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Original article

Control of *Colletotrichum truncatum* causing anthracnose/pod blight of soybean by aqueous leaf extracts, biocontrol agents and fungicides

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ABSTRACT

A study was conducted in the of Department Plant Pathology, Marathwada Agricultural University, Parbhani, Maharashtra during 2009 to 2010 to control *Colltotrichum truncatum* causing anthracnose / pod blight of soybean with plant extracts and bio-agents. All the nine aqueous leaf extracts and four species of antagonist *Trichoderma* evaluated *in vitro* were found effective against *C. truncatum* and recorded significant inhibition of the test pathogen over untreated control. However, *T. viride* was found most effective and recorded 18.53 mm mean colony diameter and recorded significantly highest growth inhibition (79.40 %) of the test pathogen. This was followed by *T. hamatum* and *Pseudomonas fluorescens* with 73.74 and 69.31 per cent growth inhibition, respectively. Of the aqueous leaf extracts evaluated, Garlic recorded significantly highest growth inhibition (81.82%) of the test pathogen. The second and third best plant extracts found were Tulsi (65.17 % inhibition) and Onion (60.31% inhibition) both of which were on par. Among the nine fungicides, Carbendazim recorded least mean colony diameter (7.52 mm) and highest inhibition (91.63 %) of mycelial growth of the test pathogen over untreated control, followed by Mancozeb which recorded mean colony diameter of 10.38 mm and mean mycelial growth inhibition of 88.45 per cent. In field, Carbandazim (@ 0.1%) recorded least mean disease intensity (19.55%), mean pod infection (9.63%), highest seed yield (2605 kg/ha) and test weight (14.33 g). It also recorded highest reductions in the disease intensity (40.73%), pod infection (75.73%) over

unsprayed control followed by Mancozeb (@ 0.1%) which recorded the minimum mean disease intensity (21.50%) pod infection (10.78%). Considering incremental cost: benefit ratio (ICBR), the most economical treatment which recorded highest cost: benefit ratio was the fungicide Carbendazim (C:B ratio, 1:14.45) followed by Carbendazium + Mancozeb (C:B ratio, 1:8.92).

1. Introduction

Soybean (*Glycine max* L. Merill) is a species of legume native to East Asia. The plant is classed as an oilseed rather than a pulse. The genus *Glycine* Willd. is divided into two subgenera, *Glycine* and *Soja*. In India area, production and productivity of soybean during 2007-2008 were 79.720 lakh ha., 64.28 lakh metric tonnes and 802 kg/ha., respectively (Anonymous, 2006). Soybeans growing major states in the country are Madhya Pradesh, Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, Rajasthan, Gujrat, Uttar Pradesh, Punjab and Haryana (Bhatnagar, 1997). About 80-85 per cent acerage of soybean in India is concentrated in Madhya Pradesh. More than 100 plant pathogens have been reported to affect soybean, but among them very few are economically important causing yield losses to the tune of 12-20 per cent (Mittal *et al.,* 1993). Among the most important diseases reported to cause economic losses to the soybean, anthracnose incited by *Colletotrichum truncutum* (Schw) Andrus and Moore causing yield losses of 16-100 per cent (Sinclair, 1992; Anonymous, 1999). Among the major fungal diseases of soybean, anthracnose (pod blight) caused by *Collecotrichum truncatum* (Schw) Andrus and Moore, has been reported as the major constraint in the successful cultivation of soybean (Khan and Sinclair, 1992 and Mittal *et al.*, 1993).

2. Materials and Methods

2.1. *In vitro* evaluation of aqueous leaf extracts

Nine aqueous leaf extracts (@ 10 and 15%) *viz.* Neem, Mehandi, Nilgiri, Bogunveilia, Parthenium, Garlic, Onion, Ginger and Eucalyptus were evaluated *in-vitro* against *C. truncatum* applying Poisoned Food Technique (Nene and Tapliyal, 1993) and using Potato Dextrose Agar (PDA) as basal culture media.-made commercial formulations of four bioagents *T. viride* (Tricho -Action, 100% w/w), *T. harzianum* (Tricho -Action, 100% w/w), *T. hamatum* (Tricho -Action, 100% w/w) and *Pseudomonas fluorescens* @ 10 and 15% each were evaluated *in-vitro* against *C. truncatum* applying Duel culture Technique (Nene and Tapliyal, 1993) and using Potato Dextrose Agar (PDA) as basal culture media.

Healthy and disease free fresh leaf sample of selected plant species were brought to the laboratory and washed with sterile distilled water and then chopped into small bits with sterilized sharp knife. Each leaf sample was then separately grind and homogenized in mechanical grinder with equal quantity of sterile distilled water (1:1, w: v). The homogenate obtained was then strained through double layered muslin cloth and filtrate collected was then filtered through Whatman No. l filter paper using volumetric flasks (50 ml capacity). The clear leaf extracts obtained formed the stock solution of 100 per cent. An appropriate quantity of each leaf, bulb and rhizome extract was incorporated separately in the molten and cooled PDA medium in conical flask (250 ml capacity) to get desired concentrations (10 and 15%) of each extract and autoclaved at 15 Lbs pressure for 15 to 20 minutes.

2.2. *In vitro* evaluation of bioagents

Four bioagents *Tricoderma viride*, *T. harzianum* , *T. hamatum* and *P. fluorescens* were also evaluated *in-vitro* applying duel culture Technique. The leaf extracts and bioagents amended PDA was then poured (15 – 20 ml/plates) in sterilized Petriplates (90 mm dia.) under aseptic conditions. Four plates / treatments / concentration where maintained and each treatment with respective concentration was replicated for four times. On solidification of PDA in Petriplats, all treatment plates where inoculated / seeded aseptically by placing in the

center with 5.0 mm uniform mycelial disc obtained from 7 days old culture of *C. truncatum* multiplied on agar plates. Petriplates containing plain PDA without any fungicide, plant extract and bioagent where inoculated with 5.0 mm disc of the test pathogen and maintained as suitable untreated control. All the treatment (inoculated) and control petriplates where then incubated at 24 + 2^0C in BOD incubator till the control plates were fully covered with mycelial growth of the test pathogen.

2.3. *In vitro* evaluation of fungicides

A total of nine fungicides (@ 100, 150, 200 ppm each) *viz.* Carbendazim (50 WP), Chlorothalonil (75 WP), Propiconazole (25 EC), Carbendazim + Mancozeb (75 WP), Mancozeb (75 WP), Difenconazole (25 EC), Fosetyl AL (80 WP), Hexaconazole 5 EC), Propineb (70 WP); were evaluated (@ 100, 150 and 200 ppm each) *in vitro* applying "Poisoned Food Technique" as described earlier against *C. trunctum*.

Observations on redial mycelial growth of *C. truncatum* where recorded in each treatment and per cent growth inhibition of the test pathogen over control was worked out (Vincent, 1927) as follows.

$$\text{Per cent inhibition (I)} = \frac{C - T}{C} \times 100$$

Where,

C = Growth of test fungus (mm) in control plate,

T = Growth of test fungus (mm) in treatment plates

2.4. *In vivo* evaluation of fungicides

The field experiment was conducted on the research farm of the Department of Plant Pathology during *Kharif*, 2009 to evaluate the efficacy of nine fungicides against *C. truncatum* with Randomized Block Design in three replications. Anthracnose susceptible soybean variety, JS-335 was sown at 30 x 10 cm spacing on 10th July, 2009. The crop was raised as per recommended package of practices and protective irrigation was given as and when required. A total of nine fungicides *viz.* Carbendazim 50 WP (@ 0.1%), Chlorothalonil 75 WP (@ 0.2%), Propiconazole 25 EC (@ 0.1%), Carbendazim + Mancozeb 75 WP (@ 0.1%), Mancozeb 75 WP (@ 0.2%), Difenconazole 25 EC (@ 0.1%), Fosetyl AL 80 WP (@ 0.1%), Hexaconazole 5 EC(@ 0.1%), Propineb 70 WP (@ 0.1%) were evaluated under field condition.

A total of three sprayings of all the treatments were undertaken at intervals of 15 days, starting first spraying at 30 days after sowing of the crops. One plot/ replication was maintained as unsprayed control without receiving any fungicides. Observations on foliage anthracnose disease were recorded before and after each sprayings and last observation on anthracnose were recorded at 15 days after last spraying. Five plants per treatment per replication were selected randomly and tagged for recording the observations. Three trifoliate leaves (bottom, middle and top) from main branch on each observation plant were selected for recording observations and per cent anthracnose disease intensity / index was worked out as detailed under 3.2.4. At harvest of the crops, observations on total number of pods / plants, number of infected and healthy pods, 100 seed weight and seed yield were recorded in all the treatments and yield data was presented on hectare basis..

2.5. Economics of fungicides

To find out the most effective and economical treatment, the economics of each treatment was worked out. While calculating the cost of production, the expenditure incurred on the accounts of fungicides, costs and labour charges for spraying were taken into account. Total monetary gain per treatment on hectare basis was worked out based on the existing selling rates of the soybean in the market. The data obtained in all the experiments (*in vitro and in vivo*) was statistically analyzed. The percentage values were transformed into Arcsine values. The standard error (SE) and critical difference (C.D.) at level P=0.05 were worked out and results obtained were compared statistically.

3. Results and discussion

3.1. *In vitro* evaluation of aqueous leaf extracts

Results (Table 1) indicated that all the botanicals tested were found inhibitory and caused significant inhibition of mycelail growth of the test pathogen over untreated control (PLATE- I). Among nine aqueous leaf extracts tested (@ 10 and 15%), Garlic recorded least mean colony diameter (16.35 mm) and highest mean mycelial growth inhibition (81.82%). This was followed by Tulsi, Onion, Ginger, Neem, Parthenium, Bogunveilia, Eucalyptus which recorded mean colony diameter of 65.17 mm, 60.31 mm, 55.25 mm, 49.72 mm, 47.09 mm, 42.90 mm, 41.11 mm and mean mycelial growth inhibition of 65.17, 60.31, 55.25, 49.72, 47.09, 42.90 and 41.11 per cent, respectively. Mehandi was found least effective and caused minimum inhibition (40.36 %) of the test pathogen.

Table 1

In vitro effect of different plant extracts on radial growth of C. *trunatum*.

Tr. No.	Treatments	Colony Diameter* (mm) at Conc.		Mean (mm)	% inhibition* at Conc.		Mean %
		10%	15%		10%	15%	
T_1	Garlic	18.27	14.44	16.35	79.70 (52.75)	83.95 (56.93)	81.82
T_2	Onion	36.36	35.07	35.71	59.60 (36.55)	61.03 (37.55)	60.31
T_3	Ginger	42.00	38.53	40.26	53.33 (31.83)	57.18 (34.44)	55.25
T_4	Neem	46.80	43.70	45.25	48.00 (29.18)	51.44 (30.74)	49.72
T_5	Mehandi	55.25	52.09	53.67	38.61 (12.53)	42.12 (13.48)	40.36
T_6	*Eucalyptus*	55.19	50.79	52.99	38.67 (22.41)	43.56 (25.16)	41.11
T_7	Bougenvilia	58.25	53.51	55.88	35.27 (11.40)	40.54 (12.34)	42.90
T_8	Parthenium	51.22	43.93	47.57	43.00 (25.97)	51.18 (27.43)	47.09
T_9	Tulsi	32.17	30.51	31.34	64.25 (39.93)	66.10 (40.79)	65.17
	Control	90.00	90.00	90.00	0.00	0.00	0.00
S.E. +		0.33	0.37	--	0.20	0.21	--
C.D.(P=0.05)		1.00	1.12	--	0.61	0.64	--

*Average of four replications.

Figures in parenthesis are angular transformed values.

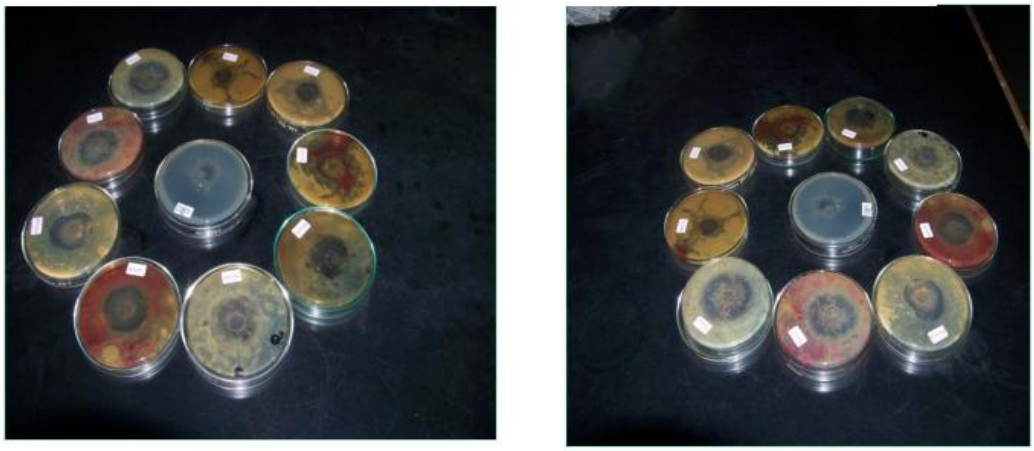

Plate 1. *In-vitro* evaluation of botanical at 10% (A) and 15% (B) on radial growth of *C. truncatum.*

Both concentrations (@ 10 and 15%) of the plant extracts tested were found effective in the inhibition of the test pathogen. However, higher concentration (@ 15%) caused maximum (range, 67.42 to 80.08 %) inhibition of mycelial growth compared to lower concentration (@ 10%) which recorded comparatively minimum inhibition of mycelial growth in the range of 61.75 to 78.01 per cent. Thus, all the botanicals and bioagents tested *in vitro* against *C. truncatum* were found effective in inhibiting the mycelial growth of the test pathogen over untreated control. The results (Fig. 1) revealed that all the botanicals / plant leaf extracts and bioagents tested *in vitro* were found significantly effective in reducing the percentage mycelial growth of *C. truncatum* over untreated control. However, plant leaf extract (@ 10 and 15%) of Garlic, recorded lowest mean colony diameter (16.35 mm) and highest mean mycelial growth inhibition (81.82%) of the test pathogen over untreated control. This was followed by the botanicals, Tulsi (mean col. dia, 31.34 mm and mean inhibition, 65.17%), Ginger (mean col. dia. 40.26 mm and mean inhibition 55.25%) , Neem (mean col. dia, 45.25 mm and mean inhibition, 49.72%), Parthenium (mean col. dia, 47.57 mm and mean inhibition, 47.09%), Bougenvilia (mean col. dia, 55.88 mm and mean inhibition, 42.90%), Eucalyptus (mean col. dia, 52.99 mm and mean inhibition, 41.11%). The plant leaf extract of Mehandi was found least effective and reported maximum mean colony diameter (53.67 mm) and lowest inhibition (40.36%) of the test pathogen. Both the concentration (10 and 15%) of plant leaf extracts / botanicals were found equally effective in the inhibition of the test pathogen. However all the treatments recorded reduced colony diameter and increased inhibition of the mycelial growth at higher concentration of 15 followed by 10 per cent. Thus, all the botanicals were found fungistatic against the test pathogen and recorded comparatively reduced colony diameter and increased mycelial growth inhibition over untreated control. Botanicals *viz*., Neem, Mehandi, Parthenium Bogunveilia and Eucalyptus were also reported fungistatic against several *Colletotrichum* species causing anthracnose, blights and leaf spots in many crops by several workers (Gomathi and Kannabiran, 2000; Chandrasekaran and Rajappan, 2002, Swamy and Kulkarni, 2003; George *et al.*, 2003; Rangarajulu *et al.* 2003; Rao and Narayana, 2005 and Gorwar *et al.*, 2006).

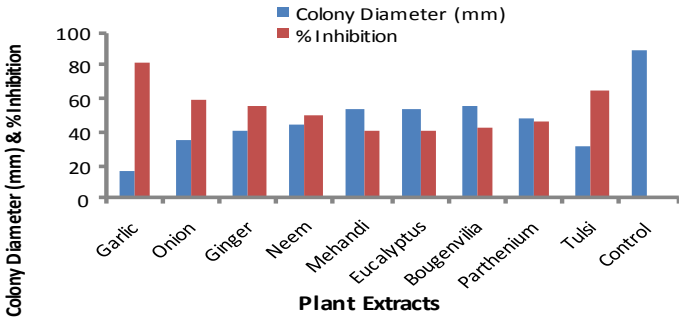

Fig. 1. *In vitro* evaluation of different plant extracts on radial growth of *C. trunatum*.

3.2. *In vitro* evaluation of bioagents

Results (Table 2) revealed that among the four bioagents, *T. viride* was found most effective and recorded 18.53 mm mean colony diameter and 79.40 per cent inhibition of the test pathogen. Mean colony diameter and per cent mycelial inhibition of test pathogen recorded by *T. harzianum, T. hamatum, P. fluorescens* were 31.87, 23.63, 27.60 and 64.58, 73.74, 69.33 respectively. Bio-agents tested were found effective in the inhibition of the test pathogen (Fig. 2, PLATE-II). However, colony diameter at 9 days caused maximum (range, 80.80 to 67.42%) inhibition of mycelial growth compared to 6 days which recorded comparatively minimum inhibition of mycelial growth in the range of 78.01 to 61.75 per cent. Of the four bioagents, *Tricoderma viride* followed by *T. hamatum* recorded mean colony diameter of 52.37 and 68.50 mm, respectively and mycelial growth inhibiting of 41.79 and 23.75 per cent, respectively. The bioagents, *T. viride*, *T. harzinum, T. virens* were reported as effective antagonists against *Colletotrichum* species by several workers (Barros *et al.,* 1995; Jaylakshmi *et al.,* 1998; Ingle *et al.,* 2002; Devis *et al.,* 2003; Raheja and Thakur, 2002; Rao and Narayana, 2005 and Kaur *et al*., 2006).

Table 2

In vitro effect of different bioagents on radial growth of C. *trunatum*.

Tr. No.	Treatments	Colony Diameter* (mm)		Mean (mm)	% inhibition*		Mean %
		6 days	9 days		6 days	9 days	
T_1	*T. viride*	19.79	17.28	18.53	79.01 (51.32)	80.80 (49.64)	79.40
T_2	*T. Harzianum*	34.42	29.32	31.87	61.75 (38.23)	67.42 (35.41)	64.58
T_3	*T. hamatum*	26.13	21.13	23.63	70.96 (45.20)	76.52 (43.60)	73.74
T_4	*P. fluorescens*	29.23	25.97	27.60	67.52 (44.49)	71.14 (41.74)	69.31
	Control	90.00	90.00	90.00	0.00	0.00	0.00
S.E. +		0.69	0.44	--	0.80	0.39	--
C.D.(P=0.05)		2.25	1.44	--	2.63	1.29	--

*Average of four replications.
Figures in parenthesis are angular transformed values

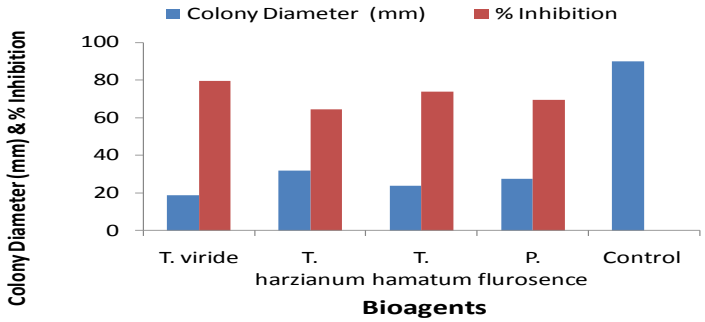

Fig. 2. *In vitro* evaluation of different bioagents on radial growth of *C. trunatum*.

Control

Plate II. *In-vitro* evaluation of bioagents on radial growth of *C. truncatum.*

3.3. *In vitro* evaluation of fungicides

Result (Table 3) indicated that all the fungicides tested significantly inhibited the mycelial growth of *C. truncatum* over untreated control at all the concentration tested (PLATE- III). Among the fungicides, tested

Carbendazim recorded least mean colony diameter (7.52 mm) and highest inhibition (91.63 %) of mycelial growth of the test pathogen over untreated control. This was followed by the fungicides, Mancozeb which recorded mean colony diameter of 10.38 mm and mean mycelial growth inhibition of 88.45 per cent, followed by Carbendazim + Mancozeb, Propiconazole, Hexaconazole, Difenconazole, Propineb, Focetyl AL, which recorded mean colony diameter of 10.38 mm, 12.04 mm, 13 . 69 mm, 14.79 mm, 16.15 mm, 36.17 mm and 44.15 mm and mean mycelial inhibition of 88.45, 86.61, 86.45, 83.56, 82.05, 59.79, and 50.94 per cent, respectively. Fungicide Chlorothalonil was found comparatively least effective and recorded 53.98 mm and 40.01 per cent mean colony diameter and mean mycelial growth inhibition, respectively. All the concentrations of the fungicides tested significantly inhibited mycelial growth of the test pathogen (Fig. 3). However, higher concentration (@ 200 ppm) recorded maximum inhibition (range, 41.13 to 9288 %) followed by 150 ppm (range, 39.78 to 91.50 % inhibition) and 100 ppm (range, 39.14 to 90.53 % inhibition).

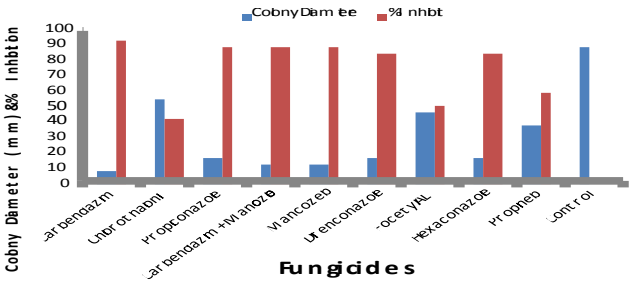

Fig 3. *in-vitro* evaluation of fungicides at different concentrations on radial growth of *C truncatum*

100ppm (A) **150ppm (B)** **200ppm (C)**

Plate III. *In-vitro* evaluation of fungicide at 100 ppm (A), 150 ppm (B) and 200 ppm(C) on radial growth of *C. truncatum.*

Thus, all the fungicides tested at various concentrations significantly inhibited the mycelial growth *C. truncatum*. However, Carbendazim was found most effective followed by Mancozeb, Carbendazim+Mancozeb, Propiconazole, Hexaconazole,Difenconazole, Propineb, Focetyl AL. Fungicide Chlorothalonil was found comparatively least effective against the test pathogen. Fungicide, Carbendazim was reported inhibitory to the *C. lindemuthianum* causing anthracnose of french bean (Chakraborty and Shyam, 1988), *C. truncatum* causing anthracnose of soybean (Ghawde *et al.*, 1996), *C. gramincola* (Singh and Dwivedi, 2002), *C. capsici* causing blight of bitter gourd (Dubey and Ekkla, 2003), *C. gloeosporioides* causing anthracnose of mango (Kumar *et al.*, 2003); fungicides. Hexaconazole, Propiconazole, Penconazole and Difenconazole were reported inhibitory to *C. truncatum, C. gleosporioides. C. capsici* and *C. lindemuthianum* by several workers (Swamy and Kulkarni, 2003; Kumar *et al.* 2003; and Gorawar *et al.*, 2005).

Table 3

In vitro effect of fungicides at different concentrations on radial growth of *C. truncatum.*

Tr. No.	Fungicides	Colony Diameter* (mm)			Mean (mm)	% Inhibition			Mean %
		100 ppm	150 ppm	200 ppm		100 ppm	150 ppm	200 ppm	
T_1	Carbendazim	8.52	7.65	6.40	7.52	90.53 (63.25)	91.50 (65.10)	92.88 (66.79)	91.63
T_2	Chlorothalonil	54.77	54.19	52.98	53.98	39.14 (40.90)	39.78 (44.24)	41.13 (48.84)	40.01
T_3	Propiconazole	14.79	13.21	13.07	13.69	83.56 (55.99)	85.32 (57.63)	85.47 (60.31)	86.45
T_4	Carbendazim + Mancozeb	13.22	11.94	10.97	12.04	85.31 (57.39)	86.73 (59.55)	87.81 (61.34)	86.61
T_5	Mancozeb	11.80	10.17	9.19	10.38	86.88 (59.84)	88.70 (60.80)	89.78 (63.83)	88.45
T_6	Difenconazole	18.71	17.18	12.56	16.15	79.21 (52.40)	80.91 (54.27)	86.04 (55.45)	82.05
T_7	Focetyl AL	45.18	44.27	43.01	44.15	49.80 (45.51)	50.81 (48.64)	52.21 (51.54)	50.94
T_8	Hexaconazole	16.19	14.77	13.41	14.79	82.01 (53.53)	83.58 (55.19)	85.10 (56.43)	83.56
T_9	Propineb	36.21	36.28	36.04	36.17	59.76 (49.02)	59.68 (52.23)	59.95 (53.80)	59.79
	Control	90.00	90.00	90.00	90.00	00.00	00.00	00.00	00.00
S.E. ±		0.18	0.20	0.17	--	0.38	0.48	0.39	--
C.D. (P=0.05)		0.74	0.78	0.70	--	1.05	1.19	1.08	--

*Average of four replications.

Figures in parenthesis are angular transformed values.

3.4. *In vivo* evaluation of fungicides

Results obtained in respect of disease intensity, per cent pod infection, pod yield, test weight and cost: benefit ratio are being presented herein following paragraphs.

3.5. Anthracnose intensity and pod infection

Results (Table 4, Fig 4) revealed that all the fungicides tested were found effective and significantly reduced the disease intensity and pod infection over unsprayed control. Among the fungicides, Carbandazim (@ 0.1%) recorded least mean disease intensity (19.55%) and mean pod infection (9.63%). It also recorded highest reductions in the disease intensity (40.73%), pod infection (75.73%) over unsprayed control. The second best fungicide found was Mancozeb (@ 0.1%) which recorded the minimum mean disease intensity (21.50%) pod infection (10.78%) and thereby caused 34.82 and 72.83 per cent reductions in the disease intensity pod infection, respectively over unsprayed control. This was followed by the fungicides, Mancozeb which recorded mean colony diameter of 10.38 mm and mean mycelial growth inhibition of 88.45 per cent, This was followed by the fungicides, Carbendazim + Mancozeb, Propiconazole, Hexaconazole, Difenconazole, Propineb, Focetyl AL, which recorded disease intensity 24.29, 24.62, 25.61, 25.64, 27.22 and 26.32 per cent respectively and pod infection 16.64, 22.54, 23.96, 24.06, 25.12 and 28.22 per cent respectively. Fungicide Chlorothalonil was found comparatively least effective and recorded 27.17 per cent disease intensity and 28.89 per cent mean pod infection.

Table 4
Effect of fungicides spraying on per cent pod infection (PPI), per cent disease intensity (PDI) in soybean *cv.,* JS-335.

Tr. No.	Treatments	Mean PPI*	PDI*				Mean	% reduction over control	
			Before I spray	30 DAS	45 DAS	60 DAS		PPI	PDI
T_1	Carbendazim	9.63	27.73	25.88	16.20	8.4	19.55	75.73	40.73
T_2	Chlorothalonil	28.89	27.477	30.11	28.77	22.35	27.17	27.19	17.64
T_3	Propiconazole	22.54	29.11	28.27	23.25	17.85	24.67	43.13	25.37
T_4	Carbendazim + Mancozeb	16.64	25.80	28.37	24.69	18.31	24.29	58.06	26.37
T_5	Mancozeb	10.78	26.73	27.20	20.91	11.19	21.50	72.83	34.82
T_6	Difenconazole	24.06	29.22	28.24	26.24	18.89	25.64	39.36	22.27
T_7	Focetyl AL	28.22	28.13	29.21	27.72	20.24	26.32	28.88	20.21
T_8	Hexaconazole	23.96	29.56	28.45	26.12	18.31	25.61	39.61	22.37
T_9	Propineb	25.12	28.40	30.58	25.97	21.96	27.22	36.69	17.49
	Control	39.68	29.64	33.67	32.50	36.18	31.99	00.00	00.00
S.E. $\pm$		0.51	0.34	0.97	0.29	0.42	-	-	-
C.D. (P=0.05)		1.53	1.01	2.88	0.86	1.26	-	-	-

3.6. Seed yield and test weight

Results (Table 5, Fig 5) obtained in respect of efficacy of fungicides against anthracnose of soybean and their effect on seed yield and test weight of soybean indicated that all the treatments significantly reduced the anthracnose / pod blight intensity and defoliation over unsprayed control and thereby increased the seed yield and test weight. Among fungicides tested, Carbendazim (@ 0.1%) recorded highest seed yield (2605 kg/ha) and test weight (14.33 g) and thereby increased the seed yield and test weight by 30.95 and 17.44, per cent respectively, over unsprayed control (yield, 1799 kg/ha, test weight, 11.83 g) with minimum mean disease intensity (19.55%) and pod infection (9.63%). The second best fungicide found was Mancozeb (@ 0.1%) which recorded seed yield of 2505 kg/ha and test weight of 14.00 g with minimum mean disease intensity (21.50%) and pod infection (10.78%) and thereby increased the seed yield by 28.18 per cent and test weight by 15.50 per cent over unsprayed control. This was followed by fungicides, Carbendazim + Mancozeb, Propiconazole, Hexaconazole, Difenconazole, Propineb, Focetyl AL respectively and test weight of 13.50, 13.16, 13.11, 13.00, 12.58 and 12.90 g, respectively with the mean disease intensities of 24.29, 24.62, 25.61, 25.64, 27.22 and 26.32 per cent, respectively and mean

pod infections of 16.64, 22.54, 23.96, 24.06, 25.12 and 28.22 per cent, respectively. Fungicides Chlorothalonil was found on par with each other in respect of the seed yield. The per cent increase in seed yield and test weight recorded by the fungicides, Carbendazim + Mancozeb, Propiconazole, Hexaconazole, Difenconazole, Propineb, Focetyl AL over unsprayed control were 25.22, 19.97, 28.41, 28.18, 14.66, 16.01 per cent and 12.67, 10.10, 9.76, 9.00, 5.96 , 8.29 respectively. Efficacy of these fungicides in controlling anthracnose diseases and increasing the yields were reported earlier by several workers (Khare *et al*., 1972; Chaudhary, 1977; Palarpawar and Ghurade, 1989; Kumar and Mukhopadhyay 1990; Bhardwaj and Thakur, 1991; Shukla and Singh, 1993; Mittal, 2001; Dubey and Ekka, 2003; and Ekbote, 2005). The botanicals and bioagents found effective against *C. truncatum* in present studies were also reported effective against *Collectrichum* sp. earlier by several workers (Chandrasekharan *et al.*, 2000; Jayalakshmi *et al.,* 1998; Joshi and Tripathi, 2002; Chandrasekharan and Rajappan, 2002; Rao and Narayana, 2005 and Kaur, *et al.*, 2006). Thus, all the fungicides evaluated under field conditions against anthracnose/ pod light of soybean were found most effective in reducing the disease as well as increasing the seed yield and test weight over unsprayed control.

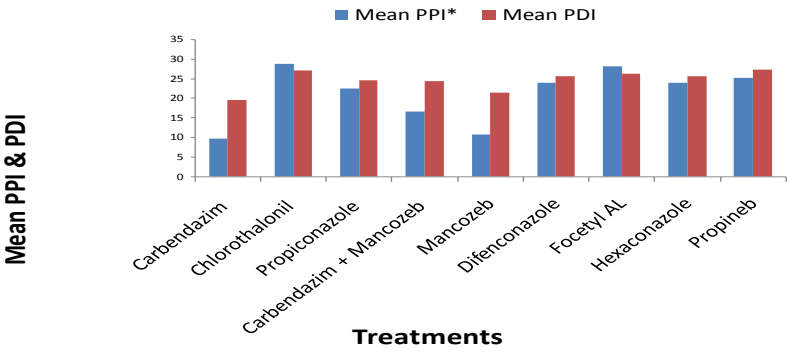

Fig.4. Effect of fungicides spraying on per cent pod infection (PPI), per cent disease intensity (PDI) in soybean *cv.,* JS-335.

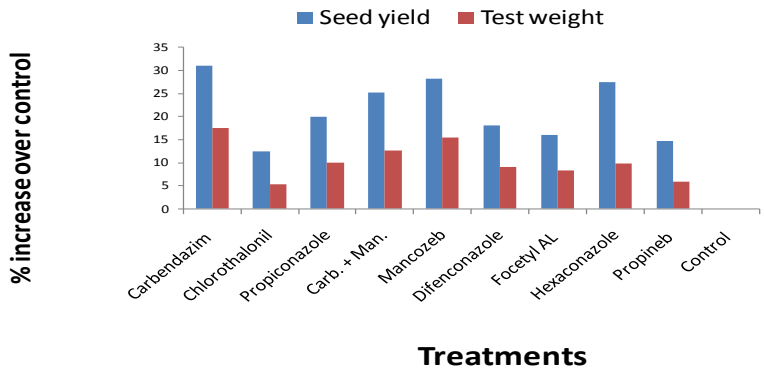

Fig. 5. Effect of fungicides on % increase over control in terms of seed yield and test weight in soybean Cv. JS-335

Table 5
Effect of fungicides on per cent pod infection (PPI) and anthracnose intensity (PDI) on seed yield and test weight in soybean Cv. JS-335.

Tr. No.	Treatments	Mean PPI	Mean PDI	Seed yield* (kg/ha)	Test weight* (g)	% increase over control	
						Seed yield	Test weight
T_1	Carbendazim	9.63	19.55	2605	14.33	30.95	17.44
T_2	Chlorothalonil	28.89	27.17	2054	12.50	12.42	5.36
T_3	Propiconazole	22.54	24.62	2248	13.16	19.97	10.10
T_4	Carbendazim + Mancozeb	16.64	24.29	2406	13.50	25.22	12.67
T_5	Mancozeb	10.78	21.50	2505	14.00	28.18	15.50
T_6	Difenconazole	24.06	25.64	2198	13.00	18.15	9.00
T_7	Focetyl AL	28.22	26.32	2142	12.90	16.01	8.29
T_8	Hexaconazole	23.96	25.61	2205	13.11	27.41	9.76
T_9	Propineb	25.12	27.22	2108	12.58	14.66	5.96
	Control	39.68	32.99	1799	11.83	-	-
S.E. $\pm$				0.31	0.25	-	-
C.D. (P=0.05)				0.94	0.75	-	-

*Average of three replications.
Figures in parenthesis are angular transformed values.

3.7. Cost: benefit ratio

Results (Table 6) obtained on economics / incremental cost: benefit ratio (ICBR) in respect of various spray treatments revealed that all the treatments significantly reduced the disease intensity (anthracnose / pod blight) and thereby increased the seed yield and test weight in soybean. All the spray treatments gave significantly maximum gross and additional income with better cost: benefit ratio over unsprayed control. All the treatments increased the seed yield (range, 2108 to 2605 kg/ha), gave maximum gross (range, 29512 to 36470 Rs./ha) and additional (range, 4326 to 11284 Rs./ha) over unsprayed control. However, fungicide Carbendazim recorded highest grain yield (2605 kg/ha) and gave highest gross income (Rs. 36470 /ha) and additional income (Rs. 11284/ha) over unsprayed control. This was followed by the fungicide Mancozeb which gave gross and additional income of Rs. 35070 and 9884 per hectare, respectively; Carbendazium + Mancozeb (Rs. 33684 and 8498/ha, respectively), Propiconazole (Rs. 31472 and 6286/ha, respectively), Hexaconazole (Rs. 30870 and 5684/ha, respectively), Difenconazole (Rs. 30772 and 5586/ha respectively), Fosctyl AL (Rs.29988 and 4802/ha respectively) and Chlorothalonil (Rs. 28756 and 3570/ha, respectively). Considering incremental cost: benefit ratio (ICBR), the most economical treatment which recorded highest cost: benefit ratio was the fungicide Carbendazim (C:B ratio, 1:14.45). This was followed by the fungicides Carbendazium + Mancozeb (C:B ratio, 1:8.92), Difenconazole (C:B ratio, 1:7.46), Mancozeb (C:B ratio, 1:4.83), Propineb (C:B ratio, 1:2.85), Hexaconazole(C:B ratio, 1:2.32) Fosctyl AL (C:B ratio, 1:1.33), Propiconazole (C:B ratio, 1:0.76) and Chlorothalonil (C:B ratio, 1:0.67) respectively. These results obtained on the economics of fungicides, botanicals and bioagents sprayings for the management of soybean anthracnose disease and anthracnose of other crop plants are in conformity with those reported earlier by several workers. (Singh *et al.* 1981; Bhardwaj and Thakur, 1991; Chandrasekaran and Rajappan, 2002; Chandrasekaran *et al.*, 2000; Gorawar *et al.*, 2006).

4. Conclusion

Biological control is an effective, ecofriendly and alternative approach for any disease management practice. The results on *C. truncatum,* revealed that, all the plant extracts and antagonists significantly reduced the growth of *C. truncatum,* either by over growing or by exhibiting inhibition zones. Most of antagonists inhibited colony growth of *C. truncatum,* by their fast and over growing nature as observed in antagonists. Similarly Deshmukh and Raut (1992) reported that *Trichoderma Harzianum* Rifai and *T. viride* Pers. overgrew colonies of *C. gloeosporioides* and *T. harzianum* was more aggressive than *T. viride*. Narendra Singh (1992) revealed that *T. harzianum* was a

strong inhibitor of *C. falcatum* under in vitro condition. Santha Kumari (2002) observed that the isolates of T1 and T2 of *T. harzianum* and the isolates of A1 and A2 of *Aspergillus niger* were found effective in inhibiting the growth of *C. gloeosporioides* causing anthracnose of black pepper under in vitro condition. Patel and Joshi (2001) and Raheja and Thakore (2002) in case of *C. gloeosporioides*. *T. virens* and *T. koningii* showed more mycelial inhibition compared to bacterial antagonists. This can be attributed to higher competitive ability of this *Trichoderma* spp. The antagonism of *Trichoderma* spp. against many fungi is mainly due to production at acetaldehyde compound (Robinson and Park, 1966 and Dennis and Webster, 1971). This may also be the reason for its antagonistic effect on *C. gloeosporioides*. Godtfredsen and Vagedal (1965) reported trichodermin, Pyke and Dictz (1960) found dermadin as major volatile antibiotic produced by *Trichoderma* spp., which suppress several plant pathogens.

Thus it was apparent that, Carbendazim and Mancozeb among the systemic and non-systemic fungicides, respectively, were significantly superior in inhibiting the growth of *C. truncatum* at all the concentrations evaluated *in vitro*. The efficacy of the individual component of an integrated measure against the target pathogen should be Cleary understood to develop an integrated control strategy. The results of the current laboratory evaluation of fungicides against *C. truncatum* of soybean will fulfill the prerequisite criteria for the selection of appropriate dose of fungicide to develop an eco-friendly integrated disease management of anthracnose of soybean in the field. Considering cost: benefit (C:B) ratio, the most economical treatment found with highest C : B ratio (1:14.45) was the fungicide Carbendazim followed by the fungicides Carbendazium + Mancozeb (C:B ratio, 1:8.92).

Table 6

Economics of fungicides sprayings for management for pod blight of soybean.

Treatments	Mean PDI	Yield * (kg/ha)	Gross income ** (400/q)	Additional income/ha	Cost. Of spraying			Net profit	C:B ratio
					Fungicides***	Labour	Total		
Carbendazim (@ 0.1%)	19.55	2605	36470	11284	579.98	150	729.98	10554.02	1:14.45
Chlorothalonil (@ 0.2%)	27.17	2054	28756	3570	1987.65	150	2137.65	1432.35	1:0.67
Propiconazole (@ 0.1%)	24.62	2248	31472	6286	3405.84	150	3555.24	2730.16	1:0.76
Carbendazim + Mancozeb (@ 0.1%)	24.29	2406	33684	8498	705.84	150	855.84	7642.16	1:8.92
Mancozeb (@ 0.2%)	21.50	2505	35070	9884	1542.50	150	1692.50	8191.50	1:4.83
Difenconazole (@ 0.1%)	25.64	498	30772	5586	510.00	150	660.00	4926.00	1:7.46
Focetyl AL (@ 0.1%)	26.32	2142	29988	4802	1905.50	150	2055.50	2746.50	1:1.33
Hexaconazole (@ 0.1%)	25.61	2205	30870	5684	1560.00	150	1710.00	3974.00	1:2.32
Propineb (@ 0.1%)	27.22	2108	29512	4326	1085.00	150	1135.00	3241.00	1:2.85
Control (Unsprayed)	32.99	1799	25186	-	-	-	-	-	-

*Mean of three replications

** Selling rate of soybean @ Rs. 1400/qt.

Figures in parenthesis are angular transformed values.

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