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## Management of downy mildew disease in bitter gourd with minimizing fungicidal applications

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**Abstract**

*Pseudoperonospora cubensis* (Berkeley & Curtis) Rostovtsev pathogen is associated with bitter gourd downy mildew. Due to recurrent outbreaks of downy mildew in bitter gourd over the past decades, it has emerged to be the most destructive disease and created a problem in India. Management of disease by minimizing fungicidal applications is the best way to manage the downy mildew disease in bitter gourd. The research study revealed that alternate use of fungicides significantly inhibited downy mildew disease in bitter gourd during the year, 2022. Seven fungicidal treatments were applied as Absolute control (water spray), Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit, GI Chitosan @ 1 ml/lit, Potassium salt of active phosphorus @ 4 g/lit, T<sub>2</sub> and T<sub>3</sub> alternatively, T<sub>2</sub> and T<sub>4</sub> alternatively, T<sub>2</sub>, T<sub>3</sub>, and T<sub>4</sub> alternatively. Overall present research showed that the treatment T<sub>7</sub> (T<sub>2</sub>, T<sub>3</sub>, and T<sub>4</sub> alternatively) i.e Metalaxyl 4% + Mancozeb 64% WP, GI Chitosan @ 1 ml/lit and Potassium salt of active phosphorus @ 4 g/lit alternatively was observed the most effective against the pathogen *Pseudoperonospora cubensis* which cause downy mildew in bitter gourd. Treatment T<sub>7</sub> (T<sub>2</sub>, T<sub>3</sub>, and T<sub>4</sub> alternatively) gave more yield than other treatments.

**Keywords:** *Pseudoperonospora cubensis*, destructive disease

**1. Introduction**

Bitter gourd is a notable vegetable fruit crop and the scientific name is *Momordica charantia*. Bitter gourd belongs to the Cucurbitaceae family and is planted as an attractive plant (Heiser 1979) [5]. It is grown in several parts of Maharashtra and India. In Maharashtra during 2021-22 total area was 3720 ha, with production is 35320 MT and the total yield was 9.50 MT/ha (Ministry of Agri. and FW, Govt. of India; ON 2941) and In India, during the year 2021-22 total area was 107000 ha, with a production of 1334000 MT and the total yield was 12.5 MT/ha (Ministry of Agri. and FW, Govt. of India; ON 2948). Bitter gourd is affected by various pathogens among them within the genus *Pseudoperonospora* (Peronosporaceae), the most popular and economically important species is *Pseudoperonospora cubensis*, Rostovzev, which causes downy mildew disease in bitter gourd. *Pseudoperonospora cubensis* is an obligate fungus pathogen hence, it is very important to manage the downy mildew disease in bitter gourd. Ridomil contains the ingredients Metalaxyl 4% and Mancozeb 64% used to manage the downy mildew illness in bitter gourd. Control of downy mildew in a bitter gourd with fungicide options like Metalaxyl + Mancozeb provided good results and offered substantial cost-benefit advantages. The use of chitosan is used to protect the bitter gourd plant from a variety of fungal, bacterial, and viral illnesses due to its antifungal, antibacterial, and antiviral properties. Potassium Salt of Active Phosphorus (PSAP) has been applied to bitter gourd crop that is exported and it has no environmental hazards or harmful risks. Continuous treatment of PSAP also lessens biotic and abiotic stress, which helps the crop become healthier. PSAP also decreased crop loss and boosts fruit production with desirable texture.

**2. Materials and Methods**

The aqueous solution of the required concentration of various treatments was prepared in water just before spraying. Three sprays of fungicide were taken up starting from the onset of the disease at 10 days intervals later to more. The first spray was carried out 45 days after sowing with a knapsack sprayer. The disease scoring was carried out from randomly selected plants in each row of each replication after five and ten days of spraying as per a 0-9 scale. Plants were observed to record the disease severity until physiological maturity. The statistical analysis was carried out according to the standard method. The percent disease intensity, percent disease control and Area Under Disease Progress Curve (AUDPC) were calculated by using the standard formulae.

## 2.1 Experiment site

The field research trial was conducted during the year, 2022 on the research farm of All India coordinated research project (AICRP) Vegetables, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India. Downy mildew disease is found throughout the year reducing the yield and quality of bitter gourd fruits.

## 2.2 Layout and plan

The field experiments were conducted in Randomized Block Design with three replication and seven treatments for disease management studies.

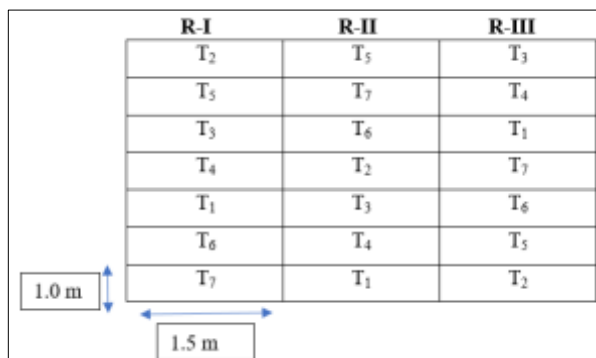
## 2.3 Details of the layout

1. Name of the crop: Bitter gourd (*Momordica charantia*)
2. Variety: Phule Greengold
3. Plot size: 740 sq.m.
4. Spacing: 1.5m X 1.0 m
5. Design: R.B.D
6. Replications: 03
7. Treatments: 07

## 2.4 Treatment details

1. Absolute control (water spray)
2. Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit
3. GI Chitosan @ 1 ml/lit
4. Potassium salt of active phosphorus @ 4 g/lit
5. T<sub>2</sub> and T<sub>3</sub> alternatively
6. T<sub>2</sub> and T<sub>4</sub> alternatively
7. T<sub>2</sub>, T<sub>3</sub>, and T<sub>4</sub> alternatively

## 2.5 Experimental layout of the research field.



## 2.6 Disease rating scales used against all fungicidal treatments

Disease rating scales used from 0-9 scale for recording

disease intensity of downy mildew. (Datar and Mayee, 1986) [3].

Scale	Leaf area infected
0	Leaf area free from infection
1	Leaf area infected up to 1%
3	Leaf area infected up to 10%
5	Leaf area infected up to 25%
7	Leaf area infected up to 50%
9	Leaf areas infected with more than 50%

## 2.7 Percent Disease Index (%)

Further, these scales will be converted to the percent diseases index using the formula given by Wheeler (1969) [8]

$$\text{Percent Disease Index (\%)} = \frac{\text{Sum of all numerical rating}}{\text{Number of leaves examined} \times \text{Maximum grade}} \times 100$$

## 2.8 Percent disease control (PDC)

The percent disease control was calculated by using the formula given below:

$$\text{PDC (\%)} = \frac{\text{PDI in control} - \text{PDI in treatment}}{\text{PDI in control}} \times 100$$

Where,

PDC= percent disease control

C= PDI in the control treatment plot

T= PDI in treatment plot

## 2.9 Area Under Disease Progress Curve (AUDPC)

The disease progress curve has given a better idea to study epidemics of plant disease. (Wilcoxson *et al.*, 1975) [9].

$$A = \sum x_i + (x_{i-1})d$$

Where,

A= AUDPC

x<sub>i</sub> = PDI at i<sup>th</sup> interval

d = Period between observations

## 2.10 Yield

At the time of harvest, the fruits from all treatments and replications were collected separately and the fruit weight of each replication was recorded.

## 3. Results and Discussion

**Table 1:** Effect of minimum fungicidal sprays on downy mildew of bitter gourd from February to April 2022

Tr. No	Treatment details	PDI before spray	PDI after spray			PDC (%)	AUDPC
			I	II	III		
T <sub>1</sub>	Absolute control (water spray)	1.13 (6.10)	8.68 (17.13)	17.53 (24.75)	22.85 (28.55)	0.0	191
T <sub>2</sub>	Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit	1.20 (6.28)	6.46 (14.72)	11.74 (20.03)	14.86 (22.67)	34.96	131.15
T <sub>3</sub>	GI Chitosan @ 1 ml/lit	1.17 (6.20)	7.71 (16.12)	12.76 (20.92)	15.40 (23.10)	32.60	143.77
T <sub>4</sub>	Potassium salt of active phosphorus @ 4 g/lit	1.83 (7.77)	4.88 (12.76)	7.60 (16.00)	11.77 (20.06)	48.49	96.40
T <sub>5</sub>	T <sub>2</sub> and T <sub>3</sub> alternatively	1.67 (7.42)	5.60 (13.68)	10.44 (18.85)	13.67 (21.69)	40.17	118.55
T <sub>6</sub>	T <sub>2</sub> and T <sub>4</sub> alternatively	1.33	5.36	9.81	12.71	44.37	110.95

		(6.62)	(13.38)	(18.25)	(20.88)		
T <sub>7</sub>	T <sub>2</sub> , T <sub>3</sub> and T <sub>4</sub> alternatively	1.66 (7.40)	3.88 (11.36)	6.64 (14.93)	10.45 (18.86)	54.26	82.87
	SE±	0.29	0.74	0.58	0.54		
	CD at 5%	NS	2.29	1.79	1.67		
PDI= Percent Disease Index, PDC= Percent Disease Control AUDPC=Area Under Disease Progress Curve, * Values in parentheses are arc sin transformed							

### 3.1 Management of downy mildew disease with minimizing fungicidal applications

Trials were conducted in a randomized block design (RBD) with seven treatments and three replications. The complete plot was divided into ridges and furrows. Three sprays of each treatment were applied immediately after occurrence of the disease, the second spray was given 15 days after the first spray, and the third spray was given 15 days after the second spray during the year, 2022. In the trial metalaxyl 4% + mancozeb 64% WP @ 2 g/lit, GI chitosan @ 1 ml/lit, and potassium salt of active phosphorus @ 4 g/lit were sprayed as a sole as well as in combinations on a variety *Phule Green Gold* of bitter melon as mentioned in the Table 19. The severity of downy mildew disease was recorded before each spray and after each spray.

#### 3.1.1 Percent disease index, percent disease control and area under disease progress curve from February to April, 2022

Table 1 indicates the effect of minimum fungicidal sprays on downy mildew of bitter melon from February to April, 2022. Before spray, data on PDI was statistically non-significant. After the first spray, treatment T<sub>7</sub> (metalaxyl 4% + mancozeb 64% WP @ 2 g/lit, GI chitosan @ 1 ml/lit, and potassium salt of active phosphorus @ 4 g/lit alternatively) was found most effective with the least percent disease index (3.88%). This was followed by T<sub>4</sub> (Potassium salt of active phosphorus @ 4 g/lit: 4.88%) and T<sub>6</sub> (metalaxyl 4% + mancozeb 64% WP @ 2 g/lit and potassium salt of active phosphorus @ 4 g/lit alternatively: 5.36%). These three treatments were statistically at par with each other. Maximum PDI (8.68) was noticed with treatment absolute control (water spray) and results were statistically at par with T<sub>3</sub> (GI Chitosan @ 1 ml/lit: 7.71%)

and T<sub>2</sub> (metalaxyl 4% + mancozeb 64% WP @ 2 g/lit: 6.46%).

Later on, the downy mildew percent disease index was increased after second spray. However, minimum increase was noticed in treatments imposed excluding water spray. Least percent disease index (6.64%) was observed in treatment T<sub>7</sub> (metalaxyl 4% + mancozeb 64% WP @ 2 g/lit, GI chitosan @ 1 ml/lit, and potassium salt of active phosphorus @ 4 g/lit alternatively). Statistically next best (7.60%) was T<sub>4</sub> (Potassium salt of active phosphorus @ 4 g/lit) and at par with most superior treatment. The least effective with more percent disease index was treatment T<sub>1</sub> (water spray) absolute control (17.53%).

Following on, similar results were obtained after third spray. The least percent disease index was observed in treatment T<sub>7</sub> i.e T<sub>2</sub>, T<sub>3</sub>, and T<sub>4</sub> alternatively (10.45%) which was found most effective. This was followed by T<sub>4</sub> i.e. Potassium salt of active phosphorus @ 4 g/lit (11.77%) and was only statistically at par with superior treatment. The least effective with more percent disease index obtained in treatment T<sub>1</sub> (water spray) absolute control (22.85%).

The highest value of Percent Disease Control (PDC) was recorded in treatment T<sub>7</sub> i.e T<sub>2</sub>, T<sub>3</sub>, and T<sub>4</sub> alternatively with a value of 54.26 and this was followed by T<sub>4</sub> i.e Potassium salt of active phosphorus @ 4 g/lit (48.49). Downy mildew disease progress over the time was calculated by using Area Under Disease Progress Curve (AUDPC). The AUDPC provided information about disease intensity which was not uniform among all fungicidal treatments. The AUDPC values ranged from 82.87 to 191. The lowest disease progress was recorded in treatment T<sub>7</sub> (T<sub>2</sub>, T<sub>3</sub>, and T<sub>4</sub> alternatively) with a value of 82.87. The highest disease progress was recorded in treatment T<sub>1</sub> (water spray) absolute control (191).

**Table 2:** Effect of minimum fungicidal sprays on downy mildew of bitter melon from May to July 2022

Tr. No	Treatment details	PDI before spray	PDI after spray			PDC	AUDPC
			I	II	III		
T <sub>1</sub>	Absolute control (water spray)	3.03 (10.02)	10.51 (18.91)	19.35 (26.09)	27.91 (31.89)	0.0	226.65
T <sub>2</sub>	Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit	2.87 (9.75)	8.89 (17.34)	14.57 (22.43)	19.37 (26.11)	30.59	172.90
T <sub>3</sub>	GI Chitosan @ 1 ml/lit	3.23 (10.35)	9.45 (18.38)	14.70 (22.54)	20.36 (26.82)	27.05	179.72
T <sub>4</sub>	Potassium salt of active phosphorus @ 4 g/lit	2.45 (9.00)	6.74 (15.04)	9.05 (17.50)	13.47 (21.53)	51.73	118.75
T <sub>5</sub>	T <sub>2</sub> and T <sub>3</sub> alternatively	2.58 (9.24)	7.73 (16.14)	13.54 (21.59)	17.87 (25.00)	35.97	157.47
T <sub>6</sub>	T <sub>2</sub> and T <sub>4</sub> alternatively	2.68 (9.42)	7.38 (15.76)	12.78 (20.94)	16.25 (23.77)	41.77	148.12
T <sub>7</sub>	T <sub>2</sub> , T <sub>3</sub> and T <sub>4</sub> alternatively	2.16 (8.45)	5.81 (13.94)	8.52 (16.97)	11.73 (20.02)	57.97	106.37
	SE±	0.51	0.83	0.77	0.50		
	CD at 5%	NS	2.55	2.37	1.55		
PDI= Percent Disease Index, PDC= Percent Disease Control AUDPC=Area Under Disease Progress Curve, * Values in parentheses are arc sin transformed							

### 3.1.2 Percent disease index, Percent disease control and area under disease progress curve from May to July, 2022

Table 2 indicates the effect of minimum fungicidal sprays on downy mildew of bitter melon from May to July, 2022. Before spray, data on PDI was statistically non significant. After the first spray, treatment T<sub>7</sub> (metalaxyl 4% + mancozeb 64% WP @ 2 g/lit, GI chitosan @ 1 ml/lit, and potassium salt of active phosphorus @ 4 g/lit alternatively) was found most effective with the least percent disease index (5.81%). This was followed by T<sub>4</sub> (Potassium salt of active phosphorus @ 4 g/lit: 6.74%), T<sub>6</sub> (metalaxyl 4% + mancozeb 64% WP @ 2 g/lit and potassium salt of active phosphorus @ 4 g/lit alternatively: 7.38%) and T<sub>5</sub> (metalaxyl 4% + mancozeb 64% WP @ 2 g/lit and GI Chitosan @ 1 ml/lit: 7.73%). These four treatments were statistically at par with each other. Maximum PDI (10.51) was noticed with treatment absolute control (water spray) and results were statistically at par with T<sub>3</sub> (GI Chitosan @ 1 ml/lit: 9.45%) and T<sub>2</sub> (metalaxyl 4% + mancozeb 64% WP @ 2 g/lit: 8.89%).

Later on, the downy mildew percent disease index was increased after second spray. However, minimum increase was noticed in treatments imposed excluding water spray. Least percent disease index (8.52%) was observed in treatment T<sub>7</sub> (metalaxyl 4% + mancozeb 64% WP @ 2 g/lit, GI chitosan @ 1 ml/lit, and potassium salt of active

phosphorus @ 4 g/lit alternatively). Statistically next best (9.05%) was T<sub>4</sub> (Potassium salt of active phosphorus @ 4 g/lit) and at par with most superior treatment. The least effective with more percent disease index was treatment T<sub>1</sub> (water spray) absolute control (19.35%).

Following on, similar results were obtained after third spray. The least percent disease index was observed in treatment T<sub>7</sub> i.e T<sub>2</sub>, T<sub>3</sub>, and T<sub>4</sub> alternatively (11.73%) which was found most effective. This was followed by T<sub>4</sub> i.e Potassium salt of active phosphorus @ 4 g/lit (13.47%) and was only statistically at par with superior treatment. The least effective with more percent disease index obtained in treatment T<sub>1</sub> (water spray) absolute control (27.91%).

The highest value of Percent Disease Control (PDC) was recorded in treatment T<sub>7</sub> i.e T<sub>2</sub>, T<sub>3</sub>, and T<sub>4</sub> alternatively with a value of 57.97 and this was followed by T<sub>4</sub> i.e Potassium salt of active phosphorus @ 4 g/lit (51.73). Downy mildew disease progress over the time was calculated by using Area Under Disease Progress Curve (AUDPC). The AUDPC provided information about disease intensity which was not uniform among all fungicidal treatments. The AUDPC values ranged from 106.37 to 226.65. The lowest disease progress was recorded in treatment T<sub>7</sub> (T<sub>2</sub>, T<sub>3</sub>, and T<sub>4</sub> alternatively) with a value of 106.37. The highest disease progress was recorded in treatment T<sub>1</sub> (water spray) absolute control (226.65)

**Table 3:** Effect of minimum fungicidal sprays on downy mildew of bitter melon during year 2022 (Pooled data)

Tr. No.	Treatment details	PDI before spray	PDI after spray			PDC (%)	AUDPC
			I	II	III		
T <sub>1</sub>	Absolute control (water spray)	2.08 (8.29)	9.59 (18.03)	18.44 (25.43)	25.38 (30.25)	0.0	208.8
T <sub>2</sub>	Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit	2.03 (8.19)	7.67 (16.07)	13.15 (21.26)	17.11 (24.43)	32.58	151.95
T <sub>3</sub>	GI Chitosan @ 1 ml/lit	2.2 (8.52)	8.58 (17.03)	13.73 (21.74)	17.88 (25.01)	29.55	161.75
T <sub>4</sub>	Potassium salt of active phosphorus @ 4 g/lit	2.14 (8.41)	5.81 (13.94)	8.32 (16.76)	12.62 (20.80)	50.27	107.55
T <sub>5</sub>	T <sub>2</sub> and T <sub>3</sub> alternatively	2.12 (8.37)	6.66 (14.95)	11.99 (20.52)	15.77 (23.39)	37.86	137.97
T <sub>6</sub>	T <sub>2</sub> and T <sub>4</sub> alternatively	2.00 (8.13)	6.37 (14.61)	11.29 (19.63)	14.48 (22.36)	42.94	129.50
T <sub>7</sub>	T <sub>2</sub> , T <sub>3</sub> and T <sub>4</sub> alternatively	1.91 (7.94)	4.84 (12.70)	7.58 (15.98)	11.09 (19.45)	56.30	94.60
	SE <sub>±</sub>	0.40	0.78	0.67	0.52		
	CD at 5%	NS	2.42	2.08	1.61		

PDI= Percent Disease Index, PDC= Percent Disease Control, AUDPCAUDPC=Area Under Disease Progress Curve, \* Values in parentheses are arc sin transformed

### 3.1.3 Percent disease index, percent disease control and area under disease progress curve during year, 2022 (Pooled data)

Table 3 indicates the effect of minimum fungicidal sprays on downy mildew of bitter melon during the year, 2022. Before spray, data on PDI was statistically non significant. After the first spray, treatment T<sub>7</sub> (metalaxyl 4% + mancozeb 64% WP @ 2 g/lit, GI chitosan @ 1 ml/lit, and potassium salt of active phosphorus @ 4 g/lit alternatively) was found most effective with the least percent disease index (4.84%). This was followed by T<sub>4</sub> (Potassium salt of active phosphorus @ 4 g/lit: 5.81%), T<sub>6</sub> (metalaxyl 4% + mancozeb 64% WP @ 2 g/lit and potassium salt of active phosphorus @ 4 g/lit alternatively: 6.37%) and T<sub>5</sub> (metalaxyl 4% + mancozeb 64% WP @ 2 g/lit and GI Chitosan @ 1 ml/lit: 6.66). These four treatments were statistically at par with each other. Maximum PDI (9.59)

was noticed with treatment absolute control (water spray) and results were statistically at par with T<sub>2</sub> (Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit: 7.67) and T<sub>3</sub> (GI Chitosan @ 1 ml/lit: 8.58).

During the next spell of time, the downy mildew percent disease index was increased after second spray. However, minimum increase was noticed in treatments imposed excluding water spray. Least percent disease index (7.58%) was observed in treatment T<sub>7</sub> (metalaxyl 4% + mancozeb 64% WP @ 2 g/lit, GI chitosan @ 1 ml/lit, and potassium salt of active phosphorus @ 4 g/lit alternatively). Statistically next best (8.32%) was T<sub>4</sub> (Potassium salt of active phosphorus @ 4 g/lit) and at par with most superior treatment. The least effective with more percent disease index was treatment T<sub>1</sub> (water spray) absolute control (18.44%). After second spray too, values of PDI of absolute control were statistically at par



with T<sub>2</sub> (Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit) and T<sub>3</sub> (GI Chitosan @ 1 ml/lit).

Consequently, similar results were obtained after third spray with respect to superior treatment. The least percent disease index was observed in treatment T<sub>7</sub> i.e T<sub>2</sub>, T<sub>3</sub>, and T<sub>4</sub> alternatively (11.09%) which was found most effective. This was followed by T<sub>4</sub> i.e Potassium salt of active phosphorus @ 4 g/lit (12.62%) and was only statistically at par with superior treatment. The least effective with more percent disease index obtained in treatment T<sub>1</sub> (water spray) absolute control (25.38%). Here noteworthy observation is, after third spray a remarkable change is noticed as against results after first and second spray. The values of PDI with respect to T<sub>2</sub> and T<sub>3</sub> were significantly superior over values of absolute control.

The highest value of Percent Disease Control (PDC) was recorded in treatment T<sub>7</sub> i.e T<sub>2</sub>, T<sub>3</sub>, and T<sub>4</sub> alternatively with a value of 56.30 and this was followed by T<sub>4</sub> i.e Potassium salt of active phosphorus @ 4 g/lit (50.27). Downy mildew disease progress over the time was calculated by using Area Under Disease Progress Curve (AUDPC). The AUDPC provided information about disease intensity which was not uniform among all fungicidal treatments. The AUDPC values ranged from 94.6 to 208.8. The lowest disease progress was recorded in treatment T<sub>7</sub> (T<sub>2</sub>, T<sub>3</sub>, and T<sub>4</sub> alternatively) with a value of 94.6. The highest disease progress was recorded in treatment T<sub>1</sub> (water spray) absolute control (208.8).

All results prove the alternative use of Metalaxyl 4% +

Mancozeb 64% WP, GI Chitosan @ 1 ml/lit and Potassium salt of active phosphorus @ 4 g/lit was most effective than using all in separate form for managing downy mildew disease in bitter gourd during year, 2022. The overall present research showed that the spraying of Metalaxyl 4% + Mancozeb 64% WP, GI Chitosan @ 1 ml/lit and Potassium salt of active phosphorus @ 4 g/lit alternatively have a synergetic effect on lowering disease intensity and were effective than treated alone.

Results obtained in the objective management of downy mildew disease with minimizing fungicidal applications have appeared similar findings with earlier workers *viz* Gupta and Jared (2014), who tested and found that the fungicides metalaxyl + mancozeb WP proved to be the best in managing the disease up to the maximum level (73.75%) with the lowest disease severity value of 16.11 percent. Later on, Farouk *et al.* (2008) [4], stated chitosan (CHI) and salicylic acid (SA) could be used in the field as a means of protection against cucumber downy mildew as well as improving its growth and yield in addition to the decrease of the fungicides used. After that, Sebastia (2016) revealed that a single application of potassium phosphite combined with fungicide could be used efficiently to manage rice stem diseases. After that, Sawant *et al.* (2016) [7] found that the downy mildew pathogen of grapes was effectively controlled by activated potassium salt of long-chain phosphorous under both conditions *in vitro* and *in vivo*.

**Table 4:** The yield of fruits (q/ha) and increased yield over control (%) from February to April 2022

Tr. No.	Treatment details	Yield q/ha	Increased yield over control
T <sub>1</sub>	Absolute control (water spray)	122.63	0.0
T <sub>2</sub>	Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit	155.47	26.77
T <sub>3</sub>	GI Chitosan @ 1 ml/lit	149.43	22.85
T <sub>4</sub>	Potassium salt of active phosphorus @ 4 g/lit	172.52	40.68
T <sub>5</sub>	T <sub>2</sub> and T <sub>3</sub> alternatively	163.50	33.32
T <sub>6</sub>	T <sub>2</sub> and T <sub>4</sub> alternatively	167.46	36.55
T <sub>7</sub>	T <sub>2</sub> , T <sub>3</sub> and T <sub>4</sub> alternatively	180.16	46.91
	S. E. (m) ±	0.87	
	C.D. at 5%	2.68	

### 3.1.4 The yield of fruits (q/ha) and increased yield over control (%) from February to April, 2022

Table 4 depicted effect of minimum fungicidal sprays on yield (q/ha) of bitter gourd from February to April, 2022. The yield values of bitter gourd fruits showed variation due to the effect of different fungicidal sprays. The yield values ranged from 122.63 q/ha to 180.16 q/ha. All the treatments were significantly differed from one another. The yield levels significantly differ from one another among all the attempted treatments. Comparatively lower yield was

obtained in treatment T<sub>1</sub> absolute control (water spray), and the value was noticed at 122.63 q/ha. The highest yield (180.16 q/ha) was obtained with treatment T<sub>7</sub> (metalaxyl 4% + mancozeb 64% WP @ 2 g/lit, GI chitosan @ 1 ml/lit, and potassium salt of active phosphorus @ 4 g/lit alternatively). It was observed that wherever under treatments Potassium salt of active phosphorus @ 4 g/lit has been added, those yield values were significantly superior over the treatment T<sub>1</sub> absolute control (water spray) as well as the sole chemical control.

**Table 5:** Effect of minimum fungicidal sprays on yield (q/ha) of bitter gourd from May to July 2022

Tr. No.	Treatment details	Yield q/ha	Increased yield over control
T <sub>1</sub>	Absolute control (water spray)	109.63	0.0
T <sub>2</sub>	Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit	152.87	39.44
T <sub>3</sub>	GI Chitosan @ 1 ml/lit	146.67	33.78
T <sub>4</sub>	Potassium salt of active phosphorus @ 4 g/lit	170.6	55.67
T <sub>5</sub>	T <sub>2</sub> and T <sub>3</sub> alternatively	159.47	45.46
T <sub>6</sub>	T <sub>2</sub> and T <sub>4</sub> alternatively	164.60	50.14
T <sub>7</sub>	T <sub>2</sub> , T <sub>3</sub> and T <sub>4</sub> alternatively	176.33	61.84
	S. E. (m) ±	0.66	
	C.D. at 5%	2.06	

### 3.1.5 The yield of fruits (q/ha) and increased yield over control (%) from May to July, 2022

Table 5 depicted effect of minimum fungicidal sprays on yield (q/ha) of bitter gourd from May to July, 2022. The yield values of bitter gourd fruits showed variation due to the effect of different fungicidal sprays. The yield values ranged from 109.63 q/ha to 176.33 q/ha. All the treatments were significantly differed from one another. The yield levels significantly differ from one another among all the attempted treatments. Comparatively lower yield was

obtained in treatment T<sub>1</sub> absolute control (water spray), and the value was noticed at 109.63 q/ha. The highest yield (176.33 q/ha) was obtained with treatment T<sub>7</sub> (metalaxyl 4% + mancozeb 64% WP @ 2 g/lit, GI chitosan @ 1 ml/lit, and potassium salt of active phosphorus @ 4 g/lit alternatively). It was observed that wherever under treatments Potassium salt of active phosphorus @ 4 g/lit has been added, those yield values were significantly superior over the treatment T<sub>1</sub> absolute control (water spray) as well as the sole chemical control.

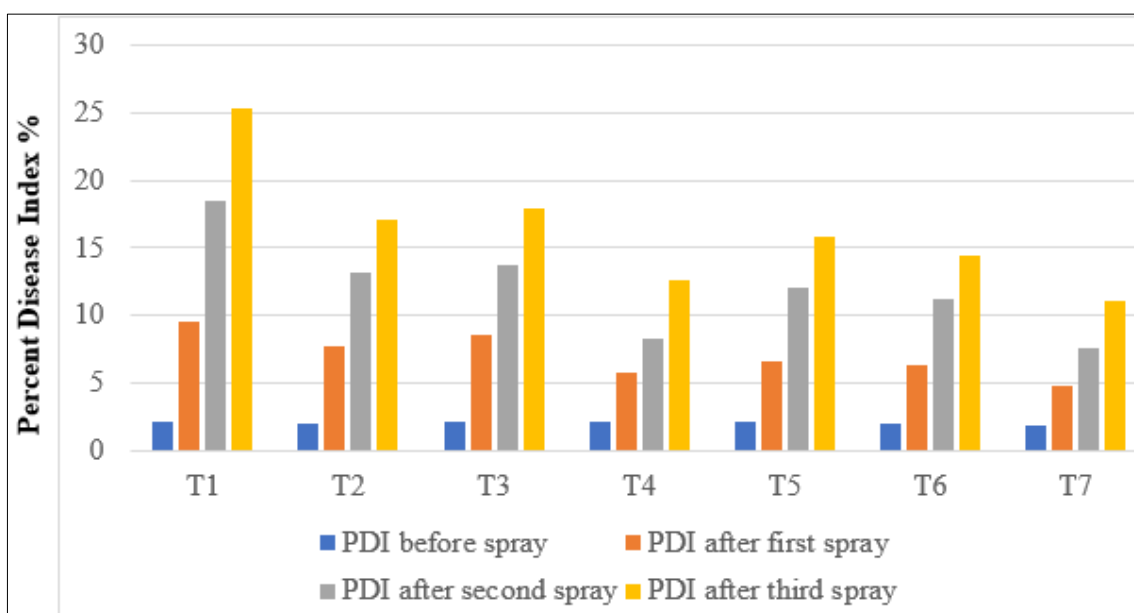
**Table 6:** Effect of minimum fungicidal spray on yield (q/ha) of bitter gourd during 2022. Pooled data

Tr. No.	Treatment details	Yield q/ha	Increased yield over control
T <sub>1</sub>	Absolute control (water spray)	116.13	0.0
T <sub>2</sub>	Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit	154.17	32.75
T <sub>3</sub>	GI Chitosan @ 1 ml/lit	148.05	27.48
T <sub>4</sub>	Potassium salt of active phosphorus @ 4 g/lit	171.59	47.75
T <sub>5</sub>	T <sub>2</sub> and T <sub>3</sub> alternatively	161.48	39.05
T <sub>6</sub>	T <sub>2</sub> and T <sub>4</sub> alternatively	166.03	42.96
T <sub>7</sub>	T <sub>2</sub> , T <sub>3</sub> and T <sub>4</sub> alternatively	178.24	53.48
	S. E. (m) ±	0.76	
	C.D. at 5%	2.37	

### 3.1.6 The yield of fruits (q/ha) and increased yield over control (%) during 2022 (Pooled data)

Table 6 depicted the effect of minimum fungicidal sprays on yield (q/ha) of bitter gourd from February to April, 2022. The yield values of bitter gourd fruits showed variation due to the effect of different fungicidal sprays. The yield values ranged from 116.13 q/ha to 178.24 q/ha. All the treatments significantly differed from one another. The yield levels significantly differ from one another among all the attempted treatments. The comparatively lower yield was

obtained in treatment T<sub>1</sub> absolute control (water spray), and the value was noticed at 116.13 q/ha. The highest yield (178.24 q/ha) was obtained with treatment T<sub>7</sub> (metalaxyl 4% + mancozeb 64% WP @ 2 g/lit, GI chitosan @ 1 ml/lit, and potassium salt of active phosphorus @ 4 g/lit alternatively). It was observed that wherever under treatments Potassium salt of active phosphorus @ 4 g/lit has been added, those yield values were significantly superior over the treatment T<sub>1</sub> absolute control (water spray) as well as the sole chemical control.



**Fig 1:** Graph depicting the effect of minimum fungicidal spray treatments on percent disease index during the year, 2022

T <sub>1</sub>	Absolute control (Water spray)	T <sub>5</sub>	T <sub>2</sub> and T <sub>3</sub> alternatively
T <sub>2</sub>	Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit	T <sub>6</sub>	T <sub>2</sub> and T <sub>4</sub> alternatively
T <sub>3</sub>	GI Chitosan @ 1 ml/lit	T <sub>7</sub>	T <sub>2</sub> , T <sub>3</sub> and T <sub>4</sub> alternatively
T <sub>4</sub>	Potassium salt of active phosphorus @ 4 g/lit		

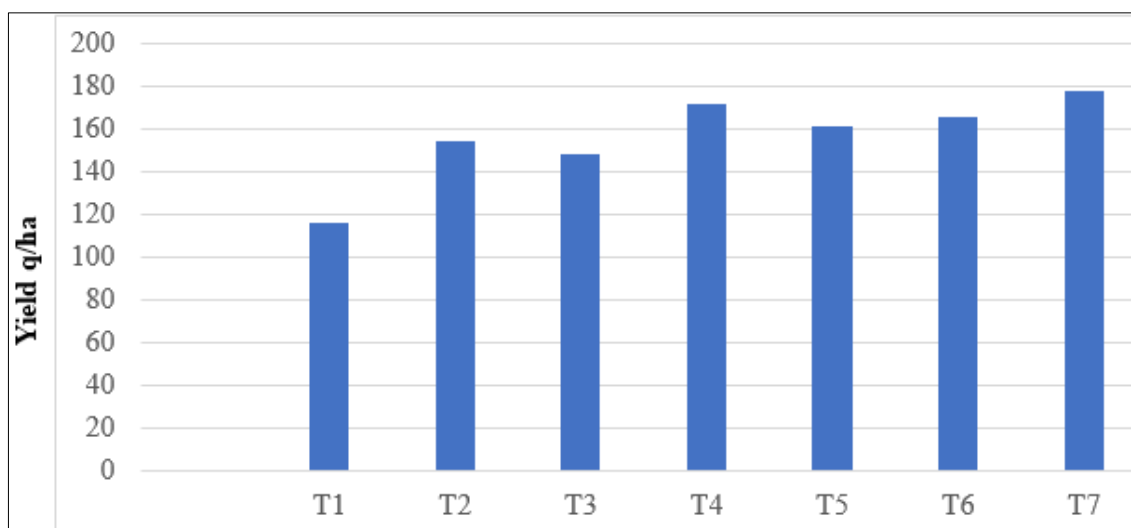


Fig 2: Graph depicting the effect of minimum fungicidal spray on yield (q/ha) of bitter gourd during the year, 2022.

T <sub>1</sub>	Absolute control (Water spray)	T <sub>5</sub>	T <sub>2</sub> and T <sub>3</sub> alternatively
T <sub>2</sub>	Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit	T <sub>6</sub>	T <sub>2</sub> and T <sub>4</sub> alternatively
T <sub>3</sub>	GI Chitosan @ 1 ml/lit	T <sub>7</sub>	T <sub>2</sub> , T <sub>3</sub> and T <sub>4</sub> alternatively
T <sub>4</sub>	Potassium salt of active phosphorus @ 4 g/lit		

#### 4. Conclusion

Among all fungicidal spray applications, the fungicidal treatment T<sub>7</sub> i.e T<sub>2</sub>, T<sub>3</sub>, and T<sub>4</sub> alternatively were found most effective against downy mildew disease of bitter gourd followed by treatment T<sub>4</sub>, T<sub>4</sub> i.e Potassium salt of active phosphorus @ 4 g/lit, T<sub>6</sub> i.e T<sub>2</sub> and T<sub>4</sub> alternatively, T<sub>5</sub> i.e T<sub>2</sub> and T<sub>3</sub> alternatively, T<sub>2</sub> i.e Metalaxyl 4% + Mancozeb 64% WP, T<sub>3</sub> i.e GI Chitosan @ 1 ml/lit and the highest disease severity obtained in T<sub>1</sub>, Absolute control (water spray) which was found less effective against downy mildew disease of bitter gourd. Thus, these results prove that the alternative use of Metalaxyl 4% + Mancozeb 64% WP, GI Chitosan @ 1 ml/lit and Potassium salt of active phosphorus @ 4 g/lit was given more yield in bitter gourd affected by downy mildew disease during the year, 2022. The overall present research shows that the spraying of Metalaxyl 4% + Mancozeb 64% WP, GI Chitosan @ 1 ml/lit and Potassium salt of active phosphorus @ 4 g/lit alternatively was the most effective for giving more yield than other treatments.

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