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Fungitoxicants and bio-formulations for the management of Chilli anthracnose caused by *Colletotrichum capsici* (Syd.) Butler & Bisby

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Abstract
Chilli (*Capsicum annum* L., Family: Solanaceae) is one of the important spice-cum-vegetable crops throughout the world. The crop is nutrient rich and having good medicinal properties. The crop is cultivated almost all the states and union territories in India. India is the third largest producer of chilli. Cultivation of chilli is menaced by several fungal, bacterial, and viral diseases. Among them, anthracnose incited by *Colletotrichum capsici* (syd) Butler & Bisby is one of the major threats. Very little work has been done for the management of the disease in Red and Lateritic Agro-climatic Zone of West Bengal. The results of *in-vitro* and field trials revealed that Carbendazim 12% + Mancozeb 63% WP, Propineb 70% WP and Mefenoxam 3.3% + Chlorothalonil 33.1% SC can be used to manage the disease effectively. Carbendazim 12% + Mancozeb 63% WP showed excellent control of anthracnose infection as compared to other treatments. The bio-formulations (Turmeric rhizome extract + cow urine, Neem leaf extract + cow urine) were found inhibitory but not as much effective as fungicides.

Keywords: Anthracnose, chilli, *Colletotrichum capsici*, disease, fungicides, bio-formulations, management

Introduction
Chilli (*Capsicum annum* L.) is one of the important spice-cum-vegetable crops civilized throughout the world. The crop is rich of nutrients and has good medicinal properties. Chilli is nutrient rich, and contains more amount of vitamin C and vitamin A in comparison to citrus and carrot, respectively (Martin *et al.*, 2004) [8]. Vitamins like A, C, B1 and B2 are highly present in green chillies (Saimbhi and Nandpuri, 1977) [14]. Chilli is cultivated almost all the states and union territories in India. Among them Andhra Pradesh is the leading producer contributing about 44% to the total production followed by Karnataka (12%), West Bengal (8%), Madhya Pradesh (7%), Maharastra (4%) and Tamil Nadu (2%). Area under chilli cultivation in India is around 793.20 thousand hectare and production and productivity around 1431.37 thousand tonnes and 1.80 tonnes/ha, respectively. India is the third largest producer of chilli. In West Bengal, chilli cultivated 63.6-thousand-hectare, production, and productivity around 100 thousand tonnes and 1.57 tonnes/ha, respectively (Geetha and Selvarani, 2017) [3]. The cultivation of chilli is menaced by many fungal, bacterial, and viral diseases. Chilli affected by nearly 40 fungal diseases (Rangaswami, 1979) [13], such as damping-off (*Rhizactonia solani* Kühn, *Pythium spp.*), Powdery mildew (*Leveillula taurica* (Lév.) G. Arnaud) and Anthracnose (*Colletotrichum capsici* (Syd.) Butler & Bisby) etc. Anthracnose is one of the major threats to chilli cultivation. Anthracnose is a Greek word which means “coal.” Genus *Colletotrichum* is a key phytopathogen and causes serious disease in wide range of crops like legumes, vegetables, fruits, bulbs, cereals, flowers, and grasses (Agrios, 2005) [1]. Ekbote (2001) [2] reported upto 25-48% yield loss of chilli from different parts of India, whereas, around 80% yield loss was recorded in chilli due to the infection of *Colletotrichum capsici* by Poonpolgul and Kumphai (2007) [12]. The Pathogen produces symptoms on leaves, twigs, and fruits. Circular and sunken spots with black or dark margins mostly appear on the upper surface of leaves in scatter manner or concentrated near the midrib. A sunken necrotic area (black greenish or dirty grey or straw colour) with numerous acervuli appears in a concentric ring manner on fruits surface.

Anthracnose symptom is commonly seen in twigs (Tripathi, 2016) [16]. The fungicide, maneb and mancozeb has suggested for management of chilli anthracnose and seed borne inoculum by the scientists (Smith, 2000, Ingale *et al.*, 2002) [15, 6]. It is essential to find out fungicides and botanicals against the pathogen to manage the disease effectively.

Methods and Materials

Isolation and characterization of the pathogen

The disease was confirmed through isolation, characterization of the fungal pathogen, and through pathogenicity (Rangaswami, 1979, Oanh *et al.* 2004) [13, 10]. Potato dextrose agar (PDA) medium was used for this purpose. Streptomycin sulphate (90%) + Tetracycline hydrochloride (10%) @ 200ppm was used to prevent bacterial contamination while culturing.

Treatment details for *in vitro* evaluation of fungitoxicants

In this study nine chemicals were used to evaluate against *C. capsici* causing chilli anthracnose through poisoned food technique. For the study, 0.1%, 0.05%, 0.025% test concentration of different chemicals (e.g. Propineb 70% WP, Carbendazim 12% + Mancozeb 63% WP, Mefenoxam 3.3% + Chlorothalonil 33.1% SC, Hexaconazole 50% SC, Difenconazole 25% EC, Propiconazole 10.7% + Tricyclazole 34.2% SE, Fluoficolide 480 SC, Fluoxapiprolin 30g/l + Fluoficolide 200g/l SC and Iprovalicarb 8.4% + Copper Oxychloride 40.6% WG) were prepared by mixing thoroughly with molten PDA medium, and poured in petriplate. After solidification the plates were inoculated individually with 5mm diameter mycelial disc taken from actively growing pure culture of *C. capsici* with the help of sterilized forceps and cork-borer. Three replications are maintained for each treatment. The media without chemicals served as control. These inoculated plates are incubated in BOD incubator at 27±1 °C for optimum growth. The radial colony growth was measured and the efficacy of fungicides was expressed as percent inhibition of mycelial growth over control, calculated by the formula suggested by Vincent (1947) [17].

$$\text{Percent mycelial inhibition} = \frac{(C - T)}{C} \times 100$$

Where,

C = Mycelial growth (mm) of pathogen in absence of fungitoxicant.

T = Mycelial growth of pathogen in presence of fungitoxicant.

Preparation of bio-formulations

In this study two botanicals along with cow urine were used to evaluate the antifungal activity against the fungus *Colletotrichum capsici* causing anthracnose disease in chilli. Leaves of neem (*Azadirachta indica* A. Juss.) and rhizome of turmeric (*Curcuma longa* L.) were used for preparation of aqueous solution. 100g of peeled turmeric rhizome and neem leaves were macerated separately with 100ml of cow urine that were filtered primarily using muslin cloth followed by Whatman No.1 filter paper. This extracts at 0.5%, 0.25% and 0.125% were evaluated against the pathogen through poison food technique. PDA medium was used for this purpose. Similar techniques were followed for inoculation and measurement of percent mycelial inhibition.

Evaluation of fungicides and bio-formulations against anthracnose disease in field condition

Seven different treatments including untreated control (Propineb 70% WP @ 0.25%, Carbendazim 12% + Mancozeb 63% WP @ 0.2%, Mefenoxam 3.3% + Chlorothalonil 33.1% SC @ 0.2%, Propiconazole 10.7% + Tricyclazole 34.2% SE @ 0.15%, and two bio formulations - Turmeric + cow urine extract @ 0.5%, Neem + cow urine extract @ 0.5% were evaluated in field condition against anthracnose of chilli. Experiments were conducted following randomized block design (RBD) with three replicates to develop a suitable management practice for this disease with a popularly grown susceptible variety 'Bullet' at Binuria village near Instructional Farm, Palli-Siksha Bhavana (Institute of Agriculture), Visva-Bharati, Sriniketan, Bolpur in Birbhum district. The experimental site is situated at 23°40′ 6″ N latitude and 87°37′57″ E longitude having an average altitude of 58.90m above mean sea level in the dry sub-humid and sub-tropical climate of the lateritic belt of West Bengal. The long-term average maximum temperature (LTA_{max}) varied from 29.46 °C to 34.3 °C and LTA_{min} temperature varied from 17.39 °C to 25.96 °C in this region. Very hot summer (34-42 °C) and cold winter (5-15 °C) is characteristics of the area. The soil type of experimental site is slightly acidic (pH 5.5-5.8) with sandy loam (ultisol) in texture. FYM and fertilizers were applied during field preparation and after transplanting of the seedlings as per the recommended package of practices (FYM @ 20t/ha and N:P:K @ 100:50:50 kg/ha). Irrigation was applied as and when required.

The data on the incidence of the disease was recorded from different treatments. Periodic progress and severity of anthracnose were recorded from ten randomly selected plants per plot. The number of infected fruits was counted and percent infection was calculated in respect of the total number of fruits per selected plant. The disease rating scale used for assessment of anthracnose was 0 to 5 (0= No infection, 1= First symptom to19% infection, 2=20-39% infection, 3=40-59% infection, 4=60-79% infection, 5=80-100% infection). The data were subjected to statistical analysis as per Gomez and Gomez (1984) [4]. Necessary transformations were made whenever required.

Result and Discussion

Confirmation of the pathogen

The disease was confirmed through the study of symptoms on fruits that was circular to angular sunken lesion with concentric rings of acervuli. The pathogen was isolated in PDA from the infected host that was started to grow after 48 hours of inoculation. It was taken 7 days to cover the whole petriplate, and another 3 days for sporulation. On microscopy, hyaline and septate mycelium with falcate conidia was observed. The purified culture when inoculated in the fresh red chilli produced characteristics symptoms. Oanh *et al.* (2004) [10] proved pathogenicity of *C. capsici* purified from diseased chillies. Infected host having black pin heads were also collected for microscopic observation. These are actually the small asexual fruiting bodies of the fungus, acervuli. Numerous conidia along with short, septate conidiophores and black coloured setae were recorded on microscopy. The pathogen was confirmed as per the observations made by Rangaswami (1979) [13].

Fig 1: Fruiting body of the fungus showing acervulus, setae and conidia

***In vitro* efficacy of fungicides at 0.025% and bio-formulations at 0.125% concentrations**

The results revealed that there was significant difference in mean radial growth of the fungus (cm) after 48 hours of observation among all the treatments. Maximum mean radial growth of the fungus were observed in untreated control (1.29cm) followed by neem + cow urine (1.03cm), Turmeric + cow urine (0.86cm), Fluoxapiprolin 30g/l + Fluopicolide 200g/l SC (0.76cm), Fluoficolide 480 SC (0.63cm), Hexaconazole 50% SC (0.56cm) and Iprovalicarb 8.4% + Copper oxychloride 40.6% WG (0.50cm). There was no significant difference among Iprovalicarb 8.4% + Copper oxychloride 40.6% WG, Hexaconazole 50% SC and Fluoficolide 480 SC. Negligible radial growth was recorded in Propiconazole 10.7% + Tricyclazole 34.2% SE (0.06cm). No growth was recorded in the treatments Propineb 70% WP, Carbendazim 12% + Mancozeb 63% WP, Mefenoxam 3.3% + Chlorothalonil 33.1% SC and Difenconazole 25% EC, they were at par and significantly differed from other treatments (Table 1).

After 120 hours of incubation, maximum mean radial growth was recorded in untreated control (3.24cm) followed by Neem + cow urine (1.83cm), Fluoficolide 480 SC (1.53cm), Fluoxapiprolin 30g/l + Fluopicolide 200g/l SC (1.50cm), Turmeric + cow urine (1.26cm) and Iprovalicarb 8.4% + Copper oxychloride 40.6% WG (1.06cm). All the treatments differed significantly from untreated control. Fluoficolide 480 SC (1.53cm) and Fluoxapiprolin 30g/l + Fluopicolide 200g/l SC (1.50cm) were statistically at par. Difenconazole 25% EC (0.30cm) gave better result than Mefenoxam 3.3% + Chlorothalonil 33.1% SC (0.53cm), Propiconazole 10.7% + Tricyclazole 34.2% SE (0.53cm) and Hexaconazole 50% SC (0.83cm). Negligible radial growth was observed in Propineb 70% WP (0.23cm) which was at par with Difenconazole 25% EC (0.30cm). No growth was recorded in the treatment Carbendazim 12% + Mancozeb 63% WP (Table 1, Fig. 2A).

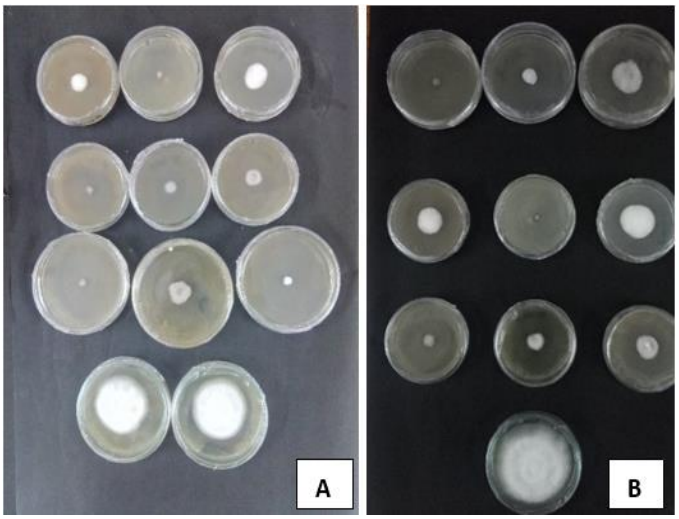

Fig 2A & B: *In vitro* study of fungitoxicants against chilli anthracnose pathogen

Table 1: Inhibition of mycelial growth through fungitoxicants at 0.025% and bio-formulations at 0.125% concentrations

Treatments	Inhibition of mycelial growth (cm)			% mycelial inhibition after 168 hrs. of inoculation
	48 hrs. after inoculation	12 hrs. after inoculation	168 hrs. after inoculation	
T_1: Propineb 70% WP	0.0	0.23	0.66	85.06
T_2: Carbendazim 12% + Mancozeb 63% WP	0.0	0.0	0.0	100
T_3: Mefenoxam 3.3% + Chlorothalonil 33.1% SC	0.0	0.53	1.26	71.49
T_4: Hexaconazole 5% SC	0.56	0.83	1.26	71.49
T_5: Difenconazole 25% EC	0.0	0.3	1.03	76.69
T_6: Propiconazole 10.7% + Tricyclazole 34.2% SE	0.06	0.53	1.1	75.11
T_7: Fluoficolide 480 SC	0.63	1.53	2.23	49.54
T_8: Fluoxapiprolin 30g/l + Fluopicolide 200g/l SC	0.76	1.5	2.53	42.76
T_9: Iprovalicarb 8.4% + Copper oxychloride 40.6% WG	0.5	1.06	1.76	60.18
T_{10}: Neem + cow urine	1.03	1.83	2.46	44.34
T_{11}: Turmeric + cow urine	0.86	1.26	1.63	63.12
T_{12}: Control	1.29	3.24	4.42	-
S.Em (±)	0.04	0.05	0.06	-
CD (p=0.01)	0.13	0.14	0.19	-
CV (%)	15.87	7.69	6.48	-

More or less similar trend was recorded after 168 hours of incubation; maximum mean radial growth was recorded in untreated control (4.42cm) followed by Neem + cow urine (2.46cm), Fluoxapiprolin 30g/l + Fluopicolide 200g/l SC (2.53cm), Fluoficolide 480 SC (2.23cm), Iprovalicarb 8.4% + Copper oxychloride 40.6% WG (1.76cm), Turmeric + cow urine (1.63cm), Mefenoxam 3.3% + Chlorothalonil 33.1% SC (1.26cm), Hexaconazole 50% SC (1.26cm), Propiconazole 10.7% + Tricyclazole 34.2% SE (1.10cm) and Difenconazole 25% EC (1.03cm). Negligible radial growth was observed in Propineb 70% WP (0.66cm). All the treatments differed significantly from untreated control. No growth was recorded in

the treatment Carbendazim 12% + Mancozeb 63% WP (Table 1).

The percent inhibition of average radial mycelial growth over control after 168 hours of observation was found highest in the treatment Carbendazim 12% + Mancozeb 63% WP, where 100% inhibition was recorded. It was followed by Propineb 70% WP (85.06%), Difenconazole 25% EC (76.69%), Propiconazole 10.7% + Tricyclazole 34.2% SE (75.11%), Mefenoxam 3.3% + Chlorothalonil 33.1% SC (71.49%), Hexaconazole 50% SC (71.49%), Turmeric + cow urine (63.12%) and Iprovalicarb 8.4% + Copper oxychloride 40.6% WG (60.18%). Similar kinds of inhibition of mycelial growth was observed in Fluoficolide 480 SC (49.54%), Neem + cow urine (44.34%) and Fluoxapiprolin 30g/l + Fluopicolide 200g/l SC (42.76%) (Table 1).

In vitro efficacy of fungicides at 0.05% and bio-formulations at 0.25% concentrations

The results revealed that there was significant difference in mean radial growth of the fungus (cm) after 48 hours of incubation. Maximum mean radial growth of the fungus were observed in untreated control (1.26cm) followed by neem+cow urine (0.86cm), Fluoxapiprolin 30g/l + Fluopicolide 200g/l SC (0.73cm) and Fluoficolide 480 SC (0.46cm). Similar types of observations (0.33cm) were recorded from Iprovalicarb 8.4% + Copper oxychloride 40.6% WG and Hexaconazole 50% SC. No growth was recorded in the treatments Propineb 70% WP, Carbendazim 12% + Mancozeb 63% WP, Mefenoxam 3.3% + Chlorothalonil 33.1% SC, Difenconazole 25% EC and Propiconazole 10.7% + Tricyclazole 34.2% SE, they were at par and significantly differed from other treatments. There was no significant difference between and Iprovalicarb 8.4% + Copper oxychloride 40.6% WG and Hexaconazole 50% SC (Table 2).

After 120 hours of incubation, maximum mean radial growth was recorded in untreated control (3.19cm) followed by Neem + cow urine (1.46cm), Fluoficolide 480 SC (1.36cm), Fluoxapiprolin 30g/l + Fluopicolide 200g/l SC (1.26cm). All the treatments differed significantly from untreated control. Negligible radial growth was observed in Propiconazole 10.7% + Tricyclazole 34.2% SE (0.13cm) and Difenconazole 25% EC (0.23cm), they were statistically at par. A moderate amount of pathogenic growth was also observed in Iprovalicarb 8.4% + Copper oxychloride 40.6% WG (0.86cm), Hexaconazole 50% SC (0.73cm) and Mefenoxam 3.3% + Chlorothalonil 33.1% SC (0.30). No growth was recorded in the treatment Propineb 70% WP and Carbendazim 12% + Mancozeb 63% WP (Table 2).

Table 2: Inhibition of mycelial growth through fungitoxicants at 0.05% and bio-formulations at 0.25% concentrations

Treatments	Inhibition of mycelial growth (cm)			% mycelial inhibition after 168 hrs. of inoculation
	48 hrs. after inoculation	12 hrs. after inoculation	168 hrs. after inoculation	
T_1: Propineb 70% WP	0.0	0.0	0.0	100
T_2: Carbendazim 12% + Mancozeb 63% WP	0.0	0.0	0.0	100
T_3: Mefenoxam 3.3% + Chlorothalonil 33.1% SC	0.0	0.30	0.86	80.36
T_4: Hexaconazole 5% SC	0.33	0.73	0.93	78.76
T_5: Difenconazole 25% EC	0.0	0.23	0.66	84.93
T_6: Propiconazole 10.7% + Tricyclazole 34.2% SE	0.0	0.13	0.46	89.49
T_7: Fluoficolide 480 SC	0.46	1.36	2.2	49.77
T_8: Fluoxapiprolin 30g/l + Fluopicolide 200g/l SC	0.73	1.26	2.3	47.48
T_9: Iprovalicarb 8.4% + Copper oxychloride 40.6% WG	0.33	0.86	1.56	64.38
T_{10}: Neem + cow urine	0.86	1.46	2.33	46.80
T_{11}: Turmeric + cow urine	0.76	1.2	1.5	65.75
T_{12}: Control	1.26	3.19	4.38	-
S.Em (±)	0.06	0.05	0.07	-
CD (p=0.01)	0.18	0.16	0.20	-
CV (%)	26.17	10.43	8.12	-

More or less similar trend was recorded after 168 hours of incubation; maximum mean radial growth was recorded in untreated control (4.38cm) followed by Neem + cow urine (2.33cm), Fluoxapiprolin 30g/l + Fluopicolide 200g/l SC (2.33cm), Fluoficolide 480 SC (2.20cm), Iprovalicarb 8.4% + Copper oxychloride 40.6% WG (1.56cm) and Turmeric + cow urine (1.50cm). There was no significant difference among Fluoxapiprolin 30g/l + Fluopicolide 200g/l SC (2.33cm), Fluoficolide 480 SC (2.20cm) and Neem + cow urine (2.33cm). Iprovalicarb 8.4% + Copper oxychloride 40.6% WG (1.56cm) and Turmeric + cow urine (1.50cm) also showed similar efficacy i.e. they were at par to each other. On the other hand, Hexaconazole 50% SC (0.93cm), Mefenoxam 3.3% + Chlorothalonil 33.1% SC (0.86cm), Difenconazole 25% EC (0.66cm) and Propiconazole 10.7% + Tricyclazole 34.2% SE (0.46cm) gave similar kinds of results. All the treatments differed significantly from untreated control. Difenconazole 25% EC (0.66cm) and Propiconazole 10.7% + Tricyclazole 34.2% SE (0.46cm) showed better result than Hexaconazole 50% SC (0.93cm) and Mefenoxam 3.3% + Chlorothalonil 33.1% SC (0.86cm). No growth was recorded in the treatment Propineb 70% WP and Carbendazim 12% + Mancozeb 63% WP (Table 2). The percent inhibition of average radial mycelial growth over control after 168 hours of observation was found highest in the treatment Propineb 70% WP and Carbendazim 12% + Mancozeb 63% WP, where 100% inhibition was recorded. It was followed by Propiconazole 10.7% + Tricyclazole 34.2% SE (89.49%), Difenconazole 25% EC (84.93%), Mefenoxam 3.3% + Chlorothalonil 33.1% SC (80.36%), Hexaconazole 50% SC (78.76%), Iprovalicarb 8.4% + Copper oxychloride 40.6% WG (64.38%) and Turmeric + cow urine (65.75%). Similar kinds of inhibition of mycelial growth was observed in Fluoficolide 480 SC (49.77%), Neem + cow urine (46.80%) and Fluoxapiprolin 30g/l + Fluopicolide 200g/l SC (47.48%) (Table 2 & Figure 2B).

In vitro efficacy of fungicides at 0.1% and bio-formulations at 0.5% concentrations

The results revealed that there was significant difference in mean radial growth of the fungus (cm) after 48 hours of incubation. Maximum mean radial growth was observed in untreated control (1.23cm) followed by neem + cow urine (0.60cm), Fluoxapiprolin 30g/l + Fluopicolide 200g/l SC

(0.56cm) and Turmeric + cow urine. No growth was recorded in the treatments Propineb 70% WP, Carbendazim 12% + Mancozeb 63% WP, Mefenoxam 3.3% + Chlorothalonil 33.1% SC, Difenconazole 25% EC and Propiconazole 10.7% + Tricyclazole 34.2% SE that were significantly differed from other treatments (Table 3).

After 120 hours of incubation, maximum mean radial growth was recorded in untreated control (3.13cm) followed by Fluoficolide 480 SC (1.06cm), Fluoxapiprolin 30g/l + Fluopicolide 200g/l SC (1.03cm), Neem + cow urine (1.10cm) and Turmeric + cow urine (1.03cm). There was no significant difference among these treatments, except untreated control. All the treatment differed significantly from untreated control. Negligible radial growth was observed in Hexaconazole 50% SC (0.56) and Iprovalicarb 8.4% + Copper oxychloride 40.6% WG (0.63cm), which were statistically at par. No growth was recorded in the treatment Propineb 70% WP, Carbendazim 12% + Mancozeb 63% WP, Mefenoxam 3.3% + Chlorothalonil 33.1% SC, Difenconazole 25% EC and Propiconazole 10.7% + Tricyclazole 34.2% SE (Table 3).

Table 3: Inhibition of mycelial growth through fungitoxicants at 0.1% and bio-formulations at 0.5% concentrations

Treatments	Inhibition of mycelial growth (cm)			% mycelial inhibition after 168 hrs. of inoculation
	48 hrs. after inoculation	12 hrs. after inoculation	168 hrs. after inoculation	
T_1: Propineb 70% WP	0.00	0.0	0.0	100
T_2: Carbendazim 12% + Mancozeb 63% WP	0.00	0.0	0.0	100
T_3: Mefenoxam 3.3% + Chlorothalonil 33.1% SC	0.00	0.0	0.0	100
T_4: Hexaconazole 5% SC	0.20	0.56	0.76	82.56
T_5: Difenconazole 25% EC	0.00	0.0	0.36	91.74
T_6: Propiconazole 10.7% + Tricyclazole 34.2% SE	0.00	0.0	0.0	100
T_7: Fluoficolide 480 SC	0.46	1.06	1.86	57.33
T_8: Fluoxapiprolin 30g/l + Fluopicolide 200g/l SC	0.56	1.03	2.16	50.45
T_9: Iprovalicarb 8.4% + Copper oxychloride 40.6% WG	0.20	0.63	1.0	77.06
T_{10}: Neem + cow urine	0.60	1.1	2.13	51.14
T_{11}: Turmeric + cow urine	0.56	1.03	1.26	71.10
T_{12}: Control	1.23	3.13	4.36	-
S.Em(±)	0.05	0.06	0.05	-
CD (p=0.01)	0.14	0.16	0.15	-
CV (%)	26.09	13.41	7.60	-

More or less similar trend was recorded after 168 hours of incubation; maximum mean radial growth was recorded in untreated control (4.36cm) followed by Fluoxapiprolin 30g/l + Fluopicolide 200g/l SC (2.16cm), Neem + cow urine (2.13cm), Fluoficolide 480 SC (1.86cm), Turmeric + cow urine (1.26cm) and Iprovalicarb 8.4% + Copper oxychloride 40.6% WG (1.00cm). They differ significantly from each other. All the treatment differed significantly from untreated control. Negligible radial growth was observed in Difenconazole 25% EC (0.36cm) and Hexaconazole 50% SC (0.76cm). No growth was recorded in the treatment Propineb 70% WP, Carbendazim 12% + Mancozeb 63% WP, Mefenoxam 3.3% + Chlorothalonil 33.1% SC, and Propiconazole 10.7% + Tricyclazole 34.2% SE (Table 3).

The percent inhibition of average radial mycelial growth over control after 168 hours of observation was found highest in the treatment Propineb 70% WP, Carbendazim 12% + Mancozeb 63% WP, Mefenoxam 3.3% + Chlorothalonil 33.1% SC, Propiconazole 10.7% + Tricyclazole 34.2% SE where 100% inhibition was recorded. It was followed by Difenconazole 25% EC (91.74%), Hexaconazole 50% SC (82.56%), Iprovalicarb 8.4% + Copper oxychloride 40.6% WG (77.06%) and Turmeric + cow urine (71.10%). Similar kinds of inhibition of mycelial growth was observed in Fluoficolide 480 SC (57.33%), Neem + cow urine (51.14%) and Fluoxapiprolin 30g/l + Fluopicolide 200g/l SC (50.45%) (Table 3).

It was found that the inhibition of the fungal growth was more with the higher concentration of fungitoxicants and bio-formulations. The results corroborated with the earlier workers. Misra (1988) [9] recorded effectiveness of Bavistin 50WP (0.05%), Benlate 50WP (0.05%), Blitox 50WP (0.3%), Dithane M-45 (0.3%) and Dithane Z-78 (0.3%) against chilli anthracnose. Gopinath *et al.* (2006) [5] examined that efficacy of fungicides like Propiconazole (0.1%, 0.05%, 0.025% ai), Difenconazole (0.05%, 0.025% ai) and carbendazim (0.1%) against chilli anthracnose at greenhouse as well as field conditions. Padghan *et al.* (2023) [11] recorded some highly effective fungicides i.e. propiconazole 25% EC (0.05 and 0.15% concentration), tebuconazole 25.9% EC (0.05 and 0.15% concentration) and trifloxystrobin 25% + tebuconazole 50% WG (0.05% concentration) against the disease in *in vitro* condition.

Management of anthracnose of chilli in field condition

The observations were taken during initial picking of the green fruits and fruit infection was recorded primarily in the untreated control plots followed by other treatments. Rate of wilting was gradually increased with increased of the age of the plants in all the treatments including untreated control. Lowest disease incidence was recorded in T_3 (Carbendazim 12% + Mancozeb 63% WP) followed by T_2 (Propineb 70% WP). It was found that PDI of anthracnose of chilli in the T_2 (9.90) was statistically at par with T_3 (3.86). Maximum disease incidence was recorded in untreated control (18.52%). After 10 days of second spraying lowest PDI was recorded in T_3 - Carbendazim 12% + Mancozeb 63% WP (5.93) followed by T_2 - Propineb 70% WP (6.72), T_1 - Mefenoxam 3.3% + Chlorothalonil 33.1% SC (7.10) and T_4 - Propiconazole 10.7% + Tricyclazole 34.2% SE (7.21). Highest PDI (26.48) was observed in control plot i.e. in T_7. The mean (pooled) PDI of anthracnose was also lowest (4.86) in T_3 followed T_2 (5.79). These two treatments are statistically significant to control anthracnose disease. The treatment T_1 - Mefenoxam 3.3% + Chlorothalonil 33.1% SC (PDI - 6.65) and T_4 - Propiconazole 10.7% + Tricyclazole 34.2% SE (PDI - 6.84) showed effectiveness against the disease, and they were at par to each other. Two bio-formulations (T_5 and T_6) were not so effective. Pooled mean PDI of anthracnose of chilli in untreated control (T_7) was calculated 22.32 (Table 4).

The most effective control (PDC – percent disease control) of

anthracnose was achieved by spraying with Carbendazim 12% + Mancozeb 63% WP (T_3) @ 2g/litre water (78.23) followed by Propineb 70% WP(T_2) @ 2.5g/litre of water (74.06) and Mefenoxam 3.3% + Chlorothalonil 33.1% SC (T_1) @ 2g/litre of water (70.21). Carbendazim 12% + Mancozeb 63% WP (T_3) showed excellent control of anthracnose infection as compared to other treatments (Table 4). Malraja and Narayanaswami (1988) [7] reported that three sprays of Mancozeb (0.25%) at 15 days' intervals shown maximum minimization of disease incidence followed on thiophanate methyl, ziram and carbendazim, whereas in present study Carbendazim 12% + Mancozeb 63% WP gave maximum protection followed by Propineb 70% WP, Mefenoxam 3.3% + Chlorothalonil 33.1% SC and Propiconazole 10.7% + Tricyclazole 34.2% SE.

Table 4: Management of anthracnose of chilli in field condition

Treatments	Dose (ml or g /l)	PDI of Anthracnose		Pooled mean of Anthracnose	PDC
		10 days after 1st spray	10 days after 2nd spray		
T_1: Mefenoxam 3.3% + Chlorothalonil 33.1% SC	2.0	6.24 (14.47)	7.10 (15.45)	6.65 (14.93)	70.21
T_2: Propineb 70% WP	2.5	4.90 (12.79)	6.72 (15.02)	5.79 (13.92)	74.06
T_3: Carbendazim 12% + Mancozeb 63% WP	2.0	3.86 (11.33)	5.93 (14.09)	4.86 (12.73)	78.23
T_4: Propiconazole 10.7% + Tricyclazole 34.2% SE	1.5	6. 40 (14.64)	7. 21 (15.56)	6.84 (15.14)	69.36
T_5: Turmeric + cow urine	5.0	8.02 (16.44)	8.72 (17.16)	8.45 (16.88)	62.15
T_6: Neem + cow urine	5.0	8.78 (17.24)	9.41 (17.86)	8.98 (17.43)	59.77
T_7: Untreated control	-	18.52 (25.49)	26. 48 (30.97)	22.32 (28.18)	-
S.Em (±)		0.74	0.65	0.68	-
CD (p=0.05)		2.10	1.80	1.92	-

*Figures in parentheses indicate angular transformed values, PDI = Percent disease Index, PDC= Percent reduction of the disease over control.

Conclusion

Anthracnose is becoming a major threat to chilli cultivation in West Bengal. Timely application of fungicides with proper dose can save the crop from this noxious pathogen. In both *in-vitro* and *in-vivo* trials, Carbendazim 12% + Mancozeb 63% WP was excellent to control the fruit rot infection followed by Propineb 70% WP and Mefenoxam 3.3% + Chlorothalonil 33.1% SC. It is important to standardize the dose of the bio-formulations (*Turmeric rhizome* extract + cow urine, Neem leaf extract + cow urine) to manage the disease in an eco-friendly manner. This information can be helpful for the development of an integrated management approach for welfare of the farming community.

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