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Fungicidal management of leaf spot disease of turmeric caused by *Colletotrichum capsici*

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Abstract
Turmeric is one of the important spice crops of India. It has socio-economic and cultural significance in India. However, the yield of the crop is not realized to its potential. Several factors attribute to the low yield of the crop. Among them, the biotic factors are playing a vital role. The leaf spot disease of turmeric caused by *Colletotrichum capsici* is an important limiting factor in turmeric cultivation. Among all recommended management practices, application of fungicides is the most efficient mode of managing this disease. Hence, in the present investigations, fourteen fungicides that included five contact fungicides, eight systemic fungicides and one combi product were evaluated *in vitro* against *Colletotrichum capsici* at different concentrations using poisoned-food technique. The studies revealed that the fungicide carbendazim was highly effective as it completely inhibited the growth of the pathogen at the lowest concentration of 10 ppm followed by propiconazole and hexaconazole which gave 100 percent inhibition at 25 ppm. The least effective fungicides were copper hydroxide, mancozeb, thiophanate methyl, difenoconazole and azoxystrobin which failed to inhibit the growth of the pathogen completely even at 500 ppm. Based on the *in vitro* results, promising fungicides were further evaluated under field conditions. The results showed that the fungicide carbendazim was very effective registering the least average PDI (20.67) with highest fresh rhizome yield (36.10 t/ha) which was followed by the fungicides *viz.*, propiconazole with average PDI of 27.02 and the yield of 35.50 t/ha and hexaconazole with average PDI of 28.83 and the yield of 34.32 t/ha.

Keywords: Turmeric, *Colletotrichum capsici*, fungicides, percent inhibition, concentrations

Introduction
India is recognized worldwide as 'Land of Spices. It is the largest producer, consumer and exporter of spices in the world followed by China. India consumes 90 percent of its production for domestic purpose. Among 109 spices grown all over the world India alone grows about 63 of them. Among them turmeric (*Curcuma longa* L.) is an important spice crops which is grown in India since time immemorial. It is an herbaceous perennial plant that belongs to the family *Zingiberaceae* (Jansen, 1981) [10]. It is considered as a sign of well-being and future and is extensively used in ceremonies and religious functions. It is grown mainly for its underground rhizome which yields yellow powder upon drying (Chattopadhyan, *et al*., 2004; Nongmaithem and Rebika, 2019) [3, 16]. Pharmaceutically, it is carminative, antiseptic and anti-parasitic for many skin infections (Guji and Woga, 2019; Ahmad *et al*., 2020) [7, 1]. It cures the sore throat, common cold and used as an appetizer and helps in digestion. It is also used in the preparation of cosmetics, soaps, skin ointments and tooth pastes. India dominates the turmeric market in the world as about 80 percent of turmeric production in the world comes from India with an average production of 13.34 lakh metric tons from the area of 3.50 lakh hectares. In India turmeric is grown in as many as 25 states and among them Telangana, Andhra Pradesh, Karnataka, Tamil Nadu and Gujarat are the leading producers of turmeric. In Karnataka, it is grown in an area of 21.31 thousand hectares with a production of 1.31 lakh metric tons. (Anon, 2022) [2].

The major production limitations in turmeric are long duration, low rhizome yield, low curcumin content of popular varieties and incidence of diseases. There is a quite substantial part of total harvest loss due to the diseases affecting the crop year after year. Among these, rhizome rot and foliar diseases are important ones. Among the foliar diseases, the leaf spot disease of turmeric caused by *Colletotrichum capsici* is more destructive and prevalent in major turmeric growing areas and losses caused by leaf spot are always considered to be a limiting factor for yield, quality of rhizomes and often results in heavy yield losses

(Devi, 2008) [5]. Severe infection of the disease results in drooping of whole foliage and losses would exceed 50 percent. Reduction in dry weight by 62.70 percent was also reported due to foliar diseases. Heavy losses have been reported in severely diseased plants (>50%) *i.e.* 25.83 and 62.12 percent on fresh weight basis and 42.10 and 62.10 percent on dry weight basis of mother and finger rhizomes respectively. Maximum losses in curcumin content (50.11%) were found in severely diseased plants. The percent curcumin content in rhizomes of diseased and healthy plants ranges from 2.08 to 4.17 respectively (Hudge and Ghugul, 2010) [8]. The disease usually appears in the field during August and September when there is high relative humidity in the atmosphere (Kadam *et al*., 2014). The symptoms of leaf spot in turmeric appear on the infected leaves in the beginning on the lower senescent leaves. The spots are elliptical to oblong in shape, measuring of 2.50 to 4.00 cm long and 1.50 to 2.50 cm in wide (Rajesh, 2012) [20]. These spots coalesce later and eventually dry up, giving a blighted appearance (Guji and Woga, 2019) [7]. The disease has been found increasing rapidly all over India over the last decade. *C. capsici* has been reported to have a wide putative host range associated with symptoms of foliar blight, leaf spot diseases (Shenoy *et al*., 2007) [25].

Most of the popular turmeric cultivars available today are susceptible to this disease, causing extensive yield losses to the turmeric production. In the absence of resistant cultivars, use of fungicides to manage the disease is an old-age practice and becomes the major component of integrated disease management strategy. When there is outbreak of epidemic for any reason perhaps use of fungicides is one of the best options available. Certain protective fungicides although hazardous to environment are still used for the control of fungal diseases (Nwankiti *et al*., 1990; Vaish and Sinha, 2003) [17, 28]. And availability of new fungicides necessitates evaluation of fungicides under *in vitro* and field conditions to know their efficacy, and initiate spray schedule in field conditions. Hence, the present study was carried out to evaluate the fungicide both *in vitro* and under field conditions for the efficacy of various fungicides against *Colletotrichum capsci*, the causal agent of leaf spot disease of turmeric.

Material and Methods

Isolation of the pathogen

Turmeric leaves exhibiting typical leaf symptoms of leaf spot were collected from Haveli experimental farm, COH, Bangalkote were used for the isolation of the pathogen. The isolation was done according to tissue segment methodology of Rangaswami (1958) [21]. The pathogen was purified using single spore isolation method (Riker and Riker, 1936) [23]. The identification was done through colony colour, morphology and spore characters. The pure culture of the pathogen was maintained on PDA slants at 27±1 °C.

In vitro evaluation of fungicides against *Colletotrichum capsici*

Fourteen fungicides that included five contact, eight systemic and one combi product (Table 1) were tested for their efficacy against *Colletotrichum capsici*, the causal agent of leaf spot disease of turmeric under *in vitro* conditions at various concentrations *viz.*, 10, 25, 50, 100, 250 and 500 ppm of their active ingredient (*a.i.*) using Poisoned food technique (Shravelle, 1961) [26]. The experiment was laid out statistically using Completely Randamized Design (CRD) with three replication for each concentration. The required quantity of individual fungicide was added separately into molten and cooled potato dextrose agar so as to get the desired concentration of the fungicides. Later, twenty ml of the poisoned medium was poured into sterile Petri plates and allowed to solidify. Mycelial discs of seven mm diameter from actively growing seven-day old culture of the fungus were cut using a sterile cork borer and such disc was placed at the center of each agar plate. Control was maintained without adding any fungicide to the medium three replications were maintained for each concentration. The plates were incubated at room temperature for 10 days and radial growth was measured when fungus attained maximum growth in control plates. Percent reduction in radial growth of the pathogen over control was calculated by using the below mentioned formula (Vincent, 1947) [29].

Table 1: Details of fungicides used in the study

Sl. No.	Common Name	Trade name	Chemical group	Mode of action	FRAC code
Contact fungicides					
1	Chlorothalonil	Kavach	Chloronitriles (phthalonitriles)	multi-site contact activity	M05
2	Mancozeb	Indofil-M-45	dithio-carbamates and relatives	multi-site contact activity	M03
3	Propineb	Antracol	dithio-carbamates and relatives	multi-site contact activity	M03
4	Copper hydroxide	Kocide 2000	inorganic	multi-site contact activity	M01
5	Copper oxychloride	Blitox	inorganic	multi-site contact activity	M01
Systemic fungicides					
6	Carbendazim	Bavistin	benzimidazoles	Interferes with tubulin polymerization	1
7	Tebuconazole	Folicur	triazole	Sterol Biosynthesis inhibitors	3
8	Difenoconazole	Score	triazole	Sterol Biosynthesis inhibitors	3
9	Propiconazole	Tilt	triazole	Sterol Biosynthesis inhibitors	3
10	Hexaconazole	Contaf	Triazole	Sterol Biosynthesis inhibitors	3
11	Fluopyram	Luna	pyridinyl-ethylbenzamides	Breaks the respiration chain	7
12	Azoxystrobin	Amistar	methoxy-acrylates	Breaks the respiration chain	11
13	Thiophanate methyl	Roko	benzimidazoles	Interferes with tubulin polymerization	1
Combi products					
14	Tebuconazole +trifloxystrobin	Nativo	triazole+oximino-acetates	Sterol Biosynthesis inhibitors+ Breaks the respiration chain	3+11

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

Where,
I = Percent inhibition
C = Radial growth in control
T = Radial growth in treatment
The percent values were transformed to arc sine values and later the data were statistically analyzed.

Field evaluation of fungicides against turmeric leaf spot disease

A field experiment on the efficacy of fungicides against leaf spot disease of turmeric was carried out at Haveli farm, Bagalkot during *kharif* 2015-16. Totally eight fungicides found promising during *in vitro* conditions were evaluated under field conditions. The experiment was laid out in Randomized Block Design (RBD) with three replications. A plot size of 2.7 m x 2.1 m was maintained for each plot with the spacing of 45 X 30 cm. The susceptible variety Cuddapah was used for the study. All the recommended cultivation practices were carried out as per the package of practices of UHS, Bagalkot.

Totally four sprays of each treatment were given after the first appearance of the disease at an interval of 30 days. Observations on disease severity were recorded on five randomly selected plants in each treatment using disease score (0-5 scale) as described by Padule and Utikar (1977) [18] after 10 days of each spray. The last observation on the disease severity was taken on 190 days after planting. The Percent Disease Index (PDI) was worked out using following formula proposed by Wheeler (1969) [30].

$$\text{Per cent Disease Index (PDI)} = \frac{\text{Sum of numerical ratings}}{\text{Number of plants assessed x Maximum grade}} \times 100$$

Yield

Crop was harvested at rhizome maturity stage and the fresh rhizome weight of each plot was recorded and yield per hectare was computed by using net plot yield data and then converted to tons per hectare and the data were statistically analyzed.

Benefit cost ratio (B:C ratio)

Total cost incurred for the application of each treatment was worked out. Gross return was calculated on the basis of prevailing market price of the produce during the harvesting season. Net returns were calculated by deducting the total cost from the gross return. Benefit cost ratio was calculated by using the formula.

$$\text{B: C ratio} = \frac{\text{Net returns (Rs./ha)}}{\text{Total cost (Rs./ha)}}$$

Results and Discussion

In vitro* evaluation of fungicides against *Colletotrichum capsici

The experimental results on *in vitro* evaluation of fungicide against *C. capsici* are presented in Table 2 and in Fig. 1. Of all the fungicides studied *in vitro*, the fungicide carbendazim was highly effective in inhibiting the growth of the pathogen even at the lowest concentration of 10 ppm and was statistically superior over all other fungicides tested at various concentrations. This was followed by two systemic fungicides *viz.*, propiconazole and hexaconazole which gave 100 percent mycelial inhibition at 25 ppm. The fungicides trifloxystrobin + tebuconazole, tebuconazole, chlorothalonil and propineb were able to inhibit the growth of the pathogen completely at 50 ppm. The fungicide copper-oxy-chloride was effective only at 500 ppm. The least effective fungicides were copper hydroxide, mancozeb, thiophanate methyl, difenoconazole and azoxystrobin which were unable to inhibit the growth of the pathogen completely even at 500 ppm. In the present study the fungicide carbendazim was found most effective in inhibiting the growth of the pathogen *C. capsici* followed by propiconazole and hexaconazole, trifloxystrobin + tebuconazole, tebuconazole, chlorothalonil and propineb (Plate 1).

Table 2: *In vitro* evaluation of fungicides against *Colletotrichum capsici*, the causal agent of turmeric leaf spot disease

Sl. No.	Fungicides		Percent inhibition of mycelial growth at different fungicidal concentrations (ppm)					
	Chemical name	Trade name	10	25	50	100	250	500
1	Trifloxystrobin + Tebuconazole 25 + 50% WP	Nativo	67.41 (55.26)	90.74 (72.33)	100.0 (89.73)	100.0 (89.73)	100.0 (89.73)	100.0 (89.73)
2	Mancozeb 75% WP	Indofil-M-45	0.00 (0.31)	0.00 (0.31)	3.70 (11.08)	6.30 (14.53)	25.93 (30.62)	34.81 (36.17)
3	Copper hydroxide 53.8%WG	Kocide 2000	0.00 (0.31)	0.00 (0.31)	5.93 (14.08)	9.63 (18.06)	25.93 (30.62)	34.44 (35.95)
4	Carbendazim 50% WP	Bavistin	100.0 (89.73)	100.0 (89.73)	100.0 (89.73)	100.0 (89.73)	100.0 (89.73)	100.0 (89.73)
5	Fluopyram 17.7%SC	Luna	70.74 (57.29)	86.30 (68.33)	89.26 (70.92)	100.0 (89.73)	100.0 (89.73)	100.0 (89.73)
6	Propiconazole 25% EC	Tilt	84.82 (67.11)	100.0 (89.73)	100.0 (89.73)	100.0 (89.73)	100.0 (89.73)	100.0 (89.73)
7	Hexaconazole 5%EC	Contaf	82.59 (65.40)	100.0 (89.73)	100.0 (89.73)	100.0 (89.73)	100.0 (89.73)	100.0 (89.73)
8	Tebuconazole 250EC	Folicur	70.37 (57.10)	86.30 (68.31)	100.0 (89.73)	100.0 (89.73)	100.0 (89.73)	100.0 (89.73)
9	Chlorothalonil 75% WP	Kavach	31.85 (34.38)	40.74 (39.68)	100.0 (89.73)	100.0 89.73)	100.0 (89.73)	100.0 (89.73)
10	Propineb 70% WP	Antracol	22.59	27.04	100.0	100.0	100.0	100.0

			(28.38)	(31.34)	(89.73)	(89.73)	(89.73)	(89.73)
11	Copper-oxy-chloride 50WP	Blitox	6.30 (14.53)	8.89 (17.27)	21.85 (27.88)	34.81 (36.18)	42.22 (40.55)	100.0 (89.73)
12	Difenoconazole 25%EC	Score	51.48 (45.87)	68.52 (55.90)	79.63 (63.21)	81.48 (64.55)	83.70 (66.23)	85.93 (68.01)
13	Azoxystrobin 22.94%SC	Amistar	5.56 (13.60)	9.63 (18.08)	13.33 (21.42)	27.04 (31.34)	30.74 (33.69)	46.30 (42.90)
14	Thiophanate methyl-70% WP	Roko	4.44 (11.91)	50.37 (45.24)	54.81 (47.79)	67.78 (55.44)	71.85 (57.99)	81.85 (64.83)
15	Control		0.00 (0.31)	0.00 (0.31)	0.00 (0.31)	0.00 (0.31)	0.00 (0.31)	0.00 (0.31)
	CD (P=0.01)		3.20	2.02	1.34	1.27	1.25	1.20
	SEm±		0.82	0.51	0.34	0.33	0.32	0.31
	CV (%)		3.95	1.96	1.02	0.89	0.86	0.77

Note: Figures in parenthesis are arc sine transformed values

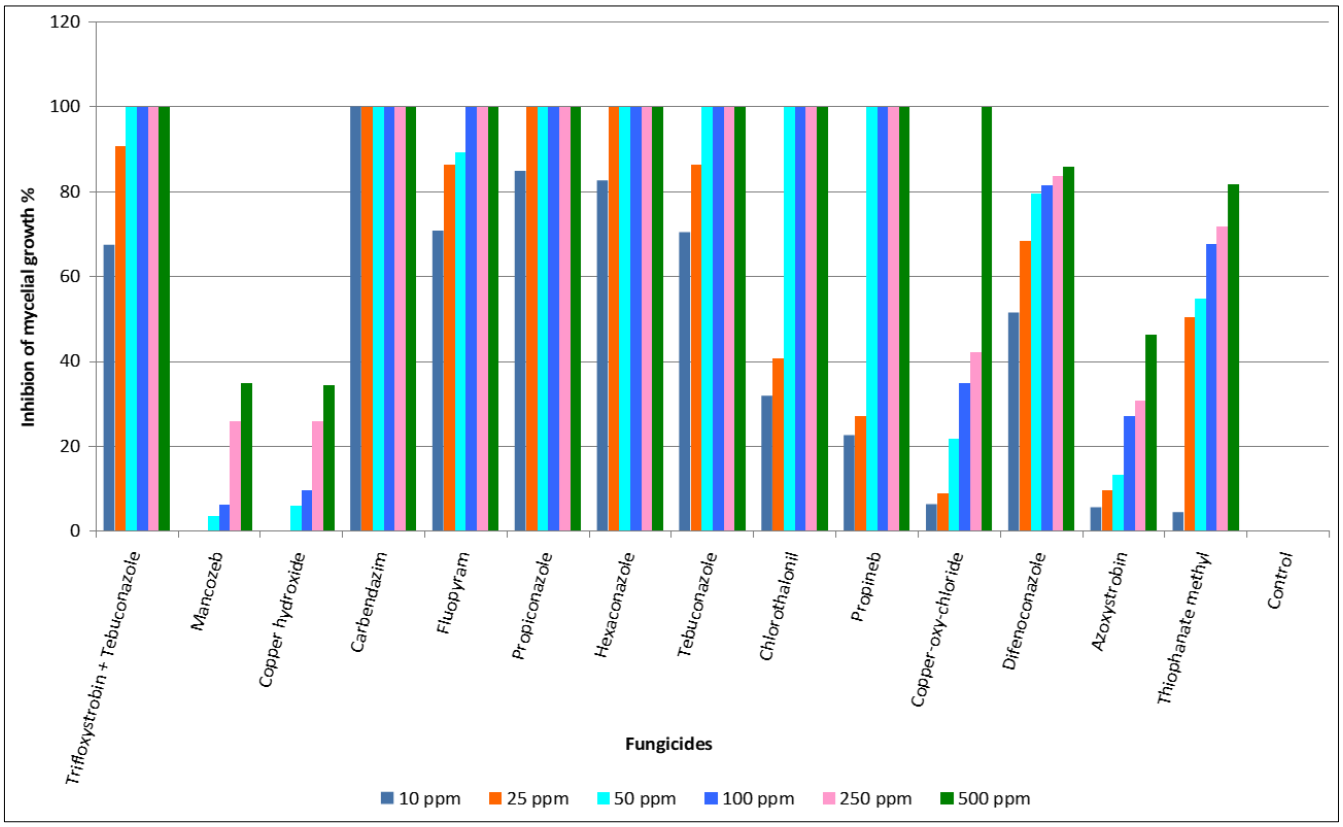
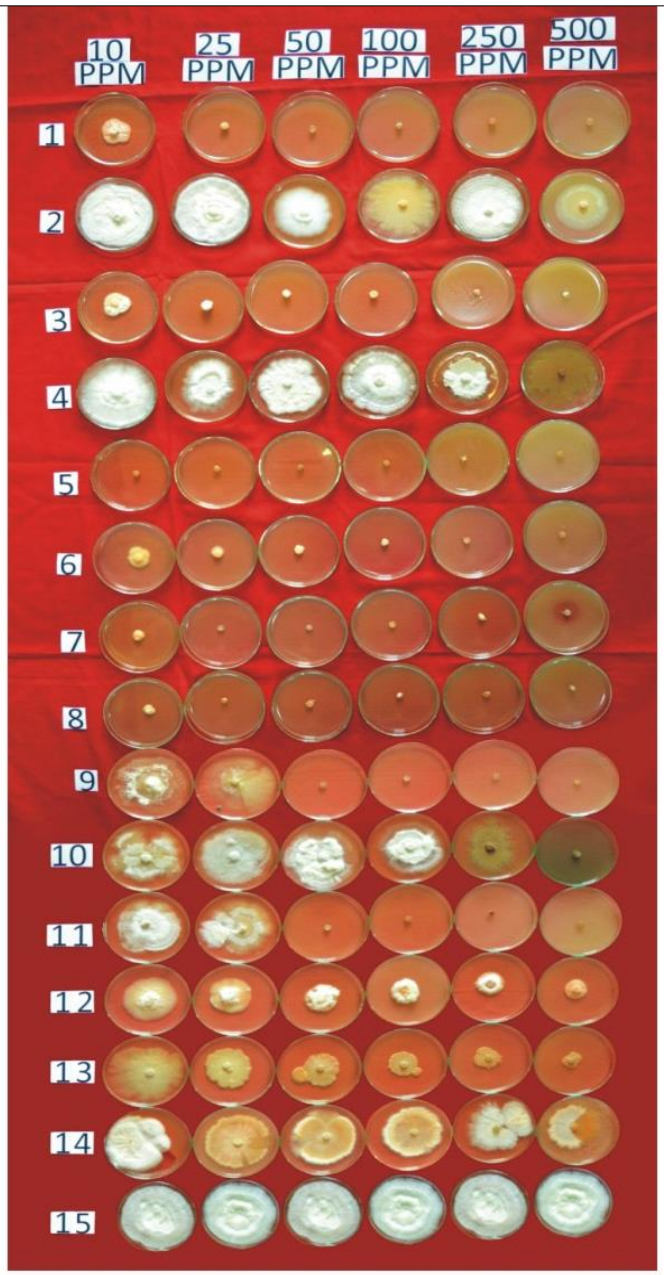


Fig 1: *In vitro* evaluation of fungicides against *Colletotrichum capsici*, the causal agent of turmeric leaf spot disease



Note: 1) Trifloxystrobin + Tebuconazole-25 + 50 % WP 2) Mancozeb-75% WP 3) Tebuconazole-250 EC 4) Copper hydroxide-53.8% WG 5) Carbendazim-50% WP 6) Fluopyram-17.7% SC 7) Propiconazole-25% EC 8) Hexaconazole-5% EC 9) Chlorothalonil-75% WP 10) Copper-oxy-chloride-50WP 11) Propineb-70% WP 12) Difenoconazole-25% EC 13) Thiophanate methyl-70%WP 14) Azoxystrobin-22.94% SC 15) Control

Plate 1: *In vitro* evaluation of fungicides against *Colletotrichum capsici*

The previous findings (Chidanandaswamy, 2001) [4] that the fungicides carbendazim, tricyc1azole and propiconazole being effective against *C. capsici*, the pathogen of leaf spot of turmeric supports our results. Similarly, the outcomes of another study revealed that the fungicide propiconazole being significantly superior to all other fungicides followed by hexaconazole and chlorothalonil among the 10 fungicides evaluated against *C. capsici* causing leaf spot of turmeric, (Jagtap *et al.*, 2013). The fungicide propiconazole was reported to be most effective followed by hexaconazole, carbendazim and tebuconazole + trifloxystrobin against *Colletotrichum gloeosporioides* inciting anthracnose in coffee (Sing *et al.*, 2012) [27]. Efficacy of carbendazim against *Colletotrichum capsici*, the causal agent of turmeric leaf spot disease has been reported by Nongmaithem, and Rebika (2019) [16]. Patel *et al*. (2022) [19] reported the fungicide propiconazole being highly effective when tested *in vitro* against *Colletotrichum capsici*, the causal agent of chilli anthracnose.

Field evaluation of fungicides against turmeric leaf spot disease

Eight fungicides which effective against *C. capsici* under *in vitro* conditions were evaluated under field conditions during 2015 and the data are presented in Table 3 and in Fig. 2.

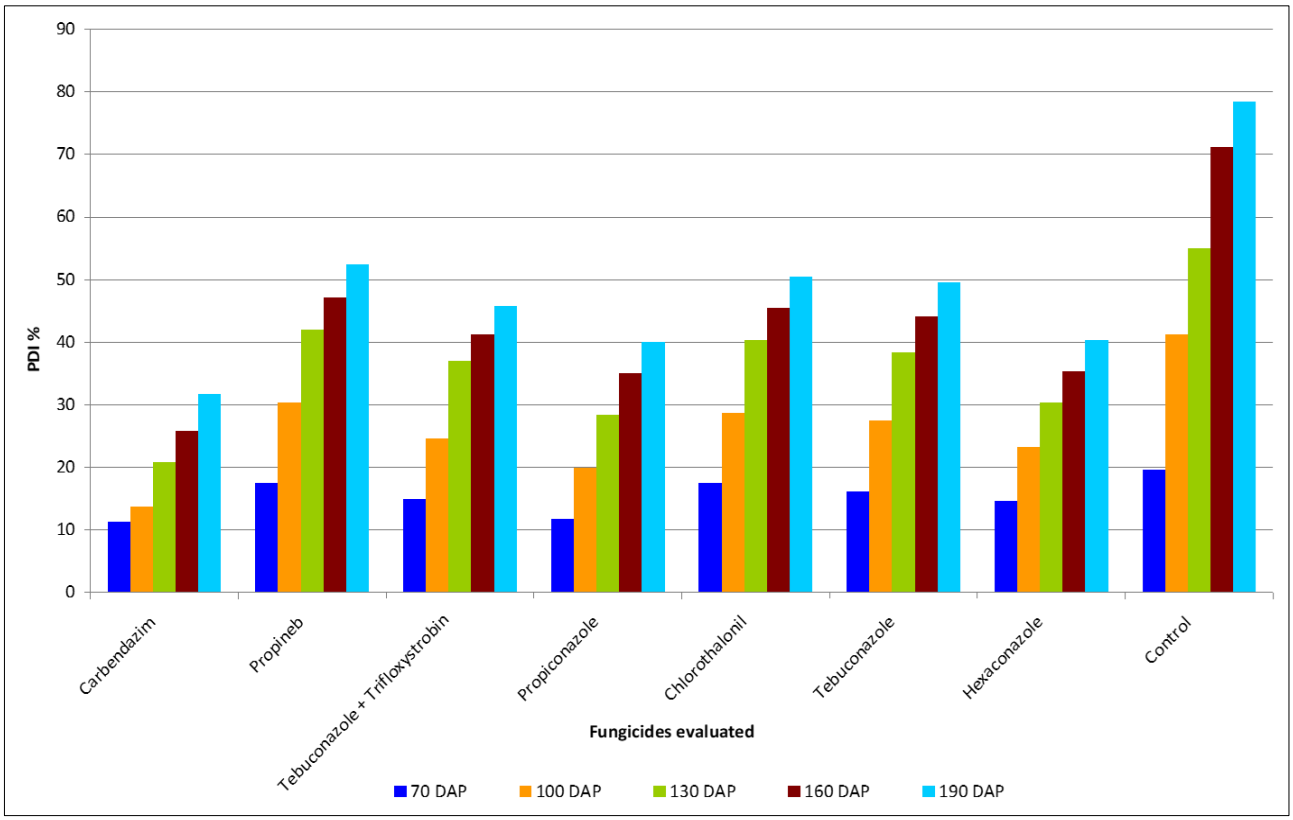


Fig 2: Efficacy of fungicides against leaf spot disease of turmeric caused by *Colletotrichum capsici* under field conditions

Table 3: Efficacy of fungicides against leaf spot disease of turmeric caused by *Colletotrichum capsici* under field conditions

Sl. No.	Treatments	Concentration	Percent Disease Index (PDI) at days after planting (DAP)					Fresh rhizome yield (t /ha)
			70 DAP	100 DAP	130 DAP	160 DAP	190 DAP	
1.	Carbendazim 50% WP	0.1%	11.25 (19.50)	13.75 (21.61)	20.83 (27.14)	25.83 (30.53)	31.67 (34.24)	36.10
2.	Propineb 70%WP	0.2%	17.58 (24.73)	30.42 (33.40)	42.08 (40.43)	47.08 (43.32)	52.50 (46.44)	30.82
3.	Tebuconazole+Trifloxystrobin 25+ 50% WP	0.05%	15.00 (22.74)	24.58 (29.72)	37.08 (37.50)	41.25 (39.95)	45.83 (42.61)	33.10
4.	Propiconazole 25%EC	0.1%	11.75 (19.57)	20.00 (26.44)	28.33 (32.14)	35.00 (36.25)	40.00 (39.22)	35.50
5.	Chlorothalonil 75% WP	0.2%	17.50 (24.72)	28.75 (32.38)	40.42 (39.47)	45.42 (42.36)	50.42 (45.24)	30.93
6.	Tebuconazole 250 EC	0.1%	16.12 (23.65)	27.50 (31.60)	38.33 (38.24)	44.17 (41.64)	49.58 (44.76)	32.10
7.	Hexaconazole 5% EC	0.1%	14.58 (22.38)	23.33 (28.83)	30.42 (33.46)	35.42 (36.52)	40.42 (39.48)	34.32
8.	Control		19.67 (26.30)	41.25 (39.90)	55.00 (47.87)	71.17 (57.53)	78.42 (62.32)	27.73
	CD (P=0.05)		2.00	3.21	1.95	1.83	1.88	3.69
	SEm±		0.65	1.06	0.64	0.60	0.62	1.22
	CV (%)		4.88	6.01	3.02	2.54	2.42	6.46

Note: Figures in parenthesis are arc sine transformed values

The effect of different fungicides on the leaf spot disease of turmeric caused by *Colletotrichum capsici* varied significantly. At 70 days after planting (DAP), the fungicide carbendazim @ 0.1% registered least PDI of 11.25 followed by the fungicide propiconazole @ 0.1% (11.75) and was statistically on par with carbendazim. This was followed by the fungicides by hexaconazole @ 0.1% (14.58) trifloxystrobin + tebuconazole @ 0.05% (15.00) and tebuconazole @ 0.1% (16.12) which were statistically on par with each other. Maximum PDI was noticed in the untreated control plot (19.67).

At 100 DAP, carbendazim showed least PDI (13.75) which was statistically superior over all other treatments. The next best fungicide was propiconazole with PDI of 20.00 which was statistically on par with the fungicide hexaconazole (23.33). The fungicides trifloxystrobin + tebuconazole (24.58), tebuconazole (27.50) and chlorothalonil (28.75) were statistically on par with each other. The highest PDI was noticed in untreated control (41.25).

At 130 DAP, minimum PDI (20.83) was noticed in the plot sprayed with carbendazim and was statistically significant over all other treatments. The fungicide propiconazole was

the next best fungicide with PDI of 28.33. However, the fungicide hexacnozole (30.42) was statistically on par with propiconazole. The fungicides trifloxystrobin + tebuconazole (37.08) and tebuconazole (38.33) were statistically on par with each other. The maximum PDI was noticed in untreated control plot with PDI of 55.00.

At 160 DAP, the fungicide carbendazim recorded minimum PDI (25.83) and it was statistically superior over all other treatment whereas propiconazole (35.00) and hexaconazole (35.42) were the next best treatments and statistically on par with each other followed by the fungicides trifloxystrobin + tebuconazole (41.25) and tebuconazole (44.17). The maximum PDI (71.17) was noticed in untreated control plot.

At 190 DAP, minimum PDI (31.67) was noticed in carbendazim and was superior over all other treatments followed by the fungicides propiconazole (40.00) and hexaconazole (40.42) which were statistically on par with each other. The fungicides trifloxystrobin + tebuconazole (45.83) and tebuconazole (49.58) were the other best treatments. The maximum PDI (78.42) was observed in untreated control plot.

Significant results were obtained with respect to the effect of different fungicides on the fresh rhizome yield of turmeric. The highest rhizome yield (36.10 t/ha) was obtained from the plot treated with the fungicide carbendazim. However, the yields obtained in the plots sprayed with the fungicides propiconazole (35.50 t/ha), hexaconazole (34.32 t/ha) and tebuconazole + trifloxystrobin (33.10 t/ha) were statistically on par with the yield obtained from the plot sprayed with the fungicide carbendazim. The least yield (27.73 t/ha) was noticed in untreated plot.

The present studies on field evaluation of fungicides against turmeric leaf spot disease revealed that the fungicide carbendazim registered least disease severity which was closely followed by the fungicides propiconazole and hexaconazole. However, the fungicide tebuconazole + trifloxystrobin was also found better compared to the other fungicides. The maximum fresh rhizome yield (36.10 t/ha) was registered in the plot treated by carbendazim followed by the plots treated with propiconazole (35.50 t/ha) and hexaconazole (34.32 t/ha) and all these were statistically on par with each other. The highest PDI and least fresh rhizome yield (27.73 t/ha) was noticed in the untreated plot (Plate 2). Similar field experiment conducted on turmeric to determine the most effective chemical against leaf spot caused by *C. Capsici* by Narasimhudu and Balasubramanian (2001) [15] revealed that the fungicide thiophanate-methyl was most effective followed by the fungicides mancozeb and carbendazim. In an another studies on the effect of different chemicals on chilli anthracnose caused by *Colletotrichum capsici* under greenhouse and field conditions by Gopinathan *et al.* (2006) [6], the fungicide propiconazole at 0.1 percent caused a dramatic reduction of disease incidence (70 percent) when compared to difenoconazole at 0.05 percent and carbendazim at 0.1 percent. Additionally, they reported an increase in fruit yield of about 86, 63 and 60 percent with above chemicals respectively as compared to control. Mina *et al.* (2009) [13] recorded the effectiveness of propiconazole against turmeric anthracnose disease under field conditions and found that propiconazole at 0.1 percent, hexaconazole at 0.1 percent, mancozeb at 0.25 percent and carbendazim at 0.1 percent are effective in managing of anthracnose of turmeric and also in obtaining significantly higher yield. Rao *et al.* (2012) [22] evaluated the efficacy of four different fungicides *viz.*, propiconazole (0.1 percent), hexaconazole (0.1 percent), tricyclazole (0.1 percent) and carbendazim + mancozeb (0.1 percent) for the management of leaf spot disease (*Colletotrichum capsici*) of turmeric (*Curcuma longa* L.) at Kammarpally (Andhra Pradesh). Rhizome treatment with carbendazim + mancozeb (0.1 percent) gave better germination (90.52 percent) and rhizome treatment and foliar application of propiconazole (0.1 percent) at 45 and 90 days after planting (DAP) were significantly superior in reducing the disease index (20.01 percent) of leaf spot disease and increasing the fresh rhizome yield (17.13 tones/ha). Mishra and Pandey (2015) [14] evaluated the efficacy of four fungicides *viz.*, hexaconazole (0.1%), propiconazole (0.1%), tricyclazole (0.1%) and carbendazim + mancozeb (0.1%) for the management of leaf spot disease of turmeric through rhizome treatment + foliar spray and foliar spray alone at 45 and 90 days after planting (DAP). Rhizome treatment with carbendazim + mancozeb gave the best results for rhizome germination (91.13%) followed by propiconazole (88.40%) and hexaconazole (87.33%). Foliar application of propiconazole (0.1%) at 45 and 90 DAP was significantly superior in minimizing percent disease intensity (27.61) with increased fresh rhizome yield (33.96 - 34.33 tones/ha).. Jibat and Asfaw (2021) [11] in their experiment in South-Western Ethiopia found on the efficacy of fungicides against turmeric leaf spot caused by *Colletotrichum capsici* the fungicide propiconazole superior not only in reducing disease severity but also maximizing rhizome fresh yield.

Benefit cost ratio (B: C ratio)

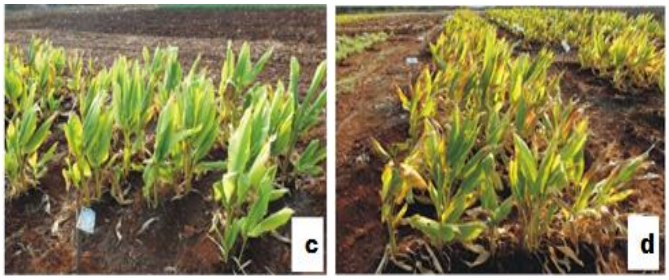
The economics of different fungicidal treatments was also studied and presented in the table 4. The fungicide carbendazim at 1 g per litre spray was proved to be the most economical treatment (BC ratio 2.44) followed by propiconazole 0.5 ml per litre (BC ratio 2.36). It is evident from the present investigations that under Bagalkot conditions the four sprays of carbendazim at the rate of 0.1 percent was the best and economical for the effective management of turmeric leaf spot followed by hexaconazole 0.05 percent with net return of Rs. 149549/- and Rs. 143467/- over the check respectively. Narasimhudu and Balasubramanian (2001) [15] reported on the fungicide mancozeb recording highest benefit: cost ratio followed by carbendazim and thiophanate-methyl in their studies on efficacy of fungicides against turmeric leaf spot disease. Similar work in the past about achieving maximum B:C ratio with the fungicide propiconazole (Mishra and Pandey, 2015; Jibat and Asfaw, 2021) [14, 11] while working on the efficacy of fungicides against turmeric leaf spot caused by *Colletotrichum capsici* supports our findings.

Table 4: Economic analysis of management of leaf spot of turmeric

Treatments	Fungicides	Cost of planting material (Rs/ha)	Cost of cultivation (Rs/ha)	Cost of fungicide (Rs/ha)	Total cost of cultivation (Rs/ha)	Total returns (Rs/ha)	Net returns (Rs/ha)	Cost benefit ratio (B:C)
T_1	Carbendazim 50% WP	40000	101633	1518	103151	252700	149549	2.44
T_2	Propineb 70%WP	40000	101633	2640	104273	215740	111467	2.06
T_3	Tebuconazole + Trifloxystrobin 25 + 50% WP	40000	101633	6600	108233	231700	123467	2.14
T_4	Propiconazole 25%EC	40000	101633	3400	105033	248500	143467	2.36
T_5	Chlorothalonil 75% WP	40000	101633	2720	104353	216510	112157	2.07
T_6	Tebuconazole 250 EC	40000	101633	5200	106833	224700	117867	2.10
T_7	Hexaconazole 5% EC	40000	101633	1430	103063	240240	137177	2.33
T_8	Control	40000	101633		101633	194110	92477	1.90

Carbendazim treated plot (a) Untreated control plot (b)

2 (a & b): 130 days after planting



Carbendazim treated plot (c) Untreated control plot (d)

2 (c & d): 160 days after planting

Plate 2: Comparison of carbendazim treated turmeric plot with untreated turmeric plot against turmeric leaf spot disease caused by *Colletotrichum capsici*

Conclusion

From the present studies, it can be concluded that the fungicide carbendazim was very effective both under *in vitro* conditions and under filed conditions followed by the fungicide propiconazole against *Colletotrichum capsici*, the causal agent of turmeric leaf spot disease. The highest fresh rhizome yield and B:C ratio were obtained with carbendazim followed by propiconazole.

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