



International Journal of Horticulture and Food Science

E-ISSN: 2663-1067

P-ISSN: 2663-1075

NAAS Rating (2026): 4.74

www.hortijournal.com

IJHFS 2026; 8(4): 15-18

Received: 17-05-2026

Accepted: 20-06-2026

Purushotam Sharma

Department of Entomology,
SKNCOA, Jobner, Jaipur,
Rajasthan, India

DK Bairwa

Department of Entomology,
COA, Kotputli, Rajasthan,
India

RP Ghasolia

Department of Plant
Pathology, SKNCOA, Jobner,
Jaipur, Rajasthan, India

ML Choudhary

Department of Horticulture,
SKNCOA, Jobner, Jaipur,
Rajasthan, India

DL Bagri

Department of Plant
Physiology, SKNCOA, Jobner,
Jaipur, Rajasthan, India

Mukesh Chand Bhatshwar

Department of Horticulture,
SKNCOA, Jobner, Jaipur,
Rajasthan, India

Corresponding Author:

Purushotam Sharma

Department of Entomology,
SKNCOA, Jobner, Jaipur,
Rajasthan, India

Bio-ecological management of lemon butterfly (*Papilio demoleus lepidoptera*: Papilionidae) in bael (*Aegle marmelos*): (Pooled data 2020-2024)

Purushotam Sharma, DK Bairwa, RP Ghasolia, ML Choudhary, DL Bagri and Mukesh Chand Bhatshwar

DOI: <https://www.doi.org/10.33545/26631067.2026.v8.i8a.827>

Abstract

The lemon butterfly (*Papilio demoleus*), a significant pest of bael (*Aegle marmelos*), causes extensive defoliation and yield losses in India's arid and semi-arid regions. Due to the environmental and health risks of chemical pesticides, this study evaluated eight bio-ecological treatments, including biopesticides and botanicals, for managing *P. demoleus* in bael orchards at Asalpur farm from 2020 to 2024. Using a randomized block design with three replications, treatments such as neem-based products, microbial agents (*Bacillus thuringiensis*, *Metarhizium anisopliae*, *Beauveria bassiana*, spinosad), and an untreated control were tested. Larval mortality was assessed at 1, 3, 7, and 15 days post-spray. Spinosad 45 SC (0.2 ml/L) achieved the highest mean mortality (77%), followed by *Bacillus thuringiensis* var. *kurstaki* (66.84%) and neem seed kernel extract (NSKE) 5% (52.59%). These treatments significantly outperformed others ($p < 0.05$), while *Beauveria bassiana*, karanj seed extract, and *Metarhizium anisopliae* were less effective (38.29-41.25%). All treatments surpassed the untreated control (4.29% mortality). These findings highlight bio-ecological approaches, particularly spinosad and *B. thuringiensis*, as sustainable alternatives for *P. demoleus* management in bael cultivation.

Keywords: Lemon butterfly, *Papilio demoleus*, bael, *Aegle marmelos*, biopesticides, eco-friendly pest control, spinosad, *Bacillus thuringiensis*, neem-based products and IPM

1. Introduction

Bael (*Aegle marmelos* Correa), a member of the Rutaceae family, is a valuable fruit tree cultivated in India's arid and semi-arid regions for its medicinal and edible fruits. Its economic importance has grown, but insect pests, particularly the lemon butterfly (*Papilio demoleus* Lepidoptera: Papilionidae), threaten productivity. The larvae of *P. demoleus* cause severe defoliation, especially from August to February, leading to significant yield losses (Singh, 1993) ^[11]. This pest primarily targets Rutaceae species, including bael, citrus, and *Murraya koenigii*, and can cause up to 100% defoliation in severe infestations (Thakare & Borle, 1969) ^[13]. With rising global demand for eco-friendly pest control, bio-ecological approaches are critical for sustainable agriculture in arid regions. Chemical pesticides have traditionally been used to control *P. demoleus*, but their adverse effects on non-target organisms, environmental pollution, and human health have raised concerns (Guerrero *et al.*, 2004) ^[4]. Consequently, there is a pressing need for sustainable pest management strategies. Bio-ecological approaches, such as biopesticides (e.g., *Bacillus thuringiensis*, *Metarhizium anisopliae*, *Beauveria bassiana*) and botanical extracts (e.g., neem, karanj), offer eco-friendly alternatives due to their target-specificity and reduced environmental impact (Sadawaste *et al.*, 2010) ^[8]. This study evaluated the efficacy of selected biopesticides and botanicals for managing *P. demoleus* in bael orchards at Asalpur farm over five years (2020-2024).

2. Materials and Methods

2.1 Study Site and Period

The experiment was conducted at Asalpur farm of SKN Agriculture University, Jobner Rajasthan, in an arid to semi-arid region with high *P. demoleus* infestation, particularly from August to February. Data were collected annually from 2020 to 2024.

2.2 Treatments

Eight treatments were evaluated:

1. Neem Seed Kernel Extract (NSKE) @ 5%
2. Karanj Seed Extract @ 5%
3. *Bacillus thuringiensis* var. *kurstaki* @ 0.1%
4. *Metarhizium anisopliae* (1x10⁹ CFU) @ 6 g/L
5. Neem oil @ 0.1%
6. Spinosad 45 SC @ 0.2 ml/L
7. *Beauveria bassiana* (1x10⁹ CFU) @ 6 g/L
8. Untreated control

2.3 Experimental Design

The trial followed a Randomized Block Design (RBD) with three replications. Each treatment was applied on two bael trees per replicate, ensuring adequate representation.

2.4 Application and Observation

Treatments were applied as foliar sprays using a knapsack sprayer (10 L capacity, 500 ml/tree). Pre-treatment larval counts were recorded by inspecting 100 leaves per tree across four cardinal directions (north, east, south, west). Post-treatment observations were made at 1, 3, 7, and 15 days after spraying. Larval mortality was calculated as a percentage.

2.5 Statistical Analysis

Data were subjected to analysis of variance (ANOVA) in

RBD. Percentage mortality data were arcsine-transformed to normalize variance. Standard error of the mean (SEm), critical difference (CD) at $p=0.05$, and coefficient of variation (CV) were calculated to assess treatment efficacy and variability.

3. Results

Pre-treatment larval counts ranged from 5.83 to 6.23 larvae per 100 leaves, indicating uniform pest pressure across treatments (Table 1). Spinosad 45 SC (0.2 ml/L) exhibited the highest mean mortality (77%), with peak efficacy (88.07%) at 3 and 7 days post-spray. *Bacillus thuringiensis* var. *kurstaki* (0.1%) followed with a mean mortality of 66.84%, achieving 94.16% mortality at 7 days. NSKE (5%) recorded a mean mortality of 52.59%, with a maximum of 76.04% at 3 days. These treatments were significantly superior ($p < 0.05$) to others.

Neem oil (0.1%) and *Metarhizium anisopliae* (6 g/L) showed moderate efficacy, with mean mortalities of 49% and 41.25%, respectively. *Beauveria bassiana* (38.29%) and karanj seed extract (39.59%) were the least effective, statistically similar to *M. anisopliae*. The untreated control had negligible mortality (4.29%). Statistical parameters (SEm: 3.403, CD: 9.827, CV: 14.753) confirmed significant differences among treatments. Figure 1 illustrates the mean mortality across treatments.

Table 1: Efficacy of treatments against *P. demoleus* (pooled data, 2020-2024)

Treatments	Pre-count	Mean % mortality / 100 leaves days after spray				Mean
		1 st day	3 rd day	7 th day	15 th day	
T ₁ : NSKE @ 5%	6.13	37.4 (37.7)	76.04 (60.69)	61.2 (51.47)	35.74 (36.71)	52.59 (46.64)
T ₂ : Karanj Seed Extract @5%	5.93	22.89 (28.58)	49.93 (44.95)	47.13 (43.35)	38.41 (38.29)	39.59 (38.79)
T ₃ : <i>Bacillus thuringiensis</i> var. <i>kurstaki</i> 0.1%	6.06	14.66 (22.51)	71.05 (57.44)	94.16 (76.01)	87.49 (69.28)	66.84 (56.31)
T ₄ : <i>Metarhizium Anisopliae</i> (1x10 ⁹ cfu) @6g/litre	6.16	14.69 (22.53)	39.53 (38.95)	64.39 (53.36)	46.39 (42.92)	41.25 (39.44)
T ₅ : Neem oil 0.1%	5.86	32.18 (34.56)	69.18 (56.27)	63.47 (52.81)	31.48 (34.12)	49.07 (44.44)
T ₆ : Spinosad 45 SC 0.2 ml/litre	6.23	68.94 (56.12)	88.07 (69.79)	88.07 (69.79)	63.1 (52.59)	77.04 (62.07)
T ₇ : <i>Beauveria bassiana</i> (1x10 ⁹ cfu) @6g/litre	5.83	12.22 (20.46)	34.94 (36.23)	65.05 (53.75)	40.95 (39.78)	38.29 (37.55)
T ₈ : Untreated check	6.09	0.78 (5.06)	4.19 (11.81)	12.21 (20.45)	0 (0)	4.29 (9.33)
SEm		3.032	3.426	3.76	3.394	3.40
CD ($p=0.05$)		8.752	9.894	10.856	9.808	9.83
CV		20.182	12.338	11.792	14.7	14.75

Figures in parentheses are arcsine-transformed values.

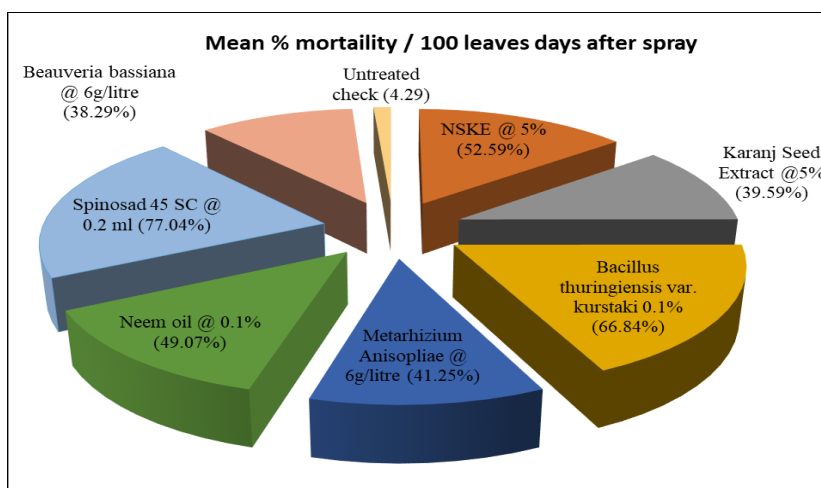


Fig 1: Mean percentage mortality per 100 leaves at different days after spraying

4. Discussion

Spinosad's superior performance (77% mean mortality) aligns with its mode of action as a bio-rational pesticide derived from *Saccharopolyspora spinosa*, which disrupts insect nervous systems (Haque *et al.*, 2019) ^[5]. Its prolonged residual activity makes it highly effective against *P. demoleus*. *Bacillus thuringiensis* var. *kurstaki* (66.84% mortality) produces crystal toxins targeting lepidopteran larvae, with peak efficacy at 7 days, consistent with previous studies (Resham *et al* 1986) ^[7], (Shivankar V J 1999) ^[9], (Fawzi *et al.*, 2007) ^[2]. NSKE (52.59% mortality), rich in azadirachtin, acts as a feeding deterrent and growth regulator, offering moderate but significant control (Sadawaste *et al.*, 2010) ^[8], (Hatim *et al* 2009) ^[6], (Singh R. *et al* 1996) ^[10], (Solunke *et al* 1991) ^[12], (Gopali *et al* 2011) ^[3].

The lower efficacy of *Beauveria bassiana* and *Metarhizium anisopliae* may result from suboptimal environmental conditions (e.g., high temperatures or low humidity) that hinder fungal spore germination and infection (Chauke *et al.*, 1999) ^[1]. Karanj seed extract's limited impact could be due to lower concentrations of active compounds compared to neem. Compared to chemical pesticides, these bio-ecological treatments offer reduced environmental risks, though their efficacy varies. The decline in mortality at 15 days suggests the need for repeated applications or integrated pest management (IPM) strategies combining multiple agents.

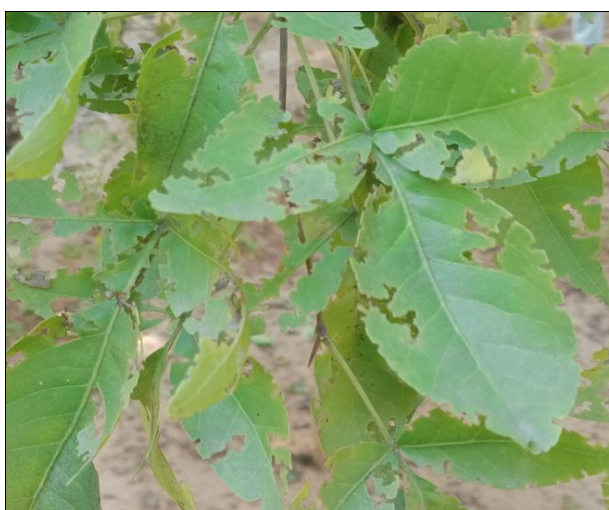
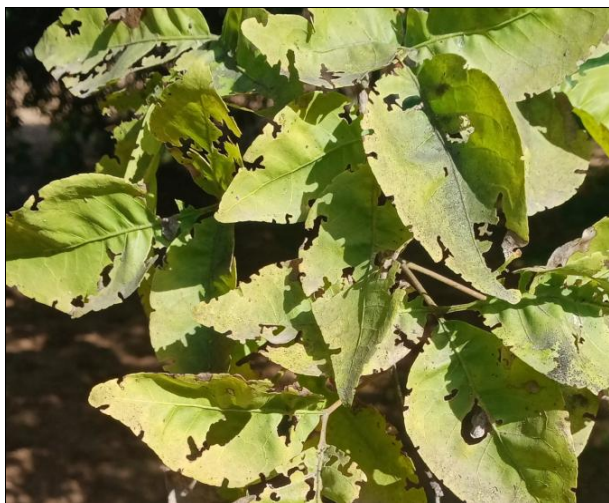


Fig 2: Lemon butterfly (*Papilio demoleus*) infected plants

5. Limitations

This study was conducted at a single site, potentially limiting the generalizability of results due to variations in climate and pest pressure. The efficacy of fungal biopesticides may be influenced by environmental factors not fully explored here. Further research across multiple locations and seasons is needed to validate these findings.

6. Conclusion

Spinosad 45 SC (0.2 ml/L), *Bacillus thuringiensis* var. *kurstaki* (0.1%), and NSKE (5%) are effective bio-ecological tools for managing *P. demoleus* in bael orchards, offering sustainable alternatives to chemical pesticides. These treatments minimize environmental and health risks while achieving significant pest control. Farmers should adopt these biopesticides within IPM frameworks, supported by training on application techniques. Policymakers should promote bio-ecological approaches through subsidies and extension services to enhance sustainable bael cultivation.

References

1. Chauke RP, Pasalwas AN, Dalal SR. Efficacy of various insecticides and plant products against the larvae of lemon butterfly (*Papilio demoleus*). In: Hi-Tech Citrus Management: Proceedings of International Symposium on Citriculture. Nagpur: NRC for Citrus; 1999. p. 928-930.
2. Fawzi AZ, Hilafy NA, Al-Okaily LN. *Bacillus thuringiensis* var. *kurstaki* as a biological control agent against lemon butterfly, *Papilio demoleus*. Journal of Kerala University. 2007;5(4):1-5.
3. Gopali JB, Sharanabasappa, Suhasylhetty YK, Kotikal, Athani SI. Seasonal abundance of citrus butterfly, *Papilio demoleus* L., and its parasitisation by natural enemies in north Karnataka on Kagzi lime. In: National Seminar on Recent Trends in Production Technology and Value Addition in Acid Lime; 2011 Aug 11-13; Bijapur, Karnataka. 2011. p. 113.
4. Guerrero KA, Veloz D, Boyce SL, Farrell BD. First New World documentation of an Old World citrus pest, the lime swallowtail *Papilio demoleus* (Lepidoptera: Papilionidae), in the Dominican Republic (Hispaniola). American Entomologist. 2004;50(4):227-229.
5. Haque R, Maleque MA, Rahman ML, Khan U, Bhuiyan L. Evaluation of new management approaches against lemon butterfly (*Papilio demoleus*) infesting Jara sweet orange in Sylhet, Bangladesh. Bangladesh Journal of Entomology. 2019;29(2):1-12.
6. Hatim GM, Idriss RE, Abdella MZ, Sid Ahmed OAA. Effect of Nimbecidin 0.03% and Agerin® on the larvae of lemon butterfly (*Papilio demodocus*). Journal of Science and Technology. 2009;10(2):100-104.
7. Resham BT, Fanindra PN, Butani DK. Insect pests of citrus in Nepal and their control. Pestology. 1986;10(4):24-27.
8. Sadawaste AK, Giri GK, Jayawar NE. Biointensive management of citrus butterfly, *Papilio demoleus*. In: National Seminar on Citrus Biodiversity for Livelihood and Nutritional Security; 2010; Nagpur, Maharashtra. 2010. p. 393.
9. Shivankar VJ. Recent trends in insect pest management of citrus. In: Hi-Tech Citrus Management: Proceedings of International Symposium on Citriculture; 1999 Nov

- 23-27; Nagpur: NRC for Citrus; 1999. p. 773-774.
10. Singh R, Mahalakshmi R, Vijayachandran SN. The lemon butterfly: Potential pest of *Aegle marmelos* in nursery and its management with neem. Insect Environment. 1996;2(3):70.
 11. Singh SP. Species composition and diapause in citrus butterflies. Journal of Insect Science. 1993;6:48-52.
 12. Solunke BR, Deshpande SV. Studies on use of plant products for the control of lemon butterfly larvae. J Maharashtra Agric Univ. 1991;16(2):302-303.
 13. Thakare KR, Borle MN. Survey report of damage caused by lemon butterfly pest in Vidharbha region. Official communication. D.O. No. 782/69. 1969.