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In vivo efficacy of fungicides against ridge gourd powdery mildew (*Erysiphe cichoracearum* DC.)

MD Navale, AP Suryawanshi and HN Markad

Abstract
Ridge gourd (*Luffa acutangula* L.), a fruit vegetable crop has commercially been grown on large scale in India, round the year. However, during recent years the crop has severely been affected by the powdery mildew disease (*Erysiphe cichoracearum* DC), causing more than 50 per cent yield losses. Though, the disease can be managed with various conventional fungicides, but new generation chemical molecules need to be assessed for their efficacy against the disease.
The results revealed that the test fungicides resulted with significant reductions in powdery mildew incidence as well as severity and significantly maximum fruit yield, over unsprayed control. However, Hexaconazole 5% EC @ 0.05% resulted with significantly least mean powdery mildew incidence (13.03%) and intensity (7.02%) with significantly highest reduction of mean disease incidence (76.40%) and intensity (58.76%). The second-best fungicide was Propiconazole 25% EC @ 0.1% with second minimum mean disease incidence (16.14%,) and intensity (8.74%) and corresponding second highest reduction of mean disease incidence (70.17%) and intensity (82.54%). In the order of merit rest of the test fungicides were Difenconazole 25% EC @ 0.1% > Dinocap 48% EC @ 0.2% > Carbendazim 50% WP @ 0.1%. Based on cumulative fruit yield and ICBR, the most effective and economical fungicide found was Hexaconazole 5% EC @ 0.05% with significantly highest fruit yield (161.17 q./ha.) and highest ICBR (4.37), followed by Propiconazole 25% EC @ 0.1% (141.72 q/ha and 3.75, respectively) and Difenconazole 25% EC @ 0.1% (118.28 q/ha and 2.81,respectively).

Keywords: *Luffa acutangula*, *Erysiphe cichoracearum*, Difenconazole

Introduction
In the fruit vegetables, ridge gourd (*Luffa acutangula* L.) plays an important role in the balance diet of human beings, by providing not only the energy rich food but also promise to supply vital protective nutrients, minerals and vitamins. Ridge gourd (*Luffa acutangula* L.), belonging to the family *Cucurbitaceae* is considered to be originated from tropical Africa and south east Asian region, including India. It is widely grown in tropical and sub-tropical parts of the world.
The family *Cucurbitaceae* contains at least 118 genera and 825 species are cultivated as vegetables. In India cucurbits like Ash gourd (*Benincasa hispida*), bitter gourd (*Momordica carantica*), cucumber (*Cucumis sativus*), bottle gourd (*Lagenaria siceraria*), sponge gourd (*Luffa cylindrica*), pumpkin (*Cucurbita maxima*), red pumpkin (*Cucurbita peopo*), ridge gourd (*Luffa acutangula* L.), round gourd (*Citrullus fistulosus*), pumpkin (*Cucurbita moschata*) and watermelon (*Citrullus lanatus*), musk melon (*Cucumis milon*), round melon (*Praecitrullus fistulosuos)*, sweet gourd (*Momordica cochinchinensis)* are cultivated round the year in one or the other region of the country (Rai *et al.*,2008) [13].
In India, ridge gourd has been cultivated on an area approximately of 9920 ha. with production of 316925 tonnes and productivity of 10.52 t/ha (Anonymous, 2015) [4].
However, the profitable production and productivity of various *Cucurbitaceous* vegetable crops have been hampered due to various biotic and abiotic factors. Among biotic factors, diseases caused by various pathogens such as *Pseudoperenospora cubensis* (downy mildew), *Erysiphe cichoracearum/Sphaerotheca fuliginea/Leveillula Taurica* (powdery mildew), *Fusarium oxysporium* (wilt), *Colletotrichum orbuculare* (anthracnose), *Pythium spithi* (damping off or root rots), *Alternaria alternata* (Alternaria leaf spot), *Cercospora citrunnia* (Cercospora leaf spot) and *Erwinia tracheiphila* (bacterial wilt) are major constraints in commercial cultivation of various *Cucurbitaceous* vegetable crops, including ridge gourd.

Material and methodology

To evaluate the efficacy of most effective fungicides, a field experiment was planned (Fig. 1) and conducted during *kharif*, 2017. On 7th August, 2017, the seeds of ridge gourd Cv. Konkan Harita were sown (150 x 50 cm) in the field plots (Gross: 4.5 × 2.5m^2 and Net: 3.0×2.0 m^2) and the crop was grown by applying all packages of practices. At first appearance of powdery mildew disease symptoms, first foliar spraying of the test fungicides was undertaken and further two sprayings were done at 10 days interval.

Experiment details

Design : RBD
Replications : Three
Treatments : Eight (8)

Treatment details

Tr. No.	Treatments	Conc.	Tr. No.	Treatments	Conc.
T_1	Difenconazole 25% EC	0.1%	T_5	Carbendazin 50% WP	0.1%
T_2	Benomyl 50% WP	0.25%	T_6	Dinocap 48% EC	0.2%
T_3	Propiconazole 25% EC	0.1%	T_7	Azoxystrobin 23% SC	0.1%
T_4	Hexaconazole 5% EC	0.05%	T_8	Control (unsprayed)	-

Observations on powdery mildew incidence and intensity were recorded at first appearance of the disease. Further, observations on powdery mildew (incidence, intensity) were recorded one day before first and second spray treatments and 15 days after third spraying. For recording powdery mildew intensity, ten plants per treatment per replication were selected randomly and tagged. On these tagged plants, three leaves (one each from bottom, middle and top) per plant were selected and recorded the disease intensity by applying 0 - 9 disease (PLATE I) rating scale (Mayee and Datar,1986) as described below.

Grade/Scale	Descriptions
0	No symptoms on the leaf.
1	Small powdery specks on the leaves covering < 1% leaf area.
3	Powdery lesions small, scattered, covering 1-10% leaf area.
5	Powdery patches big, scattered, covering 11-25% of the leaf area.
7	Powdery patches big, coalescing and covering 25-50% leaf area, leaves shedding.
9	Powdery growth covering > 51% leaf area, leaves turn yellow, dry up and shed off.

Plate I: Ridge gourd Powdery mildew disease rating

Per cent disease incidence was calculated by applying following formula.

$$\% \text{ Disease Incidence} = \frac{\text{No. of infected plant observed}}{\text{Total no. of plant observed}} \text{ X } 100$$

Further, per cent disease intensity (PDI) and its reduction/control (PDC), over untreated control were calculated by applying following formulae (Mc Kinney, 1923) [9].

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

$$\% \text{ Dis. control (PDC)} = \frac{\text{PDI in control plot - PDI in treatment plot}}{\text{PDI in control plot}} \text{X100}$$

Ridge gourd fruits were harvested one day before each spray treatment and also at harvestable stage of the fruits. Cumulative fruit yield data (kg/plot and qt. / ha.) were calculated. Also, the most economical treatment was determined, based on incremental cost: benefit ratio (ICBR).

Result and discussion

In vivo efficacy of fungicides against ridge gourd powdery mildew

The results obtained in field experiments revealed that all of the seven fungicides tested were effective against ridge gourd

powdery mildew, which resulted with significantly minimum powdery mildew incidence (Table 1.) as well as intensity (Table 2.) recorded at various intervals and also their significant reductions over untreated control.

Powdery mildew incidence

Results (Table 1, Fig.1) revealed that the test fungicides significantly influenced the powdery mildew incidence which was found to be steadily decreased after first, second and third sprayings, which ranged from 15.30-31.57 per cent, 13.24 - 27.50 percent and 10.55-28.51 percent, respectively. However, after third spraying, the powdery mildew incidence was significantly least with Hexaconazole @ 0.05% (10.55%), followed by Propiconazole @ 0.1% (13.65%), Difenconazole @ 0.1% (15.98%), Dinocap @ 0.2% (18.44%) and Carbendazim @ 0.1% (20.63%), as against significantly highest incidence (54.44%) in untreated control.

Mean powdery mildew incidence with the treatments ranged from 13.03 to 29.19 per cent. However, it was least with Hexaconazole @ 0.05% (13.03%), followed by Propiconazole @ 0.1% (16.14%), Difenconazole @ 0.1% (17.68%), Dinocap @ 0.2% (20.79%), Carbendazim @ 0.1% (23.22%), Azoxystrobin @ 0.1% (26.55%) and Benomyl @ 0.3% (29.19%), as against maximum mean incidence (47.3%) in untreated control. All of the test fungicides resulted with considerable reduction disease incidence in the range of 42.25 - 72.19 and 47.63-80.62 per cent, respectively after second and third sprayings and further, mean reduction in the range of 44.94 – 76.80 percent, over untreated control. However Hexaconazole 5 EC @ 0.05% resulted with highest disease incidence reduction of 72.19 and 80.62 per cent, respectively after second and third sprayings and maximum mean disease incidence reduction (76.24%). This was followed by Propiconazole @ 0.1% (65.43, 74.92 and 70.17%, respectively), Difenconazole @ 0.1% (62.99, 70.64 and 66.81%, respectively), Dinocap @ 0.2% (56.80, 66.12 and 61.46%, respectively), Carbendazim @ 0.1% (50.54, 62.10 and 56.32%, respectively), Azoxystrobin @ 0.1% (44.47, 56.33 and 50.40%, respectively) of Carbendazim @ 0.25% (42.25, 47.63 and 44.94%, respectively), and Benomyl 50% WP (42.25, 47.63 and 44.94%, respectively), of disease incidence reduction after second and third sprayings and mean disease incidence reduction, over untreated control.

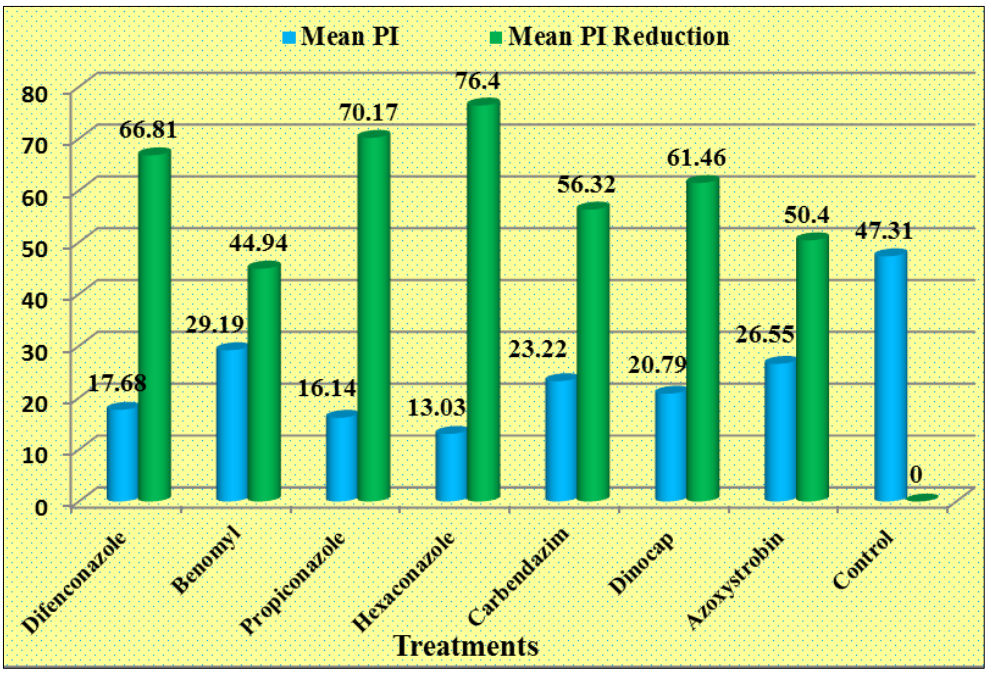

Fig 1: Effect of various fungicides on ridge gourd powdery mildew mean incidence and its mean reduction

Table 1: Efficacy of various fungicides against incidence of powdery mildew of ridge gourd (cv. Konkan Harita)

Treatments		Conc. (%)	PI* After sprayings			Mean PI	% Reduction in PI over control After sprayings		Mean PI Reduction
			First	Second	Third		Second	Third	
T_1	Difenconazole 25% EC	0.1	19.46 (26.17)	17.62 (24.81)	15.98 (23.56)	17.68 (28.86)	62.99 (52.52)	70.64 (57.19)	66.81 (54.82)
T_2	Benomyl 50% WP	0.25	31.57 (34.18)	27.50 (31.62)	28.51 (32.27)	29.19 (32.70)	42.25 (40.54)	47.63 (43.64)	44.94 (42.09)
T_3	Propiconazole 25% EC	0.1	18.33 (25.34)	16.46 (23.93)	13.65 (21.68)	16.14 (23.68)	65.43 (53.98)	74.92 (59.94)	70.17 (56.89)
T_4	Hexaconazole 5% EC	0.05	15.30 (23.02)	13.24 (21.33)	10.55 (18.95)	13.03 (21.15)	72.19 (58.17)	80.62 (63.88)	76.40 (60.93)
T_5	Carbendazin 50% WP	0.1	25.50 (30.32)	23.55 (29.03)	20.63 (27.01)	23.22 (28.80)	50.54 (45.30)	62.10 (52.00)	56.32 (48.63)
T_6	Dinocap 48% EC	0.2	23.36 (28.90)	20.57 (26.97)	18.44 (25.43)	20.79 (27.12)	56.80 (48.90)	66.12 (54.40)	61.46 (51.62)
T_7	Azoxystrobin 23% SC	0.1	29.62 (32.97)	26.44 (30.94)	23.77 (29.17)	26.55 (31.01)	44.47 (41.82)	56.33 (48.63)	50.40 (45.22)
T_8	Control (unsprayed)	-	39.88 (39.16)	47.62 (43.63)	54.44 (47.54)	47.31 (43.45)	-	-	-
	SEm ±		0.30	0.23	0.39	-	-	-	-
	CD (P = 0.05)		0.90	0.71	1.19	-	-	-	-

* Average of three replications PI- Per cent incidence
Figures in parenthese are arcsine transformed values

Powdery mildew intensity

Results (Table 2, Fig.2) revealed that the test fungicides significantly influenced the powdery mildew intensity which was found to be steadily decreased after first, second and third sprayings, which ranged from 9.02-25.11 percent, 7.50 -12.53 per cent and 4.55-11.00 percent, respectively. However, after third spraying, the powdery mildew intensity was significantly least with Hexaconazole @ 0.05% (4.55%), followed by Propiconazole @ 0.1% (5.66%), Difenconazole @ 0.1% (7.55%), Dinocap @ 0.2% (8.18%), Carbendazim @ 0.1% (9.36%), Azoxystrobin @ 0.1% (10.00%) and Benomyl @ 0.25% (11.00%), as against significantly highest intensity (40.73%) in untreated control. Mean powdery mildew intensity with the treatments ranged from 7.02 to 16.21 per cent. However, it was least with Hexaconazole @ 0.05% (7.02%), followed by Propiconazole @ 0.1% (8.74%), Difenconazole @ 0.1% (9.89%), Dinocap @ 0.2% (11.17%), Carbendazim @ 0.1% (12.90%), Azoxystrobin @ 0.1% (14.4 5%) and Benomyl @ 0.25% (16.21%), as against maximum mean intensity (38.50%) in untreated control.

All of the test fungicides resulted with considerable reduction in disease intensity in the range of 68.42-81.09 and 72.99-88.83 percent, respectively after second and third sprayings and further, mean reduction in the range of 70.70-84.96 percent, over untreated control. However, Hexaconazole 5 EC @ 0.05% resulted with highest disease intensity reduction of 81.09 and 88.83 per cent, respectively after second and third sprayings and maximum mean disease intensity reduction (84.96%). This was followed by Propiconazole @ 0.1% (78.98, 86.10 and 82.54%, respectively), Difenconazole @ 0.1% (78.98, 86.10 and 82.54%, respectively), Difenconazole @ 0.1% (77.32, 81.46 and 79.39% respectively), Dinocap @ 0.2% (76.48, 79.91 and 78.19% respectively), Carbendazin @ 0.1% (74.49, 77.02 and 75.75%, respectively), Azoxystrobin @ 0.1% (72.78, 75.44 and 78.19%, respectively) and Benomyl @ 0.25% (68.42, 72.99 and 70.70%, respectively), of disease intensity reduction after second and third sprayings and mean disease intensity reduction, over untreated control.

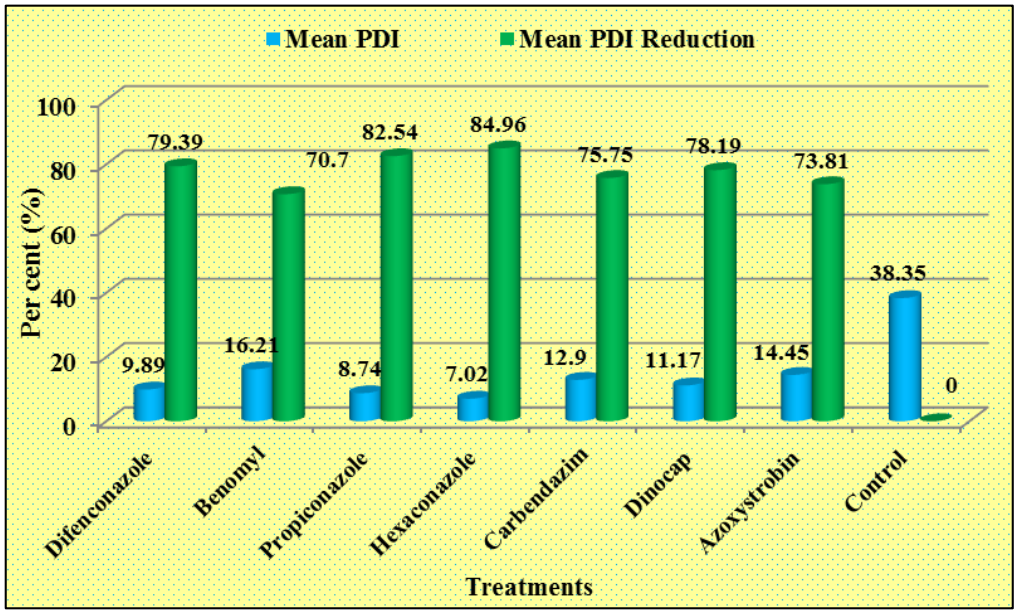

Fig 2: Effect of various fungicides on ridge gourd powdery mildew mean Intensity and its mean reduction

Table 2: Efficacy of various fungicides against intensity of powdery mildew of ridge gourd (Cv. Konkan Harita)

Treatments		Conc. (%)	PDI* After sprayings			Mean PDI (%)	% Reduction in PDI over control After sprayings		Mean PDI Reduction (%)
			First	Second	Third		Second	Third	
T_1	Difenconazole 25% EC	0.1	13.12 (21.23)	9.00 (17.45)	7.55 (15.94)	9.89 (18.32)	77.32 (61.56)	81.46 (64.49)	79.39 (63.20)
T_2	Benomyl 50% WP	0.25	25.11 (30.07)	12.53 (20.73)	11.00 (19.36)	16.21 (23.74)	68.42 (55.81)	72.99 (58.68)	70.70 (57.22)
T_3	Propiconazole 25% EC	0.1	12.24 (20.47)	8.34 (16.78)	5.66 (13.76)	8.74 (17.19)	78.98 (62.71)	86.10 (68.10)	82.54 (65.30)
T_4	Hexaconazole 5% EC	0.05	9.02 (17.47)	7.50 (15.89)	4.55 (12.31)	7.02 (15.36)	81.09 (64.22)	88.83 (70.47)	84.96 (67.18)
T_5	Carbendazin 50% WP	0.1	19.23 (26.00)	10.12 (18.54)	9.36 (17.81)	12.90 (21.04)	74.49 (59.66)	77.02 (61.35)	75.75 (60.49)
T_6	Dinocap 48% EC	0.2	16.02 (23.59)	9.33 (17.78)	8.18 (16.61)	11.17 (19.52)	76.48 (60.98)	79.91 (63.37)	78.19 (62.15)
T_7	Azoxystrobin 23% SC	0.1	22.33 (28.19)	11.04 (19.40)	10.00 (18.43)	14.45 (22.34)	72.18 (58.16)	75.44 (60.29)	73.81 (59.21)
T_8	Control (unsprayed)	-	35.11 (36.33)	39.68 (39.04)	40.73 (39.65)	38.50 (38.35)	-	-	-
	SEm ±		0.14	0.24	0.30	-	-	-	-
	CD (P = 0.05)		0.42	0.73	0.93	-	-	-	-

* Average of three replications,
PDI- Per cent Disease Intensity,
Figures in parenthese are arcsine transformed values

Effect on fruit yield

Results (Table 3, Fig.3) revealed that the test fungicides significantly influenced the fruit yield, which ranged from 64.38-161.17 q/ha, as against 41.46 q/ha in untreated control. However, it was significantly highest with Hexaconazole @ 0.05% (161.17 q/ha), with least mean powdery mildew intensity (7.02%), followed by Propiconazole @ 0.1% (141.72 q/ha. and 8.74%, respectively) Difenconazole @

0.1% (118.28 q/ha. and 9.89%, respectively), Dinocap @ 0.2% (105.67 q/ha. and 11.17%, respectively), Carbendazim @ 0.1% (92.79 q/ha. and 12.90%, respectively), Azoxystrobin @ 0.1% (74.85 q/ha. and 14.45%, respectively) and Benomyl @ 0.25% (64.38 q/ha. and 16.21%, respectively), as against significantly least fruit yield (41.46 q/ha) and highest mean disease intensity (38.50%) in untreated control.

All of the test fungicides resulted with considerable increase in fruit yield, over untreated control. However, it was considerably highest with Hexaconazole 5 EC @ 0.05% (74.28%), followed by Propiconazole @ 0.1% (70.74%), Difenconazole @ 0.1% (64.95%), Dinocap @ 0.2% (60.76%).

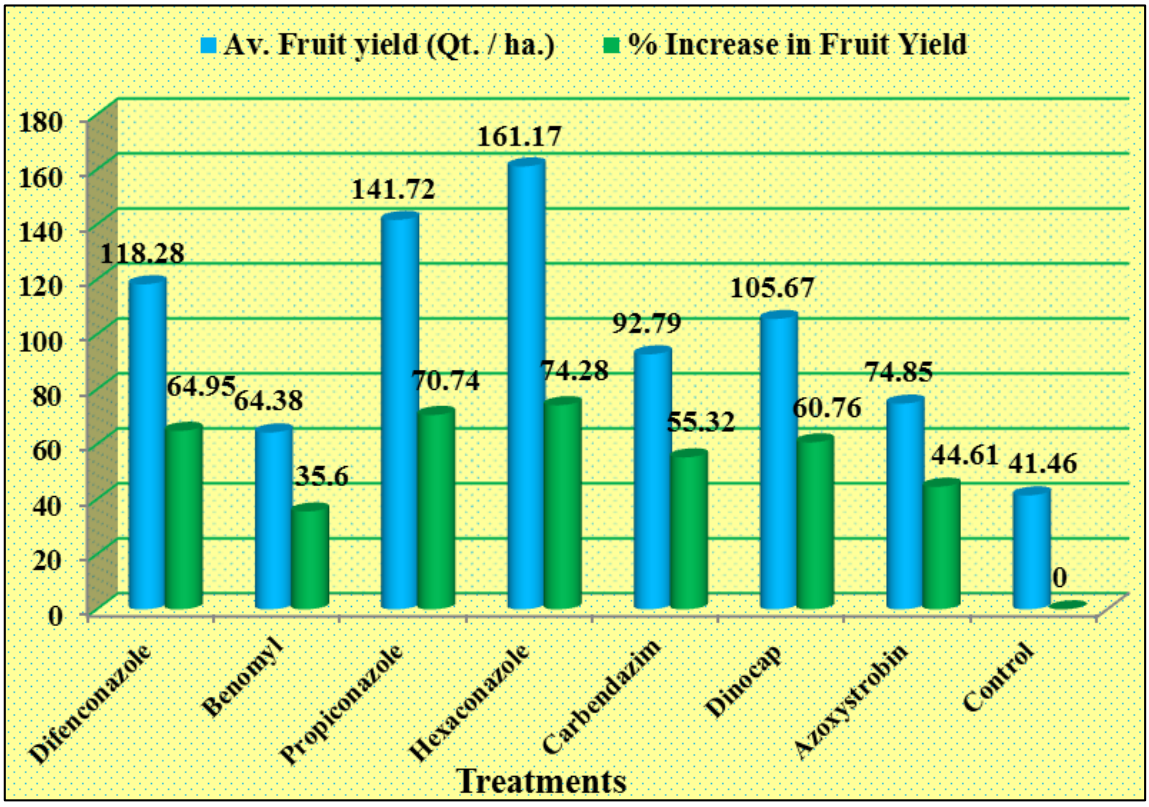

Fig 3: Effect of various fungicides on ridge gourd fruit yield and its increase over untreated control

Table 3: Effect of various fungicidal sprays on fresh fruit yield

Treatments		Conc.	Mean PDI (%)	Av. Fruit* Weight (kg)	Av. Fruit Yield*		% Increase in Fruit Yield
					kg/plot	q / ha	
T_1	Difenconazole 25% EC	0.1	9.89 (18.32)	0.09	13.32	118.28	64.95
T_2	Benomyl 50% WP	0.25	16.21 (23.74)	0.062	7.25	64.38	35.60
T_3	Propiconazole 25% EC	0.1	8.74 (17.19)	0.105	15.96	141.72	70.74
T_4	Hexaconazole 5% EC	0.05	7.02 (15.36)	0.110	18.15	161.17	74.28
T_5	Carbendazin 50% WP	0.1	12.90 (21.04)	0.078	10.45	92.79	55.32
T_6	Dinocap 48% EC	0.2	11.17 (19.52)	0.085	11.90	105.67	60.76
T_7	Azoxystrobin 23% SC	0.1	14.45 (22.34)	0.068	8.43	74.85	44.61
T_8	Control (unsprayed)	-	38.50 (38.35)	0.055	4.67	41.46	-
	SEm ±	-	-	0.01	0.29	0.31	-
	CD (P = 0.05)	-	-	0.03	0.90	0.94	-

*Mean of three replications, Figures in parenthese are arcsine transformed values Carbendazim @ 0.1% (55.32%), Azoxystrobin @ 0.1% (44.61%) and Benomyl @ 0.25% (35.60%).

Economics of various fungicidal spray treatments

The results (Table 4.) indicated that all of the fungicidal spray treatments were found effective and economical in managing ridge gourd powdery mildew, increasing fruit yield with maximum ICBR, over untreated control. However, based on ICBR, the most economical treatments found was Hexaconazole 5 EC @ 0.05% with highest ICBR (4.37), followed by Propiconazole @ 0.1% (3.75), Difenconazole @ 0.1% (2.81), Dinocap @ 0.2% (2.31), Carbendazim @ 0.1% (1.94) and Azoxystrobin @ 0.1% (1.28).

These results are in conformity to the findings of several earlier workers. The fungicides *viz.*, Hexaconazole 5% EC, Propiconazole 25% EC, Difenconazole 25% EC, Dinocap 48% EC, Carbendazim 50% WP, Azoxystrobin 23% SC, etc. at their recommended field dosages were reported effective and economical for the management of powdery mildews of various crop hosts such as Mungbean (Khunti *et al*., 2002) [8], Okra (Rahman and Bhattiprolu, 2005; Khalikar *et al*., 2011; Magar *et al*., 2017) [12, 7, 10], Cucumber (Anand *et al*., 2008) [3], Pea (Surwase *et al*., 2009) [15], Coriander (Akbari and Parakhia, 2010) [1], Sunflower (Dinesh *et al*., 2011; Akhileshwari *et al*., 2012) [5], Cluster bean (Sangani *et al*.,

2015) [14] and linseed (Gohokar *et al*., 2016) [6].

Table 4: Economics of various fungicides sprayed to manage powdery mildew of ridge gourd (Cv. Konkan Harita)

Treatments		Conc. (%)	Cost of cultivation (₹)	Cost of spraying (₹)		Total cost of production (3+4+5)	Yield* q/ha	Gross** Income/ Ha (₹)	Addit. Income/ha (₹) (8-Control)	Net profit/ ha (8-6)	ICBR
				Fungicides #	Labour wages Δ						
1		2	3	4	5	6	7	8	9	10	11
T_1	Difenconazole 25%EC	0.1	123154	9110	750	133014	160	480000	354000	346986	2.81
T_2	Benomyl 50% WP	0.25	123154	8871	750	132775	79	237000	111000	104225	0.84
T_3	Propiconazole 25% EC	0.1	123154	1798	750	125702	196	588000	462000	462298	3.75
T_4	Hexaconazole 5% EC	0.05	123154	3325	750	127229	22	666000	540000	538771	4.37
T_5	Carbendazin 50% WP	0.1	123154	2489	750	126393	122	366000	240000	539607	1.94
T_6	Dinocap 48% EC	0.2	123154	11188	750	135092	140	420000	294000	284908	2.31
T_7	Azoxystrobin 23% SC	0.1	123154	2793	750	126697	95	285000	159000	158308	1.28
T_8	Control (unsprayed)	-	-	-	-	-	42	126000	-	-	-

*Mean of three replications
PDI- Per cent Disease Intensity
**Selling rates of ridge gourd fruits @ ₹ 3000/q.
ICBR - Incremental Cost: Benefit ratio
#As per the rates mentioned in chapter III
Figures in parenthese are arcsine transformed values.
Δ labour wages spraying ₹ 250/day

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