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In vitro evaluation of fungicide combination on turmeric anthracnose [*Colletotrichum capsici* (Syd) butler and Bisby]

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Abstract
Turmeric (*Curcuma longa* L.) is one of the most important spice crop cultivated in India. India is considered as the largest producer, consumer and exporter of turmeric in the globe. Turmeric is affected by anthracnose, so for its management combinations of fungicides evaluated under *in vitro* condition, the highest per cent inhibition was obtained by Cymoxanil + Mancozeb followed by Metiram + Pyraclostrobin and Carbendazim + Mancozeb in inhibiting the growth *C. capsici* at all the four different concentrations tested *viz*. 100, 250, 500 and 1000 ppm.

Keywords: Evaluation of combinations of fungicides on turmeric anthracnose [*Colletotrichum capsici* (Syd.) butler and Bisby]

Introduction
Turmeric (*Curcuma longa* L.) is one of the most important spice crop cultivated in India. The crop yield is affected by several biotic and abiotic factors, among them, anthracnose of turmeric caused by *Colletotrichum capsici* was found increasing and occurring regularly every year. It has become as major constraint in successful cultivation of turmeric in Gujarat. Leaf spot disease of turmeric caused by *C. capsici* was reported for the first time from Coimbatore district of Madras by Mc Rae in 1917 [3]. Later, it was reported from turmeric growing regions like Cuddapah, Kurnool, Guntur, Krishna and Godavari districts of Andhra Pradesh and Coimbatore of Madras State (Ramakrishnan, 1954) [6]. Disease is soil-borne noticed on the leaves from July to October. In Gujarat, leaf spot of turmeric caused by *C. gloeosporioides* was first time reported by Patel *et al*. (2005) [5]. Leaf spot is the most important disease of turmeric resulting in losses of 25.83-62.12 per cent fresh weight and 42.10-62.10 per cent dry weight of rhizomes (Nair and Ramakrishnan, 1973) [4]. It causes extensive spotting of leaves. The leaves may eventually dry and thus adversely affect the formation of rhizomes. The incidence of turmeric leaf spot caused by *C. capsici* reported 50 per cent yield loss (Ramakrishnan, 1954) [6]. Hence, different combinations of fungicides tested against *Colletotrichum capsici*.

Materials and Methods
Different combinations of fungicides (Table 1) were tested for their effect on mycelium growth of *C. capsici* using poisoned food technique (Sinclair and Dhingra, 1985) [8] at four concentrations. The technique involves cultivation of test organism on a medium containing the test chemical. In experiment PDA was used as a basal medium. The calculated quantities of fungicides were thoroughly mixed in the molten almost cool PDA medium before pouring into Petri plates aseptically, so as to get desired concentration of each fungicide separately. 20 ml of fungicide amended medium was poured in each 90 mm sterilized Petri plates and allowed to solidify. The plates were aseptically inoculated with 5 mm disc cut from the periphery of 12 days of old actively growing cultures of *C. capsici*. Controls without fungicides amended were maintained for comparison. The experiments were conducted in completely randomized design with three replication of each treatment and the inoculated plates were incubated at 28±2°C. The colony diameter was measured after 7 days when the control plates were full of fungal growth. Per cent inhibition of growth of mycelium for each treatment was calculated by using the formula given by Vincent (1947) [9].

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

Where
I = Percent inhibition
C = Radial growth in control
T = Radial growth in treatment

Result and Discussion

The relative efficacy of six different combinations of fungicides was tested at 100, 250, 500 and 1000 ppm concentrations. The observations regarding per cent inhibition of linear growth are presented in Table 2.

The perusal of data makes it clear that the combination of fungicides Cymoxanil + Mancozeb followed by Metiram + Pyraclostrobin and carbendazim + Mancozeb performed effectively at their lower concentration of 250 ppm with cent per cent growth inhibition of the pathogen. Cent per cent inhibition was also observed in carbendazim + mancozeb at its 500 ppm. 88.30 per cent mean inhibition was observed in azoxystrobin + tebuconazole at 1000 ppm. Least per cent inhibition at all four concentrations was observed in zineb + hexaconazole. Mean per cent inhibition ranged between 45.06 per cent and 99.97 per cent. Maximum toxicity index (399.88) was observed in Cymoxanil + Mancozeb followed by Metiram + Pyraclostrobin (399.81).

Within fungicides, all four levels of fungicides significantly differed from each other. Higher concentration of all the fungicides gave significantly more inhibition as compared to their lower level.

The outcome of per cent growth inhibition at 100 ppm indicated that the significantly highest growth inhibition was obtained in the treatment of Cymoxanil + Mancozeb (99.94 %) which was statistically at par with Metiram + Pyraclostrobin (99.87 %). The next effective treatment was azoxystrobin + tebuconazole (83.05 %) whereas zineb + hexaconazole (28.61 %) recorded minimum growth inhibition among all treatments.

Whereas at 250 ppm, the significantly highest growth inhibition of cent per cent was obtained in the treatment of cymoxanil + mancozeb (99.98) which was statistically at par with Metiram + Pyraclostrobin and Carbendazim + Mancozeb.

Similarly at 500 ppm, the significantly highest growth inhibition of cent per cent was again obtained in the treatment of Cymoxanil + Mancozeb which was statistically at par with Metiram + Pyraclostrobin and Carbendazim + Mancozeb.

Growth inhibition at 1000 ppm showed the significantly highest growth inhibition again in cymoxanil + mancozeb which was statistically at par with Metiram + Pyraclostrobin and Carbendazim + Mancozeb. The next best fungicide combination was azoxystrobin + tebuconazole (88.30 %).

The results revealed that among all combinations of fungicides tested at four different concentrations, Cymoxanil + Mancozeb, Metiram + Pyraclostrobin and carbendazim + Mancozeb were proved to be best and inhibited growth at all concentrations.

These findings were in favour of work done by Sarodee *et al*. (2015) [7] evalualuated fungicides against leaf spot of turmeric caused by *C. capcisi*. The efficacy of six fungicides were tested among which the fungicides, carbendazim 12 per cent + mancozeb 63 per cent @ 0.2 per cent was found significantly effective in inhibiting the mycelial growth of the pathogen. Similar results were also obtained by Madhusudhan (2002) [2] and Jagtap *et al*. (2012) [1] against *C. truncatum*.

Table 1: List of combinations of fungicides tested and their concentrations

S. No.	Technical/active Ingredient	Concentration in ppm*			
		1	2	3	4
1.	Zineb 60% WP + Hexaconazole 4%WP.	100	250	500	1000
2.	Carbendazim 50% WP + Mancozeb 75% WP.	100	250	500	1000
3.	Cymoxanil 8% WP + Mancozeb 64% WP.	100	250	500	1000
4.	Carbendazim 12% WP + Mancozeb 63% WP.	100	250	500	1000
5.	Metiram 55% WG + Pyraclostrobin 5% WG.	100	250	500	1000
6.	Azoxystrobin 11% + Tebuconazole 18.30%	100	250	500	1000
7.	Control	-			

*Concentration: 1, 2, 3 and 4 used for mycelium growth inhibition of *C. capsici*

Table 2: Effect of different combinations of fungicides on growth inhibition of *C. capsica*

Sr. No.	Technical/ Active Ingredient	Per cent inhibition*				Mean	Toxicity Index#
		100 ppm	250 ppm	500 ppm	1000 ppm		
1.	Cymoxanil 8% WP + Mancozeb 64% WP.	88.56 (99.94)	89.19 (99.98)	89.19 (99.98)	89.19 (99.98)	89.03 (99.97)	399.88
2.	Metiram 55% WG + Pyraclostrobin 5% WG.	87.92 (99.87)	89.19 (99.98)	89.19 (99.98)	89.19 (99.98)	88.87 (99.95)	399.81
3.	Carbendazim 12% WP + Mancozeb 63% WP.	61.52 (77.25)	89.19 (99.98)	89.19 (99.98)	89.19 (99.98)	82.27 (94.29)	377.19
4.	Carbendazim 50% WP + Mancozeb 75% WP.	60.99 (76.48)	67.22 (85.00)	89.19 (99.98)	89.19 (99.98)	76.65 (90.36)	361.44
5.	Azoxystrobin 11% SC + Tebuconazole 18.30% SC.	65.69 (83.05)	65.97 (83.41)	67.37 (85.19)	70.00 (88.30)	67.26 (84.99)	339.95
6.	Zineb 60% WP + Hexaconazole 4% WP.	32.34 (28.61)	42.64 (45.88)	43.61 (47.57)	49.71 (58.18)	42.08 (45.06)	180.24
	Mean	66.17 (83.68)	73.90 (92.31)	77.96 (95.65)	79.41 (96.62)	-	-
		Fungicide (F)		Concentration (C)		F × C	
	S. Em. ±	0.23		0.19		0.46	
	C. D. at 5%	0.66		0.54		1.31	
	C. V.%	1.08					

* Mean of three replications
\# Maximum toxicity index = 400.00
Data were arcsine transformed before analysis; values in parentheses are retransformed value.

Summary and Conclusion

Availability of new fungicides necessitates evaluation of fungicides under *in vitro* conditions to know their efficacy, and apply them in field conditions. Hence in the present study combinations of fungicides were found to be effective for controlling anthracnose. Among the all combinations of fungicides evaluated under *in vitro* condition, the highest per cent inhibition was obtained by Cymoxanil + Mancozeb followed by Metiram + Pyraclostrobin and carbendazim + Mancozeb in inhibiting the growth *C. capsici* at all the four different concentrations tested *viz*. 100, 250, 500 and 1000 ppm.

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