm.

Average radial mycelial growth recorded with all the fungicides tested was ranged from 0.00 mm (Carbendazim and SAFF) to 59.05 mm (Benomyl), as against 90 mm in untreated control. However, significantly least average mycelial growth was recorded with Carbendazim and SAFF (0.00 mm) Propiconazole (18.37 mm), followed by the fungicides *viz*., Hexaconazole (25.15 mm), Chlorothalonil (34.53mm), Mancozeb (45.76 mm),Capton (53.22 mm). The highest mean radial mycelial growth was recorded with Benomyl (59.05 mm)

4.6.3 Mycelial growth inhibition of *Fusarium solani*

Results revealed that (Table and Fig) all the test fungicides (each @ 500 ppm, 1000 ppm, 2000 ppm, 2500 ppm) significantly inhibited mycelial growth of test pathogen over untreated control (0.00 mm). Further, the per cent mycelial growth inhibition was increased with increase in concentrations of the fungicides tested. (Plate)

At 500 ppm, percent mycelial growth inhibition was ranged from 24.30 (Benomyl) to 100 % (Carbendazim and SAFF). However, significantly highest mycelial inhibition was recorded with the fungicides *viz.*, Carbendazim and SAFF (each 100%). This was followed by fungicides *viz.*, Propiconazole (70.61 %), Hexaconazole (62.58%), Chlorothalonil (52.10 %), Mancozeb (39.12 %), Captan (31.37 %) and Benomyl (24.30 %). Fungicide Benomyl (24.30 %) was found comparatively least effective with minimum mycelial inhibition.

At 1000 ppm, per cent mycelial growth inhibition was ranged from 30.98 (Benomyl) to 100 per cent (Carbendazim and SAFF). However, significantly highest mycelial inhibition was recorded with the fungicides *viz.*, Carbendazim and (SAFF) each 100 per cent. These was followed by the fungicides *viz*., Propiconazole (76.16%) Hexaconazole (68.21%), Chlorothalonil (57.71%), Mancozeb (44.73 %), Captan (36.99 %) and Benomyl (30.98 %), Fungicide Benomyl was found comparatively less effective with minimum mycelial growth inhibition of 30.98 per cent.

At 2000 ppm, similar trend but with increased mycelial growth inhibition than that of 500 and 1000 ppm was observed. It was ranged from 37.60 (Benomyl) to 100 per cent (Carbendazim and SAFF). However, significantly highest mycelial inhibition was recorded with the fungicides *viz.*, Carbendazim and SAFF (each 100 %). These was followed by the fungicides *viz.*, Propiconazole (82.93%), Hexaconazole (76.02 %), Chlorothalonil (65.39 %), Mancozeb (52.49 %), Captan (44.67 %) and least inhibition was found in Benomyl (37.60 %). Fungicide Benomyl was recorded comparatively less effective with minimum mycelial growth inhibition of 37.60 per cent.

At 2500 ppm, the all fungicides tested exhibited similar trend but with increased mycelial growth inhibition as compared to that of at 500, 1000 and 2000 ppm It was ranged from 44.68 % (Benomyl) to 100 % (Carbendazim and SAFF). However, significantly highest mycelial inhibition was recorded with the fungicides *viz.*, Carbendazim and SAFF (each 100 %). These were followed by the fungicides *viz*, Propiconazole (86.64 %), Hexaconazole (81.77%), Chlorothalonil (71.32%), Mancozeb (60.24%), Captan (50.42%) and Benomyl (44.68%). However, Benomyl was found comparatively less effective with 44.68 per cent mycelial inhibition.

Average mycelial growth inhibition recorded with of all the test fungicides was ranged from 34.39 (Benomyl) to 100 per

cent (Carbendazim and SAFF) Per cent. However, highest average mycelial growth inhibition was recorded with Carbendazim and SAFF (each 100 %). These were followed by the fungicides *viz.*, Propiconazole (79.09 %), Hexaconazole % (72.15 %), Chlorothalonil (61.63 %), Mancozeb (49.15 %), Captan (40.86 %). The fungicide Benomyl was found comparatively less effective with minimum mycelial inhibition of 34.39 per cent.

Thus, all the fungicides tested were found fungistatic against *F. solani* significantly inhibited its mycelial growth, over untreated control. However, fungicides found most effective in the order of merit were Carbendazim and SAFF, Propiconazole, Hexaconazole, Chlorothalonil, Mancozeb, Captan and Benomyl.

These results are in accordance to the finding of previous workers viz. Kore and Mane (1992) [3], Vijay Kumar (2001) [14], Wazir Ali Maitol *et al*., (2013) [16].

Table 1: *In Vitro* efficacy of fungicides against mycelial growth and inhibition of *Fusarium solani*

Tr. No	Treatment Name	Colony diameter (mm)					% inhibition				% Mean
		500 ppm	1000 ppm	2000 ppm	2500 ppm	Mean	500 ppm	1000 ppm	2000 ppm	2500 ppm	
T1	Carbendazim 50 WP	00.00	00.00	00.00	00.00	00.00	100 (90.00)	100 (90.00)	100 (90.00)	100 (90.00)	100 (90.00)
T2	Hexaconazole	34.00	28.61	21.58	16.41	25.15	62.58 (52.28)	68.21 (55.67)	76.02 (60.67)	81.77 (64.72)	72.15 (58.14)
T3	Propiconazole	26.45	21.46	15.36	10.22	18.37	70.61 (56.88)	76.16 (60.77)	82.93 (65.59)	86.64 (68.56)	79.09 (62.78)
T4	Benomyl	68.13	62.12	56.16	49.79	59.05	24.3 (29.53)	30.98 (33.82)	37.6 (37.82)	44.68 (41.94)	34.39 (35.90)
T5	Captan	61.77	56.71	49.79	44.62	53.22	31.37 (34.06)	36.99 (37.45)	44.67 (41.94)	50.42 (45.24)	40.86 (39.73)
T6	Chlorothalonil	43.11	38.06	31.15	25.81	34.53	52.1 (46.20)	57.71 (49.43)	65.39 (53.96)	71.32 (57.61)	61.63 (51.72)
T7	Mancozeb	54.79	49.74	42.76	35.78	45.76	39.12 (38.71)	44.73 (41.97)	52.49 (46.42)	60.24 (50.90)	49.15 (44.51)
T8	SAFF 75 WP (Carbendazim 12 % + Mancozeb 63 %)	0.00	0.00	0.00	0.00	0.00	100 (90.00)	100 (90.00)	100 (90.00)	100 (90.00)	100 (90.00)
T9	Control (untreated)	90	90	90	90	90	0.00	0.00	0.00	0.00	0.00
	SE ±	0.36	0.46	0.37	0.43	0.41	0.43	0.38	0.36	0.77	0.49
	CD (P=0.05)	1.07	1.37	1.18	1.28	1.23	1.28	1.14	1.09	2.28	1.45

*-Mean of three replications, Figures in parenthesis are angular transformed values

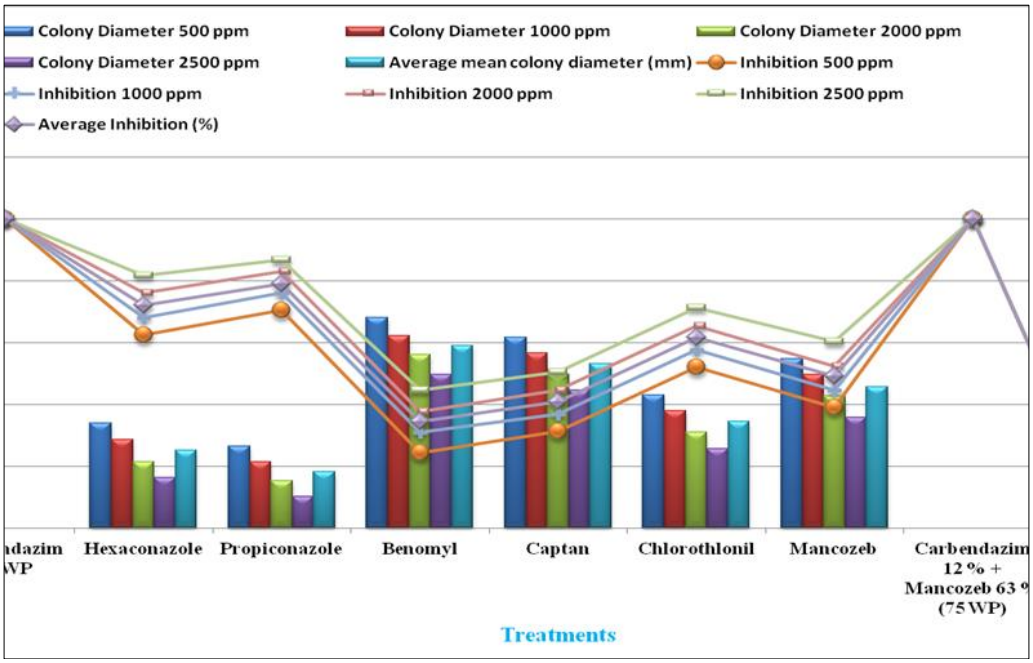

Fig 1: *In vitro* effect of systemic fungicides on mycelial growth and inhibition of *Fusarium solani*

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