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Field evaluation of neem leaf extract and other botanical formulations against powdery mildew (*Erysiphe cichoracearum*) on bhendi (var. Ankur-41)

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Abstract
A field experiment was conducted in summer 2025 at Jaya Agricultural College, Vyasapuram, Tamil Nadu, to evaluate botanical and chemical treatments against powdery mildew (*Erysiphe cichoracearum*) in Bhendi (Var. Ankur-41). The trial followed a Randomized Block Design with five treatments: Neem Leaf Extract 10% (T_1), Neem Leaf Extract 20% (T_2), Garlic Extract 5% (T_3), Wettable Sulphur (T_4), and an untreated control (T_5), each replicated thrice. Neem Leaf Extract 20% (T_2) significantly reduced disease severity (PDI: 21.5), closely followed by Wettable Sulphur (T_4) with the lowest PDI of 18.8, compared to 52.5 in the control. Statistical analysis showed highly significant differences ($F = 716.9$, $p<0.001$). T_2 also recorded the highest yield parameters: plant height (53.0 cm), fruits per plant (23), fruit weight (43.0 g), and yield (4.50 t/ha), followed by T_4. These were statistically significant ($F = 32.0$, $p<0.001$). Phytotoxicity scores were minimal for botanicals (T_1: 0.5, T_2: 0.7, T_3: 0.6), while T_4 showed mild scorch symptoms (score: 2.5). No phytotoxicity was observed in the control. In conclusion, Neem Leaf Extract 20% proved to be an effective and eco-friendly alternative to chemical fungicides, offering strong disease control and yield benefits with minimal phytotoxic risk-suitable for sustainable and organic farming practices.

Keywords: Powdery mildew, bhendi, neem leaf extract, garlic extract, wettable sulphur, phytotoxicity

Introduction
Bhendi (*Abelmoschus esculentus*), commonly known as okra, is a nutritionally and economically significant vegetable crop widely cultivated across India, including Tamil Nadu, and in other tropical and subtropical regions. Rich in essential vitamins, minerals, and dietary fiber, it is a staple in many diets and grown year-round due to its short duration and high market demand, particularly by small and marginal farmers. However, its cultivation is frequently threatened by fungal diseases, especially powdery mildew (*Erysiphe cichoracearum*), which appears as white powdery patches on leaves, stems, and pods. This disease reduces photosynthesis, causes early defoliation, and severely affects yield and pod quality, particularly under warm and dry conditions. While chemical fungicides like wettable sulphur are commonly used for control, their overuse has led to concerns including pathogen resistance, environmental pollution, toxic residues, and health risks. In response, there is growing interest in eco-friendly, plant-based alternatives. Neem (*Azadirachta indica*), known for its antifungal, antibacterial, and insecticidal properties, contains compounds like azadirachtin, nimbin, and salannin that inhibit fungal growth. Other botanicals such as garlic, ginger, tulsi, and pongamia also possess fungitoxic effects. This study was conducted to evaluate the efficacy of neem leaf extract and selected botanicals under field conditions for managing powdery mildew in bhendi. The research focuses on disease severity, plant growth, yield performance, and phytotoxicity, comparing botanical treatments with a chemical fungicide and control. The goal is to identify sustainable, low-cost, and environmentally safe disease management options suitable for organic and smallholder farming systems.

Materials and Methods
The field experiment was conducted during the summer season of 2025 at Jaya Agricultural College, Vyasapuram, Tamil Nadu (13.1047°N, 79.7087°E) in a sandy loam soil plot (0.4 cents). The region's tropical climate with temperatures between 30-38°C and moderate humidity favored powdery mildew development. Bhendi (*Abelmoschus esculentus*) variety Ankur-41, known for high yield and moderate susceptibility to powdery mildew, was used.

The experiment followed a Randomized Block Design (RBD) with five treatments-Neem Leaf Extract 10% (T_1), Neem Leaf Extract 20% (T_2), Garlic Extract 5% (T_3), Wettable Sulphur (T_4), and untreated control (T_5)-each replicated three times across 15 plots (1.5 m × 1.0 m) with 8 plants per plot. Standard agronomic practices were followed.

Botanical extracts were prepared by soaking fresh Neem leaves (100 g for 10%, 200 g for 20%) or garlic cloves (50 g) in 1 litre water overnight, filtered, and supplemented with 1 ml surfactant. Wettable sulphur was applied as per manufacturer recommendations. Treatments were sprayed three times at 10-day intervals starting at symptom onset using a calibrated hand sprayer during early morning or late afternoon.

Disease severity value was converted to (PDI) percent disease index (Wheeler, 1969) [10]. The disease incidence was assessed by recording severity of disease in a locality by adopting 0-9 scale (Mayee and Datar, 1986) and 0-5 scales (Sangeetha and Siddaramaiah, 2007) [4, 8].

$$\text{PDI (\%)} = \frac{\text{Sum of individual ratings}}{\text{Total no. of plant observed x Max disease grade}} \text{x100}$$

Growth and yield parameters including plant height, fruit length, girth, number, and weight were recorded. Phytotoxicity was evaluated on 10 plants per plot using a 0-10 scale following each spray.

Results

The present study evaluated the efficacy of various botanical extracts and a chemical fungicide in controlling powdery mildew (*Erysiphe cichoracearum*) on Bhendi (*Abelmoschus esculentus*) and their impact on plant growth, yield, and phytotoxicity.

Disease Severity (Percent Disease Index)

The treatments significantly influenced powdery mildew severity, as reflected by the Percent Disease Index (PDI) assessed at 7, 14, and 21 days after the first spray. The effect of treatments on powdery mildew severity is presented in Table 1. The untreated control group exhibited the highest disease incidence, with PDI values escalating from 37.9% at 7 days to 66.5% at 21 days, indicating rapid disease progression in the absence of treatment (Figure 1). In contrast, Neem Leaf Extract at 20% concentration (T_2) consistently showed the lowest disease severity among all treatments, with a final mean PDI of 21.5%. This is in agreement with findings by Moharam (2012) [5] and Jadav & Kadvani (2019) [2], who reported significant reductions in powdery mildew severity using neem-based treatments. Wettable Sulphur (T_4), a standard chemical control, also demonstrated effective disease suppression, resulting in a mean PDI of 18.8%. Both these treatments reduced disease severity by over 60% relative to the control. Neem Leaf Extract at 10% (T_1) and Garlic Extract at 5% (T_3) provided moderate disease control, lowering the final PDI to 29.8% and 34.3%, respectively. These results correspond with Sani *et al.* (2022) [9], who found garlic and neem to be effective against powdery mildew *in vitro*. The highly significant F-value (716.9) in the ANOVA for PDI at 21 days indicates that these differences were statistically robust and unlikely due to chance (Table 2).

Growth Parameters and Yield

The positive impact of the treatments extended beyond disease management to improved plant growth and yield. The influence of treatments on plant growth and yield is detailed in Table 3. Neem Leaf Extract at 20% resulted in the tallest plants, with an average height of 53.0 cm, significantly taller than untreated plants, which averaged 42.0 cm. This treatment also produced the highest number of fruits per plant (23) and the greatest average fruit weight (43.0 g), culminating in the highest yield of 4.50 tonnes per hectare. These findings corroborate those of Pasupuleti & Lal (2025) [7], who observed improved yield and growth in crops treated with neem oil against fungal pathogens. Wettable Sulphur treatment closely followed with a plant height of 51.0 cm, 22 fruits per plant, and a yield of 4.30 t/ha. Both Neem 10% and Garlic 5% treatments led to moderate improvements in growth and yield parameters compared to the control but were significantly less effective than Neem 20% and Sulphur. The ANOVA results for yield (F = 32.0) confirmed the significant influence of the treatments on productivity (Table 4), underscoring the ability of botanical extracts, particularly Neem 20%, to enhance Bhendi yield in addition to disease control.

The enhanced yield and growth metrics (Table 3) suggest that disease control contributed directly to improved plant health. T_2-treated plants recorded the highest yield (4.50 t/ha), closely matched by T_4 (4.30 t/ha), though the yield difference was not statistically significant (Table 4). This demonstrates that botanical treatments, particularly neem, can match chemical controls in agronomic performance, as suggested by Lewis *et al.* (2008) [3].

Phytotoxicity Assessment

Phytotoxicity scores (Table 5) revealed distinct differences in the safety profiles of the treatments. Both concentrations of Neem Leaf Extract (10% and 20%) and Garlic Extract caused no or only very mild phytotoxic symptoms, with scores below 1 on the adopted scale, indicating negligible adverse effects on leaf tissue. This aligns with earlier observations by Bhushan & Yadhav (2024) [1], who reported minimal to no phytotoxicity from botanical sprays. Conversely, Wettable Sulphur treatment led to mild phytotoxicity characterized by leaf scorch affecting 11-30% of foliage, reflected in a higher phytotoxicity score of 2.5. These findings highlight the relative safety of botanical extracts for Bhendi plants and suggest their suitability for repeated foliar applications without risk of damaging the crop.

Discussion

The PDI reductions reported in Table 1 confirm that the findings of this study demonstrate that Neem Leaf Extract at 20% concentration is highly effective in managing powdery mildew in Bhendi, showing a significant reduction in disease severity comparable to that achieved by the chemical fungicide Wettable Sulphur. The reduction of disease by Neem 20% was about 59% compared to the untreated control, closely matching the 64% reduction seen with sulphur. The statistical significance shown in Table 2 supports these findings. Similar efficacy of neem in fungal disease suppression has been documented by Moharam (2013) [5] and Jadav & Kadvani (2019) [2]. This aligns with previous research indicating that neem's bioactive compounds-such as azadirachtin, nimbin, and salannin-have strong antifungal properties that inhibit the growth of powdery mildew fungi, as noted by Wheeler (1969) [10].

The enhanced yield and growth metrics (Table 3) suggest that disease control contributed directly to improved plant health. In terms of crop performance, Neem 20% treated plants exhibited the highest growth and yield parameters, including

plant height, fruit number, fruit weight, and total yield, which were significantly better than untreated controls and similar to sulphur-treated plants, though the yield difference was not statistically significant (Table 4). This suggests that effective disease management through neem extract not only limits infection but also promotes overall plant health and productivity, likely by reducing pathogen-induced stress, consistent with the findings of Pasupuleti & Lal (2025) [7].

Phytotoxicity assessments revealed that neem treatments caused no visible damage or adverse effects on the plants, in contrast to wettable sulphur, which induced mild leaf scorch symptoms. This highlights neem's safety for repeated applications and suitability for organic farming and integrated pest management (IPM) systems, where minimizing chemical residues and environmental impact is essential (Mayee & Datar, 1986) [4].

The highly significant statistical results for both disease severity and yield parameters further validate the efficacy and reliability of neem extract as an eco-friendly disease management strategy. Considering the environmental and health concerns related to chemical fungicides, neem 20% presents an effective, sustainable, and low-cost alternative, especially beneficial for smallholder farmers and in IPM programs, as emphasized by Sani *et al.* (2022) and supported by Lewis *et al.* (2008) [3, 9].

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Fig 1: Powdery mildew symptoms (white fungal growth) observed on Bhendi leaves in untreated control plots (T5) during peak disease severity at 21 days after first spray.

Table 1: Effect of Treatments on Disease Severity (Percent Disease Index) at Different Intervals

Treatment	7 DAS	14 DAS	21 DAS	Mean Final PDI
T1 - Neem Leaf Extract 10%	20.8[a]	30.5[a]	38.2[a]	29.8[a]
T2 - Neem Leaf Extract 20%	14.2[b]	21.8[b]	28.5[b]	21.5[b]
T3 - Garlic Extract 5%	24.7[a]	35.0[a]	43.1[a]	34.3[a]
T4 - Wettable Sulphur	12.5[b]	17.9[b]	26.0[b]	18.8[b]
T5 - Control	37.9[c]	53.1[c]	66.5[c]	52.5[c]

Note: Means followed by different superscript letters differ significantly at $p<0.05$ according to LSD test.

Table 2: ANOVA for Percent Disease Index (PDI) at 21 DAS

Source	df	SS	MS	F	CD (5%)
Treatments	4	2208.0	552.0	716.9	0.77
Error	10	7.7	0.77	—	—
Total	14	2215.7	—	—	—

Highly significant at $p<0.001$

Table 3: Effect of Treatments on Growth and Yield Parameters

Treatment	Plant Height (cm)	Fruits/Plant	Fruit Weight (g)	Yield (t/ha)
T1 - Neem Leaf Extract 10%	47.5[b]	20.0[b]	38.0[b]	3.90[b]
T2 - Neem Leaf Extract 20%	53.0[a]	23.0[a]	43.0[a]	4.50[a]
T3 - Garlic Extract 5%	45.0[b]	19.0[b]	36.0[b]	3.70[b]
T4 - Wettable Sulphur	51.0[a]	22.0[a]	42.0[a]	4.30[a]
T5 - Control	42.0[c]	18.0[c]	34.0[c]	3.40[c]

Note: Means followed by different superscript letters differ significantly at $p<0.05$ according to LSD test.

Table 4: ANOVA for Fruit Yield (t/ha)

Source	df	SS	MS	F	CD (5%)
Treatments	4	2.048	0.512	32.0	0.32
Error	10	0.160	0.016	—	—
Total	14	2.208	—	—	—

Significant at $p<0.001$

Table 5: Phytotoxicity Observations

Treatment	Phytotoxicity Score	Description
T1 - Neem Leaf Extract 10%	0.5	None to very mild
T2 - Neem Leaf Extract 20%	0.7	None to very mild
T3 - Garlic Extract 5%	0.6	None to very mild
T4 - Wettable Sulphur	2.5	Mild scorch (11-30%)
T5 - Control	0.0	Healthy (no symptoms)

Note: Sulphur caused mild phytotoxicity; all botanicals showed negligible or no visible injury.

Conclusion

A field study at Jaya Agricultural College, Tamil Nadu, evaluated botanical and chemical treatments against powdery mildew in Bhendi (var. Ankur-41). Neem Leaf Extract at 20% (T_2) and Wettable Sulphur (T4) significantly reduced disease severity, with mean final PDIs of 21.5 and 18.8, respectively, compared to 52.5 in the untreated control. Neem 20% also led to the highest yield (4.50 t/ha) and improved growth parameters, closely followed by sulphur. Phytotoxicity was minimal in neem treatments, while sulphur caused mild leaf scorch. Overall, Neem 20% proved to be an effective, safe, and eco-friendly alternative to chemical fungicides for managing powdery mildew in Bhendi.

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