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Effects of Fungicide Control of Downy Mildew (*Pseudoperonospora cubensis*) on Yield and Disease Management of Ridge Gourd (*Luffa acutangula*)

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Seven fungicides were compared for the control of downy mildew on ridge gourd. All treatments had significantly lower rates of disease progress curves and disease severity levels than that of the control. The highest yields were obtained from crops treated with metalaxyl + mancozeb, fosetyl-Al, and chlorothalonil. These treatments also proved to be the most economical considering the treatment costs.

Keywords : crop loss assessment, downy mildew, fungicides, ridge gourd

Ridge gourd (*Luffa acutangula* [L.] Roxb.) is an annual monoecious climbing plant. The young fruits, 15-40 cm long and club-shaped with distinctly ribbed surface, are used as vegetables. The fruit is a good source of protein (0.5% 100 g^{-1} of the edible portion), carbohydrates (3.4%), carotene (37 mg), and vitamins (18 mg). The plant is believed to be indigenous to the Asian region, especially to India and Malaysia (Herklots, 1972). It has a long history of cultivation in tropical Asia, Africa, and the Middle East. In India, it is grown throughout the country and can be cultivated several times all-year round in some places. However, there is no exact data available on the total cultivation area or yields produced.

Along with other cucurbits, ridge gourd is attacked by a wide range of diseases. Among those reported as causing substantial losses are powdery mildew (*Erysiphe cichoracearum* De candolle), cercospora leaf spot (*Cercospora lagenariae* Rang and Chand, *C. momordicae* Mc. Rae), anthracnose (*Colletotrichum lagenarium* Pass. Ellis and Halsted, *C. gloeosporioides* Penz.), downy mildew (*Pseudoperonospora cubensis* [Berk. and Curt.] Rostow), and fusarium wilt (*Fusarium oxysporum* f.sp. *niveum* [E.F. Smith] Synder and Hansen). Among these diseases, downy mildew has become a major limiting factor in production in many parts of India, especially in some areas of Maharashtra state.

Downy mildew of ridge gourd is characterized by formation of yellow, more or less angular, spots on the upper leaf surface. The disease spreads rapidly, kills the plants through defoliation, and leads to heavy yield losses. There is little information available on cultivar differences, but it appears that most commonly grown types are vulnerable to the disease.

On cucurbit crops, Patel and Patel (1980) found that chlorothalonil and mancozeb provided satisfactory control of downy mildew on muskmelon. Suhag et al. (1988) reported that foliar sprays of Ridomil MZ (metalaxyl + mancozeb) and Blitox (copper oxychloride) at 20-day intervals gave satisfactory control of downy mildew on sponge gourd. In Pakistan, Khalil et al. (1992) also reported that copper oxychloride and mancozeb were effective for the control of the disease on muskmelon. Recently, Gupta and Shyam (1996) studied the anti-sporulant activity of various fungicides against *P. cubensis* on cucurbits. They found that Ridomil MZ gave maximum reduction in spore numbers, while chlorothalonil was the least effective. However, there is no information available on the control of downy mildew on ridge gourd yet. This study was conducted to determine the effectiveness of a range of fungicides for the control of downy mildew on ridge gourd.

Materials and Methods

Seeds of ridge gourd cv. Konkan Harita were obtained from the Vegetable Improvement Scheme, Dapoli, India. The seeds have not been treated with any fungicide and were planted on June 18 during the Kharif season of 1998-1999. The plant spacing was 1.5 m between rows and 0.9 m within rows, according to local recommendations. The experimental design was a randomized block with three replicates.

Farmyard manure (15 t ha^{-1}) was used as an organic amendment prior to planting. Inorganic fertilizer was added at the rate of 100 kg ha^{-1} nitrogen, 50 kg ha^{-1} phosphate, and 50 kg ha^{-1} potassium. Also prior to planting, 50 kg ha^{-1} P, 50 kg ha^{-1} K, and 30 kg ha^{-1} N were applied.

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Fungicides fosetyl-Al, thiophanate methyl, metalaxyl + mancozeb, ziram, chlorothalonil, copper oxychloride, and mancozeb (Table 1) were used for the control of downy mildew. First symptom appeared at 41 days after sowing. Fungicides were applied on the 42nd day according to the manufacturer's recommended rates using a knapsack sprayer. Disease assessments were made 1 day prior to each subsequent 15-day interval fungicide application. For disease assessments, 10 leaves per replicate per treatment were taken at random and scored for disease severity. Care was taken to ensure that the selected leaves were from the same positions on each plant. For each treatment, the weight of harvested fruits was recorded periodically for each replicate. All harvesting finished on 12 October 1998.

Areas under disease progress curves (AUDPC) were calculated using the midpoint method of Campbell and Madden (1990). Non-linear curve fitting for disease progress curves and subsequent statistical analysis were performed using SAS. Logistic models of disease progress were used throughout as these gave consistently better data fits than Gompertz or other models. For logistic model fitting, values of r (rate of disease increase) and Y_0 (initial disease levels) were estimated using two methods. The first K_{max} (maximum disease) was estimated as a third model parameter, and the second values of K_{max} were constrained at 1.0.

Table 1. Fungicides used for the control of downy mildew on ridge gourd

Common name	Trade name	Formulation
Fosetyl-Al	Aliette	80% WP
Thiophanate methyl	Roko	70% WP
Metalaxyl + Mancozeb	Ridomil MZ	72% WP
Ziram	Cuman-L	27% SC
Chlorothalonil	Kavach	75% WP
Copper oxychloride	Blitox	50% WP
Mancozeb	Sparsh	75% WP

Results

The effect of fungicide treatments on disease severity is shown in Table 2. For all treatments, the severity of disease increased with time. The increase was highest in control plants without fungicide treatment, with disease severity reaching 81% at 116 days after sowing. Meanwhile, plants treated with metalaxyl + mancozeb showed the lowest disease incidence, with a final disease severity of 13%. Table 2 also shows significant difference among the AUDPC values for each fungicide treatment. The AUDPC value for plants sprayed with metalaxyl + mancozeb (662.5) was significantly lower than that of the other treatments. Control plants have a significantly higher AUDPC value than those of all treated plants. The plants treated with thiophanate methyl also showed an AUDPC value significantly higher than that of other fungicide treatments.

Yields in each treatment are shown in Table 3. Maximum yield of 17.0 t ha^{-1} was obtained from plants treated with metalaxyl + mancozeb, while lowest yield was from plants not sprayed with any fungicide (7.3 t ha^{-1}). The other treatments showed intermediate yields of between 15.95 t ha^{-1} (fosetyl-Al) and 9.39 t ha^{-1} (thiophanate methyl).

Table 4 shows parameter estimates for logistic disease progress where K_{max} was not constrained. There were no significant differences in the values for initial disease (Y_0) or the rate of disease increase (r) among the different fungicide treatments. The estimated values of K_{max} suggested that treatment with metalaxyl + mancozeb significantly reduced the final level of disease compared with all other treatments. Using this method of parameter estimation, the control plants had the highest disease level, although the value was not significantly different from

Table 2. Severity of downy mildew and area under the downy mildew severity curve for ridge gourd cv. Konkan Harita following treatment with seven fungicides

	Disease severity (%)						
	Days after sowing						
Fungicide	41	56	71	86	101	116	AUDPC[a]
Fosetyl-Al	2.5	5.8	10.8	19.2	30.0	32.5	1250.0
Thiophanate methyl	1.67	10.00	19.17	32.50	50.83	57.50	2131.3
Metalaxyl + mancozeb	1.67	5.00	8.33	10.83	12.50	13.33	662.5
Ziram	2.50	9.17	17.50	31.67	43.33	51.67	1931.3
Chlorothalonil	2.50	7.50	13.33	23.33	32.50	36.67	1443.8
Copper oxychloride	3.33	9.17	16.67	26.67	42.50	45.83	1793.8
Mancozeb	1.67	8.33	15.87	25.00	40.00	42.50	1668.8
Control	2.50	10.83	21.67	40.83	67.50	80.83	2737.5
LSD (0.05)							153.3

[a] Area under the disease progress curve.

those plants sprayed with thiophanate methyl.

Table 5 shows estimates of Y_0 and r when K_{max} was set at 1.0. For all treatments, the estimates of Y_0 were higher and those of r were lower than when K_{max} was not constrained. As mentioned previously, there were no significant differences among the fungicide treatments in terms of their estimated Y_0 values. The estimated rates of disease increase (r) were significantly different. The estimated disease increase rate in the control was significantly higher than that in all other treatments. The estimated disease increase rate in plants treated with metalaxyl + mancozeb was significantly lower than that in all other fungicide treatments. The three parameters that most usefully described differences in fungicide performance in controlling downy mildew were significantly correlated ($r > 0.9833$).

Table 3. Effect of fungicide treatments for the control of downy mildew on the yield of ridge gourd

Treatment	Yield (t ha^{-1})
Fosetyl-Al	16.0[a]
Thiophanate methyl	9.4
Metalaxyl + mancozeb	17.0
Ziram	10.3
Chlorothalonil	15.6
Copper oxychloride	11.8
Mancozeb	12.1
Control	7.3

[a] Means of three replicates.

Table 4. Estimates of logistic disease increase parameters for the progress of downy mildew on ridge gourd (K_{max} unconstrained)

	Parameter estimates[a]		
Fungicide	K_{max}	Y_0	r
Fosetyl-Al	0.3777	.0020	.0641
Thiophanate methyl	0.6546	.0024	.0672
Metalaxyl + mancozeb	0.1368	.0020	.0674
Ziram	0.5933	.0034	.0647
Chlorothalonil	0.4111	.0022	.0646
Copper oxychloride	0.5327	.0028	.0632
Mancozeb	0.4848	.0025	.0681
Control	0.7530	.0023	.0655
LSD	0.2079	NS[b]	NS[b]

[a] Values are means of three replicates.
[b] Not significantly different among fungicides at $P < 0.05$.

Table 5. Estimates of logistic disease increase parameters for the progress of downy mildew on ridge gourd ($K_{max} = 1.0$)

	Parameter estimates[a]	
Fungicide	Y_0	R
Fosetyl-Al	.0143	.0314
Thiophanate methyl	.0114	.0428
Metalaxyl + mancozeb	.0212	.0179
Ziram	.0144	.0382
Chlorothalonil	.0167	.0316
Copper oxychloride	.0161	.0356
Mancozeb	.0161	.0349
Control	.0116	.0516
LSD (0.05)	NS[b]	.0067

[a] Values are means of three replicates.
[b] Not significantly different among fungicides at $P < 0.05$.

Table 6. Relationship between estimated parameters used to describe the ability of fungicides to control downy mildew on ridge gourd

	AUDPC	r when $K_{max} = 1.0$	Unconstrained K_{max}
AUDPC	1		
r when $K_{max} = 1.0$	0.9899	1	
Unconstrained K_{max}	0.9857	0.9833	1

There was a significant relationship between the mean AUDPC for replicate plants treated with each fungicide and the yield harvested from the same plants (Fig. 1). The relationship was better described by a logistic function ($R^2 = 97.2$, $P < 0.001$) than by a linear function ($R^2 = 91.5$, $P < 0.001$). The logistic function suggests a maximum yield of 17.26 t ha^{-1} when the disease is fully controlled, while the asymptotic yield falls to 7.32 t ha^{-1}. There was also a significant logistic relationship between estimated K_{max} and yield (Fig. 2). In this case, the estimated maximum yield was 17.38 t ha^{-1}, falling asymptotically to 6.99 t ha^{-1}.

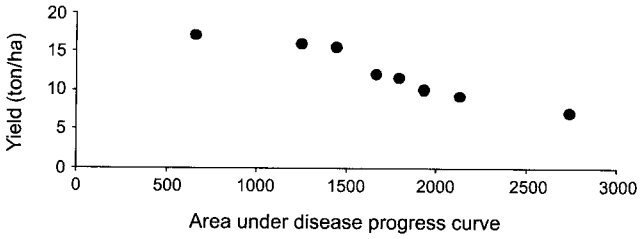

Fig. 1. Relationship between area under the downy mildew disease progress curve and yield (t ha^{-1}) of ridge gourd.

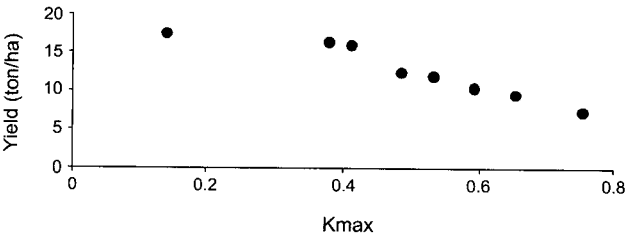

Fig. 2. Relationship between estimated maximum disease severity (K_{max}) and ridge gourd yield (t ha^{-1}).

Table 7. Cost-benefit ratios for fungicide treatment on ridge gourd for the control of downy mildew in relation to economic return from higher yields

Treatment	Harvest value (US$ ha^{-1})	Cost of treatments (US$ ha^{-1})	Economic value of crop (US$ ha^{-1})	Change into relative to control (%)
Control	1505.8	0.0	1505.8	0
Thiophanate methyl	1944.1	56.4	1887.6	25.3
Ziram	2123.6	29.7	2093.9	39.0
Copper oxychloride	2432.7	38.8	2393.8	58.9
Mancozeb	2512.0	30.5	2481.4	64.7
Chlorothalonil	3222.9	91.2	3131.7	107.9
Fosetyl-Al	3301.6	106.1	3195.5	112.2
Metalaxyl + mancozeb	3519.0	64.7	3454.3	129.4
Estimated maximum	3624.6			

The current market price for ridge gourd in India is approximately US$ 210 t^{-1}. Thus, the maximum likely return can be estimated at US$ 3624.60 ha^{-1}. Based on the local price of fungicides and labour, the cost-benefit ratio of the treatments can be estimated (Table 7). Despite the differences in the cost of the treatments, the relative performance of the different fungicides was unchanged when the cost of the treatments was taken into consideration. The data suggests that an economic return, relative to the control, would be 129.4% when metalaxyl + mancozeb was applied to the crop.

Discussion

Downy mildew is a serious disease of cucurbits in most environments. In India, annual losses of ridge gourd have not been estimated but are believed to be substantial (Kagadi, 1999). The extent of sporulation of downy mildew pathogen on a range of varieties has shown significant differences (Thomas and Jourdain, 1992). Furthermore, a significant level of host specialization exists within populations of *P. cubensis*. Consequently, commercial varieties of some crops, such as cucumber, with high levels of resistance will be available. However, there is no information available yet on ridge gourd variety with high resistance to downy mildew. Therefore, fungicidal control is likely to remain the principal means to reduce losses.

In this study, there were no differences in the estimated starting value for disease severity (Y_0) among the treatments, either when k_{max} was constrained at 1.0 or when k_{max} was unconstrained. Field plots were located in an area frequently planted with ridge gourd. Presumably, there existed sufficient inoculum sources to establish simultaneously the experimental plots for a number of disease foci.

Previous reports on the fungicidal control of downy mildew on ridge gourd suggest that, of the fungicide options available, metalaxyl + mancozeb provides good disease control and offers substantial cost benefit advantages. In cucumber, Samoucha and Cohen (1984) reported that metalaxyl + mancozeb provides the most effective downy mildew control. In India Maheshwari and Gupta (1990) also reported that the same fungicide combination was the most effective for downy mildew control on sponge gourd. In Honduras, Grove (1980) reported that mancozeb alone and chlorothalonil provided effective control of downy mildew on susceptible cantaloupe melons. Given reports of resistance to metalaxyl in *P. cubensis* (O'Brien and Weinert, 1995), recommendations for the use with mancozeb should be recommended for cucurbits such as ridge gourd.

Results of this study also suggest that fosetyl-Al and chlorotalonil can provide effective control of downy mildew, even though Gupta and Shyam (1996) have previously reported that chlorothalonil was the least effective of the fungicides tested against downy mildew on cucurbits. Results also show the effectiveness of all the selected fungicides in reducing the rate of downy mildew disease progress, even on those plots treated with the least effective fungicide (thiophanate methyl), compared with the untreated control plots. With k_{max} constrained at 1.0, the estimated rate of progress in plots treated with metalaxyl + mancozeb (0.0179) was 30% of that for the untreated control. Results also suggest reduced crop yield with an increase in either area under the disease progress curve (Fig. 1) or the estimated maximum severity of disease (k_{max}, Fig. 2). The predicted maximum and minimum yield levels were similar for both methods of estimation.

Although the cost of chemical varied from US$29.70 per ha (ziram) to US$106.11 per ha (fosetyl-Al), this had little effect on the overall cost-benefit relationship when the economic value of the crop was calculated (Table 7). Even taking the cost of labour into account, crop return from the plot treated with metalaxyl + mancozeb was considerably higher (129%) than that from the control.

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