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Integrated management of okra leaf spot caused by *Alternaria chlamydospora*

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Abstract
Okra (*Abelmoschus esculentus* (L.) Moench) crop is being affected by several fungal, bacterial, viral and nematode induced diseases. However, leaf spot, caused by *Alternaria chlamydospora* has been common occurrence, causing quantitative as well as qualitative losses in okra. Therefore, in present study, four fungicides (two systemic, one each contact and combi-fungicide), bioagent *T. viride* and Neem oil were integrated by giving three srays at an interval of 15 days, for management of Alternaria leaf spot of okra (Hyb. NOH-1684). The experiment was planned and conducted in RBD with ten treatments replicated thrice, at the Department of Plant Pathology, College of Agriculture, Latur, VNMKV, Parbhani (MS), during *Kharif*, 2017.

The results revealed that all the treatments significantly influenced leaf spot disease incidence, intensity, fruit parameters, fruit yield and incremental cost: benefit ratio (ICBR), over untreated control. Based on average disease intensity and its reduction over untreated control, the most effective treatment found was Carbendazim 25% + Mancozeb 50% WS @ 0.25%, with least average disease intensity (15.51%) and its highest reduction (50.09%), followed by Hexaconazole 5% EC @ 0.1% + Neem oil @ 0.2% (16.87% and 45.72%, respectively), Hexaconazole 5% EC @ 0.1% (17.45% and 43.85%, respectively) and Mancozeb 75% WP @ 0.25% + Neem oil @ 0.2% (17.58% and 43.43%, respectively). Rest of the treatments were found also effective. All the treatments also improved fruit parameters and fruit yield. Based on ICBR, the most economical and effective treatment found was Carbendazim 25% + Mancozeb 50% WS @ 0.25%, and Hexaconazole 5% EC @ 0.1% + Neem oil @ 0.2% (2.70), followed by Hexaconazole 5% EC @ 0.1% (2.60); whereas, it was least with Neem oil @ 0.2% (1.79).

Keywords: Okra, *Alternaria chlamydospora*, Fungicides, Neem oil, *T. viride*, intensity, fruit yield

Introduction
Okra is an important vegetable crop with a diverse array of nutritional quality and potential health benefits. India ranks first in area and production of okra and has been commercially grown in the states of Andhra Pradesh, West Bengal, Jharkhand, Orissa, Utter Pradesh, Madhya Pradesh, Karnataka, Gujarat and Maharashtra. India occupies an area of 507 thousands hectares under the cultivation of this crop with a production of 5853 thousands tones and productivity of 11.5 tones / ha. In Maharashtra, *Bhendi* is grown throughout the year, providing continuous and remunerative source of income to the farmers. It is extensively grown in the districts *viz*., Ahmednagar, Amravati, Aurangabad, Dhule, Jalgaon, Nagpur, Nashik, Osmanabad, Parbhani, Latur and Pune. In Maharashtra, it was cultivated on an area of 10.55 thousands hectares with an annual production of 84.50 thousands tones and productivity of 8.01 tones/ha.

However, biotic and abiotic stresses under changing climate are major hurdles in profitable production of various crops including okra. Okra crop is being affected by several fungal, bacterial, viral and nematode induced diseases. Okra crop is being affected by major fungal diseases *viz.*, Alternaria leaf spot (*Alternaria alternata / A. chlamydospora*), causing 30-50% or more yield losses (Thippeswamy *et al.*, 2007; Pansambal *et al.*, 2015a) [36, 28], powdery mildew (*Erisiphe cichoracearum* and *Leveillula taurica*), causing 17-86.6% losses (Sridhar *et al.*,1989) [35], root / charcoal rot (*Microphomina phaseolina*), wilt (*Fusarium oxysporum* f. sp. *vasinfectum*), *Cercospora* leaf spot (*Cercospora abelmoschi, C. malayensis*) and damping off (*Pythium* sp., *Rhizoctonia* sp.), viral Yellow vein mosaic (YVMV) causing 50-90% qualitative and quantitative losses (Jambhale and Nerkar, 1981) [19].

A number of essential oils having bioactive chemicals with antifungal properties, easily biodegradable and non - toxic to other microflora and microfauna have been reported effective (*in vitro* and *in vivo*) against many fungal pathogens, including *Alternaria* spp. Essential oils

such as *Eucalyptus*, *Cassia*, Thime, Clove, Mint, Neem, Garlic, Ginger, Lemongrass, Mustard, Castor etc. were reported as effective against many *Alternaria* spp., including *A. chlamydospora*, earlier by many workers (Feng and Zheng, 2006; Bahagoli and Behdad, 2012; Devi and Basu, 2013; Bhattarai and Jha, 2016; Rahmatzai *et al*., 2017) [16, 5, 11, 7, 31].

The field experiment "Management of okra Alternaria leaf spot caused by *Alternaria chlamydospora* Mouchacca" was planned and conducted on Research Farm of the Department of Plant Pathology, College of Agriculture, Latur, during *Kharif*, 2017 season.

Materials and Methods

Integrated disease management (*in vivo*)

Those fungicides, bioagents and essential oils found effective under present *in vitro* studies, against *A. chlamydospora* were integrated for the management of Alternaria leaf spot of okra and one plot / treatment / replication was maintained as unsprayed control. four fungicides (two systemic, one each contact and combi-fungicide), bioagent *T. viride* and Neem oil were integrated by giving three srays at an interval of 15 days, for management of Alternaria leaf spot of okra (Hyb. NOH-1684).

Experimental Details

Design : RBD
Replications : Three
Treatments : Ten
Plot size : Gross=3.0 x 2.25 m^2 and Net = 2.40 x 1.95 m^2
Spacing : 30 x 15 cm

Table: Treatment Details

Tr. No.	Treatments	Dosages (g or ml/lit. water)
T_1	Hexaconazole 5% EC	1.0 ml
T_2	Tebuconazole 25.9% EC	1.0 ml
T_3	Mancozeb 75% WP	2.5 g
T_4	Carbendazim 25% + Mancozeb 50% WS	2.0 g
T_5	*Trichoderma viride* (1 x 10^7 cfu/g)	10.0 g75
T_6	Neem oil	2 ml
T_7	Hexaconazole 5% EC + Neem oil	1.0 ml + 2.0 ml
T_8	*T. viride* + Neem oil	10 g + 2.0 ml
T_9	Mancozeb 75 % WP + Neem oil	2.5 g +2.0 ml
T_{10}	Control (unsprayed)	---------

Healthy seeds of okra Hyb. NOH- 1684 were sown in the field plots, at recommended spacing. The crop was grown by applying all recommended package of practices and irrigated the crop, whenever required. A total of three foliar sprayings of the test treatments were undertaken at an interval of 15 days, starting first spraying at first appearance of Alternaria leaf spot symptoms.

Observations on leaf spot incidence and intensity were recorded, starting from first appearance of the disease symptoms, one day before each spraying and fifteen days after third spraying. The disease incidence was recorded by counting number of plants showing Alternaria leaf spot symptoms and number of disease free plants, in all the treatments replicated thrice and per cent disease incidence was calculated, by applying following formula.

$$\% \text{ Disease Incidence} = \frac{\text{No. of plants showing disease symptoms}}{\text{Total No. of plants/plot}} \times 100$$

Table: Disease rating scale

Scale/Grade	Descriptions
0	No symptoms on the leaves
1	Small, brown spots covering > 1 % or less of the leaf area.
3	Lesions small, scattered, brown to black with concentric rings, covering 1- 10% of the leaf area.
5	11-25% of the leaf area affected.
7	26-50% of leaf area affected with lesions enlarging, slightly sunken in the center with concentric rings.
9	Lesions enlarging (10 mm), coalescing to form bigger patches covering >50 % leaf area.

For recording Alternaria leaf spot intensity, five plants per treatment per replication were selected randomly, tagged and recorded observations on leaf blight intensity, by choosing three foliage (bottom, middle, top) per plant, by applying following 0-9 disease rating scale (Mayee and Datar, 1986) [25].

Per cent disease intensity / index was calculated by applying the following formula (McKinney, 1923) [26]

$$\% \text{ Disease Intensity} = \frac{\text{Summation of numerical ratings observed}}{\text{No. of leaves /plants observed x Maximum rating}} \times 100$$

Per cent disease control (PDC) over untreated control was calculated by applying the following formula.

$$\% \text{ Disease Control (PDC)} = \frac{\text{PDI in Control plot - PDI in Treatment plot}}{\text{PDI in Control plot}} \times 100$$

Fruit yield

Okra fruits were harvested in various picking, preferably one day before each spraying, cumulative fruit yield dada was obtained and calculated on hectare basis. Also economics of the treatments attempted was calculated.

Economics of the treatments

To find out most effective and economical treatment, the incremental cost benefit ratio (ICBR) was worked out. For the purpose, cost of cultivation / production (Appendix II), cost of plant protection, gross monetary returns and net profit were considered, to calculate ICBR of the treatments imposed to manage Alternaria leaf spot of okra.

Statistical analysis

The data obtained in all the experiments (*in vitro* and *in vivo*) was statistical analyzed (Panse and Sukhatme, 1978) [30]. The per cent values were transformed into arcsine values. The standard error (S.E.±) computed and critical difference (C.D.) was computed at P = 0.01 and P=0.05, respectively for *in vitro* and *in vivo* experiments and interpreted the results.

Results and discussion

Present studies on Alternaria leaf spot of okra (*A. chlamydospora*) were undertaken during *kharif*, 2017 *in vivo* bioefficacy of fungicides, bioagents and essential oils and disease management. The results obtained on all these aspects are presented in this chapter.

Symptomatology

Alternaria leaf spot diseased specimens of okra crop collected from farmers' fields, exhibited typical symptoms such as:

initially irregularly shaped, minute, dark brown spots, with yellow coloured edge of the leaflet, which later expanded, turned brown and caused leaf spot.

Symptoms of Alternaria leaf spot of okra observed in present studies were also reported earlier by many workers. Minute, irregularly shaped, dark brown spots on margins and tips of leaflets were induced by *A. chlamydospora* in okra, causing leaf spot of okra (Pansambal *et al.*, 2015) [28].

Disease incidence

Results (Table 1 and Fig. 1) revealed that all the treatments significantly influenced leaf spot disease incidence in okra. The disease appeared first at about 55 to 60 days after sowing, which later increased steadily upto second spraying and decreased thereafter.

At first appearance, the disease incidence ranged from 9.32 to 12.82 per cent, as against 13.91 per cent in untreated control. However, it was numerically least with the treatment T_8 of *T. viride* + Neem oil (9.32), followed by Carbendazim 25% + Mancozeb 50% WS (10.36%) followed by Hexaconazole 5% EC + Neem oil (10.72), Neem oil (10.78%), Hexaconazole 25% EC (11.03%), Mancozeb 75% WP + Neem oil (12.82%), Tebuconazole 25.9% EC (11.87%), Mancozeb 75% WP (12.17%), T_5 of *T. viride* (12.76), as against 13.91% in untreated control. Thus, all the treatments were non-significant.

Fifteen day after 3 rd spray and compared to 1 st and 2 nd spray, the disease incidence steadily decreased, which ranged from 15.30 to 31.11 per cent, as against 72.40% in untreated control. However, it was significantly least with the treatment Carbendazim 25% + Mancozeb 50% (75% WS) (15.30%), followed by Hexaconazole 5% EC + Neem oil (16.80%), Mancozeb 75% WP + Neem oil (17.20%) and Hexaconazole 5% EC (18.20%). All of the treatment were on par to each other except *T. viride* (1 x 10^7 cfu/g) and Neem oil, which resulted with significantly highest disease incidence of 22.40 and 31.11 per cent, but minimum over untreated control (72.40%).

Table 1: Efficacy of various treatments against leaf spot incidence in okra

Tr. No.	Treatments	Rate/ conc.	Disease Incidence (%)*				Av. DI (%)	Av. Red. (%)
			At 1st Appear.	After 1st Spray	After 2nd Spray	15 Days After 3rd Spray		
T_1	Hexaconazole 5% EC	1.0 ml/lit	11.03 (19.40)	14.90 (22.71)	22.22 (28.12)	18.20 (25.25)	16.59 (24.04)	52.52 (46.44)
T_2	Tebuconazole 25.9% EC	1.0 ml/lit	11.87 (20.15)	15.00 (22.77)	23.60 (29.06)	19.00 (25.84)	17.37 (24.63)	50.28 (45.16)
T_3	Mancozeb 75% WP	2.5 g/lit	12.17 (20.42)	16.10 (23.66)	26.20 (30.79)	21.00 (27.27)	18.87 (25.75)	45.99 (42.70)
T_4	Carbendazim 25% + Mancozeb 50% (75% WS)	2.5 g/lit	10.36 (18.78)	13.80 (21.80)	18.10 (25.18)	15.30 (23.03)	14.39 (22.30)	58.81 (50.07)
T_5	*T. viride* (1 x 10^7 cfu/g)	10 g/lit.	12.76 (20.93)	16.20 23.73)	27.80 (31.82)	22.40 (28.25)	19.79 (26.41)	43.36 (42.18)
T_6	Neem oil	2 ml/lit	10.76 (19.15)	18.40 (25.40)	58.33 (49.80)	31.11 (33.90)	30.44 (33.49)	12.88 (21.03)
T_7	Hexaconazole 5% EC + Neem oil	1.0 ml + 2 ml/lit	10.72 (19.11)	13.77 (21.78)	18.40 (25.40)	16.80 (24.20)	14.92 (22.72)	57.30 (49.20)
T_8	*T. viride* (1 x 10^7 cfu/g) + Neem oil	10 g/lit.+ 2 ml/lit	09.32 (17.78)	13.80 (21.81)	26.00 (30.66)	21.00 (27.27)	17.53 (24.75)	49.82 (44.90)
T_9	Mancozeb 75% WP + Neem oil	2.5 g/lit+ 2 ml/lit	12.82 (20.98)	15.40 (23.11)	21.80 (27.83)	17.20 (24.50)	16.81 (24.20)	51.89 (46.08)
T_{10}	Control (Unsprayed)	--	13.91 (21.90)	19.94 (26.52)	36.66(37.26)	72.40 (58.31)	34.94 (36.24)	--
	S.E. ±	--	1.58	1.59	1.34	1.98	--	--
	C.D. (P=0.05)	--	NS	4.71	3.98	5.91	--	--

*- Mean of three replications, Conc.: Concentration, Appear: Appearance, Av.: Average, DI: Disease incidence, Red.: Reduction
Figures in parenthesis are arcsine transformed values.

Average incidence and average reduction

With all of the treatments attempted, average disease incidence and average reduction in disease incidence, over untreated control were ranged from 14.39 to 30.44 per cent and 12.88 to 58.81 per cent, respectively. However, the treatment Carbendazim 25% + Mancozeb 50% WS was found most effective with least average disease incidence (14.39%) and highest reduction (58.81%) in average disease incidence, followed by Hexaconazole 5% EC + Neem oil (14.92% and 57.30%, respectively), Hexaconazole 25% EC (16.59% and 52.52%, respectively), Mancozeb 75% WP + Neem oil (16.81% and 51.89%, respectively), Tebuconazole 25.9% EC (17.37 and 50.28 %, respectively), Mancozeb 75% WP (18.87 and 45.99%, respectively), *T. viride* + Neem oil (17.53 and 49.82%, respectively) and *T. viride* (19.79 and 43.36%, respectively). Whereas, the Neem oil was found least effective with maximum disease incidence (30.44%) and negligible reduction in average disease incidence (12.88%).At 15 days after third spraying (Table. 6, Fig.7), leaf blight incidence ranges from 18.10 to 72.40 per cent. However, it was significantly minimum with the treatment T_4 Carbendazim 25% + Mancozeb 50% WS (18.10) followed by T_7 of Hexaconazole 5% EC + Neem oil (18.40), T_1 Hexaconazole 25% EC (22.22), T_9 of Mancozeb 75% WP + Neem oil (21.80), T_2 Tebuconazole 25.9% EC (23.60), T_3 of Mancozeb 75% WP (26.20), T_8 of *T. viride* + Neem oil (26.00), T_5 of *T. viride* (27.80) and T_6 of Neem oil (58.33).

Disease intensity

Results (Table 2 and Fig. 2) revealed that all the treatments significantly influenced leaf spot disease intensity in okra. The disease appeared first at about 55 to 60 days after sowing, which later increased steadily upto second spraying and decreased thereafter.

At first appearance, the disease intensity ranged from 10.90 to 14.72 per cent, as against 14.21 per cent in untreated control. However, it was numerical least with the treatment Mancozeb 75% WP + Neem oil (10.90%), followed by Carbendazim 25% + Mancozeb 50% WS (11.11%), *T. viride* + Neem oil (12.42), *T. viride* (12.50%) and Tebuconazole 25.9% EC (12.65%). Rest of the treatment recorded disease intensity in the range of 13.32 to 14.72%, as against 14.21% in untreated control. Thus, all the treatments were non-significant.

After 1st and 2nd sprays, disease intensity ranged from 15.19 to 26.02 per cent and 19.33 and 32.29 per cent, respectively, as against 29.66% and 38.22%, respectively in untreated control. All the treatments were at par to each other, except *T. viride* and Neem oil with significantly highest disease intensity of 24.40 and 26.00 per cent, respectively after 1st spray and 26.50 and 32.29 per cent, respectively after 2nd spray.

Fifteen day after 3rd spray and compared to 1st and 2nd spray, the disease intensity steadily decreased, which ranged from 16.80 to 34.20 per cent, as against 42.20% in untreated control. However, it was significantly least with the treatment Hexaconazole 5% EC (16.80%), followed by Carbendazim 25% + Mncozeb 50% (17.90%), Hexaconazole 5% EC + Neem oil (18.25%), Tebuconazole 25.9 % EC (18.48%), Mancozeb 75% WP + Neem oil (20.12%), all of which were on par to each other. Whereas, the treatment which showed comparatively and significantly maximum disease intensity were *T. viride* + Nemm oil (22.64%) followed by *T. viride* (24.60%) and Neem oil (34.20%). But were significantly superior over untreated control (42.20%).

Average intensity and average reduction

With all of the treatments attempted, average disease intensity and average reduction in disease intensity, over untreated control were ranged from 15.51 to 26.45 per cent and 14.90 to 50.09 per cent, respectively. However, the treatment Carbendazim 25% + Mancozeb 50% WS was found most effective with least average disease intensity (15.51%) and its highest reduction (50.09%), followed by Hexaconazole 5% EC + Neem oil (16.87% and 45.72%, respectively), Hexaconazole 25% EC (17.45% and 43.85%, respectively), Mancozeb 75% WP + Neem oil (17.58% and 43.43%, respectively), Tebuconazole 25.9% EC (17.72 and 42.99 %, respectively), *T. viride* + Neem oil (19.06 and 38.67%, respectively), Mancozeb 75% WP (20.36 and 34.49%, respectively), and *T. viride* (22.00 and 29.21%, respectively). Whereas, the Neem oil was found least effective with maximum disease intensity (26.45%) and negligible reduction in average disease intensity (14.90%)

Table 2: Efficacy of various treatments against leaf spot intensity in okra

Tr. No.	Treatments	Rate / conc.	Disease intensity (%)*				Av. PDI (%)	Av. PDC (%)
			At 1st Appear.	After 1st Spray	After 2nd Spray	15 days After 3rd Spray		
T_1	Hexaconazole 5% EC	1.0 ml/lit	14.43 (22.33)	16.33 (28.83)	22.22 (28.12)	16.80 (24.20)	17.45 (24.69)	43.85 (41.47)
T_2	Tebuconazole 25.9 % EC	1.0 ml/lit	12.65 (20.83)	16.63 (24.07)	23.10 (28.73)	18.48 (25.46)	17.72 (24.90)	42.99 (40.97)
T_3	Mancozeb 75% WP	2.5 g/lit	14.25 (22.18)	20.74 (27.09)	25.00 (30.00)	21.44 (27.58)	20.36 (26.82)	34.49 (35.96)
T_4	Carbendazim 25% + Mancozeb 50% (75% WS)	2.5 g/lit	11.11 (19.47)	14.05 (22.01)	18.99 (25.83)	17.90 (25.03)	15.51 (23.19)	50.09 (45.05)
T_5	*T. viride* (1 x 10^7 cfu/g)	10 g/lit.	12.50 (20.70)	24.40 (29.60)	26.50 (30.98)	24.60 (29.73)	22.00 (27.97)	29.21 (32.72)
T_6	Neem oil	2 ml/lit	13.32 (21.41)	26.00 (30.66)	32.29 (34.63)	34.20 (35.79)	26.45 (30.95)	14.90 (22.71)
T_7	Hexaconazole 5% EC + Neem oil	1.0 ml + 2 ml/lit	14.72 (22.56)	15.19 (22.94)	19.33 (26.08)	18.25 (25.29)	16.87 (24.25)	45.72 (42.55)
T_8	*T. viride* (1 x 10^7 cfu/g) + Neem oil	10 g/lit. + 2 ml lit.	12.42 (20.64)	18.08 (25.16)	23.10 (28.73)	22.64 (28.41)	19.06 (25.89)	38.67 (38.45)
T_9	Mancozeb 75% WP + Neem oil	2.5 g/lit + 2 ml lit	10.90 (19.28)	16.29 (23.80)	23.00 (28.66)	20.12 (26.65)	17.58 (24.79)	43.43 (41.22)
T_{10}	Control (Unsprayed)	--	14.21 (22.15)	29.66 (33.00)	38.22 (38.19)	42.20 (40.51)	31.08 (33.88)	--
	S.E. ±	--	1.40	1.32	1.25	1.10	--	--
	C.D. (P=0.05)	--	NS	3.65	3.75	3.30	--	--

*Mean of three replications, Figures in parenthesis are arcsine transformed values

Conc.: Concentration, Appear: Appearance, Av.: Average, PDI: Per cent disease intensity, PDC: Per cent disease control

Effect on fruit yield and fruit parameters

Results (Table 2) revealed that the treatments integrated to manage leaf spot disease, significantly influenced the fruit parameters as well as fruit yield in okra.

Effect on fruit parameters

The results (Table 3) revealed that all of the treatments attempted to manage Alternaria leaf spot disease, slightly influenced okra fruit parameters (length and girth), but were comparatively increased over untreated control. The fruit length and girth varied from 10.64 to 11.13 cm and 5.24 to 6.10 cm, respectively, and were numerically higher than the untreated control.

Fruit yield

The results (Table 3, Fig. 3 and Fig. 4) revealed that all of the treatment attempted to manage leaf spot disease, significantly influence the fruit yield (kg /plot and tones / ha), which also resulted with significant increase in fruit yield over untreated control.

Among the treatments, the fruit yield (kg / plot) ranged from 6.07 to 9.33 kg / plot and fruit yield (tones / ha) ranged from 8.99 to 13.67 tones / ha, as against 5.46 kg / plot and 8.09 tones / ha in untreated control. However, the treatment Carbendazim 25% + Mancozeb 50% was found most effective significantly highest fruit yield (9.33 kg / plot and 13.82 tones / ha), with significantly least disease intensity (15.51%), followed by Hexaconazole + Neem oil (9.23 kg / plot and 13.63 tones / ha), Hexaconazole 5% EC (8.96 kg / plot and 13.27 tones / ha), Mancozeb 75% WP + Neem oil (8.88 kg / plot and 13.16 tones / ha), Tebuconazole 25.9% EC (8.85 kg / plot and 13.11 tones / ha), *T. viride* + Neem oil (8.73 kg / plot and 12.93 tones / ha), Mancozeb 75% WP (8.10 kg / plot and 12.00 tones/ha) and *T. viride* (7.71 kg /plot and 11.42 tones / ha). Whereas, Neem oil was found least effective with significantly minimum fruit yield (6.07 kg /plot and 8.99 tones/ha), but comparatively maximum over untreated control (5.46 kg/plot and 8.09 tones / ha).

The per cent increase in fruit yield (tones / ha), over untreated control was ranged from 10.01 to 41.46 per cent. However, it was significantly highest with the treatment Carbendazim 25% + Mancozeb 50% WS (41.46%), followed by Hexaconazole + Neem oil (40.82%), Hexaconazole 5% EC (39.04%), Mancozeb 75% WP + Neem oil (38.53%), Tebuconazole 25.9% EC (38.29%), *T. viride* + Neem oil (37.43%), Mancozeb 75 % WP (32.58%) and *T. viride* (29.16%).

Table 3: Effect of various treatments on fruit parameters and fruit yield of okra

Tr. No.	Treatments	Rate/conc.	Mean PDI (%)	Fruit Parameters		Av. Fruit yield*		% Yield Increase over control
				Length (cm)	Girth (cm)	Kg / plot	Tones / ha	
T_1	Hexaconazole 5% EC	1.0 ml/lit	17.45 (24.69)	10.97	5.86	8.96	13.27	39.04
T_2	Tebuconazole 25.9% EC	1.0 ml/lit	17.72 (24.90)	10.84	5.64	8.85	13.11	38.29
T_3	Mancozeb 75% WP	2.5 g/lit	20.36 (26.82)	10.64	5.50	8.10	12.00	32.58
T_4	Carbendazim 25% + Mancozeb 50% (75% WS)	2.5 g/lit	15.51 (23.19)	11.16	6.10	9.33	13.82	41.46
T_5	*T. viride* (1 x 10^7 cfu/g)	10 g/lit.	22.00 (27.97)	10.82	5.30	7.71	11.42	29.16
T_6	Neem oil	2 ml/lit	26.45 (30.95)	10.57	5.24	6.07	8.99	10.01
T_7	Hexaconazole 5% EC + Neem oil	1.0 ml + 2 ml/lit	16.87 (24.25)	11.13	6.02	9.23	13.67	40.82
T_8	*T. viride* (1 x 10^7 cfu/g) + Neem oil	10 g/lit+ 2 ml/lit	19.06 (25.89)	11.10	5.60	8.73	12.93	37.43
T_9	Mancozeb 75% WP + Neem oil	2.5 g/lit+2 ml/lit	17.58 (24.79)	10.90	5.83	8.88	13.16	38.53
T_{10}	Control (Unsprayed)	--	31.08 (33.88)	10.38	5.16	5.46	8.09	----
	S.E. ±	--	--	0.12	0.16	0.20	0.37	--
	C.D. (P=0.05)	--	--	0.34	0.47	0.60	0.59	--

*Mean of three replications, Av.: Average, Conc.: Concentration, PDI: % Disease intensity
Figures in parentheses are arcsine transformed value

Thus, from the ongoing results on integrated effect of various treatments, it is inferred that 3 sprayings at 15 days interval of the treatment Carbendazim 25% + Mancozeb 50% @ 2.5 g / lit. or Hexaconazole 5% EC + Neem oil @ 1.0 ml + 2 ml/lit or Hexaconazole 5% EC @ 1 ml / lit or Mancozeb 75% WP + Neem oil @ 2.5 g/lit+2 ml/lit or Tebuconazole 25.9% EC @ 1.0 ml/lit or *T. viride* (1 x 10^7 cfu/g) + Neem oil @ 10 g/lit+ 2 ml/lit could efficiently manage okra leaf spot disease and consequently gave better fruit yield, over other treatments.

These results of the present study on integrated efficacy of the test fungicides, bioagents and essential oil against okra Alternaria leaf spot (*A. chlamydospora*) are in agreement with the reports of many earlier workers. These fungicides were also reported effective for the management of okra leaf spot (Pansambal *et al.*, 2015) [28], onion blight Ramjegathesh *et al.* 2011; Manu *et al*., 2014; Rao *et al.*, 2015; Behera *et al*., 2017) [32, 24, 33, 6], early blight of tomato and potato (Ganie *et al*., 2013b; Falake *et al*., 2014; Kumar and Barnwal, 2016; Kumar and Biswas, 2016; Biswas and Kumar, 2017 [17, 15, 21, 22, 8], Alternaria leaf blight of cotton (Dighule *et al.*, 2011; Singh and Ratnoo, 2013; Anil and Ashtaputre 2014) [12, 34, 1], Alternaria leaf spot of cabbage (Chavan *et al.*, 2015; Dabbas and Kumar, 2015; Dinh 2015; Ekabote *et al*., 2017) [9, 10, 13, 14], Fruit rot of chilli (Ginoya and Gohel, 2015) [18] and leaf blight of sunflower (Vijayalakshmi *et al*., 2018) [37].

Various *Trichoderma* spp. (*T viride*, *T. hamatum*, *T.harzianum*) and *P. fluorescens*, alone or in combination with compatible fungicides were reported effective to manage leaf blights / spots caused by several phytopathogenic *Alternaria* spp. (Dighule *et al.*, 2011; Mishra, 2012; Ganie *et al.*, 2013a; Falake *et al.*, 2014; Dabbas and Kumar, 2015 [10]; Anwar *et al*., 2017; Biswas and Kumar, 2017; Vijayalakshmi *et al*., 2018) [12, 17, 15, 8, 37]

The essential oils *viz.*, Neem oil, Eucalyprtus oil, Garlic oil, Mint oil, Clove oil, Karanj oil, Lemmon grass oil, Cinnamon oil etc., applied alone or in combination with fungicides and bioagents were reported to manage effectively various leaf blights / spots caused by several phytopathogenic *Alternaria* spp. (Feng and Zheng, 2006; Babagoli and Behdad 2012; Devi and Basu, 2013; Bhattarai and Jha, 2016; Jhala and Mali 2017; Rahmatzai *et al*., 2017) [16, 5, 11, 7, 31].

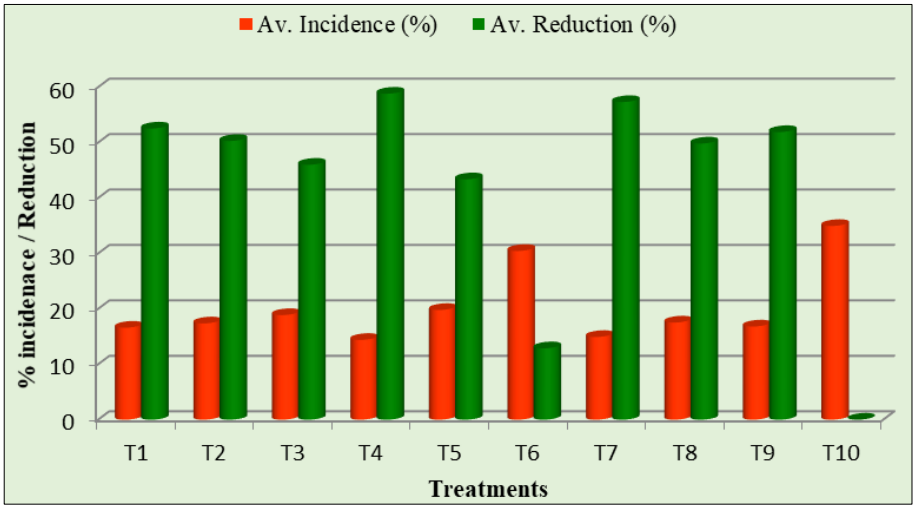

Fig 1: Effect of various treatments on okra Alternaria leaf spot incidence and its reduction

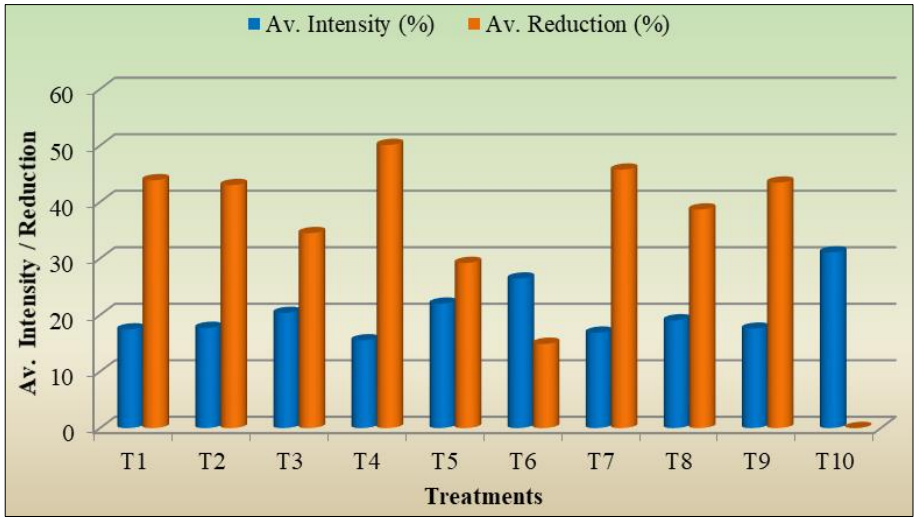

Fig 2: Effect of various treatments on okra Alternaria leaf spot intensity and its reduction

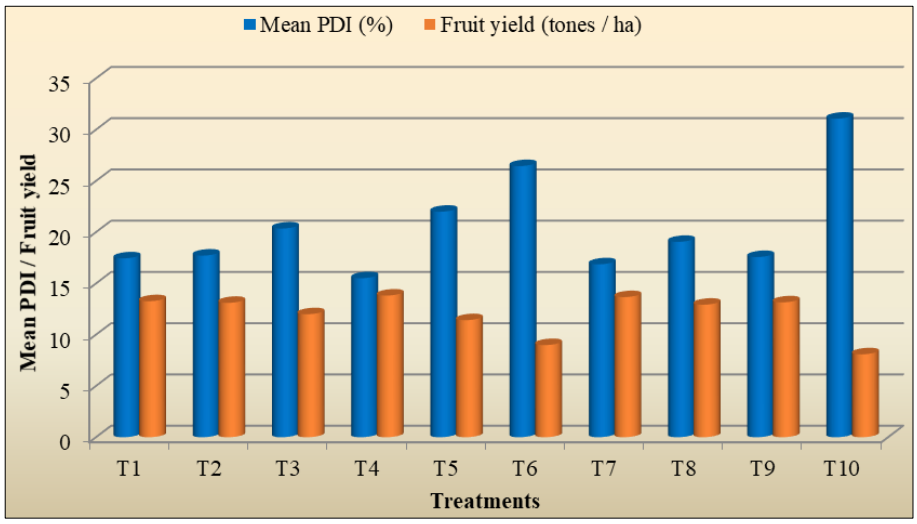

Fig 3: Effect of various treatments integration on okra Alternaria leaf spot intensity and fruit yield

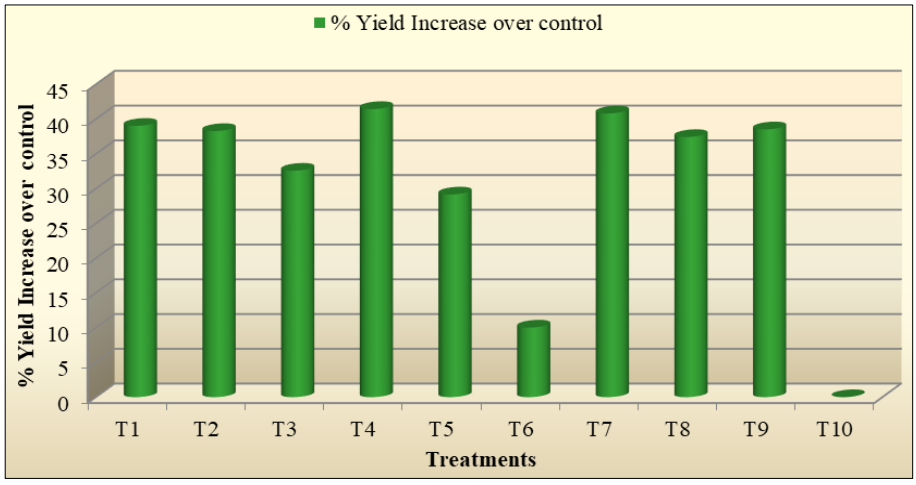

Fig 4: Effect of various treatments integration on increase in okra fruit yield, over untreated control

Economics of the treatments integrated to manage okra Alternaria leaf spot

Results obtained (Table 4, Fig. 5) on economics in respect of various treatments integrated to manage okra Alternaria leaf spot (*A. chlamydospora*) revealed that the treatments attempted showed varied incremental cost: benefit (ICBR).

Among various treatments, Carbendazim 25% + Mancozeb 50% WS of @ 1 ml / lit was found most effective, with highest gross return (Rs. 246600/-), highest net profit (Rs. 154967/-) and highest ICBR (2.69). The next best treatments found were Hexaconazole 5% EC + Neem oil @ 1.0 ml + 2 ml/lit (gross income Rs. 245800/-, net profit Rs. 154813/- and ICBR 2.70), Hexaconazole 5% EC @ 1 ml /lit (gross income Rs. Rs. 236200/-, net profit Rs. 145456 /- and ICBR 2.60). However, the treatment Neem oil @ 2 ml / lit. Resulted with comparatively minimum ICBR (1.79), which was closely related to untreated control (ICBR 1.61).

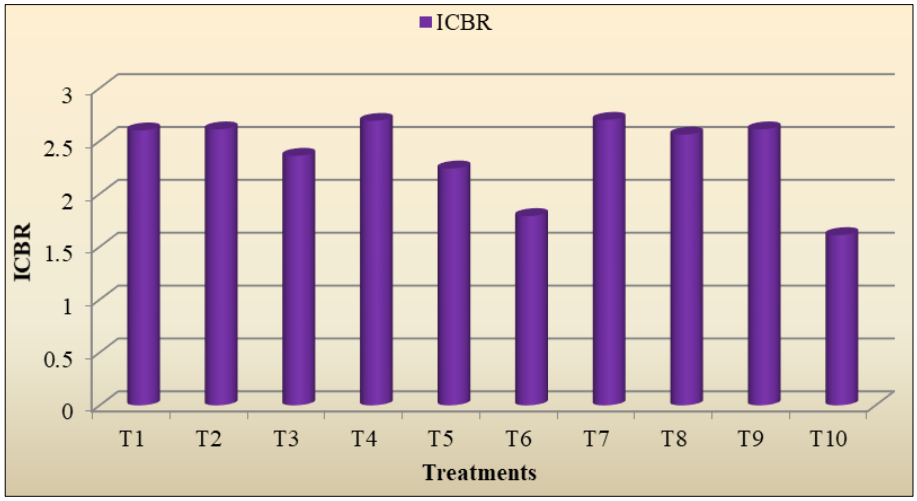

Fig 5: Effect of various treatments integrated to manage okra Alternaria leaf spot on ICBR

These results of the present study on integrated efficacy of the test fungicides, bioagents and essential oil against okra Alternaria leaf spot (*A. chlamydospora*) are in agreement with the reports of many earlier workers. Pansambal *et al. (*2015) [28] reported the fungicides *viz.*, Propiconazole 25% EC @ 0.1%, Hexaconazole 5% EC @ 0.1%, Copper oxychloride 50% WP @ 0.25%, Tebuconazole 25.9% EC @ 0.1% and Difenconazole 25% EC @ 0.1% as effective against okra leaf spot disease. These fungicides were also reported effective for the management of onion blight (Ramjegathesh *et al.* 2011; Manu *et al*., 2014; Rao *et al.*, 2015; Behera *et al*., 2017) [32, 24, 33, 6], early blight of tomato and potato (Ganie *et al.*, 2013b; Falake *et al*., 2014; Kumar and Biswas, 2016; Biswas and Kumar, 2017; Kumar *et al*., 2017) [17, 15, 22, 8], Alternaria leaf blight of cotton (Dighule *et al.*, 2011; Singh and Ratnoo, 2013; Anil and Ashtaputre 2014) [12, 34, 1], Alternaria leaf spot of cabbage (Chavan *et al.*, 2015; Dabbas and Kumar, 2015; Dinh 2015; Ekabote *et al*., 2017) [9, 10, 13, 14], Fruit rot of chilli (Ginoya and Gohel, 2015) [18] and leaf blight of sunflower (Vijayalakshmi *et al*., 2018) [37].

Various *Trichoderma* spp. (*T viride*, *T. hamatum*, *T.harzianum*) and *P. fluorescens*, alone or in combination with compatible fungicides were reported effective to manage leaf blights / spots caused by several phytopathogenic *Alternaria* spp. (Dighule *et al.*, 2011; Mishra, 2012; Ganie *et al.*, 2013a; Falake *et al.*, 2014; Dabbas and Kumar, 2015; Anwar *et al*., 2017; Vijayalakshmi *et al*., 2018) [12, 17, 15, 37]

The essential oils *viz.*, Neem oil, Eucalyprtus oil, Garlic oil, Mint oil, Clove oil, Karanj oil, Lemmon grass oil, Cinnamon oil etc., applied alone or in combination with fungicides and bioagents were reported to manage effectively various leaf blights / spots caused by several phytopathogenic *Alternaria* spp. (Feng and Zheng, 2006; Babagoli and Behdad 2012; Devi and Basu, 2013; Bhattarai and Jha, 2016; Jhala and Mali 2017; Rahmatzai *et al*., 2017) [16, 5, 11, 7, 31].

Conclusion

The field integration of various most effective fungicides, bioagents and essential oils (alone and in combination), it is inferred that 3 sprayings of the fungicides Carbendazim 25% + Mancozeb 50% @ 2.5 g / lit. or Hexaconazole 5% EC + Neem oil @ 1.0 ml + 2 ml/lit or Hexaconazole 5% EC @ 1 ml / lit or Mancozeb 75% WP + Neem oil @ 2.5 g/lit+2 ml/lit could be employed to manage effectively and economically the okra Alternaria leaf spot disease.

Table 4: Economics of various treatments integrated to manage okra Alternaria leaf spot disease

Tr. No.	Treatments	Rate/conc.	PDI (%)	Fruit yield (q/ha)	Market. fruit yield*	Gross returns Δ (Rs/ha)	Cost of Cultivation (Rs/ha) **	Cost of Plant Protection (Rs/ha)		Total cost Rs./ha	Net Profit	ICBR
								Treatments***	Lab. Charges ΔΔ			
1	2	3	4	5	6	7	8	9	10	11	12	13
T_1	Hexaconazole 5% EC	1.0 ml/lit	17.45	13.27	11.81	236200	90089	505.05	150	90744	145456	2.60
T_2	Tebuconazole 25.9% EC	1.0 ml/lit	17.72	13.11	11.67	233400	90089	262.63	150	90502	142898	2.61
T_3	Mancozeb 75% WP	2.5 g/lit	20.36	12.00	10.68	213600	90089	189.90	150	90429	123171	2.36
T_4	Carbendazim 25% + Mancozeb 50% 75%WS	2.5 g/lit	15.51	13.82	12.33	246600	90089	1393.94	150	91633	154967	2.69
T_5	*T. viride* (1 x 10^7 cfu/g)	10 g/lit.	22.00	11.42	10.16	203200	90089	484.85	150	90724	112476	2.24
T_6	Neem oil	2 ml/lit	26.45	8.99	8.09	161800	90089	242.42	150	90481	71319	1.79
T_7	Hexaconazole 5% EC + Neem oil	1.0 ml + 2 ml/lit	16.87	13.67	12.29	245800	90089	747.78	150	90987	154813	2.70
T_8	*T. viride* (1 x 10^7 cfu/g) + Neem oil	10 g/lit.+ 2 ml/lit	19.06	12.93	11.64	232800	90089	727.27	150	90993	141807	2.56
T_9	Mancozeb 75% WP + Neem oil	2.5 g/lit+2 ml/lit	17.58	13.16	11.84	236800	90089	432.32	150	90671	146129	2.61
T_{10}	Control (Unsprayed)	--	31.08	8.09	7.25	145000	90089	----	----	90089	54911	1.61

*Mean of three replication, Δ: selling rates of okra pods/ fruit @ Rs. 20 Rs/kg, Labour charges: 150 Rs/labour, ** As per Annexure II, *** As per costs mentioned in the chapter III, ΔΔ: Seed treatments and spraying charges @ 150 Rs/labour, ICBR: Incremental cost: benefit ratio.

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