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Evaluation of botanical and entomopathogenic fungal spray modules for the management of jassid (*Amrasca biguttula biguttula*) in okra

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Abstract
Seven spray modules were evaluated against jassid, *Amrasca biguttula biguttula*, on okra during the 2025 *kharif* season at the insectary farm of Entomology Section, College of Agriculture, Nagpur, in a randomized block design with three replications. Modules M_1–M_3 received azadirachtin 1.00% EC (2 ml l^{-1}) at 30 days after sowing (DAS), followed at 40 DAS by *Metarhizium anisopliae* (M_1), *Beauveria bassiana* (M_2) or *Lecanicillium lecanii* (M_3), and a consortium of the three fungi at 50 DAS. Modules M_4–M_6 followed the same sequence, replacing azadirachtin with neem oil (10 ml l^{-1}) and using *M. anisopliae* (M_4), *B. bassiana* (M_5) or *L. lecanii* (M_6) at the second spray. Module M_7 received water and served as the control. *Pooled jassid* density was significantly lower in M_1–M_6 (1.56–2.02 jassids $leaf^{-1}$) than in M_7 (5.07 jassids $leaf^{-1}$); differences among the six biopesticide modules were not significant. M_1 recorded the lowest pooled density (1.56 jassids $leaf^{-1}$) and a 69.23% reduction over the control. The highest marketable fruit yield (61.96 q ha^{-1}), net incremental benefit (Rs. 1,41,374 ha^{-1}) and incremental cost-benefit ratio (1:18.73) were recorded in M_3. These yield and economic results reflect the performance of the complete modules against the crop pest complex and cannot be attributed to jassid suppression alone.

Keywords: Azadirachtin, Biopesticides, Jassid, *Metarhizium anisopliae*, Neem oil, Okra

Introduction

Okra [*Abelmoschus esculentus* (L.) Moench] hosts over seventy insect species (Rao *et al.*, 2003) [1]. Among them, the jassid *Amrasca biguttula biguttula* (Ishida), together with whitefly and aphid, forms the principal group of sap-feeding pests (Meena *et al.*, 2005) [2]. Both nymphs and adults settle on the lower leaf surface and drain sap, which makes the leaf margins curl and turn yellow. Estimates of the resulting fruit loss run from 40 to 56% (Krishnaiah, 1980) [3], and where half of the plants showed severe cupping, seed yield dropped by 79.03% (Mahal *et al.*, 1994) [4].

Botanical and microbial alternatives to insecticides have been examined by several workers. Field application of neem oil brought jassid numbers down by roughly 77% (Solangi *et al.*, 2013) [5], whereas neem and tobacco extracts killed 64–67% of jassids across two seasons (Iqbal *et al.*, 2017) [6]. Under laboratory conditions, oil and powder formulations of *M. anisopliae* and *B. bassiana* killed more than 96% of okra leafhoppers (Naik *et al.*, 2009) [7]. On okra plants, a blend of *Verticillium lecanii* and *M. anisopliae* lowered leafhopper counts (Palthiya, 2014) [8], and *L. lecanii* mixed with neem oil, each at half dose, performed on a par with imidacloprid without harming predators (Halder *et al.*, 2021) [9]. Nearly all of this work evaluated products singly or as tank mixes. It remains unclear whether spraying a botanical first, a single fungus next and a bioinoculant consortium last can hold jassid density low over the growing period. The present study addressed that question.

Materials and Methods

The experiment was conducted during the 2025 *kharif* season at the insectary field of the Entomology Section, College of Agriculture, Nagpur (21°10′ N, 79°19′ E; 321.26 m above mean sea level). The okra cultivar NOL-303 (Julie) was sown by dibbling on 15 July 2025, with rows 60 cm apart and 45 cm between plants. Each net plot measured 2.4 m × 3.1 m, fertiliser was given at 100:50:50 kg ha^{-1} N:P:K, and other agronomic operations followed standard recommendations. Seven programmes (Table 1) were allotted to plots in three randomised blocks. Spray solutions were mixed in the field immediately before use and applied at 30, 40 and 50 days after sowing (DAS), that is, on 14 August, 24 August and 3 September 2025; control plots were sprayed with water. Marketable fruit yield was also recorded for each treatment and ex

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pressed as q ha^{-1}. Yield and treatment-cost data from the same field trial were used to report incremental benefit and ICBR; the okra price used in the economic calculation was Rs. 4,000 q^{-1}. Total treatment cost included the cost of biopesticides and spraying labour (Rs. 7,546 ha^{-1} for azadirachtin-based modules and Rs. 13,300 ha^{-1} for neem-oil-based modules). The gross value of additional yield was calculated using the market price of Rs. 4,000 q^{-1}; net incremental benefit was obtained by subtracting total treatment cost from this value, and ICBR was expressed as treatment cost:net incremental benefit.

Jassid abundance (nymphs plus adults) was recorded from three leaves, one each from the upper, middle and lower canopy, of five tagged plants in every plot. Observations were taken one day before the first spray (1 DBS) and nine days after the first, second and third sprays (9 DAFS, 9 DASS and 9 DATS). Counts were subjected to square-root transformation [$\sqrt{x+0.5}$] before analysis of variance, and means were separated using SE(m) ± and critical difference (CD) at the 5% level. Reduction over control (%) was computed as $\frac{C-T}{C} \times 100$ from untransformed means, where C and T are the control and treatment means.

Results

At the start of the trial, jassid density in the plots lay between 2.49 and 2.84 per leaf and the differences were non-significant, so the infestation was evenly spread (Table 2). Nine days after the first spray, all sprayed plots held fewer jassids than the control (4.40 per leaf). The azadirachtin programmes had the lowest densities (M_1, 1.87; M_3, 1.93; M_2, 2.00), while the neem oil programmes were slightly higher (M_4, 2.13; M_6, 2.20; M_5, 2.27). Following the second spray, the two programmes containing *M. anisopliae* recorded the lowest values (M_1, 1.60; M_4, 1.67), whereas the control stood at 4.80. Nine days after the third spray, densities were 1.20 in M_1, 1.33 in M_4, 1.53 in M_3, 1.60 in M_6, 1.80 in M_2 and 1.87 in M_5; the untreated plots reached 6.00 per leaf.

Pooled over the three sprays, M_1 had the lowest density (1.56 per leaf), followed by M_4 (1.71), M_3 (1.73), M_6 (1.87), M_2 (1.89) and M_5 (2.02), compared with 5.07 in the control. Each biopesticide programme was significantly better than the control (CD at 5% = 0.21), but none differed significantly from another. Mean reduction over control (Fig 1) was greatest in M_1 (69.23%), then M_4 (66.27%) and M_3 (65.88%), and smallest in M_5 (60.16%). The reduction grew with successive sprays, rising from 48.41–57.50% at 9 DAFS to 68.83–80.00% at 9 DATS.

Marketable fruit yield and economic performance of the complete sequential modules were also considered (Table 3). M_3 recorded the highest yield (61.96 q ha^{-1}), followed by M_6 (59.54 q ha^{-1}), while the control yielded 24.73 q ha^{-1}. With a yield critical difference of 9.00 q ha^{-1} at the 5% level, M_3 was statistically at par with M_2 (55.78 q ha^{-1}), M_5 (53.36 q ha^{-1}) and M_6 (59.54 q ha^{-1}). M_3 had the highest ICBR (1:18.73) and net incremental benefit (Rs. 1,41,374 ha^{-1}). These are module-level outcomes; because the programmes also targeted other sucking pests, they cannot be interpreted as yield or economic effects caused by jassid suppression alone.

Discussion

The fall in jassid density in every sprayed plot indicates that a botanical applied first checked the early build-up of the pest. Azadirachtin and neem oil act as antifeedants and growth regulators, so nymphs feed and moult poorly and the population rises slowly. These observations agree with (Solangi *et al.*) [5] and (Bhandari *et al.*) [10], who reported that neem-based extracts and oils significantly reduced jassid populations under field conditions. In the present trial, azadirachtin was numerically ahead of neem oil after the first spray, although the difference was not significant.

The consistently lower counts in the schedules containing *M. anisopliae* (M_1 and M_4) point to the high virulence of this fungus against jassid, whose body is protected by a fairly hard cuticle. This is supported by (Wawdhane *et al.*) [11], who assessed several microbial agents and concluded that *M. anisopliae* holds good promise for regulating jassid populations, and by (Naik and Shekharappa) [7], who obtained very high hopper mortality with *Metarhizium* formulations. The schedules with *L. lecanii* (M_3 and M_6) and *B. bassiana* (M_2 and M_5) were also effective and remained at par with M_1, showing that all three fungi contribute to suppression when applied after a botanical. The bioinoculant consortium at 50 DAS produced the sharpest fall in every schedule (68.83–80.00% reduction), so it helps to sustain control as the crop advances.

Yield and economic results provide a complementary assessment of the full spray modules. Although M_1 had the lowest pooled jassid density, M_3 recorded the highest marketable yield and ICBR. M_3 yield was statistically at par with M_2, M_5 and M_6 based on the reported critical difference. This difference between numerical jassid density and yield ranking is plausible because module performance reflects the combined effects of treatments on the sucking-pest complex, crop response and input costs; the present trial does not isolate the contribution of jassid suppression to yield.

Conclusion

Every sequential biopesticide programme tested reduced jassid density on okra significantly relative to the untreated plots. The azadirachtin–M. anisopliae–consortium programme (M_1) recorded the lowest pooled numerical density (1.56 per leaf versus 5.07 in the control) and the greatest reduction over control (69.23%); however, differences among the six biopesticide programmes were not significant. Across the complete modules, M_3 (azadirachtin followed by *L. lecanii* and the consortium) recorded the highest marketable fruit yield (61.96 q ha^{-1}) and the highest ICBR (1:18.73). These yield and economic outcomes reflect the overall module performance against the crop pest complex rather than an isolated effect on jassid. The results support further evaluation of these programmes across seasons and locations.

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Conflict of interest: The authors declare no conflict of interest.

Table 1. Details of the sequential biopesticide modules tested against *Amrasca biguttula biguttula* on okra

Module	Spray 1 (30 DAS)	Spray 2 (40 DAS)	Spray 3 (50 DAS)
M_1	Azadirachtin 1.00% EC (2 ml l^{-1})	*Metarhizium anisopliae* 1.15% WP, 1 × 10^8 CFU g^{-1} (5 g l^{-1})	Bioinoculant (*Metarhizium anisopliae*, *Beauveria bassiana*, *Lecanicillium lecanii*) 2 × 10^8 CFU ml^{-1} (10 ml l^{-1})
M_2	Azadirachtin 1.00% EC (2 ml l^{-1})	*Beauveria bassiana* 1.15% WP, 1 × 10^8 CFU g^{-1} (5 g l^{-1})	Bioinoculant (*Metarhizium anisopliae*, *Beauveria bassiana*, *Lecanicillium lecanii*) 2 × 10^8 CFU ml^{-1} (10 ml l^{-1})
M_3	Azadirachtin 1.00% EC (2 ml l^{-1})	*Lecanicillium lecanii* 1.15% WP, 2 × 10^8 CFU g^{-1} (5 g l^{-1})	Bioinoculant (*Metarhizium anisopliae*, *Beauveria bassiana*, *Lecanicillium lecanii*) 2 × 10^8 CFU ml^{-1} (10 ml l^{-1})
M_4	Neem oil (10 ml l^{-1})	*Metarhizium anisopliae* 1.15% WP, 1 × 10^8 CFU g^{-1} (5 g l^{-1})	Bioinoculant (*Metarhizium anisopliae*, *Beauveria bassiana*, *Lecanicillium lecanii*) 2 × 10^8 CFU ml^{-1} (10 ml l^{-1})

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Module	Spray 1 (30 DAS)	Spray 2 (40 DAS)	Spray 3 (50 DAS)
M_5	Neem oil (10 ml l^{-1})	*Beauveria bassiana* 1.15% WP, 1 × 10^8 CFU g^{-1} (5 g l^{-1})	Bioinoculant (*Metarhizium anisopliae*, *Beauveria bassiana*, *Lecanicillium lecanii*) 2 × 10^8 CFU ml^{-1} (10 ml l^{-1})
M_6	Neem oil (10 ml l^{-1})	*Lecanicillium lecanii* 1.15% WP, 2 × 10^8 CFU g^{-1} (5 g l^{-1})	Bioinoculant (*Metarhizium anisopliae*, *Beauveria bassiana*, *Lecanicillium lecanii*) 2 × 10^8 CFU ml^{-1} (10 ml l^{-1})
M_7 (control)	Water spray		

DAS: days after sowing; EC: emulsifiable concentrate; WP: wettable powder; CFU: colony-forming units.

Table 2. Mean Jassid population per leaf under different biopesticide modules at each spray interval

Module	1 DBS	9 DAFS	9 DASS	9 DATS	Cumulative
M_1	2.49 (1.71)	1.87 (1.52)	1.60 (1.43)	1.20 (1.30)	1.56 (1.43)
M_2	2.62 (1.75)	2.00 (1.57)	1.87 (1.53)	1.80 (1.51)	1.89 (1.54)
M_3	2.64 (1.76)	1.93 (1.55)	1.73 (1.48)	1.53 (1.42)	1.73 (1.49)
M_4	2.82 (1.81)	2.13 (1.61)	1.67 (1.47)	1.33 (1.35)	1.71 (1.48)
M_5	2.84 (1.81)	2.27 (1.65)	1.93 (1.55)	1.87 (1.54)	2.02 (1.58)
M_6	2.80 (1.80)	2.20 (1.63)	1.80 (1.50)	1.60 (1.44)	1.87 (1.53)
M_7 (control)	2.71 (1.78)	4.40 (2.21)	4.80 (2.30)	6.00 (2.55)	5.07 (2.36)
F test	NS	Sig.	Sig.	Sig.	Sig.
SE(m)±	0.17	0.14	0.11	0.07	0.07
CD at 5%	–	0.42	0.35	0.23	0.21
CV (%)	16.75	14.07	12.11	8.11	7.28

DBS: days before spray; DAFS, DASS, DATS: days after first, second and third spray; NS: non-significant; Sig.: significant at 5%. Data in parentheses are square-root transformed [$\sqrt{x+0.5}$] values.

Table 3. Marketable fruit yield and economic performance of the sequential biopesticide modules

Module	Yield (q ha^{-1})	Yield increase over control (q ha^{-1})	Total treatment cost (Rs. ha^{-1})	Net incremental benefit (Rs. ha^{-1})	ICBR (cost:benefit)
M_1	49.59	24.86	7,546	91,894	1:12.18
M_2	55.78	31.05	7,546	1,16,654	1:15.46
M_3	61.96	37.23	7,546	1,41,374	1:18.73
M_4	47.04	22.31	13,300	75,940	1:5.71
M_5	53.36	28.63	13,300	1,01,220	1:7.61
M_6	59.54	34.81	13,300	1,25,940	1:9.47
M_7 (control)	24.73	—	—	—	—

Note: Okra price = Rs. 4,000 q^{-1}. Gross value of yield increase = yield increase over control × market price; net incremental benefit = gross value of yield increase − total treatment cost. ICBR is expressed as treatment cost:net incremental benefit (1:x). Yield CD at 5% = 9.00 q ha^{-1}.

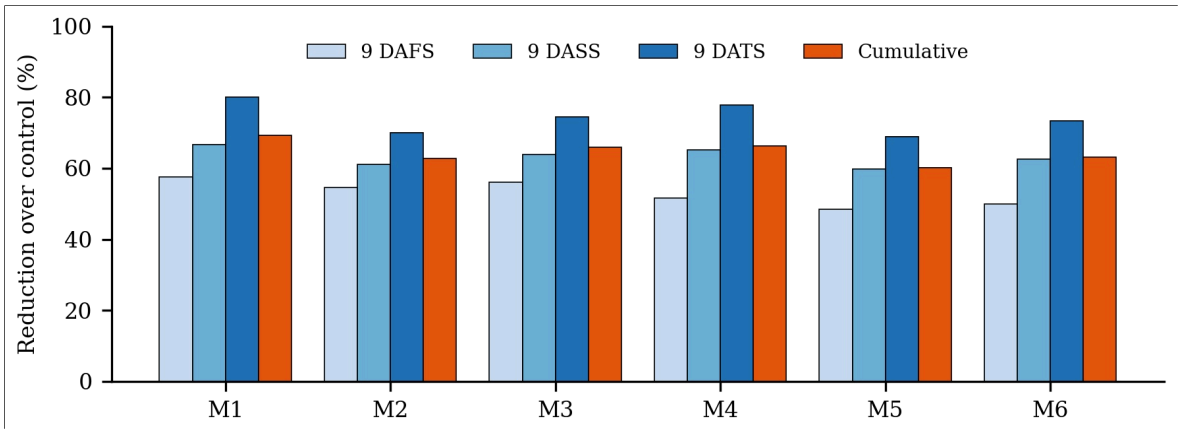


Figure 1. Reduction (%) in jassid population over the untreated control (water-spray) after each spray and for the cumulative mean under different biopesticide modules.

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