J.Mycopathol.Res. 63(3) : 621-629, 2025, ISSN : 0971-3719 (Print), 2583-6315 (Online) 10.57023/JMycR.63.3.2025.621

Field management of Anthracnose disease of chilli caused by *Colletotrichum capsici*

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Received : 11.03.2025 Accepted : 25.07.2025 Published : 29.09.2025

The sustainability of chilli-based agriculture is menaced by anthracnose and die-back incited by *Colletotrichum capsici* is one of the major threats. Therefore, for the sustainable management the main focus was on identification of fungicide compatible potential biocontrol agent against *C. capsici* to develop effective management strategies. Five fungicides (Carbendazim @ 0.1%, Propiconazole @ 0.1%, Hexaconazole @ 0.1%, Azoxystrobin @ 0.1%, and Copper oxychloride @ 0.3%) and five biocontrol agents *Trichoderma* spp. *viz. T. harzianum*, *T. afroharzianum*, *T. asperellum* (1), *Trichoderma asperellum* (2) and *Trichoderma* sp. 1 were evaluated under *in vitro* conditions. The results indicated that among the five fungicides evaluated, Carbendazim, Propiconazole, Hexaconazole and Azoxystrobin were the most effective against *C. capsici* with 100% inhibition and least inhibition recorded at Copper oxychloride (76.40%). All the five *Trichoderma* spp. were significantly inhibited the mycelial growth of the pathogen with maximum inhibition being shown by *T. harzianum* (77.39%). For the compatibility study, four potential fungicides were tested with *T. harzianum*. Among the four fungicides tested, Azoxystrobin @ 0.1% was found the most compatible with *T. harzianum*. Field experiment was also conducted with seven different treatments and found that T_6 *i.e.* seedlings dipped with *T. harzianum* before transplanting and followed by foliar spray with Azoxystrobin @ 0.1% recorded the least fruit rot incidence (20.83%) of chilli with maximum fruit yield. Therefore, these studies revealed that the potential biocontrol agent, *T. harzianum* was highly compatible with Azoxystrobin which can be exploited for field evaluation.

Keywords : Azoxystrobin, chilli, *Colletotrichum capsici*, *Trichoderma harzianum*,

INTRODUCTION

Chilli (*Capsicum annum* L.) is considered to be one of the most important spice crops in India, which belongs to Solanaceae family. Since prehistoric times it was known to the peoples of Peru (Kanuajia *et al*. 2017). Chilli is a necessary spice of every Indian household and used in many ways such as spices, condiments, vegetables, sauce, pickles and chutney for culinary purpose (Patel *et al*. 2015). Chillies are good resource for vitamins like A, B and C. Chilli contains more amount of vitamin C compared to Orange.

It also contains minerals like Ca, P, Fe, Na, Cu and steam volatile oils, carotenoids, fatty oils etc. (Kareem *et al.* 2016). In India during 2020-2021 the annual chilli production is 19.14 lakh tonnes and productivity is 2576 kg per ha under the area 7.43 lakh ha. The recent data (2020-2021) shows that Andhra Pradesh is the leading chilli producing state in India. In Nagaland state, the area, production and productivity of green chillies is estimated 5.82 thousand hectares, 41.90 thousand tonnes and 7.20 tonnes/hectare respectively whereas for dry chillies, 0.80 thousand hectares, 1.00 thousand tonnes and 1.25 tonnes per hectare respectively (Anon, 2015).

Chilli is highly prone to several fungal diseases and among them; anthracnose disease caused by *Colletotrichum capsici* (Syd.) is considered a limiting factor in their production in India and worldwide, causing heavy crop and economic losses. In India, three most important species of *Colletotrichum* such as *C. capsici*, *C. acutatum* and *C. gleosporoides* were identified as

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pathogens causing chilli anthracnose. *C. capsici* is the major pathogen that damage at the ripe fruit stage of the plant (Saxena *et al*., 2014) and it is a highly destructive pathogen that attacks chilli and causing major crop losses (Saxena *et al*. 2016**).** As of 2022**,** the anthracnose disease is reported to cause 10–54 % reduction in crop yield in India (Suarthi *et al*. 2022). Synthetic fungicides have been efficient in controlling plant pathogenic fungi. However, their prolonged usage over decades has altered natural biological systems, occasionally leading to the development of fungal resistance. They have harmed non-target creatures, raising environmental and human health issues. Furthermore, the creation of eco-friendly formulations of antifungal plant-derived chemicals seeks to reduce the environmental effect and ensure sustainable disease management techniques in chilli agriculture **(**Srivastava *et al*. 2022). As a result, alternative crop protection strategies have emerged. So, looking to the economic importance of chilli and anthracnose disease, an investigation on evaluation of most effective fungicides compatible potential *Trichoderma* spp. against *C. capsici* was identified in order to develop an effective management strategy.

MATERIALS AND METHODS

Isolation and maintenance of pathogen

These studies were carried out in the Department of Plant Pathology, Nagaland University, SASRD, Medziphema campus, Nagaland. The isolation of the pathogen was done using standard tissue isolation technique. The pathogen was identified based on its mycelial,conidial characteristics following standard mycological keys (Barnett and Hunter, 1972). After identification of the pathogen, sub-cultured PDA slants, incubated at 25±2°C were used in further efficacy studies.

In vitro evaluation of fungicides against Colletotrichum capsici

Five selected fungicides viz., Propiconazole, Hexaconazole, Copper oxychloride, Carbendazim and Azoxystrobin were evaluated under *in vitro* condition, by Poisoned food technique (Nene and Thapliyal, 1993) against *Colletotrichum capsici* to select the most promising fungicides. The potato dextrose agar media was prepared, and autoclaved for 15 mins at 121˚C. The required quantity of each fungicide or chemical was incorporated into 60 ml sterilized PDA and these were pored into Petriplates of 90 mm dia . These petriplates were inoculated at the center with a 5 mm fungal disc from seven days old culture of the pathogen. Control (without chemicals) was maintained for comparison. The petriplates were incubated at 25±2°C. The radial growth of the pathogen was recorded, and the percent inhibition was calculated. Records were taken after 24 hours of incubation. The percent inhibition of the test pathogen over control was calculated using the following formula (Vincent 1947) as follows,

$$\text{Percent Inhibition} = \frac{C-T}{C} \times 100$$

Where, C = Radial growth of pathogen in control plate

T = Radial growth of pathogen in experimental plate

In vitro evaluation of biocontrol agents against Colletotrichum capsici

The fungal biocontrol agents used in the present investigation, *viz*. *T. harzianum, Trichoderma afroharzianum, T. asperellum* 1*, Trichoderma asperellum* 2 and *Trichoderma* sp. 1 were obtained from the Department of Plant Pathology, Nagaland University, SASRD, Medziphema Campus. The antagonistic activity of biocontrol agents against *C. capsici* was determined by using dual culture technique under *in vitro* (Hamzah *et al.* 2018). The Petri plates containing culture were then incubated at 28±2°C with three replications and suitable control. The Per cent inhibition was calculated by using the formula of Vincent (1947).

$$\text{Percent Inhibition} = \frac{C-T}{C} \times 100$$

Where, C = Radial growth of pathogen in control plate

T = Radial growth of pathogen in experimental plate

Compatibility test of T harzianum and fungicides

The compatibility of the most effective biocontrol agent, *T. harzianum* and four most effective fungicides were tested by poisoned food technique (Nene and Thapliyal, 1993). The biocontrol agent was allowed to grow on the medium poisoned with fungicides. Observations were recorded on radial growth and sporulation of the test pathogen and percent growth inhibition of the pathogen over control was calculated by the formula of Vincent (1947).

Integrated management of chilli anthracnose under field condition

In this experiment, susceptible chilli variety Pusa jwala were sown for two consecutive years (2018- 2020) in the field. The experiments were carried out in Randomized Block Design (RBD) with three replications . Different treatments were evaluated in the field.

Seedling treatment

A suspension containing 5 g of *T. harzianum* formulation in 500 ml of water was prepared. The chilli seedlings of 25-30 days old were treated by dipping the roots in the suspension for 15 mins and then shade dried for 15 mins before transplanting. Similarly, chilli seedlings of 25-30 days old were treated by dipping the roots in the required dose of fungicide (Thakur and Tripathi, 2015).

Foliar spray

Talc-based formulation of *T. harzianum* @ 5g/ 500ml water and fungicide at recommended dose were sprayed starting from 55 DAT at 2 times at an interval of 15 days. The percent disease severity on leaves or fruits was recorded by using 0-5 scale (Jeyalakshmi and Seetharaman, 1998) where 0- no disease, 1- up to 5%, 2- 5 to 10%, 3- 10 to 25 %, 4- 25 to 50 % and 5- above 50%. The percent disease index was calculated by using following formula.

$$PDI = \frac{\text{Sum of all Numerical rating}}{\text{No. of plants observed x Maximum rating}} \times 100$$

RESULTS AND DISCUSSION

The results from all the observations were analyzed statistically to assess the efficiency of different treatments applied. The findings thus obtained were discussed under the following heads with appropriate tables, figure and plates wherever necessary.

Isolation and identification of pathogen

The test pathogen was isolated and obtained from naturally infected chilli fruits showing symptoms of the disease. The pure colonies which developed from the infected fruit were used to identify the pathogen based on microscopic observation by taking the mycelial and conidial characters as means of identification. The test pathogen was identified as *Colletotrichum capsici* based on the morphological characteristics. Under microscopic observation, it was found that the pathogen showed conidiophores (either septate or aseptate) of hyaline to faintly brown, cylindrical in shape and producing a single celled hyaline conidia having a shaped of falcate, fusiform with a central oil globule. The setae were observed to be dark brown in colour which is paler at the apex, rigid and tapering towards the apex. The colour of the isolate in PDA medium was observed to be light grey to dark in colour.

Based on the mention characteristic features (Fig.1), the identification of the isolated pathogen was confirmed as the fungus *Colletotrichum capsici* (Syd.). Present findings were in conformity with the findings of Desai and Prasad (1955), Sutton (1973), and Kulshrestha *et al.* (1976). This was also in accordance with the description of Ahmed (1982) and Singh (1995).

In vitro evaluation of fungicides against Colletotrichum capsici

As given in Table 1 and Fig. 2, the observations obtained indicate that among the five fungicides evaluated, Azoxystrobin (0.1 %), Carbendazim (0.1 %), Propiconazole (0.1 %), Hexaconazole (0.1%), were found to be the most effective against *Colletotrichum capsici* with 100 per cent inhibition at their respective concentration. Whereas Copper oxychloride @ 0.3 % were

Table 1 : Efficacy of fungicides on per cent inhibition of *Colletotrichum capsici*

	Treatment	Concentration used (%)	Per cent inhibition				
			24 hours PI	48 hours PI	72 hours PI	96 hours PI	MEAN
T_1	Carbendazim 50% WP	0.1	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100
T_2	Copper oxychloride 50 %WP	0.3	73.32 (58.90)	71.91 (58.00)	77.89 (61.95)	82.50 (65.27)	76.40
T_3	Hexaconazole 25% EC	0.1	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100
T_4	Propiconazole 25% EC	0.1	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100
T_5	Azoxystrobin 23% SC	0.1	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100
T_0	Control		0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0
	SEm±		0.14	0.28	0.14	0.11	
	CD (P=0.05)		0.42	0.82	0.42	0.34	

Note: Data in the table are mean values and those in parenthesis arc sine transformed values

Table 2: Efficacy of *Trichoderma* spp. on per cent inhibition of *Colletotrichum capsici*

	Treatments	Per cent inhibition			
		24 hours	48 hours	72 hours	96 hours
T_1	*Trichoderma harzianum*	26.14 (30.74)	37.54 (37.78)	55.91 (48.40)	77.39 (61.61)
T_2	*Trichoderma afroharzianum*	11.91 (20.16)	24.86 (29.90)	27.77 (31.79)	64.10 (53.19)
T_3	*Trichoderma asperellum* (1)	13.77 (21.47)	26.71 (31.09)	48.91 (44.37)	72.24 (58.23)
T_4	*Trichoderma asperellum* (2)	18.69 (25.48)	33.30 (35.23)	51.60 (45.92)	73.14 (58.82)
T_5	*Trichoderma* sp. 1	8.31 (16.46)	24.83 (29.85)	29.38 (32.81)	64.10 (53.19)
T_0	Control	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SEm±	1.77	1.21	0.88	1.02
	CD (P=0.05)	5.26	3.59	2.60	3.04

Note: Data in the table are mean values and those in parenthesis arc sine transformed values

Table 3: *In vitro* compatibility test of *T. harzianum* and fungicides

	Treatments	Per cent inhibition				
		24 hours	48 hours	72 hours	Mean	Compatibility
T_1	*Trichoderma harzianum* + Carbendazim 50%WP	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100	NC
T_2	*Trichoderma harzianum* + Hexaconazole 25% EC	100.00 (90.00)	100.00 (90.00	100.00 (90.00)	100	NC
T_3	*Trichoderma harzianum* + Propiconazole 25% EC	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100	NC
T_4	*Trichoderma harzianum* + Azoxystrobin 23% SC	7.35 (15.70)	2.14 (8.31)	1.38 (5.78)	3.62	C
T_0	Control	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0	
	SEm±	0.25	0.27	0.23		
	CD (P=0.05)	0.76	0.80	0.69		

Note*:* Data in the table are mean values and those in parenthesis arc sine transformed value NC = Non Compatibl C=Compatible

recorded the least per cent inhibition of 76.40 %. The effects of all the tested fungicides are significantly differ at different levels of inhibition from that of control at every 24 hours interval. These findings were in agreement with Jagtap *et al*. (2013) that Propiconazole, Hexaconazole, Azoxystrobin and Chlorothalonil were found to be more effective at all concentrations, against *C. capsici* by poison food technique.

In vitro evaluation of *Trichoderma* spp. against *Colletotrichum capsici*

The data obtained were presented in Table 2 and illustrated in Fig. 3. Among the biocontrol agents *T. harzianum* was found most effective with per cent inhibition (26.14 %, 37.54 %, 55.91 %, and 77.39 % at 24, 48, 72, 96 hours) of incubation respectively. The highest per cent inhibition of 77.39 % was recorded in *T. harzianum* which was followed by *T. asperellum* 2 (73.14 %) and was found to be statistically at par with *Trichoderma asperellum* 1 (72.24 %). The findings supported the result of (Alam *et al.* (2014) who reported that *T. harzianum* recorded maximum inhibition of about (80.90 %) followed by *T. koniigii* (68.75 %) and *T. viride* (65.85 %) against *C. capsici* under *in vitro.* *(*Laxman (2006) also reported that among all the fungal bioagents tested, *T. harzianum* was found to be more effective in suppressive the growth of *C. truncatum* followed by *T. viride*.

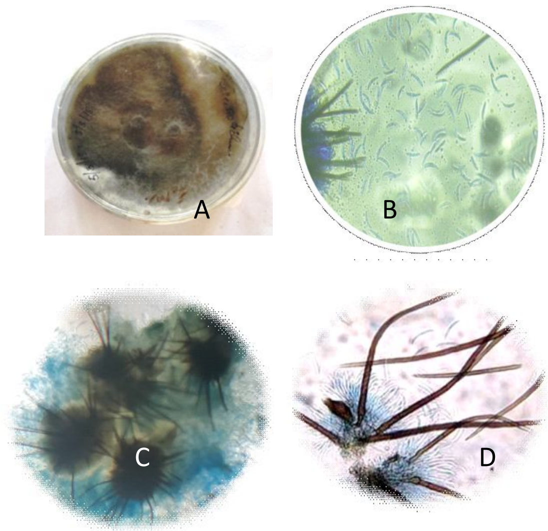

Fig. 1: Characteristics of *Colletotrichum capsici***.** (A) Growth in Petriplate. (B) Conidiophore (10X) (C) Conidia (40X) (D) Setae (40 X)

Table 4: Effect of different treatments on Per cent Disease Incidence of chilli plant at different days after transplanting

Treatments	Per cent Disease Incidence (%)														
	70 DAT			80 DAT			90 DAT			100 DAT			110DAT		
	2018-2019	2019-2020	Pooled	2018-2019	2019-2020	Pooled	2018-2019	2019-2020	Pooled	2018-2019	2019-2020	Pooled	2018-2019	2019-2020	Pooled
T_1 – Control	38.90 (38.56)	40.23 (39.36)	39.57 (38.96)	39.55 (38.96)	40.88 (39.75)	40.22 (39.35)	58.33 (49.82)	59.66 (50.59)	59.00 (50.20)	59.00 (50.21)	60.34 (50.98)	59.67 (50.60)	61.78 (51.84)	63.11 (52.62)	62.45 (52.23)
T_2 – Seedling dip with *Trichoderma harzianum* @ 5g/ 500ml water	30.78 (33.70)	32.12 (34.52)	31.45 (34.11)	31.16 (33.93)	32.49 (34.75)	31.83 (34.33)	33.33 (35.26)	34.66 (36.07)	34.00 (35.66)	33.55 (35.40)	34.89 (36.20)	34.22 (35.80)	34.20 (35.79)	35.53 (36.59)	34.87 (36.19)
T_3 – Seedling dip with Azoxystrobin @ 0.1%	25.75 (30.49)	27.08 (31.36)	26.42 (30.93)	25.80 (30.52)	27.13 (31.39)	26.47 (30.95)	26.08 (30.70)	27.41 (31.57)	26.75 (31.13)	26.67 (31.09)	28.00 (31.95)	27.34 (31.52)	27.60 (31.69)	28.93 (32.54)	28.27 (32.12)
T_4 – Foliar spray with *Trichoderma harzianum* @ 5g/ 500ml water	27.62 (31.70)	28.95 (32.55)	28.29 (32.13)	28.15 (32.04)	29.48 (32.88)	28.82 (32.46)	28.62 (32.33)	29.95 (33.18)	29.29 (32.76)	29.00 (32.58)	30.33 (33.41)	29.67 (33.00)	29.00 (32.58)	30.33 (33.41)	29.67 (33.00)
T_5 – Foliar spray with Azoxystrobin @ 0.1%	26.25 (30.81)	27.58 (31.68)	26.92 (31.25)	26.50 (30.98)	27.83 (31.84)	27.17 (31.41)	27.60 (31.69)	28.94 (32.54)	28.27 (32.12)	28.22 (32.08)	29.55 (32.93)	28.89 (32.51)	28.56 (32.30)	29.89 (33.14)	29.23 (32.72)
$T_6 - T_2 + T_5$	17.92 (25.04)	19.26 (26.03)	18.59 (25.53)	18.56 (25.51)	19.89 (26.48)	19.23 (26.00)	18.75 (25.63)	20.08 (26.62)	19.42 (26.13)	19.00 (25.83)	20.33 (26.79)	19.67 (26.31)	20.16 (26.68)	21.50 (27.62)	20.83 (27.15)
$T_7 - T_3 + T_4$	22.55 (28.34)	23.88 (29.25)	23.22 (28.80)	22.78 (28.51)	24.11 (29.41)	23.45 (29.06)	22.98 (28.63)	24.31 (29.53)	23.65 (29.09)	25.10 (30.06)	26.43 (30.93)	25.77 (30.50)	25.67 (30.44)	28.08 (31.96)	26.87 (31.10)
SEm±	0.77	0.38	0.42	0.65	0.40	0.03	0.91	0.70	0.03	0.81	0.78	0.02	0.74	0.63	0.15
CD (P=0.05)	2.33	1.15	0.15	1.97	1.23	0.12	2.76	2.12	0.11	2.46	2.35	0.08	2.25	1.92	0.51

Note: Data in the table are mean values and those in parenthesis are arc sine transformed values DAT= Days after transplanting

Table 5: Effect of different treatments on plant height of chilli at different days after sowing

Treatments	Plant height (cm)														
	60 DAT			80 DAT			100DAT			120 DAT			140DAT		
	2018-2019	2019-2020	Pooled	2018-2019	2019-2020	Pooled	2018-2019	2019-2020	Pooled	2018-2019	2019-2020	Pooled	2018-2019	2019- 2020	Pooled
T_1 – Control	11.25	10.58	10.92	16.66	16.00	16.33	31.35	30.54	30.94	45.00	43.96	44.48	45.33	44.23	44.78
T_2 – Seedling dip with *Trichoderma harzianum* @ 5g/ 500ml water	18.56	18.22	18.39	36.20	35.53	35.86	65.00	63.93	64.47	73.00	72.61	72.80	73.67	72.10	72.89
T_3 – Seedling dip with Azoxystrobin @ 0.1%	15.90	15.23	15.57	24.00	23.33	23.67	38.32	37.51	37.92	58.32	57.95	58.13	61.00	59.43	60.22
T_4 – Foliar spray with *Trichoderma harzianum* @ 5g/ 500ml water	17.96	17.29	17.62	27.92	27.25	27.58	41.26	40.27	40.77	63.20	62.12	62.66	65.00	64.18	64.59
T_5 – Foliar spray with Azoxystrobin @ 0.1%	17.96	17.29	17.62	27.82	27.16	27.49	42.00	41.67	41.84	63.33	62.95	63.14	65.00	64.31	64.66
$T_6 - T_2 + T_5$	21.12	20.46	20.79	36.20	35.53	35.86	65.00	63.94	64.47	73.00	72.61	72.80	73.67	72.47	73.07
$T_7 - T_3 + T_4$	18.58	21.25	19.92	32.56	31.89	32.23	58.82	57.95	58.39	68.15	67.78	67.97	66.66	65.49	66.07
SEm±	0.50	1.47	0.71	0.76	0.30	0.02	1.17	0.84	0.14	1.31	1.02	0.19	1.56	1.45	0.19
CD (P=0.05)	1.50	4.46	2.46	2.32	0.92	0.077	3.56	2.54	0.499	3.98	3.08	0.65	4.73	4.39	0.66

***In vitro* compatibility test of bioagents and fungicides.**

The potential *Trichoderma harzianum* was selected for fungicidal compatibility study, since it has shown maximum inhibition of *Colletotrichum capsici* growth under dual culture studies when compared to other four biocontrol agents *viz*., *T. afroharzianum, T. asperellum* 1, *Trichoderma asperellum* 2, *Trichoderma* sp. 1. Poisoned food technique was used to evaluate the compatibility of *T. harzianum* with four effective fungicide *viz*., Carbendazim, Hexaconazole, Propiconazole and Azoxystrobin. The least per cent inhibition was found in Azoxystrobin (3.62%) and was considered to be the most compatible fungicide with the bioagent, *T. harzianum* as presented in Table 3 and Fig. 4. The present research findings were also in agreement with Vineela *et al.* (2017) and Tomer *et al.* (2018).

Integrated management of chilli anthracnose under field condition'

For the integrated disease management, susceptible variety Pusa jwala was studied for the two consecutive years 2018-2019 and 2019-2020 under field condition under RBD design. The

Table 6 : Effect of different treatments on yield parameters of chilli plant

Treatments	Number of fruits plant^{-1}			Fruit length (cm)			Fruit diameter (cm)			Fruit yield (gm plant^{-1})		
	2018-2019	2019-2020	Pooled	2018-2019	2019- 2020	Pooled	2018- 2019	2019- 2020	Pooled	2018- 2019	2019- 2020	Pooled
T_1 – Control	8.00	7.00	7.50	5.67	5.32	5.49	0.57	0.53	0.55	48.33	47.67	48.00
T_2 – Seedling dip with *Trichoderma harzianum* @ 5g/ 500ml water	19.00	18.00	18.50	10.00	9.70	9.85	1.10	1.00	1.05	88.67	88.00	88.33
T_3 – Seedling dip with Azoxystrobin @ 0.1%	13.00	12.33	12.67	8.67	8.35	8.51	1.13	1.10	1.12	83.67	83.00	83.33
T_4 – Foliar spray with *Trichoderma harzianum* @ 5g/ 500ml water	23.00	22.00	22.67	10.33	10.03	10.18	1.20	1.17	1.18	185.33	183.67	184.50
T_5 – Foliar spray with Azoxystrobin @ 0.1%	20.00	19.67	19.83	9.67	9.36	9.51	1.00	1.00	1.00	133.33	130.00	131.67
$T_6 – T_2 + T_5$	30.00	28.67	29.67	12.67	12.37	12.52	1.20	1.10	1.15	316.67	313.33	315
$T_7 – T_3 + T_4$	26.00	24.67	25.33	11.33	11.08	11.21	1.47	1.40	1.43	216.67	213.33	215
SEm±	0.71	0.63	0.30	0.52	0.47	0.02	0.05	0.03	0.02	9.66	8.11	7.64
CD (P=0.05)	2.15	1.91	1.05	1.59	1.43	0.06	0.15	0.09	0.075	29.29	24.61	26.42

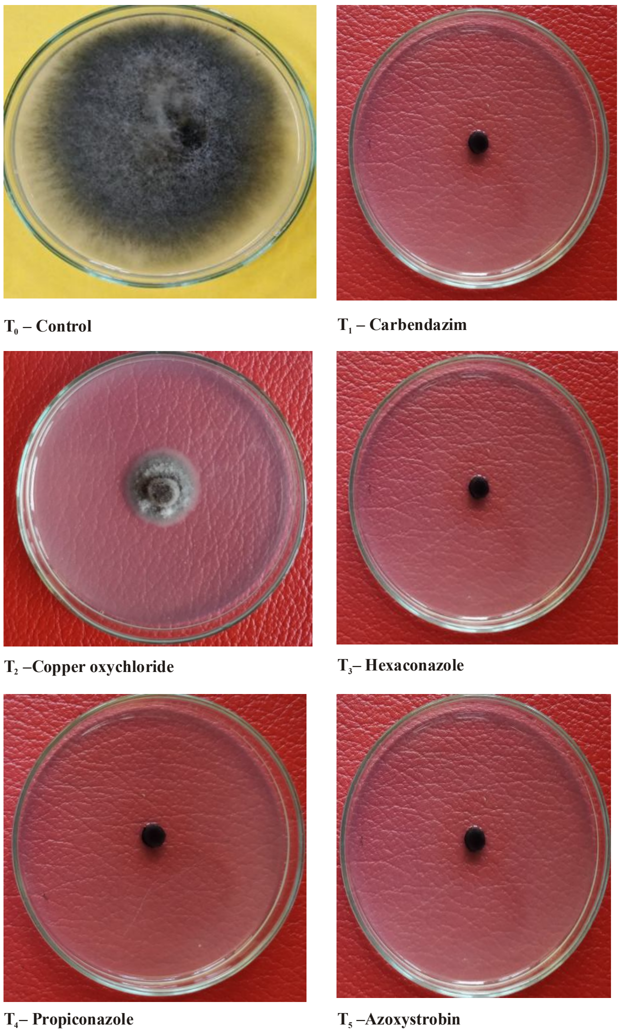

Fig. 2: Evaluation of fungicide against *Colletotrichum capsici*

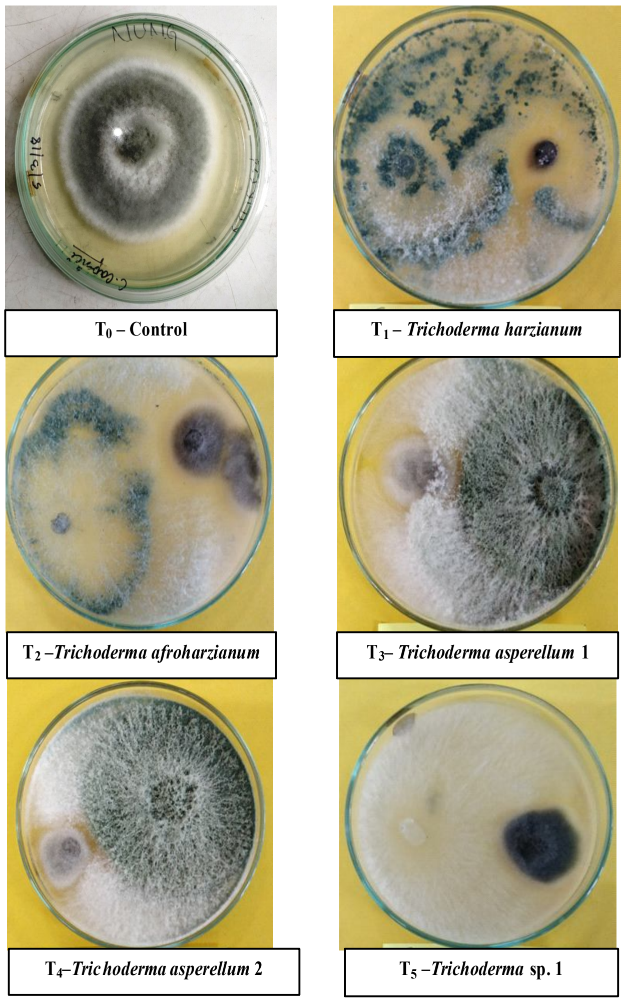

Fig.3: Evaluation of *Trichoderma* spp. against *Colletotrichum capsici*

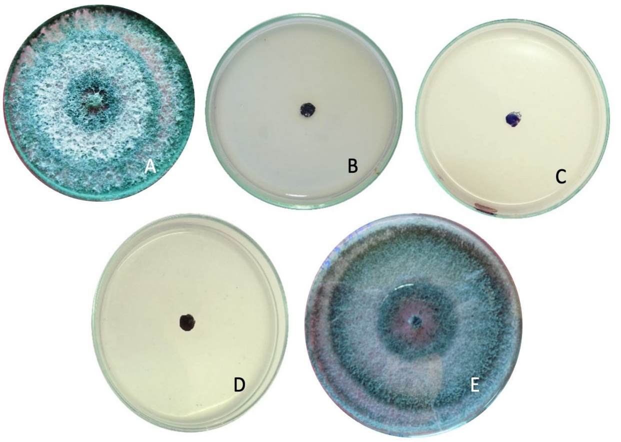

Fig.4: Compatibility evaluation of *T. harzianum* on fungicides. A: T_0 – Control ; B: T_1 – *T. harzianum*+ Carbendazim; C: T_2 – *T. harzianum* + Hexaconazole; D: *T. harzianum* + Propiconazole ; E: T_4 – *T. harzianum* +Azoxystrobin

different treatments were imposed as presented in Table 4. In this context the biocontrol agent *T. harzianum* and fungicide Azoxystrobin @ 0.1% were used as they found to be the most effective against the pathogen and also most compatible under *in vitro* study.

The data on percent disease incidence of chilli and plant growth parameters, like plant height, number of fruits per plant, fruit length, fruit width and fruit yield in each of the treatment were recorded. From the data presented in Table 4. it was evident that all the treatments were significantly superior over control in reducing the percent disease incidence at 70, 80, 90, 100 and 110 DAT. Under the pooled data at 110 DAT, the minimum percent disease incidence of 20.86% was observed in treatment T_6 i.e. seedling dip with *T. harzianum* and foliar spray with Azoxystrobin @ 0.1% which was followed by T_7 (26.87 %) and T_3 (28.27 %) and which was statistically significant. Maximum incidence was recorded in control (T_1) 62.45 %.

The result was in agreement with Setiawati *et al*. (2016) who reported that application of *Trichoderma harzianum* and Azoxystrobin 23% SC were significantly effective in reducing the incidence of anthracnose disease of *Colletotrichum capsici* and resulted higher yield than in other treatments.

The effect of various treatments in relation to plant height is presented in Table 5. Plant height was found to be significantly increased with all the treatments on 60, 80, 100, 120 and 140 DAS. Maximum plant height was observed in T_6 (73.07cm) and T_2 (72.89cm) and was statistically at par, which was followed by T_7 (66.07cm) which was statistically at par with T_5 (64.66cm) at 140 DAT. However, the minimum plant heights of chilli plants were recorded in control (T_1) with 44.78 cm at 140 DAS. It was evident in this present study that chilli plants treated with *T. harzianum* were significantly taller compared to untreated plants as reported by Subash *et al*. (2013), Kumar *et al*. (2019). In case of number of fruits per plant, maximum fruits was observed in T_6 (29.67 cm) followed by T_7 (24.67 cm). Maximum fruit length was also observed in T_6 (12.52 cm) followed by T_7 (11.21) (Table 6). Minimum fruit length was observed in control T_1 (5.49 cm). For fruit width, maximum width was recorded in T_7 (1.43 cm) followed by T_4 (1.18cm) and T_6 (1.15 cm) which was statistically at par. Regarding fruit yield, maximum yield was observed in T_6 (315g/ plants) followed by T_7 (215g/ plants).

CONCLUSION

Therefore, based on the findings of this research, the conclusion drawn is that by integrating of bio-control agent *Trichoderma harzianum* as seedling dip treatment of 25-30days old chilli seedlings with combination of foliar spray of fungicide Azoxystrobin @ 0.1% starting from 55 DAT at two times at an interval of 15 days were effectively reduced the disease incidence to a maximum extent as well as increased in productivity.

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