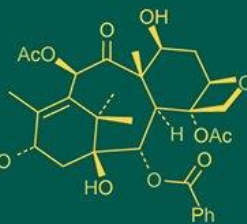
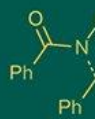


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Field-based bio-efficacy assessment of sequential biopesticidal schedules against whitefly (*Bemisia tabaci* Gennadius) on okra (*Abelmoschus esculentus* L. moench)

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Abstract

During the Kharif season of 2025, a field investigation was conducted at the experimental unit of the Entomology Section, College of Agriculture, Nagpur, to compare seven sequentially applied biopesticide schedules (M1 through M7) against whitefly (*Bemisia tabaci* Gennadius) infesting okra cultivar NOL-303 (Julie). Three replicated blocks arranged in a randomised layout formed the basis of the trial. Within each schedule, a botanical spray, either Azadirachtin 1.00% EC or neem oil, was applied thirty days post-sowing, followed after a further ten days by one entomopathogenic fungal spray (*Metarhizium anisopliae*, *Beauveria bassiana* or *Lecanicillium lecanii* at 1×10^8 CFU/gm or 2×10^8 CFU/gm, respectively), and finally, at fifty days post-sowing, by a three-fungus bioinoculant mixture (2×10^8 CFU/ml); schedule M7 received water spray and served as the control. Counts of whitefly taken a day prior to the opening spray fell within a narrow band of 2.53 to 2.84 insects per leaf across every plot, confirming an even starting pest load. When data from all three sprays were pooled, schedule M3, combining Azadirachtin with *Lecanicillium lecanii* and the consortium, produced the sharpest decline, reducing the population to 1.59 whiteflies per leaf, closely trailed by M6 (1.78) and M2 (1.79); the untreated check, by contrast, carried an average of 5.07 insects per leaf, corresponding to cumulative reductions over control of 68.64%, 64.89% and 64.69% for M3, M6 and M2, respectively. Every treated schedule was found to differ significantly from the check. These outcomes point to an Azadirachtin followed by *L. lecanii* sequence as a workable, environment-friendly component for whitefly management programmes in okra.

Keywords: Azadirachtin, *Bemisia tabaci*, biopesticide, IPM, *Lecanicillium lecanii*, okra

Introduction

Bemisia tabaci Gennadius ranks among the most economically damaging sap-sucking pests confronting okra [*Abelmoschus esculentus* (L.) Moench] cultivation worldwide, and its impact extends well beyond the phloem sap withdrawn directly by its nymphal and adult stages. Colonies settled on the lower leaf surface deposit copious honeydew, and the sooty mould that develops on it visibly darkens the canopy and cuts photosynthetic output, ultimately depressing pod yield and quality (Meena and Kanwat, 2005) [1]. A further complication peculiar to this pest is its capacity to transmit Bhendi Yellow Vein Mosaic Virus, a disease able to inflict severe crop loss once vector populations cross a threshold density. The prospect of using entomopathogenic fungi against whitefly is not a recent one: glasshouse trials conducted several decades ago on *Verticillium lecanii* were the first to establish that hyphomycete fungi could infect and kill this insect under controlled conditions (Quinden, 1984) [2]. That early evidence has since carried over into open-field research across Indian vegetable systems, where botanical extracts and microbial formulations, applied singly or in combination, have repeatedly lowered *B. tabaci* populations on okra (Anitha, 2007; Mahmood *et al.*, 2014; Sridharan *et al.*, 2015) [3, 6, 7]. Insecticide sprays nonetheless remain the default recourse for most growers, a habit that hastens resistance build-up within whitefly populations and depletes naturally occurring predators and parasitoids, strengthening the case for fungal-and plant-based alternatives (Janghel and Singh Rajput, 2016; Sarkar *et al.*, 2016) [8, 9].

What remains comparatively unexamined is whether these tools, rather than being deployed in isolation, can be combined in a planned sequence, a botanical spray to blunt early population build-up, a targeted fungal spray to follow through, and a broader fungal consortium to sustain control later in the season, so as to outperform any single intervention used alone. The present field trial was designed to test this sequential approach against whitefly infesting okra.

Materials and Methods

Experimental site and treatments

The present trial was carried out in Kharif 2025 at the experimental unit of the Entomology Section, College of

Agriculture, Nagpur (21°10' N, 79°19' E; 321.26 m above mean sea level), located within Maharashtra's Vidarbha tract. Seeding of okra cultivar NOL-303 (Julie) took place on 15 July 2025, with rows spaced 60 cm apart and plants spaced 45 cm within rows, across plots sized 2.4 m by 3.1 m. The experiment was laid out in a Randomized Block Design (RBD) with seven treatment schedules and three replications. Table 1 details the make-up of each schedule: a botanical spray thirty days post-sowing, a fungal spray ten days on, and a three-fungus bioinoculant mixture (2×10^8 CFU/ml) at the fifty-day mark, with a ten-day gap separating consecutive sprays; schedule M7 received plain water at every stage.

Table 1: Sequential biopesticidal modules evaluated against *Bemisia tabaci* on okra

Module	30 DAS	40 DAS	50 DAS (Bioinoculant consortium)
M1	Azadirachtin 1.00% EC (2 ml/L)	<i>Metarhizium anisopliae</i> 1×10^8 CFU/gm 1.15% WP (5 g/L)	Bioinoculant consortium (<i>M. anisopliae</i> + <i>B. bassiana</i> + <i>L. lecanii</i>), 2×10^8 CFU/ml (10 ml/L)
M2	Azadirachtin 1.00% EC (2 ml/L)	<i>Beauveria bassiana</i> 1×10^8 CFU/gm 1.15% WP (5 g/L)	Bioinoculant consortium (<i>M. anisopliae</i> + <i>B. bassiana</i> + <i>L. lecanii</i>), 2×10^8 CFU/ml (10 ml/L)
M3	Azadirachtin 1.00% EC (2 ml/L)	<i>Lecanicillium lecanii</i> 2×10^8 CFU/gm 1.15% WP (5 g/L)	Bioinoculant consortium (<i>M. anisopliae</i> + <i>B. bassiana</i> + <i>L. lecanii</i>), 2×10^8 CFU/ml (10 ml/L)
M4	Neem oil (10 ml/L)	<i>Metarhizium anisopliae</i> 1×10^8 CFU/gm 1.15% WP (5 g/L)	Bioinoculant consortium (<i>M. anisopliae</i> + <i>B. bassiana</i> + <i>L. lecanii</i>), 2×10^8 CFU/ml (10 ml/L)
M5	Neem oil (10 ml/L)	<i>Beauveria bassiana</i> 1×10^8 CFU/gm 1.15% WP (5 g/L)	Bioinoculant consortium (<i>M. anisopliae</i> + <i>B. bassiana</i> + <i>L. lecanii</i>), 2×10^8 CFU/ml (10 ml/L)
M6	Neem oil (10 ml/L)	<i>Lecanicillium lecanii</i> 2×10^8 CFU/gm 1.15% WP (5 g/L)	Bioinoculant consortium (<i>M. anisopliae</i> + <i>B. bassiana</i> + <i>L. lecanii</i>), 2×10^8 CFU/ml (10 ml/L)
M7	Control (Water spray)		

Recording of whitefly population

Whitefly numbers were tallied on leaves selected from the lower, middle and upper canopy of five tagged plants within every plot. Counts were logged a single time before the opening spray and then repeated nine days after each of the three subsequent applications.

Statistical analysis

Prior to running the analysis of variance, all counts underwent square-root transformation [$\sqrt{(x+0.5)}$]. Comparisons among treatment means relied on standard error and critical difference values worked out at the 5% probability level, with both raw and transformed figures reported together in Table 2.

Results

One day ahead of the first spray, whitefly numbers across the seven plots varied only slightly, from 2.53 to 2.84 insects per leaf, with no statistically meaningful differences, evidence that the pest load was evenly spread before

treatments began (Table 2). By the ninth day after the first spray, schedule M3 had already brought the count down to its lowest point (1.98 insects/leaf), a figure on par with M2 (2.02) and M1 (2.11); the untreated check, meanwhile, had climbed to 4.40 insects/leaf. This lead widened with each subsequent spray: nine days after the third application, M3's population stood at just 1.13 whiteflies/leaf against 5.60/leaf in the check, with M6 (1.29), M2 (1.47) and M5 (1.47) trailing not far behind.

Pooling data across all three sprays (Table 2; Fig. 1) confirmed M3 as the top-performing schedule at 1.59 whiteflies/leaf, ahead of M6 (1.78) and M2 (1.79); the untreated check averaged 5.07 insects/leaf over the same period. Every biopesticide schedule proved significantly superior to the check (CD at 5% = 0.28). On a cumulative basis, schedule M3 recorded the highest percent reduction in whitefly population over control (68.64%), followed by M6 (64.89%) and M2 (64.69%), whereas M4 recorded the lowest reduction (58.97%) among the treated schedules (Table 3).

Table 2: Effect of biopesticidal modules on population of *Bemisia tabaci* (mean whiteflies/leaf; data in parentheses are square-root transformed values) across three sprays on okra

Module	1 DBS	9 DAFS	9 DASS	9 DATS	Cumulative
M1	2.53 (1.72)	2.11 (1.60)	2.02 (1.58)	1.67 (1.46)	1.93 (1.56)
M2	2.64 (1.76)	2.02 (1.58)	1.89 (1.54)	1.47 (1.39)	1.79 (1.51)
M3	2.69 (1.77)	1.98 (1.55)	1.67 (1.46)	1.13 (1.25)	1.59 (1.44)
M4	2.80 (1.80)	2.42 (1.70)	2.09 (1.61)	1.73 (1.49)	2.08 (1.60)
M5	2.80 (1.80)	2.36 (1.68)	1.96 (1.56)	1.47 (1.39)	1.93 (1.56)
M6	2.84 (1.82)	2.22 (1.65)	1.82 (1.52)	1.29 (1.33)	1.78 (1.51)
M7 (Control)	2.73 (1.78)	4.40 (2.21)	5.22 (2.39)	5.60 (2.47)	5.07 (2.36)
F test	NS	Sig.	Sig.	Sig.	Sig.
SE (m)±	0.16	0.12	0.10	0.12	0.09
CD at 5%	-	0.39	0.30	0.36	0.28
CV (%)	15.79	12.54	9.91	12.89	9.38

DAS: Days After Sowing; DBS: Days Before Spray; DAFS/DASS/DATS: Days After First/Second/Third Spray; NS: Non-significant; Sig.: Significant.

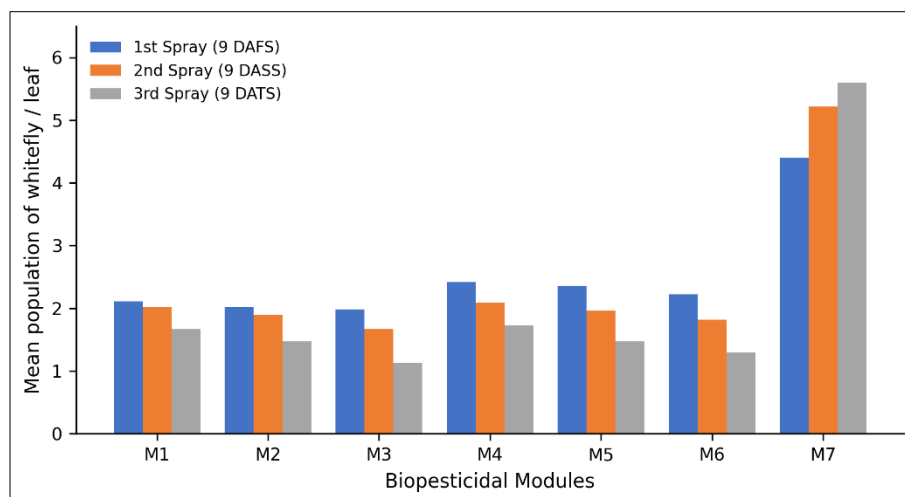


Fig 1: Efficacy of different biopesticidal modules against *Bemisia tabaci* in okra

Table 3: Percentage reduction in whitefly population over control under different biopesticidal modules at successive spray intervals

Module	9 DAFS (%)	9 DASS (%)	9 DATS (%)	Cumulative (%)
M1	52.05	61.30	70.18	61.93
M2	54.09	63.79	73.75	64.69
M3	55.00	68.01	79.82	68.64
M4	45.00	59.96	69.11	58.97
M5	46.36	62.45	73.75	61.93
M6	49.55	65.13	76.96	64.89
M7 (Control)	0.00	0.00	0.00	0.00

Per cent reduction over control was worked out as $[(\text{Control-Treatment})/\text{Control}] \times 100$, using untransformed mean whitefly population values.

Discussion

M3's edge over the other schedules can plausibly be traced to how its two active components complement one another through the season: Azadirachtin's antifeedant action likely curbs population build-up early on, leaving a smaller whitefly cohort for *L. lecanii*, sprayed ten days afterward, to act against. Whitefly nymphs, once settled, remain stationary on the underside of the leaf, which may keep them in prolonged contact with fungal spores deposited there, a condition that could favour infection more than it would for a mobile insect, though this point was not tested directly within the present trial. The ability of *Verticillium* (now reclassified as *Lecanicillium*) *lecanii* to suppress glasshouse whitefly was first shown decades ago by Quinden (1984) [2], and later research pairing *L. lecanii* with other entomopathogenic fungi against *B. tabaci* on okra has similarly reported robust suppression (Palthiya, 2014; Janghel and Singh Rajput, 2016) [5, 8]. Broader evidence of *Beauveria bassiana* and *Metarhizium anisopliae* acting against sap-feeding pests, documented for aphids by Ekesi *et al.* (2000) [4], reinforces the case for a fungus-led strategy. Botanical oils have also proven effective against whitefly in separate studies: Sridharan *et al.* (2015) [7] achieved good control using mineral-oil blends with neem or pongamia, while Patel *et al.* (2017) [10] and Sarkar *et al.* (2016) [9] both recorded substantial whitefly reduction using bio-rational treatments on okra.

The consortium spray given at fifty days post-sowing seems to have carried control through the later crop stages, aligning with findings that microbial biopesticide blends can restrain the broader sucking-pest complex, whitefly

included, in crops such as Bt cotton (Raghunandan *et al.*, 2018; Wawdhane *et al.*, 2020) [11, 13]. The neem oil-based schedules (M4 to M6) generally trailed those built around Azadirachtin, although M6, pairing neem oil with *L. lecanii*, came close to matching the leading Azadirachtin-based schedules, again pointing to the fungal element as the more decisive factor within the sequence. Similar patterns, with *L. lecanii* or combined fungal-botanical schedules outperforming other treatments against whitefly, have also been noted by Naik *et al.* (2019) [12] and Halder *et al.* (2021) [14]. Read alongside the comparative work of Jain *et al.* (2021) [15], the present findings add weight to sequential, fungus-anchored biopesticide schedules as a practical route to whitefly control in okra.

Conclusion

Taken together, results from the three sprays identify the Azadirachtin-*L. lecanii*-consortium sequence (Module M3) as the most dependable option among those tested for controlling *Bemisia tabaci* on okra, holding the cumulative population to 1.59 whiteflies/leaf against 5.07 whiteflies/leaf in the untreated check, a cumulative reduction over control of 68.64%. Since this schedule relies exclusively on botanical and microbial inputs, it offers a practical starting point for eco-friendly whitefly management in okra, though testing across further seasons and locations would help confirm its consistency.

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Conflict of Interest

The authors declare no conflict of interest in connection with this study.

References

1. Meena NK, Kanwat BL. Seasonal incidence of major sucking pests and shoot and fruit borer on okra, *Abelmoschus esculentus* (L.) Moench. Indian Journal of Plant Protection. 2005;33(2):210-213.
2. Quinden RJ. The use of *Verticillium lecanii*, an entomopathogenic fungus, to control glasshouse

- whiteflies. In: Proceedings of a Conference at Brighton, England. 1984;22-25:9-12.
3. Anitha KR. Seasonal incidence and management of sucking pest of okra [MSc Thesis]. Dharwad: University of Agricultural Sciences; 2007.
 4. Ekesi S, Akpa AD, Onu I, Ogunlana MO. Entomopathogenicity of *Beauveria bassiana* and *Metarhizium anisopliae* to the cowpea aphids, *Aphis craccivora* Koch (Homoptera: Aphididae). Archives of Phytopathology and Plant Protection. 2000;33(2):171-180.
 5. Palthiya R. Efficacy of entomopathogenic fungi for the control of sucking pests of okra [MSc Thesis]. Rahuri: Mahatma Phule Krishi Vidyapeeth; 2014.
 6. Mahmood K, Eijaz S, Khan MA, Sajjad A. Effects of biopesticides against jassid [*Amrasca devastans* (Dist.)] and whitefly [*Bemisia tabaci* (Genn.)] on okra. International Journal of Biology and Biotechnology. 2014;11:161-165.
 7. Sridharan S, Chandrashekhar K, Ramakrishnan N. Bioefficacy, phytotoxicity, and biosafety of mineral oil on management of whitefly in okra. International Journal of Vegetable Science. 2015;21(1):28-35.
 8. Janghel M, Singh Rajput M. Efficacy of bio-pesticides against whitefly *Bemisia tabaci* on okra. Plant Archives. 2016;16(1):102-104.
 9. Sarkar S, Patra S, Samanta A. Efficacy of different bio-pesticides against sucking pests of okra (*Abelmoschus esculentus* L. Moench). Journal of Applied and Natural Science. 2016;8(1):333-339.
 10. Patel GP, Tayde AR, Simon S. Evaluation of bio-rational and chemical insecticides against leafhopper, *Amrasca biguttula biguttula* (Ishida) and whitefly, *Bemisia tabaci* (Gennadius) on okra. Journal of Entomology and Zoology Studies. 2017;5(4):1966-1968.
 11. Raghunandan BL, Godhani PH, Patel MV, Patel NM, Mehta DM. Field evaluation of microbial bio-pesticides for the management of sucking pests in Bt cotton. Journal of Entomology and Zoology Studies. 2018;6(4):994-998.
 12. Naik O, Kannan GS, Chakravarthy AK. Impact of integrated pest management modules on natural enemies of whitefly, *Bemisia tabaci* (Genn.) in bitter gourd ecosystem. Journal of Biological Control. 2019;33(1):63-69.
 13. Wawdhane PA, Nandanwar VN, Mahankuda B, Ingle AS, Chaple KI. Bio-efficacy of insecticides and bio pesticides against major sucking pests of Bt-cotton. Journal of Entomology and Zoology Studies. 2020;8(3):829-833.
 14. Halder J, Divekar P, Rani AT. Compatibility of entomopathogenic fungi and botanicals against sucking pests. Egyptian Journal of Biological Pest Control. 2021;31(30):63-67.
 15. Jain D, Kumar H, Chouhan BS, Singh B, Sumeriya H. Comparative efficacy of different bio and synthetic insecticides against sucking pests of okra (*Abelmoschus esculentus* L. Moench). The Pharma Innovation Journal. 2021;SP-10(5):719-727.