Comparative Evaluation of Fungicidal Efficacy against *Colletotrichum truncatum* Infecting Chilli: *In-Vitro* and Field Perspectives

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Abstract

Anthracnose, caused by *Colletotrichum truncatum*, is a significant threat to chilli (*Capsicum annuum*) cultivation, leading to substantial yield losses. This study evaluates the efficacy of various fungicides in managing anthracnose under both *in-vitro* and field conditions, CoA,V. C. Farm, Mandya, during *kharif* 2023 and 2024. *In-vitro* assays revealed that Azoxystrobin 8.3% + Mancozeb 66.7 % WG and Tebuconazole 25.9 % EC exhibited 100 per cent mycelial growth inhibition across all concentrations tested, outperforming other fungicides. Field trials demonstrated that these systemic fungicides significantly reduced disease severity, with Azoxystrobin + Mancozeb achieving the lowest mean per centdisease index (PDI) of 22.87 per cent in 2023 and 23.15 per cent in 2024. Correspondingly, this treatment yielded the highest dry chilli output of 2132.25 kg/ha in 2023 and 2332.62 kg/ha in 2024, along with the highest benefit-cost (B:C) ratio of 3.26 and 3.16, respectively. Other effective treatments included Tebuconazole 25.9% EC and Chlorothalonil 75% WP, which also significantly suppressed disease progression and enhanced yield. Conversely, contact fungicides like Propineb 70% WP and Mancozeb 75% WP showed lower efficacy, with higher PDIs and reduced yields. The pooled data from both years confirmed that systemic fungicides, particularly Azoxystrobin + Mancozeb, were most effective in controlling anthracnose, improving yield and offering the best economic returns. These findings underscore the importance of integrating systemic fungicides into disease management strategies to mitigate the impact of anthracnose on chilli production.

Keywords : Anthracnose, Fungicides, Yield, B:C ratio, PDI, Chilli

Chilli peppers (*Capsicum* spp.) are among the most important horticultural crops worldwide, valued for their nutritional richness, economic importance and pharmaceutical potential (Sudre *et al*., 2010; Kavyashri *et al.,* 2018 and Rajendran & Thomas, 2021). Originating from the tropical regions of Central and South America, the genus *Capsicum* comprises around 38 species (Kalwij, 2012 and DeWitt & Bosland, 2009).

Among the various factors limiting chilli production, biotic stresses play a particularly detrimental role (Sahitya *et al*., 2014). Among these, anthracnose disease-primarily incited by species belonging to the genus *Colletotrichum*-is recognized as one of the most destructive threats, severely affecting yield and post-harvest fruit quality (Pakdeevaraporn *et al.,* 2005). The disease poses a major management challenge due to its complex etiology involving multiple *Colletotrichum* species that differ in virulence, pathogenicity and host range (Thines *et al.,* 2006). Among them, *Colletotrichum capsici* (syn. *C. truncatum*) is considered the most wide spread and virulent species associated with anthracnose in *Capsicum* (Than *et al*., 2008; Mongkolporn *et al.,* 2010 and Park *et al*., 2012).

In India, anthracnose poses a significant constraint in both open-field and protected cultivation systems, particularly during the rainy season, resulting in an estimated 20-50 per cent reduction in fruit yield across key chilli-producing states, including Andhra Pradesh, Karnataka, Tamil Nadu and Maharashtra (Garg *et al.,* 2014). The disease results in severe fruit rot and surface blemishes, significantly diminishing both yield and fruit quality, thereby posing a substantial challenge to chilli growers and the spice industry. The characteristic sunken, necrotic lesions on fruits greatly reduce market acceptability and also threaten global chilli production and trade (Dean *et al.,* 2012 and Diao *et al*., 2017). Anthracnose and fruit rot of chilli, primarily incited by *Colletotrichum* spp. (Than *et al.*, 2008).

Members of the *Colletotrichum* genus are hemi-biotrophic fungi that employ a two-phase infection strategy in their host plants, including *Capsicum* spp. (Bailey & Jeger, 1992; Gan *et al*., 2013; Thines *et al.,* 2006 and Alkan *et al*., 2015). Anthracnose infection can affect the crop from early growth stages through harvest (Agrios, 2005 and Saxena *et al.,* 2016). Characteristic symptoms include small, sunken, necrotic lesions on leaves, stems and most critically, on mature fruits, where pre- and post-harvest infections drastically reduce market value and yield (Saxena *et al*., 2016). In severe cases, infection can also extend to seeds during storage, further compounding losses (Bansal & Grover, 1969 and Sumayya *et al.,* 2025).

The frequent breakdown of host resistance in a limited number of anthracnose-resistant chilli varieties has necessitated reliance on chemical control as the most practical and effective strategy for disease management under field conditions. The recurrent emergence of new virulent strains of *C. truncatum* often renders resistant cultivars ineffective, emphasising the importance of integrated chemical approaches. In this context, the application of fungicides remains a key component in reducing disease incidence and protecting crop yield. Furthermore, the use of resistance-inducing compounds has gained scientific attention as an alternative or complementary strategy, as these chemicals can stimulate the plant's innate defence mechanisms, providing broad-spectrum and durable resistance. However, due to the pathogen's high adaptability, the prolonged and indiscriminate use of specific fungicides frequently leads to the evolution of resistant fungal populations, thereby compromising their long-term efficacy.

Therefore, continuous evaluation and comparative screening of fungicides against *C. truncatum* are essential to determine their present effectiveness, monitor possible shifts in pathogen sensitivity and identify new chemical molecules or combinations with enhanced efficiency. Such studies not only assist in developing sustainable and site-specific management strategies but also contribute valuable insights for integrated disease management programs in chilli cultivation (Than *et al.,* 2008). In this context, the present study aims to Comparative evaluation of fungicidal efficacy against *Colletotrichum truncatum* infecting chilli: *in vitro* and field perspectives.

Material and Methods

Chemical Management of Anthracnose of Chilli

In-vitro Assay of Chemicals Against a Pathogen by the Poison Food Technique

In-vitro efficacy of different fungicides (Table 1) against anthracnose was studied by the Poisoned food technique under laboratory conditions at different concentration *viz.,* 10, 50, 100, 250 and 500 ppm. The required quantities of each test chemical were added to a conical flask containing 100ml of melted PDA medium so as to get the required concentration. The flask containing the poisoned medium was well shaken to facilitate a uniform mixture of chemicals and 20ml of medium was poured into sterilized Petri plates. Then the plates were inoculated with a mycelial disc and incubated at 28-29 ^{0}C and radial growth was taken when maximum growth was observed in the control plate.

TABLE 1

List of fungicides used to study its efficacy *In-vitro* against the pathogen

Common name	Trade name
Thiophanate methyl 70% WP	Roko
Propineb 70% WP	Antracol
Tebuconazole 25.9% EC	Folicur
Mancozeb 75% WP	Indofil M-45
Chlorothalonil 75% WP	Kavach
Fluopyram 17.7% + Tebuconazole 17.7% SC	Luna Experience
Carbendazim 12% + Mancozeb 63% WP	Saaf
Tebuconazole 50% + Trifloxystrobin 25% WG	Nativo
Azoxystrobin 8.3% + Mancozeb 66.7% WG	Equation Pro
Metiram55%+Pyraclostrobin5%WG	Cabrio Top

The efficacy of chemicals was expressed as per cent inhibition of radial growth over the control, which was calculated by using the Vincent (1947) formula.

$I = C - T / C \times 100$

Where;

I = Per cent inhibition,

C = Radial growth of fungus in control,

T = Radial growth of fungus in treatment

Chemical Management of Chilli Anthracnose under Field Conditions

The field experiment was conducted for two seasons during *kharif* 2023 and 2024 at the College of Agriculture, V.C. Farm, Mandya to evaluate the efficacy of fungicides against anthracnose disease. The 30-day-old seedlings were planted in a Randomized Complete Block Design with 11 treatments, including an untreated plot and three replications (Table 2) with a spacing 60 x 45cm, between rows and plants, respectively. For each replication, a plot size of 4.00 x 3.00m was maintained. Application of fertilizer and other cultural practices was followed as per the University packages of practices (Anonmous., 2022), except for plant protection.

TABLE 2

Treatment details of fungicides used in the management of chilli anthracnose disease, *Kharif* 2023 and 2024

Treatments	Chemicals	Dosage
T1	Thiophanate methyl 70% WP	1g/lt
T2	Propineb 70% WP	3g/lt
T3	Tebuconazole 25.9% EC	1ml/lt
T4	Mancozeb 75% WP	2g/lt
T5	Chlorothalonil 75% WP	2g/lt
T6	Fluopyram 17.7% + Tebuconazole 17.7% SC	1ml/lt
T7	Carbendazim 12% + Mancozeb 63% WP	2g/lt
T8	Tebuconazole 50% + Trifloxystrobin 25% WG	1g/lt
T9	Azoxystrobin 8.3% + Mancozeb 66.7% WG	3g/lt
T10	Metiram55% + Pyraclostrobin5%WG	1g/lt
T11	Control	

Chilli Nursery

The seedlings for the experiment were raised before transplanting in the nursery from the popular and susceptible hybrid of chilli SVHA 8913 seeds (Bayer Seeds Pvt Ltd.). The seedlings were sown in the fourth week of September 2023 and the first week of August 2024 during *kharif*. For raising seedlings the protrays were filled with sterilized cocopeat having 6.6 pH. The seeds were treated with 0.1 per cent carbendazim prior to sowing to control the seed-borne diseases. The seeds were placed in a cavity at a depth of around 1 cm and covered with the cocopeat. The protrays were then watered and staked in an upright position and were covered with polythene paper for 5 days for uniform germination. After initiation of germination, the polythene paper was removed and the trays were arranged in a single layer on weed mat in 50 per cent shade net house. Need based light irrigation was given as per requirement for maintaining optimum moisture level in the protray. After the production of two true leaves the water-soluble fertilizer 19:19:19 was drenched @ 5g per litre along with irrigation water. The drenching of mancozeb @ 3g per litre was done at 10 and 20 days after germination for controlling the damping off disease in growing seedlings. After 30 days from sowing (15 to 20 cm height with 4 to 5 healthy leaves), the seedlings were transplanted into the main field. Before transplanting, seedlings were hardened for 4 to 5 days under open sun with delayed irrigation to impart stress.

Preparation of the Main Field and Transplanting

The main field was prepared by one deep ploughing followed by harrowing, so that the soil of the plot could become loose and friable. The well-decomposed farm yard manure was added @ 15 t per ha before the last harrowing. The ridges and furrows were prepared at a distance of 45 cm during the *kharif* season. The flat beds were prepared for transplanting the seedlings. The spot application of the recommended dose of chemical fertilizer (150 kg N, 50 kg P and 50 kg K per ha) was given. The main field was irrigated on the previous evening of transplanting. The selected healthy seedlings were transferred from the protray to the main field in the evening to minimize the mortality. After transplanting, immediate irrigation was given. Regular irrigation was given to maintain optimum soil moisture in the field. Gap filling was done one week after transplanting to maintain the optimum plant population in the field.

The entire quantity of FYM along with 50 kg N and a full dose of phosphorus and potash was applied as a basal dose before transplanting, whereas a remaining dose of N was given in two equal splits of 50 kg each at 30 and 60 days after transplanting, along with earthing up. Drenching and spraying of 19:19:19 @ 10g per litre was also given at weekly intervals up to 60 days from planting. Various intercultural operations *viz.*, weeding and earthing up were carried out two to three times during every season depending upon the intensity of the weeds. The plot was kept weed-free especially till the initial 60 days after transplanting.

Assessment of Disease

Four sprays of fungicides were given to the experimental plot during the cropping season. The first spray was given immediately after the onset of the disease and the remaining three sprays was given at 20-day intervals (60, 80, 100 and 120 DAT). Observation on the per cent disease index (PDI) was recorded using a 0-9 scale given by Mayee and Datar (1986) and the yield in kg/ha of treatments was recorded during the two seasons of *kharif.* Five plants were tagged randomly for each treatment and severity was scored as the physiological maturity stage.

Disease rating based on their Percent Disease Index (PDI) values

Scale	Description
0	No symptoms on the leaf or branch or fruit
1	1-10% or less infection of leaf or branch or fruit
3	11-25% infection on the leaf or branch or fruit
5	26-50% infection of leaf or branch or fruit
7	51-75% infection of leaf or branch or fruit
9	75% and above infection area of leaf or branch or fruit

Fruit Yield and Cost Economics

Treatment dry chilli fruit yield (kg/plot) from different pickings, including untreated control, was pooled to record the total plot yield, extrapolated to a hectare basis and subjected to statistical analysis. The cost economics of each treatment was worked out as per market price, labour wages and additional cost during the course of the study and the benefit-cost ratio was calculated.

Results and Discussion

In-vitro* Evaluation of Fungicides Against *C.truncatum

The *in vitro* evaluation of ten fungicides, each tested at five concentrations (10, 50, 100, 250 and 500 ppm), exhibited significant variation in the inhibition of mycelial growth of *C.truncatum* (Table 3, Plate 1 and Fig. 1). Among the treatments, Azoxystrobin 8.3% +

TABLE 3

In vitro* evaluation of fungicides against *C.truncatum

Fungicides	Concentration (ppm) 10	50	100	250	500	Mean growth inhibition (%)
Thiophanate methyl 70% WP	39.62 (39.01) *	79.62 (63.17)	98.44 (83.36)	100.00 (90.00)	100.00 (90.00)	85.53 (71.70)
Propineb 70% WP	61.11 (51.41)	72.22 (58.19)	85.93 (67.97)	95.15 (78.35)	100.00 (90.00)	82.88 (70.25)
Tebuconazole 25.9% EC	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)
Mancozeb 75% WP	52.04 (46.17)	80.74 (63.98)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	86.55 (73.37)
Chlorothalonil 75% WP	77.04 (61.34)	82.59 (63.34)	92.22 (73.81)	94.44 (76.36)	100.00 (90.00)	89.25 (73.37)
Fluopyram 17.7% + 17.7% SC Tebuconazole	76.66 (61.12)	84.07 (66.48)	87.41 (69.21)	80.94 (97.41)	100.00 (90.00)	89.11 (73.55)
Carbendazim 12% + Mancozeb 63%	61.11 (51.41)	72.22 (58.19)	87.41 (69.27)	98.15 (82.35)	100.00 (90.00)	83.77 (70.25)
Tebuconazole 50% + Trifloxystrobin 25% WG	60.74 (51.20)	82.22 (65.06)	85.93 (67.97)	93.00 (74.57)	100.00 (90.00)	84.77 (71.16)
Azoxystrobin 8.3% + Mancozeb 66.7% WG	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)
Metiram 55% + Pyraclostrobin 5% WG	64.44 (53.39)	84.81 (67.06)	87.40 (69.20)	100.00 (90.00)	100.00 (90.00)	87.33 (73.93)
ConcentrationMean (%)	61.80 (53.42)	74.71 (61.59)	81.27 (67.83)	89.09 (77.38)	90.90 (81.81)	87.33 (75.25)

	Fungicide (F)	Conc. (C)	F x C
SE m ±	0.55	0.37	1.23
C.D @1%	1.44	0.97	3.22

Mancozeb 66.7% WG and Tebuconazole 25.9% EC emerged as the most potent fungicides, achieving 100 per cent mean inhibition of mycelial growth and proving significantly superior to all other treatments. These were followed by Chlorothalonil 75% WP, which recorded 89.25 per cent mean inhibition. In contrast, Propineb 70% WP exhibited the lowest efficacy, with 82.55 per cent mean inhibition. A progressive increase in mycelial inhibition was observed with rising fungicide concentration, indicating a concentration-dependent response of *C. truncatum* to the tested fungicides.

Analysis of the interaction effects between fungicides and concentrations (F × C) revealed that Azoxystrobin 8.3% + Mancozeb 66.7% WG and Tebuconazole 25.9% EC consistently achieved complete (100%) inhibition of mycelial growth across all tested concentrations (10–500 ppm), confirming their broad-spectrum efficacy under *in-vitro* conditions. The next most effective treatments were Metiram 55% + Pyraclostrobin 5% WG and Thiophanate methyl 70% WP, which achieved 100 per cent inhibition at 250 ppm and 500 ppm, respectively.

Plate 1 : *In vitro* plate assay depicting radial mycelial growth and growth-inhibition patterns of *Colletotrichum truncatum* under different fungicide treatments and concentration ranges, with untreated PDA plates shown as controls

Statistical analysis further confirmed that fungicide type, concentration and their interaction exerted a highly significant influence on mycelial growth inhibition. The inhibitory effects observed can be attributed to the disruption of essential physiological and biochemical processes within the fungal cells. Fungicides belonging to the strobilurin group, such as azoxystrobin and trifloxystrobin, suppress mitochondrial respiration by inhibiting electron transport at the cytochrome *bc* complex, resulting in reduced ATP synthesis, energy deprivation and eventual cell death. Similarly, triazole fungicides like tebuconazole act by inhibiting the enzyme C14-demethylase, a key catalyst in ergosterol biosynthesis. Since ergosterol is an essential structural component of fungal cell membranes, its depletion leads to membrane destabilisation, leakage of cellular contents and inhibition of fungal growth.

The present findings were supported with the records of Preethi *et al.* (2019) evaluated five fungicides *viz.,* Kasugamycin (Kasu B 3% SL), Pyraclostrobin + Metiram (Cabrio Top 60% WG), Azoxystrobin (Onestar 23% SC), Fusilazole (Cursor

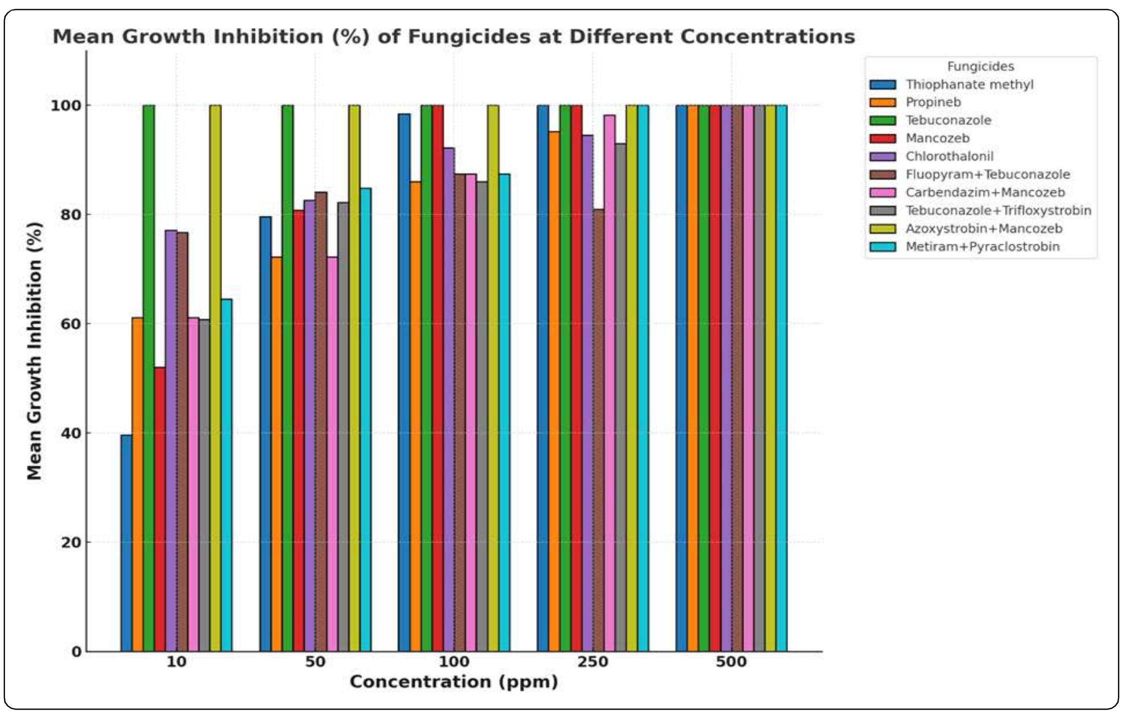


Fig. 1 : Effect of fungicide treatments on anthracnose disease caused by *C. Truncatum* under *in vitro*

40%EC) and Folicur 250 EC (Tebuconazole) against *C. truncatum* by poison food technique. Pyraclostrobin + Metiram was effective in inhibiting mycelia growth of pathogen and found to be superior with per cent inhibition of 84.11 followed by Fusilazole (76.89).

Similarly, Veerendra *et al.* (2018) evaluated six chemicals against *C. capsici* under *in-vitro* conditions by adoption of the poisoned food technique with different concentrations *viz.,* 20, 50, 100, 250, 500 and 1000 µg/ml, respectively. Thiophanate Methyl and Copper Oxychloride were found to be best among the fungicides, inhibiting the mycelial growth at all six concentrations tested. Ahiladevi *et al.* (2014) reported that Azoxystrobin @ 0.12 per cent was very effective in reducing the mycelial growth.

Barhate *et al.* (2012) reported that out of seven fungicides tested, Hexaconazole (0.1 per cent), Mancozeb (0.2 per cent), Carbendazim (0.05 per cent) and Chlorothalonil (0.2 per cent) with 86.66, 85.55, 84.44, 73.33, 68.88 and 65.55 per cent growth inhibition over control, respectively. Misra *et al.* (2008) tested eight fungicides under *in-vitro* conditions and reported that all the *C. capsici* isolates were highly sensitive to Carbendazim (0.2 per cent), Chlorothalonil (0.1 per cent) and Mancozeb, providing more than 50 per cent of inhibition.

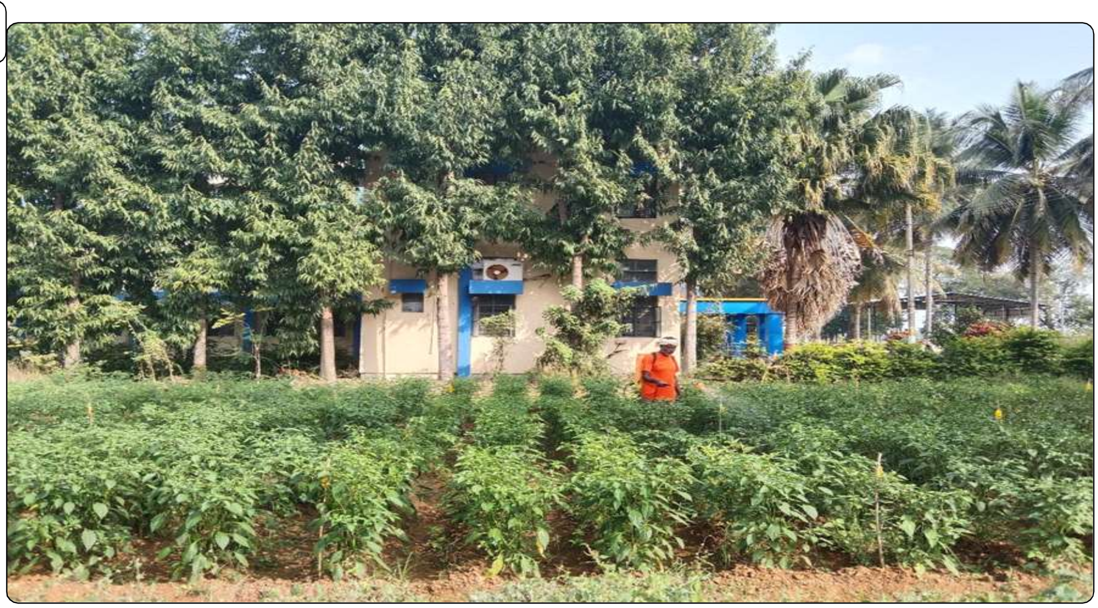
Field Evaluation of Fungicides Against *C. Truncatum*

During *kharif* 2023 and 2024, a field experiment was carried out at College of Agriculture, V.C. Farm, Mandya, Karnataka to evaluate different fungicides for the management of anthracnose of chilli caused by *C. truncatum* (Plate 2).

The field evaluation conducted during *kharif* 2023 and *kharif* 2024 assessed the efficacy of various fungicides in managing anthracnose disease of chilli caused by *C. truncatum*. Data on disease severity and yield parameters were recorded to determine the comparative performance of different treatments. Four foliar applications of fungicides were carried out at 60, 80, 100 and 120 days after inoculation (DAI), following the appearance of initial disease symptoms. For each treatment, five plants were randomly tagged within the net plot to record per cent disease index (PDI) at 10 days after each spray. The results revealed significant differences among fungicidal treatments, with all formulations showing considerable disease suppression compared to the untreated control.

During *Kharif* 2023, the untreated control recorded the highest per cent disease index (PDI) (61.03%), indicating severe disease development under natural epiphytotic conditions (Table 4). Among the fungicidal treatments, Azoxystrobin 8.3% + Mancozeb

A



B

Plate 2 : Experimental plot of the chemical management of chilli against anthracnose disease (A: *Kharif* 2023 and B: *Kharif* 2024)

TABLE 4

Effect of chemical treatments on anthracnose disease severity in chilli under field conditions (*kharif* 2023)

Sl no.	Treatment	Percent disease index (PDI)*							Per cent reduction over control
		Conc.	Before spray	First spray	Second spray	Third spray	Fourths pray	Avg.* PDI	
T1	Thiophanate methyl 70% WP	0.1%	30.51	36.45	37.69	35.3	34.06	34.81	42.97
T2	Propineb 70% WP	0.3%	35.51	41.45	42.69	44.3	46.54	42.10	31.02
T3	Tebuconazole 25.9% EC	0.1%	32.93	23.03	24.27	24.05	22.81	25.42	58.35
T4	Mancozeb 75% WP	0.2%	36.99	36.03	37.27	42.82	44.06	39.44	35.38
T5	Chlorothalonil 75% WP	0.2%	38.76	26.14	27.38	24.97	23.73	28.20	53.8
T6	Fluopyram 17.7% + Tebuconazole 17.7% SC	0.1%	34.28	30.33	31.57	27.47	26.23	29.98	50.88
T7	Carbendazim 12% + Mancozeb 63%	0.2%	39.61	31.18	32.42	29.53	28.29	32.21	47.23
T8	Tebuconazole 50% + Trifloxystrobin 25% WG	0.1%	33.43	39.2	36.96	39.2	40.44	37.85	37.99
T9	Azoxystrobin 8.3% + Mancozeb 66.7% WG	0.3%	28.66	27.59	24.03	18.15	15.91	22.87	62.53
T10	Metiram 55% + Pyraclostrobin 5% WG	0.1%	33.9	32.02	33.26	28.11	26.87	30.84	49.47
T11	Control		22.72	44.79	61.95	85.94	89.75	61.03	0.00
	SE m ±		0.71	1.73	2.06	3.28	2.95		
	C.D @ 5%		2.07	5.11	6.07	9.67	8.71		

66.7% WG was the most effective, with the lowest PDI (22.87) and the highest reduction over control (62.53%). Tebuconazole 25.9% EC also provided high levels of suppression (25.42 PDI; 58.35% reduction). Treatments such as Chlorothalonil 75% WP (28.20 PDI; 53.80% reduction) and Fluopyram 17.7% + Tebuconazole 17.7% SC (29.98 PDI; 50.88% reduction) yielded comparable results. Moderate efficacy was observed with Metiram 55% + Pyraclostrobin 5% WG (30.84% PDI) and Carbendazim + Mancozeb (32.21 PDI). Contact fungicides, namely Mancozeb 75% WP (39.44 PDI) and Propineb 70% WP (42.10 PDI), were the least effective.

Similar trends were recorded during *kharif* 2024 (Table 5), with the untreated control exhibiting the highest PDI (70.35). Azoxystrobin + Mancozeb again proved superior (23.15PDI; 67.10% reduction), followed by Tebuconazole 25.9% EC (26.10 PDI; 62.91% reduction) and Chlorothalonil 75% WP (29.29 PDI; 58.37% reduction). Moderate levels of control were obtained with Fluopyram + Tebuconazole SC (34.28 PDI), Metiram + Pyraclostrobin WG (36.59 PDI) and Carbendazim + Mancozeb (41.55 PDI). The contact fungicides - Thiophanate methyl, Mancozeb and Propineb-recorded higher PDIs but still outperformed the untreated control.

Pooled analysis across two years (Table 6 and Fig. 2) confirmed the consistency of treatment effects. Azoxystrobin + Mancozeb remained the most effective treatment (23.01 PDI; 64.82% reduction over control), followed by Tebuconazole 25.9% EC (25.76 PDI; 60.63% reduction) and Chlorothalonil 75% WP (28.75 PDI; 56.09% reduction). Moderate control was achieved by Fluopyram + Tebuconazole SC and Metiram + Pyraclostrobin WG, whereas Carbendazim + Mancozeb, Thiophanate methyl and Tebuconazole + Trifloxystrobin provided intermediate

TABLE 5

Effect of chemical treatments on anthracnose disease severity in chilli under field conditions (*Kharif* 2024)

Sl no.	Treatment	Percent disease index (PDI)*						Avg.* PDI	Per cent reduction over control
		Conc.	Before spray	First spray	Second spray	Third spray	Fourths pray		
T1	Thiophanate methyl 70% WP	0.1%	30.03	38.02	41.28	43.52	44.75	39.52	43.84
T2	Propineb 70% WP	0.3%	34.02	39.02	44.28	49.52	54.75	44.32	37.02
T3	Tebuconazole 25.9% EC	0.1%	21.03	27.60	29.86	27.62	24.38	26.10	62.91
T4	Mancozeb 75% WP	0.2%	39.45	44.60	41.35	43.59	44.82	42.76	39.23
T5	Chlorothalonil 75% WP	0.2%	24.14	28.71	29.97	31.21	32.44	29.29	58.37
T6	Fluopyram 17.7% + Tebuconazole 17.7% SC	1%	32.33	33.90	34.16	35.40	35.63	34.28	51.28
T7	Carbendazim 12% + Mancozeb 63%	0.2%	29.18	38.77	42.03	46.27	51.50	41.55	40.95
T8	Tebuconazole 50% + Trifloxystrobin 25% WG	0.1%	35.72	37.75	36.5	39.74	40.97	38.14	45.80
T9	Azoxystrobin 8.3% + Mancozeb 66.7% WG	0.3%	24.59	29.16	23.91	20.67	17.44	23.15	67.10
T10	Metiram 55% + Pyraclostrobin 5% WG	0.1%	30.62	36.59	35.34	38.58	41.81	36.59	48.00
T11	Control		38.21	55.65	77.67	89.01	91.22	70.35	0.00
	SE m ±		0.71	1.73	2.06	3.28	2.95		
	C.D @5%		2.07	5.11	6.07	9.67	8.71		

TABLE 6

Effect of chemical treatments on anthracnose disease severity in chilli under field conditions (Pooled *Kharif* 2023 and 2024)

Sl no.	Treatment	Percent disease index (PDI)*						Avg.* PDI	Per cent reduction over control
		Conc.	Before spray	First spray	Second spray	Third spray	Fourths pray		
T1	Thiophanate methyl 70% WP	0.1%	30.27	37.24	39.49	39.41	39.41	37.17	43.41
T2	Propineb 70% WP	0.3%	34.77	40.24	43.49	46.91	50.65	43.21	34.02
T3	Tebuconazole 25.9% EC	0.1%	26.98	25.32	27.07	25.84	23.6	25.76	60.63
T4	Mancozeb 75% WP	0.2%	38.22	40.32	39.31	43.21	44.44	41.1	37.31
T5	Chlorothalonil 75% WP	0.2%	31.45	27.43	28.68	28.09	28.09	28.75	56.09
T6	Fluopyram 17.7% + Tebuconazole 17.7% SC	0.1%	33.31	32.12	32.87	31.44	30.93	32.13	51.08
T7	Carbendazim 12% + Mancozeb 63%	0.2%	34.4	34.98	37.23	37.90	39.90	36.88	44.09
T8	Tebuconazole 50% + Trifloxystrobin 25% WG	0.1%	34.58	38.48	36.73	39.47	40.71	38.00	41.90
T9	Azoxystrobin 8.3% + Mancozeb 66.7% WG	0.3%	26.63	28.38	23.97	19.41	16.68	23.01	64.82
T10	Metiram 55% + Pyraclostrobin 5% WG	0.1%	32.26	34.31	34.3	33.35	34.34	33.72	48.74
T11	Control		30.47	50.22	69.81	87.97	89.88	68.95	0.00
	SE m ±		0.71	1.73	2.06	3.28	2.95		
	C.D @5%		2.07	5.11	6.07	9.67	8.71		

*Are arc sine transformed values

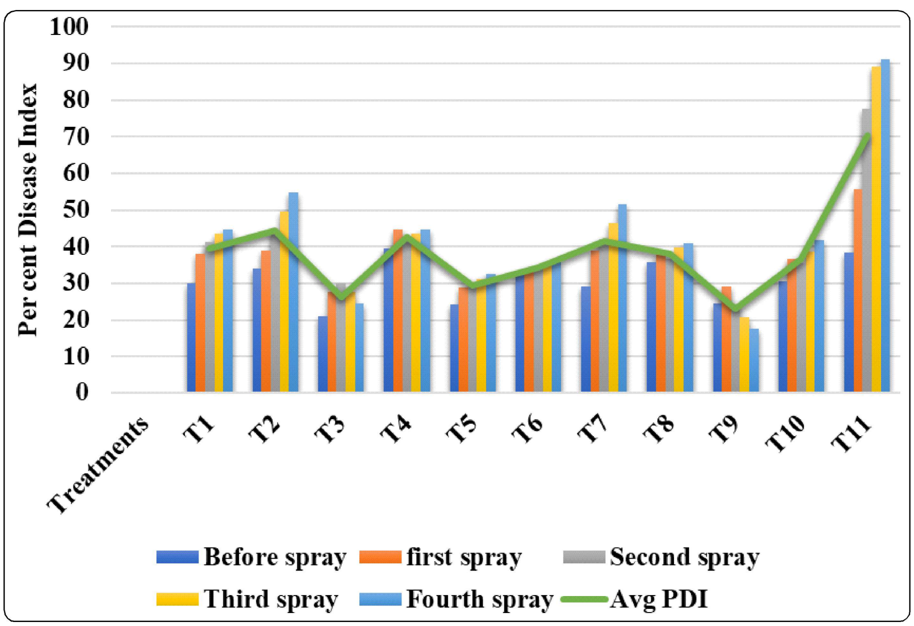


Fig. 2 : Percent disease index (PDI) of chilli anthracnose at different spray intervals under various fungicidal treatments (Pooled *kharif* 2023-24)

levels of suppression. Mancozeb and Propineb consistently recorded the lowest efficacy among the treatments evaluated. Across both seasons, all fungicidal treatments significantly reduced disease severity compared with the untreated control, demonstrating their effectiveness under field conditions. The superior performance of Azoxystrobin + Mancozeb may be attributed to the dual action of azoxystrobin, a systemic QoI fungicide that inhibits mitochondrial respiration and mancozeb, a multi-site protectant that prevents pathogen establishment. This combination offers both protective and curative activity, explaining its consistent high efficacy. Tebuconazole 25.9% EC also performed reliably, likely due to its systemic action on ergosterol biosynthesis, resulting in disrupted fungal cell membrane formation. Chlorothalonil, with its broad-spectrum multi-site protective activity, provided dependable control under varying environmental conditions.

The combination fungicides Fluopyram + Tebuconazole, Metiram + Pyraclostrobin and Carbendazim + Mancozeb demonstrated moderate performance, reflecting their mix of systemic and protective modes of action. However, environmental factors or inherent formulation characteristics may have influenced their relative efficacy. Contact fungicides such as Mancozeb, Propineb and Thiophanate methyl consistently performed at a lower level, which aligns with their non-systemic, protective nature and limited curative potential.

These findings are in agreement with earlier reports by Jain *et al.* (2016) evaluated the fungicides under field conditions. Triazole fungicides tebuconazole, hexaconazole, myclobutanil and chloronitrile fungicide chlorthalonil were effective in descending order against anthracnose disease for two consecutive seasons. Similarly, Subedi *et al.* (2015) and Anand *et al.* (2020).

Significant differences were observed among the fungicidal treatments for anthracnose severity and dry chilli yield during *kharif* 2023 and 2024. In *kharif* 2023 (Table 7), the untreated control (T11) exhibited

TABLE 7

Effect of chemical treatments against anthracnose disease on dry chilli yield during *Kharif* 2023

Treatment	Mean PDI	Dry chilli (Kg/ha)	B:C ratio
T_1	34.81	764.86	1.25
T_2	42.10	625.69	1.20
T_3	25.42	1782.57	2.88
T_4	39.44	967.16	1.77
T_5	28.20	1436.99	2.78
T_6	29.98	1362.23	2.69
T_7	32.21	553.60	1.28
T_8	37.85	916.45	1.72
T_9	22.87	2132.25	3.26
T_{10}	30.84	1149.23	2.15
T_{11}	61.03	290.16	1.25
SE m ±		17.22	
C.D @5%		50.79	

the highest PDI (61.03), accompanied by the lowest yield (290.16 kg/ha) and a poor B:C ratio (1.25), confirming the heavy yield losses under unmanaged conditions. Among the fungicides, Azoxystrobin 8.3% + Mancozeb 66.7% WG (T9) consistently performed best, recording the lowest PDI (22.87), highest yield (2132.25 kg/ha) and maximum B:C ratio (3.26). Tebuconazole 25.9% EC (T3) and Chlorothalonil 75% WP (T5) were the next most effective treatments, with moderate disease suppression and improved yields. Fluopyram + Tebuconazole (T6) also showed satisfactory control. The overall trend indicates that systemic triazole- and strobilurin-based fungicides provide superior protection against anthracnose, resulting in higher productivity and economic returnscomparedto contact fungicides.

Moderate effectiveness was observed with Metiram + Pyraclostrobin (T10) (30.84PDI; 1149.23 kg/ha; B:C 2.15), while Mancozeb (T4) and Tebuconazole + Trifloxystrobin (T8) showed intermediate control (yield: 916-967 kg/ha; B:C: 1.72-1.77). In contrast, Thiophanate methyl (T1), Propineb (T2), and Carbendazim + Mancozeb (T7) were least effective, producing higher PDI (32.21-42.10) and lower yields (553–765 kg/ha) with poor B:C ratios (1.20-1.28).

A similar trend was recorded during *kharif* 2024 (Table 8). Azoxystrobin + Mancozeb (T9) again proved superior, showing 23.15 per cent PDI, 2332.62 kg/ha yield and the highest B:C ratio (3.16), followed by Tebuconazole 25.9% EC (T3) (26.10 PDI; 1565.88 kg/ha; B:C 2.78) and Chlorothalonil 75% WP (T5) (29.29 PDI; 1320.16 kg/ha; B:C 2.56). Fluopyram + Tebuconazole (T6)

Table 8

Effect of chemical treatments against anthracnose disease on dry chilli yield during *Kharif* 2024

Treatment	Mean PDI	Dry chilli (Kg/ha)	B:C ratio
T_1	39.52	548.08	1.23
T_2	44.32	498.86	1.21
T_3	26.10	1565.88	2.78
T_4	42.76	850.38	1.93
T_5	29.29	1320.16	2.56
T_6	34.28	1245.48	2.46
T_7	41.55	548.08	1.27
T_8	38.14	699.68	1.71
T_9	23.15	2332.62	3.16
T_{10}	36.59	1032.48	2.05
T_{11}	70.35	226.68	1.21
SE m ±		13.51	
C.D @5%		39.84	

Table 9

Effect of chemical treatments against anthracnose disease on dry chilli yield during the *Kharif* 2023 and 2024 (pooled data)

Treatment	Mean PDI	Dry chilli (Kg/ha)	B:C ratio
T_1	37.17	656.47	1.23
T_2	43.21	562.27	1.21
T_3	25.76	1674.22	2.83
T_4	41.1	908.77	1.85
T_5	28.75	1378.57	2.67
T_6	32.13	1303.85	2.58
T_7	36.88	550.84	1.28
T_8	38	808.07	1.72
T_9	23.01	2237.44	3.21
T_{10}	33.72	1090.86	2.10
T_{11}	68.95	257.92	1.23
SE m ±		15.37	
C.D @5%		45.32	

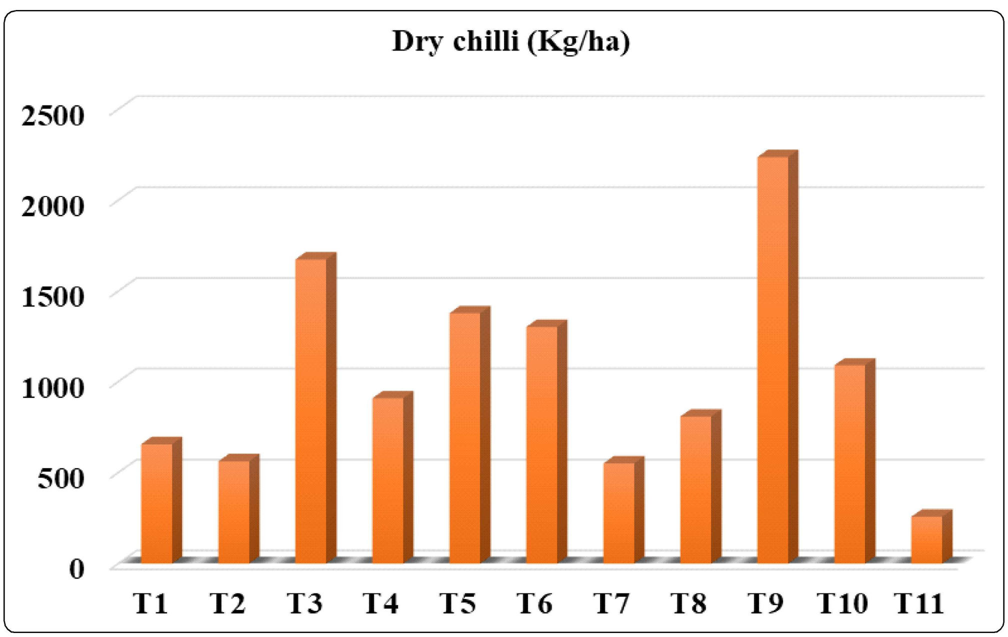


Fig. 3 : The figure depicts the variation in dry chilli yield among eleven fungicidal treatments (T1–T11)

and Metiram + Pyraclostrobin (T10) showed moderate efficacy, whereas Thiophanate methyl (T1), Carbendazim + Mancozeb (T7) and Propineb (T2) remained least effective (39.52-44.32 PDI; 498.86-548.08 kg/ha; B:C 1.21-1.27).

Pooled data across both seasons (Table 9 and Fig. 3) confirmed consistent treatment effects. Azoxystrobin + Mancozeb (T9) maintained the lowest mean PDI (23.01) and the highest yield (2237.44 kg/ha) with the greatest B:C ratio (3.21), while the untreated control (T11) showed the highest PDI (68.95), lowest yield (257.92 kg/ha) and poorest B:C ratio (1.23). A clear negative relationship was evident between disease incidence and yield, emphasizing the importance of effective anthracnose management. Pandey and Gupta (2015) reported that highest total yields (1947.95 g $plot^{-1}$) as well as healthy red chilli fruits (1286.66 g $plot^{-1}$) were recorded in foliar sprays with mancozeb @ 0.3 % followed by azoxystrobin @ 0.1 % (1125.00 g $plot^{-1}$) and lowest yield in control (550 g $plot^{-1}$).

The study established that Azoxystrobin 8.3% + Mancozeb 66.7% WG and Tebuconazole 25.9% EC were the most effective fungicides against *C. truncatum*, providing complete mycelial inhibition *in vitro* and the lowest disease severity under field conditions. These treatments also resulted in the highest yield and B:C ratio, confirming their superior efficacy and economic viability. Strobilurin and triazole-based fungicides proved significantly more effective than contact fungicides. Integrating these systemic fungicides into management programs can ensure effective, sustainable control of chilli anthracnose.

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