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Eco-friendly management of okra powdery mildew (*Erysiphe cichoracearum*) using bio-agents, plant extracts and essential oils

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Abstract
Okra (*Abelmoschus esculentus* (L.) Moench, also known as lady's finger, is a vital vegetable crop belonging to the *Malvaceae* family. It is predominantly cultivated in tropical and subtropical climates and is highly valued for its nutritional, medicinal, and economic importance. Powdery mildew caused by *Erysiphe cichoracearum* is one of the most widely spread, destructive disease and limiting factor in the production of okra in Marathwada region of Maharashtra State. Studies conducted to find out eco-friendly management strategies against okra powdery mildew using bioagents, plant extract and essential oils. Disease intensity declined after each spray. The essential oil Neem seed oil @ 4ml/L of water showed lowest mean disease intensity (25.18%) with maximum per cent disease control (62.24%). On the basis of effectiveness in controlling the powdery mildew disease of okra the treatments recorded in the order of merit were Neem seed oil (62.24%) @ 4ml/L, Neem leaf extract (54.35%) @ 10ml/L, *Trichoderma harzianum* (49.33%) @ 5ml/L, *Trichoderma viride* (46.52%) @ 5ml/L, *Bacillus substilis* (38.17%) @ 5ml/L, Onion extract (35.63%) @ 10ml/L and *Eucalyptus* oil (28.35%) @ 1ml/L of water.

Keywords: Okra, Powdery mildew, *Erysiphe cichoracearum*, Eco-friendly

Introduction
Okra (*Abelmoschus esculentus* (L.) Moench), commonly referred to as 'ladies' fingers' or 'bhindi' in local vernacular, is a flowering plant species widely cultivated for its edible seed pods and classified within the family *Malvaceae*. This vegetable is a significant dietary component, rich in essential nutrients, vitamins, and minerals, making it a valuable addition to human diets (Kumar *et al*., 2010) [5]. Okra is an excellent source of dietary fiber, vitamins A and C, and minerals like calcium, potassium, and iron (Anonymous, 2016).

Okra containing 2% protein, 0.2% fat, 0.7% minerals, 2% fiber, 7.5% carbohydrates, 66 mg calcium, 56 mg phosphorus, 0.4 mg iron, 0.08 mg vitamin B1, 0.08 mg vitamin B2, and 0.6 mg niacin, with a calorific value of 33 Kcal per 100 g serving (Anonymous, 2016). The cultivation of okra operates as a valuable crop, providing a source of income for many farmers and contributing to food security in various regions. Okra is grown in many parts of the world, with major producers including India, Nigeria, and Sudan (FAO, 2020).

It has several economic and nutritional importance, but also okra production is significantly constrained by a variety of biotic and abiotic stresses. Among biotic factors, diseases caused by fungi, bacteria, and viruses greatly affect crop yield and quality. Powdery mildew, in particular, is one of the major fungal diseases of okra, especially under conditions of high humidity and moderate temperatures, leading to considerable yield losses if not managed properly (Singh *et al*., 2020) [13].

Numerous pathogens, including bacteria, viruses, and fungus, affect okra and cause various illnesses. In okra production, diseases significantly lower yield (Sastry & Singh, 1974). Some important diseases include fusarium wilt (*Fusarium oxysporum* f. sp. *vasinfectum*), powdery mildew (*Erysiphe cichoracearum*), cercospora leaf spot (*Cercospora malayensis*, *C. abelmoschi*), enation leaf curl, yellow vein mosaic virus, and damping off (*Pythium* spp., *Rhizoctonia* spp.) (Singh *et al*., 2014) [15].

Among the fungal diseases, powdery mildew is of a regular occurrence throughout the okra growing regions of India. The disease caused by the fungus *Erysiphe cichoracearum* posing

a serious problem and becoming a limiting factor for successful production of okra. It has accounted yield losses up to 17-18 percent.

Powdery mildew is a prevalent and significant disease affecting okra crop worldwide. Reports of its occurrence have been documented globally, including Mexico (Diaz-Franco, 1999) [2]. In India, the disease has been reported in various regions, such as Delhi (Prabhu *et al*., 1971) [9], Karnataka (Sohi & Sokhi, 1974) [16], Himachal Pradesh (Raj *et al*., 1992) [10], and Maharashtra (Jambhale & Nerkar, 1983) [3]. It is seen from July to September every year and first appears with the onset of Monsoon (Choudhary, 1975) [1]. It occurs on epidemic scale in areas of lower night temperature coupled with lower relative humidity. Average temperature ranged between 16.33 to 30.930C, humidity ranged between 53.43 to 84.56 per cent, rainfall of 6.5 mm with wind speed of 4.56 km/hr. was found to be an ideal condition for powdery mildew disease developed on Okra (Kavyashree *et al*., 2022) [4].

Recent studies have highlighted the potential of ecofriendly approaches, such as the use of botanicals, biocontrol agents, and cultural practices, in managing powdery mildew of okra (Singh *et al*., 2024; Kumar *et al*., 2024) [14, 7]. For instance, a study by Sharma *et al*., (2024) [12] reported that the application of neem oil and potassium phosphite significantly reduced the severity of powdery mildew on okra.

Materials and Methods

Disease management

Evaluation of bio-agents, plant extracts and essential oils.

A field trial was conducted to test the efficacy of different bioagents, plant extracts and essential oils against powdery mildew on okra variety 'Parbhani Kranti'. The experiment was conducted during the *Kharif* season of 2024-25.

Details of experiment

Statistical Design: RBD (Randomized Block Design)
No. of Treatments: Eight
No. of Replications: Three
Variety: Parbhani Kranti
Spacing (cm): 60 x 30
Plot size (m): 3.0 x 2.10
No. of sprays: 2 spray

Observations

The first spraying was conducted immediately after the onset of the disease. Subsequent second spraying were taken at fifteen days' intervals. Observations regarding the intensity of the powdery mildew disease were conducted on ten randomly selected plants. For each assessed plant, three leaves from the bottom, middle, and upper portions were selected for detailed observation. The first observation was taken at first appearance of the disease while the subsequent two observations were conducted prior to each spraying event. The percent disease index (PDI) was calculated. Furthermore, the percent disease control (PDC) for each treatment was calculated using the following formula.

Percent Disease Control (PDC)

$$\text{PDC} = \frac{\text{PDI in control plot} - \text{PDI in treatment plot}}{\text{PDI in control plot}} \times 100$$

Where,
PDC - percent disease control
PDI - percent disease index

Treatment details

Sr. No.	Treatments	Dose (ml/litre of water)
1	*Trichoderma harzianum* ($1x10^9$ CFU/ml)	5 ml
2	*Trichoderma viride* ($1x10^9$ CFU/ml)	5 ml
3	*Bacillus substilis* ($2x10^8$ CFU/ml)	5 ml
4	Neem leaf extract	10 ml
5	Onion extract	10 ml
6	Neem seed oil	4 ml
7	*Eucalyptus* oil	1 ml
8	Control(unsprayed)	-

Results and Discussion

Disease management

Effect of Bio-agents, Plant extracts and Essential oils on disease intensity of Okra powdery mildew

The result presented in Table 1, illustrates the efficacy of various bio-agents, plant extracts and essential oils in managing Okra powdery mildew under different treatments, measured as disease intensity after the first, second and third sprays. The treatment includes three bio-agents, two plant extracts, two essential oils and an untreated control. All bio-agents, plant extracts and essential oils were applied at its recommended dose and their disease management efficiencies were evaluated across three consecutive spraying application at 15 days' interval.

Table 1: Effect of Bio-agents, Plant extracts and Essential oils on disease intensity of Okra powdery mildew

Tr. No.	Treatments details	Dose (ml/L)	Per cent disease intensity after spraying			Mean PDI
			First	Second	Third	
T_1	*Trichoderma harzianum* ($1x10^9$ CFU/ml)	5 ml	38.39 (38.28)*	34.65 (36.06)	29.61 (32.96)	34.21 (35.79)
T_2	*Trichoderma viride* ($1x10^9$ CFU/ml)	5 ml	40.43 (39.48)	36.51 (37.17)	31.47 (34.12)	36.13 (36.94)
T_3	*Bacillus substilis* ($2x10^8$ CFU/ml)	5 ml	44.24 (41.69)	42.34 (40.59)	39.77 (39.09)	42.11 (40.46)
T_4	Neem leaf extract	10 ml	35.47 (36.55)	30.37 (33.44)	26.46 (30.95)	30.76 (33.68)
T_5	Onion extract	10 ml	46.61 (43.05)	43.31 (41.15)	41.58 (40.15)	43.83 (41.45)
T_6	Neem seed oil	4 ml	31.07 (33.87)	25.38 (30.25)	19.11 (25.92)	25.18 (30.11)
T_7	*Eucalyptus* oil	1 ml	49.72 (44.83)	48.60 (44.19)	48.88(44.35)	49.06 (44.46)
T_8	Control	-	58.82 (50.08)	67.51 (55.24)	83.66 (66.15)	69.99 (56.78)
	S.E.+	-	0.88	0.95	0.74	-
	C.D @5%	-	2.56	2.77	2.15	-

*Figures in parenthesis are arcsine transformed values, PDI- Per cent Disease Intensity.

After the first spray, the mean percent disease intensity was observed in the range of 31.07% (T_6) to 58.82% (T_8). The lowest disease intensity (31.07%) was recorded in field receiving spray of Neem seed oil (T_6), followed by Neem leaf extract (T_4) (35.47%), *Trichoderma harzianum* (T_1) (38.39%), *Trichoderma viride* (T_2) (40.43%), *Bacillus substilis* (T_3) (44.24%), Onion extract (T_5) (46.61%) and *Eucalyptus* oil (T_7) (49.72%). The untreated control (T_8) plots recorded highest intensity 58.82%.

After the second spray, the mean percent disease intensity was observed in the range of 25.38% (T_6) to 67.51% (T_8). The lowest disease intensity (25.38%) was recorded in plots receiving spray of Neem seed oil (T_6), followed by Neem leaf extract (T_4) (30.37%), *Trichoderma harzianum* (T_1) (34.65%), *Trichoderma viride* (T_2) (36.51%), *Bacillus substilis* (T_3) (42.34%), Onion extract (T_5) (43.31%) and *Eucalyptus* oil (T_7) (48.60%). The untreated control (T_8) plots recorded highest intensity 67.51%.

After the third spray, the mean percent disease intensity was observed in the range of 19.11% (T_6) to 83.66% (T_8). The lowest disease intensity (19.11%) was recorded in plots receiving spray of Neem seed oil (T_6), followed by Neem leaf extract (T_4) (26.46%), *Trichoderma harzianum* (T_1) (29.61%), *Trichoderma viride* (T_2) (31.47%), *Bacillus substilis* (T_3) (39.77%) and Onion extract (T_5) (41.58%). The *Eucalyptus* oil (T_7) recorded increased in intensity from 48.60% to 48.88%. The untreated control (T_8) plots recorded highest intensity 83.66%.

Neem seed oil (T_6) recorded per cent disease intensity of 31.07%, 25.38% and 19.11% after the first, second and third sprays respectively. The mean per cent disease intensity was 25.18%. Neem leaf extract (T_4) recorded per cent disease intensity of 35.47%, 30.37% and 26.46% after the first, second and third sprays respectively. *Trichoderma harzianum* (T_1) recorded per cent disease intensity of 38.39%, 34.65% and 29.61% after the first, second and third sprays respectively. *Trichoderma viride* (T_2) recorded per cent disease intensity of 40.43%, 36.51% and 31.47% after the first, second and third sprays respectively. *Bacillus substilis* (T_3) recorded per cent disease intensity of 44.24%, 42.34% and 39.77% after the first, second and third sprays respectively. Onion extract (T_5) recorded per cent intensity 46.61%, 43.31% and 41.58% after the three sprays respectively. *Eucalyptus* oil (T_7) recorded per cent disease intensity 49.72%, 48.60% and 48.88% after the first, second and third sprays respectively.

Untreated control (T_8) consistently recorded the highest per cent disease intensity among all treatments, with disease intensity of 58.82%, 67.51% and 83.66%, resulting in highest mean per cent disease intensity of 69.99%.

From the mean disease intensity (Table 1) it was found that treatments significantly reduced powdery mildew intensity after first, second and third sprays over the untreated control. However, Neem seed oil (T_6) @ 4ml/L of water was found to be most effective with lowest mean disease intensity of 25.18%. The second best treatment observed was Neem leaf extract (T_4) which recorded comparatively lesser mean disease intensity of 30.76%. Other treatments in order to merit of effectivity were *Trichoderma harzianum* (T_1) (34.21%), *Trichoderma viride* (T_2) (36.13%), *Bacillus substilis* (T_3) (42.11%), Onion extract (T_5) (43.83%) and *Eucalyptus* oil (T_7) (49.06%).

The results revealed that all treatments effectively controlled powdery mildew in Okra Cv. Parbhani Kranti, reducing disease intensity from 25.18 to 49.06% as compared to 69.99% in untreated plots.

Effect of Bio-agents, Plant extracts and Essential oils on per cent disease control of Okra powdery mildew:

After second spray, the per cent disease control was observed in the range of 28.01% (T_7) to 62.40% (T_6). The highest per cent disease control (62.40%) was recorded in the plots receiving spray of Neem seed oil (T_6). The lower per cent disease control (28.01%) was recorded in the plots receiving spray of *Eucalyptus* oil (T_7). Other treatments in order of effectivity were Neem leaf extract (T_4) (55.01% PDC), *Trichoderma herzianum* (T_1) (48.67% PDC), *Trichoderma viride* (T_2) (45.93% PDC), *Bacillus substilis* (T_3) (37.28% PDC) and Onion extract (T_5) (35.86% PDC). Neem seed oil (T_6) was found effective over all the treatments.

Table 2: Effect of Bio-agents, Plant extracts and Essntial oils on percent disease control of Okra powdery mildew:

Tr. No.	Treatments details	Dose (ml/L)	PDC after spraying			Mean* PDC
			First	Second	Third	
T_1	*Trichoderma harzianum* ($1x10^9$ CFU/ml)	5 ml	34.73	48.67	64.60	49.33
T_2	*Trichoderma viride* ($1x10^9$ CFU/ml)	5 ml	31.26	45.93	62.38	46.52
T_3	*Bacillus substilis* ($2x10^8$ CFU/ml)	5 ml	24.78	37.28	52.46	38.17
T_4	Neem leaf extract	10 ml	39.69	55.01	68.37	54.35
T_5	Onion extract	10 ml	20.75	35.86	50.29	35.63
T_6	Neem seed oil	4 ml	47.17	62.40	77.16	62.24
T_7	*Eucalyptus* oil	1 ml	15.47	28.01	41.57	28.35
T_8	Control	-	-	-	-	-

* PDC- Per cent Disease Control

After third spray, the per cent disease control was observed in the range of 41.57% (T_7) to 77.16% (T_6). The highest per cent disease control (77.16%) was recorded in the plots receiving spray of Neem seed oil (T_6). The lowest per cent disease control (41.47%) was recorded in the plots receiving spray of *Eucalyptus* oil (T_7). Other treatments in order of effectivity were Neem leaf extracts (T_4) (68.37% PDC), *Trichoderma harzianum* (T_1) (64.60% PDC), *Trichoderma viride* (T_2) (62.38% PDC), *Bacillus substilis* (T_3) (52.46% PDC) and Onion extract (T_5) (50.29% PDC). Neem seed oil (T_6) was found effective over all the treatments.

The mean per cent disease control (PDC) achieved with all the treatments (Table 2) ranged from 28.35% (T_7) to 62.24% (T_6). The highest mean per cent disease control 62.24% recorded in the plots receiving spray of Neem seed oil (T_6). The second highest mean per cent disease control 54.35% recorded in the plots receiving spray of Neem leaf extract (T_4). These were followed by *Trichoderma harzianum* (T_1)

(49.33% PDC), *Trichoderma viride* (T_2) (46.52% PDC), *Bacillus substilis* (T_3) (46.52% PDC) and Onion extract (T_5) (35.63% PDC). The lowest mean per cent disease control recorded in the plots receiving spray of *Eucalyptus* oil (T_6).

The results revealed that all treatments effectively controlled powdery mildew in Okra Cv. Parbhani Kranti, ranged per cent disease control from 28.35% (T_7) to 62.24% (T_6) over the untreated control (T_8).

Similar results observed on Okra powdery mildew earlier reported by, Kumar *et al*., (2018) [6] reported that Neem seed oil exhibited a highly curative effect (68.15%) and significantly reduced disease severity (29.92%).

Singh *et al.,* (2020) [13] reported that Neem oil was effective in reducing powdery mildew severity and increasing yield in green gram.

Patel *et al.,* (2020) [8] reported that Neem leaf extract at 10% concentration reduced powdery mildew severity in Okra.

Conclusion

The study demonstrated the effectiveness of eco-friendly approaches in managing powdery mildew disease in okra. Neem seed oil (4ml/L) was the most effective treatment, with a mean percent disease control of 62.24%, followed by Neem leaf extract (54.35%). *Trichoderma harzianum* and *Trichoderma viride* also showed significant disease control, with 49.33% and 46.52%, respectively. These findings suggest that using botanicals and bio-agents can be a viable alternative to chemical fungicides, providing a sustainable approach to disease management in okra cultivation. The results have implications for developing eco-friendly disease management strategies for okra.

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