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In vitro evaluation of different fungicides against the fusarium wilt of carnation (*Fusarium oxysporum* f.sp. *dianthi*)

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Abstract
Carnation wilt disease caused by *Fusarium oxysporum* f.sp. *dianthi* is the most serious disease of the carnation crop causing considerable economic losses. Wilt of carnation is a soil-borne disease and these diseases are difficult to control due to complex soil eco-system. In the present study efficacy of three non-systemic and six systemic fungicides was evaluated under *in vitro* conditions against the wilt pathogen (*Fusarium oxysporum* f.sp. *dianthi*). Among non-systemic fungicides, Saaf (Carbendazim 12% + Mancozeb 63%) was found most effective with average inhibition of 60.19 per cent in mycelial growth of the wilt pathogen. Among systemic fungicides, Bavistin was found most effective with 92.04 per cent average inhibition in mycelial growth while Systhane was found least effective treatment with 25.68 per cent average inhibition in mycelial growth of the pathogen.

Keywords: Carnation, *Fusarium oxysporum* f.sp. *dianthi,* fungicides, carbendazim

Introduction
Carnation (*Dianthus caryophyllus* L.) is one of the major cut flower grown all over the world. *Fusarium* wilt is the most prevalent disease in carnation caused by *Fusarium oxysporum* f.sp. *dianthi* and up to 79 per cent incidence has been recorded in different parts of the Himachal Pradesh (Chandel and Katoch, 2001) [3]. Eight races have been reported within this forma specialis by Garibaldi (Garibaldi, 1983) [5] and Race 2 is found worldwide (Manicom *et al.* 1990) [9]. The fungus is soil inhabitant and has the potential ability to cause significant yield reduction and loss in flower quality (Jacob and Krebs, 1985) [6]. The planting is done through cuttings and therefore the plant becomes more susceptible to this disease. Wilting occurs on the affected side of the plant, followed by vascular discolouration and stem necrosis.

Materials and Methods
The efficacy of nine fungicides viz., mancozeb (Dithane M-45 75% WP), iprodione 25% + carbendazim 25% WP (Quintal), captaf (Captan 50% WP) (500, 750, 1000 ppm), carbendazim (Bavistin 50% WP), hexaconazole (Contaf 5% EC), difenoconazole (Score 25% EC), carbendazim 12% + mancozeb 63% WP (Saaf), pyraclostrodin 5% + metiram 55% WG (Cabrio Top) and myclobutanil (Systhane 10% WP) (50, 100, 200 ppm) each were tested against the pathogen by poisoned food technique given by Falck (1907) [4].
Double strength PDA medium was prepared by doubling the quantity of all the constituents except distilled water and the medium was sterilized at 1.05 kg/cm^2 pressure for 20 minutes. Simultaneously, solutions of different fungicides were also prepared in sterilized distilled water at double concentration so as to get desired concentration of fungicides after mixing the fungicide solutions in the equal volume of double strength media.
Solutions of different fungicides were added separately to equal quantities of double strength PDA medium aseptically before pouring in Petri plates. These plates were then inoculated with the seven days old culture of *Fusarium oxysporum* f.sp. *dianthi* in the centre. A control treatment was also maintained in which only plain sterilized water was added to double strength medium. Each treatment was replicated thrice and the inoculated plates were incubated at 27±1 °C in BOD incubator. The colony diameter of test pathogen was recorded till the control plates were full with the mycelium of the test pathogen. The per cent inhibition in the mycelial growth of the pathogen was calculated according to formula given by Vincent (1947).

$$I = \frac{C-T}{C} \times 100$$

Where,

I - Per cent inhibition of mycelial growth
C - Linear mycelial growth in control (mm)
T - Linear mycelial growth in treatment (mm)

Results and Discussion

The efficacy of three non-systemic and six systemic fungicides were tested for their inhibitory effect on mycelial growth of wilt pathogen (*Fusarium oxysporum* f.sp. *dianthi*) by the poison food technique. All the non-systemic fungicides inhibited the mycelial growth of wilt pathogen (*Fusarium oxysporum* f.sp. *dianthi*) as compared to control (Table 1). Among non-systemic fungicides, Saaf (carbendazim 12% + mancozeb 63%) was found most effective with average inhibition of 60.19 per cent in mycelial growth of the wilt pathogen at all tested concentrations. Captaf was found least effective with 37.47 per cent average inhibition in mycelial growth of the pathogen. However, the overall inhibitory effect of all the fungicides increased with increase in concentration. Among the non-systemic and combi-products evaluated, carbendazim + mancozeb (98.88% inhibition) was on par with carbendazim + iprodione (98.42%) followed by mancozeb (89.53%) (Kishore and Kulkarni, 2008) [7]

Systemic fungicides were also found effective against the wilt pathogen. Among different systemic fungicides, carbendazim was found most effective and significantly superior among all the treatments with 92.04 per cent average inhibition in mycelial growth of the wilt pathogen followed by Score (81.42%) (Table 2). Further, Contaf and Quintal were next seen in efficacy which reduced the growth of the fungus by 78.58 and 77.16 per cent, respectively and both differed significantly with each other. Systhane was found least effective among all with 25.68 per cent average inhibition in mycelial growth of the pathogen. As concentration of the fungicides increased, there was corresponding increase in per cent mycelial inhibition of the pathogen.

Among nine fungicides tested, carbendazim was found most effective against wilt pathogen (*Fusarium oxysporum* f.sp. *dianthi*) at all different concentrations. Generally, a positive co-relation observed between concentrations of the tested fungicides and inhibition of wilt pathogen (*Fusarium oxysporum* f.sp. *dianthi*). In earlier studies, carbendazim has been most effective under *in vitro* conditions in inhibiting the mycelial growth of *Fusarium* spp. followed by benomyl and thiobendazoles (Valaskova, 1983) [15]. Wojdya (1994) [17] found benomyl, carbendazim, tebuconazole and difenoconazole as most effective fungicides against *F. avenaceum* causing stem rot of carnation under *in vitro* conditions. Chandel and Katoch (2001) [3] reported that Bavistin (carbendazim) and Kri-benomyl (benomyl) completely inhibited the vegetative growth of *F. oxysporum* f.sp. *dianthi* at 100 and 200 ppm under *in vitro* condition. Carbendazim was found to completely inhibited the mycelial growth of *F. oxysporum* f.sp. *dianthi* at all three concentrations (500, 1000 and 1500 ppm) followed by 95.55 per cent inhibition at 250 ppm under *in vitro* conditions (Kishore, 2007) [8]. In another study, carbendazim was found most effective with 90.6 per cent average inhibition in mycelial growth of the wilt pathogen followed by hexaconazole with mycelial reduction of 87.96 per cent (Negi, 2009) [11]. Raheja and Patel (2011) [12] found that bavistin completely inhibited the mycelial growth of *Fusarium oxysporum* f.sp. *cumini* causing wilt in cumin at 500 ppm under *in vitro* condition. Ainmisha and Zacharia (2011) [1] also reported the efficacy of carbendazim with 70.0 per cent inhibition in mycelial growth of *F. oxysporum* f.sp. *ciceri* causing wilt in chickpea. Effectiveness of carbendazim against *Fusarium* sp. has been reported by several other workers also (Mathur *et al.*, 1988; Sharma, 2000; Bhat and Srivastava, 2003; Singh *et al*., 2010) [10, 13, 2, 14].

Table 1: *In vitro* efficacy of non- systemic fungicides against the wilt pathogen (*Fusarium oxysporum* f. sp. *dianthi*)

Fungicide	Per cent inhibition in mycelial growth at different concentrations (ppm)			Mean
	500	750	1000	
Mancozeb	33.89 (35.59)	43.33 (41.15)	52.59 (46.47)	43.27 (41.07)
Saaf*	52.04 (46.15)	58.15 (49.67)	70.37 (57.00)	60.19 (50.94)
Captaf	24.44 (29.62)	33.52 (35.36)	54.44 (47.53)	37.47 (37.50)
Mean	36.79 (37.12)	45.00 (42.06)	59.13 (50.33)	

Figures in parentheses are arc sine transformed values
*Tested at 50, 100 and 200 ppm concentration
CD $_{(0.05)}$
Fungicides (4.57)
Concentration (4.57)
Fungicides x Concentration (7.92)

Table 2: *In vitro* efficacy of systemic fungicides against the wilt pathogen (*Fusarium oxysporum* f. sp. *dianthi*)

Fungicide	Per cent inhibition in mycelial growth at different concentrations (ppm)			
	50	100	200	Mean
Bavistin	84.81 (67.05)	91.30 (72.82)	100.00 (89.96)	92.04 (76.61)
Contaf	72.96 (58.65)	79.63 (63.15)	83.15 (65.74)	78.58 (62.51)
Systhane	16.11 (23.65)	26.48 (30.96)	34.44 (35.92)	25.68 (30.18)
Score	79.07 (62.75)	81.11 (64.22)	84.07 (66.45)	81.42 (64.47)
Cabrio Top	17.04 (24.37)	31.85 (34.34)	57.04 (49.03)	35.31 (35.91)
Quintal*	73.15 (58.77)	77.41 (61.60)	80.92 (64.08)	77.16 (61.49)
Mean	57.19 (49.20)	64.63 (54.51)	73.27 (61.86)	

Figures in parentheses are arc sine transformed values
*Tested at 500, 750 and 1000 ppm concentration
CD $_{(0.05)}$
Fungicide (4.57)
Concentration (3.23)
Fungicide x Concentration (7.92)

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