**Economic Evaluation and Impacts of Insecticides and Bio-Pesticides in Controlling the Brinjal Shoot and Fruit Borer (*Leucinodes orbonalis* Guenee)**

**Abstract:**

The present investigation were carried out with a view to find out the incremental cost benefit ratio of different insecticides and bio-pesticides against brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenee) in Kharif season at the Student’s Instructional Farm (SIF), Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, during Kharif 2022 and 2023. The study aimed to evaluate the efficacy and cost-effectiveness of different insecticidal and bio-pesticidal treatments for managing *L. orbonalis* and enhancing brinjal yield. Based on the findings, Spinosad 45 SC recorded the highest yield of 110.78 q/ha with an ICBR of 4.72, followed by Emamectin benzoate 5% SG (97.22 q/ha, ICBR 2.86) and Lambda cyhalothrin 5 EC (97.00 q/ha, ICBR 9.47). Neem oil 1500 ppm proved to be the most cost-effective treatment, achieving the highest ICBR of 17.82 with a yield of 79.22 q/ha. NSKE 5% (76.78 q/ha) ranked third in cost-effectiveness with an ICBR of 4.99. *Bacillus thuringiensis var. kurstaki* recorded a yield of 59.67 q/ha and an ICBR of 2.00, while *Beauveria bassiana* (54.11 q/ha, ICBR 0.76) and *Metarhizium anisopliae* (53.00 q/ha, ICBR 0.64) showed relatively lower efficacy. The untreated control resulted in the lowest yield of 37.44 q/ha. Thus, for maximum yield, Spinosad 45 SC and Emamectin benzoate 5% SG are the most effective treatments, whereas for cost-effective management, Neem oil 1500 ppm and Lambda cyhalothrin 5 EC are the best options for controlling *L. orbonalis* in brinjal cultivation.

**Keywords:** Brinjal shoot, fruit borer, ICBR, Bio-pesticide, Insecticide , Spinosad

**Introduction**

Brinjal (*Solanum melongena* L.), commonly referred to as eggplant or aubergine, is an important solanaceous vegetable crop cultivated extensively in tropical, subtropical and warm temperate climates worldwide. Native to India, this vegetable has been cultivated since the 3rd century and is regarded as the "King of Vegetables" due to its high nutritional and economic value. The chromosomal constitution of brinjal is 2n = 24 and it is highly adaptable to diverse climatic conditions, thriving best in temperatures between 13–21°C (Ramzan *et al.,* 2021). Brinjal is a rich source of essential nutrients, including carbohydrates, proteins, vitamins (A, B-complex, C, E and K) and minerals (calcium, iron, magnesium, manganese, phosphorus, potassium and zinc), contributing significantly to balanced diets and human health (Naeem *et al.,* 2019). Its phytochemical components, particularly glycoalkaloids like solasodine, exhibit anticancer properties, while dietary fiber aids in digestion and reduces the risk of colorectal cancer (Shen *et al.,* 2017; Friedman *et al.,* 2006). Vegetable farming plays a crucial role in Indian agriculture, not only as a primary source of nutrition but also as a means of economic sustenance for millions of farmers. Vegetables occupy approximately 2-5% of the total cropped area in India, with per capita vegetable consumption standing at 135 grams per day, significantly lower than the recommended 300 grams. India is the second-largest producer of vegetables globally, contributing approximately 15.4% to total vegetable production, with an estimated 199.88 million tonnes of vegetables produced in 2021-22 (MA & FW, 2022). Brinjal accounts for a significant portion of India's horticultural production, with a cultivation area of 0.74 million hectares, yielding 12.7 million tonnes annually. The leading states in brinjal production include West Bengal, Odisha, Jharkhand, Gujarat, Bihar and Madhya Pradesh, contributing nearly 75% of the total cultivated area and 72.62% of total production (MA & FW, 2022). Despite its economic significance, brinjal cultivation faces major constraints due to pest infestations, which can result in substantial yield losses. The brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenee) is the most destructive pest affecting brinjal production across India, Pakistan, Sri Lanka, Nepal, Bangladesh, Thailand and other Asian countries (AVRDC, 1994). This pest is monophagous, infesting brinjal from the seedling stage to crop maturity, causing yield losses ranging from 11-93% (Ghosh and Senapati, 2009). The larvae bore into shoots and fruits, rendering them unmarketable and significantly impacting farmers' income. The economic threshold level (ETL) of this pest is estimated at 5% shoot and 10% fruit infestation (Shirale *et al.,* 2012). Other major insect pests of brinjal include hadda beetle (*Henosepilachna vigintioctopunctata*), stem borer (*Euzophera perticella*), ash weevil (*Myllocerus subfasciatus*), brown leafhopper (*Cestius phycitis*) and aphids (*Aphis gossypii*), all of which contribute to substantial crop damage (Dwivedi *et al.,* 2014). The management of brinjal pests relies heavily on synthetic insecticides, which, while effective, pose serious risks to non-target organisms, including beneficial insects, pollinators and natural predators. Conventional insecticides such as organophosphates, carbamates, pyrethroids and neonicotinoids have broad-spectrum activity, leading to adverse effects on beneficial insects, including pollinators and natural predators. Furthermore, the excessive use of chemical pesticides has led to pest resistance, environmental contamination and human health hazards. Beneficial insects such as coccinellid beetles, syrphid flies (*Episyrphus balteatus*), green lacewings (*Chrysoperla carnea*) and spiders (*Oxyopes* sp.) play a vital role in suppressing pest populations (Borkakati *et al.,* 2019). However, the indiscriminate use of insecticides often disrupts ecological balance, leading to secondary pest outbreaks and pesticide residues in food crops. In response to these challenges, the use of bio-pesticides has emerged as an eco-friendly and sustainable alternative to chemical pesticides. Bio-pesticides, derived from natural sources such as bacteria, fungi, viruses and plant extracts, offer selective pest control with minimal environmental impact. Common bio-pesticides used against *L. orbonalis* include *Bacillus thuringiensis* (Bt), neem-based formulations (*Azadirachta indica*) and entomopathogenic fungi such as *Beauveria bassiana* and *Metarhizium anisopliae*. These bio-control agents not only reduce pest populations but also help maintain natural predator-prey dynamics, thereby promoting integrated pest management (IPM) strategies. The Incremental Cost Benefit Ratio (ICBR) is a critical economic evaluation tool used to assess the financial viability of different pest control measures. The ICBR quantifies the additional benefits derived from pest management interventions relative to their costs, helping farmers make informed decisions about sustainable pest control strategies. This study aims to evaluate the ICBR of different insecticides and bio-pesticides in managing brinjal shoot and fruit borer infestations. By comparing the effectiveness, environmental impact and economic returns of chemical and biological control methods, this research seeks to provide a comprehensive analysis of cost-effective and eco-friendly pest management solutions for brinjal farmers.

**Materials and Methods**

The present investigation entitled "Incremental cost benefit ratio of different insecticides and bio-pesticides against brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenee)"

**Experimental Site:** The experiment was conducted at the Student’s Instructional Farm (SIF), Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh (26°-28°N latitude, 80.21°-84.34°E longitude, altitude 125.9 m). The site is located in the alluvial tract of the Gangetic plain with assured irrigation through tube wells. The soil type was sandy loam with average fertility, good drainage, and regular cultivation history.

**Experimental Design and Layout:** The experiment was conducted using a Randomized Block Design (RBD) with three replications and nine treatments, covering a total of 27 plots. Each plot measured 3 × 3 m², with a 1.5 m block border cum irrigation channel and a 0.5 m plot border. The total experimental area was 429 m² (33 m × 13 m) and the brinjal variety used was Kalyanpur Type-3. The spacing between rows and plants was 60 × 60 cm, requiring 25 seedlings per plot (9 m²) for proper establishment.

**Meteorological Observations:** Weather parameters, including temperature, relative humidity, rainfall, sunshine hours, and wind speed, were recorded from the meteorological observatory at SIF, CSAUAT, Kanpur, during the Kharif seasons of 2022 and 2023. The weekly mean values were used for correlation analysis.

**Nursery Raising:** Brinjal seeds were sown in well-prepared raised nursery beds (15 cm high, 3m × 1m) in rows 6 cm apart and 0.5 cm deep during the last week of June in both cropping seasons. Organic manure was incorporated, and beds were covered with straw for moisture retention. Irrigation was provided using sprinklers, and seedlings were thinned at the first true leaf stage for transplanting after four weeks.

**Field Preparation:** The field was prepared with one deep ploughing using a soil-turning plough, followed by two cross harrowings and two cultivations with planking. Weeds and plant debris were removed. Transplanting rows were marked with a 60 cm × 60 cm spacing layout based on the statistical experiment design.

**Fertilizer Application:** Farm Yard Manure (25 t/ha) was applied before the last ploughing. Recommended doses of fertilizers (100 kg N/ha, 40 kg P₂O₅/ha, and 40 kg K₂O/ha) were applied in the form of Urea, DAP, and Muriate of Potash. Half of the nitrogenous fertilizer and full doses of phosphorus and potassium were applied as basal dressing, while the remaining nitrogen was top-dressed during the vegetative and fruiting stages.

**Transplanting of Seedlings:** Thirty-day-old seedlings were transplanted in the last week of July in both years at a 60 cm × 60 cm spacing. Transplanting was conducted in the late afternoon during sunny days and seedlings were watered twice daily until establishment.

**Treatments:** Details of treatments presented in the table 1 for the calculation of incremental cost benefit ratio of different insecticides and bio-pesticides against brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenee): T1: Neem oil 1500 ppm @ 1 ml/L, T2: Neem Seed Kernel Extract (NSKE) 5% @ 5 ml/L, T3: *Beauveria bassiana* @ 5 ml/L, T4: *Metarhizium anisopliae* @ 5 ml/L, T5: *Bacillus thuringiensis* var. Kurstaki @ 5 ml/L, T6: Emamectin benzoate 5% SG @ 1 g/L, T7: Spinosad 45% SC @ 0.20 ml/L, T8: Lambda cyhalothrin 5% EC @ 2 ml/L, and T9: Control (Untreated).

**Observation recorded**

**Yield:** The brinjal fruits yield were taken on an individual plot basis in kg/plot, which were converted into q/ha for making comparison between treatments to see the effectiveness of treatments against shoot and fruit borer and it were calculated after maturity of crop.

**Incremental Cost Benefit Ratio:** Fruit yield of different treatments were recorded and Incremental Cost Benefit Ratio were calculated on the basis of net profit obtained from additional yield. Incremental cost benefit ratio was calculated using following formula: -

Incremental Cost Benefit Ratio$=\frac{Net Profit}{Total Cost of Plant Protection or Treatment}$

**Statistical analysis**

The data were transformed necessarily as and when required. Standard error of mean in each case and the critical difference only for significant cases were computed at 5% level of probability. Standard error and critical difference were calculated by following formula.

**Standard error** = $\sqrt{\frac{2MES}{R}}$

**MES**= error mean sum of square, error variance

**R** = Replication

**Critical difference (C.D.) @ 5% = SE (d) × t 5%** at error degree of freedom

The observations were analyzed statistically to compare the effects of treatments. The per cent increase yield over control were calculated by following formula:

**Percent increase yield over control** = $\frac{X-Y}{X}X100$ (Abbot’s, 1987)

Where,

X= per cent fruit infestation in control plot,

Y= per cent fruit infestation in treated plot by different insecticides

Then X-Y = per cent control by treatment

**Results and Discussion**

The present study evaluated the efficacy of different insecticides and bio-pesticides against brinjal shoot and fruit borer (*Leucinodes orbonalis Guenee*) during Kharif 2022 and 2023. The data experimental finding presented in the table 2, 3 and both year fluctuations of yield and ICBR show in the figure 1. The results, expressed in terms of Incremental Cost Benefit Ratio (ICBR), yield improvement, and net benefit, were compared with previous studies conducted by Warghat *et al.* (2020), Vinayaka *et al.* (2019), Ghodake *et al.* (2024), and Dabhade *et al.* (2024). Neem oil 1500 ppm exhibited the highest ICBR (18.12 in 2022 and 17.82 in 2023), significantly increasing yield to 77.00 q/ha and 79.22 q/ha, respectively, which aligns with Dabhade *et al.* (2024) and Warghat *et al.* (2020), who reported similar trends. NSKE 5% ranked third with an ICBR of 5.19 (2022) and 4.99 (2023), yielding 75.22 q/ha and 76.78 q/ha, consistent with findings from Dabhade *et al.* (2024). Warghat *et al.* (2020) also noted that botanical pesticides such as neem-based products provided sustainable control of *Leucinodes orbonalis* while ensuring economic feasibility. Among the bio-pesticides, *Beauveria bassiana* 2 × 10⁹ spores/ml recorded the lowest ICBR (1.13 in 2022 and 0.76 in 2023), with yields of 54.78 q/ha and 54.11 q/ha, aligning with Warghat *et al.* (2020) and Ghodake *et al.* (2024). Similarly, *Metarhizium anisopliae* 2 × 10⁹ spores/ml showed an ICBR of 0.83 (2022) and 0.64 (2023), with yields of 51.89 q/ha and 53.00 q/ha, corresponding to previous research. *Bacillus thuringiensis var. Kurstaki* 1 × 10⁹ CFU/ml recorded an ICBR of 2.51 (2022) and 2.00 (2023), with yields of 60.56 q/ha and 59.67 q/ha, similar to Ghodake *et al.* (2024) and Vinayaka *et al.* (2019), who observed moderate effectiveness of microbial insecticides under field conditions. Among the chemical insecticides, Emamectin Benzoate 5% SG demonstrated an ICBR of 2.77 (2022) and 2.86 (2023), with yield improvements to 93.00 q/ha and 97.22 q/ha, aligning with Vinayaka *et al.* (2019) and Warghat *et al.* (2020). Spinosad 45% SC ranked fourth, with an ICBR of 4.41 (2022) and 4.72 (2023), yielding 103.89 q/ha and 110.78 q/ha, confirming its effectiveness as per Vinayaka *et al.* (2019) and Ghodake *et al.* (2024). Lambda Cyhalothrin 5% EC secured second place in both years, recording an ICBR of 8.81 (2022) and 9.47 (2023), with yields of 90.33 q/ha and 97.00 q/ha, consistent with Vinayaka *et al.* (2019), who emphasized the high efficacy of synthetic pyrethroids in controlling *Leucinodes orbonalis*. A comparative analysis with the findings of Warghat *et al.* (2020) suggests that while botanical pesticides provide sustainable control, synthetic insecticides such as Lambda Cyhalothrin and Spinosad yield higher returns. The results of Ghodake *et al.* (2024) and Dabhade *et al.* (2024) further reinforce that although microbial pesticides are environmentally friendly, they offer lower economic benefits compared to chemical alternatives. Additionally, the results align with Vinayaka *et al.* (2019), highlighting the superior performance of Spinosad and Emamectin Benzoate in maximizing brinjal productivity. The study highlights that Neem oil 1500 ppm remains the most economically viable option, providing the highest cost-benefit ratio among the treatments tested. Lambda Cyhalothrin and Spinosad also demonstrated excellent returns with significant yield increases. Comparisons with previous research confirm the reliability of these treatments in managing *Leucinodes orbonalis*. However, bio-pesticides such as *Beauveria bassiana* and *Metarhizium anisopliae* showed limited efficacy, aligning with past research. Future studies should focus on integrated pest management approaches, combining bio-rational and chemical strategies to enhance sustainable brinjal cultivation.

**Conclusion**

Among the different treatments, Spinosad 45% SC recorded the highest yield (110.78 q/ha) followed by Emamectin benzoate 5% SG (97.22 q/ha) and Lambda cyhalothrin 5 EC (97.00 q/ha). In terms of economic viability, Neem oil 1500 ppm emerged as the most cost-effective treatment with the highest Incremental Cost-Benefit Ratio (ICBR) of 17.82, followed by Lambda cyhalothrin 5% EC (9.47) and NSKE 5% (4.99). These findings align with the studies of Shrivastava and Jat (2022), Warghat *et al.* (2020) and Vinayaka *et al.* (2019), who reported the superior efficacy of Spinosad and Emamectin benzoate in pest management. Hence, Spinosad 45 SC is recommended for higher yields, while Neem oil 1500 ppm is suggested for economic sustainability in brinjal pest management.

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**Table 1: Details of treatments**

|  |  |  |  |
| --- | --- | --- | --- |
| **S. No.** | **Name of Treatments** | **Trade Name** | **Dose** |
| **T1** | Neem oil 1500 ppm | Amar Neem | 1 ml/L |
| **T2** | NSKE 5% | Prepared in laboratory | 5 ml/L |
| **T3** | *Beauveria bassiana* | Green Beauveria | 5 ml/L |
| **T4** | *Metarhizium anisopliae* | Green Meta | 5 ml/L |
| **T5** | *Bacillus thuringiensis* Var. *Kurstaki* | Green Larvicide | 5 ml/L |
| **T6** | Emamectin benzoate 5% SG | Metro | 1 g/L |
| **T7** | Spinosad 45% SC | Tracer | 0.20 ml/L |
| **T8** | Lambda cyhalothrin 5% EC | Reeva-5 | 2 ml/L |
| **T9** | Control (Untreated) | - | - |

**Table 2: Incremental Cost Benefit Ratio (ICBR) of different insecticides and bio-pesticides against brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenee) during *Kharif*, 2022**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S. No.** | **Name of Treatments** | **Qty. of Insecticides req./ha for 3 spray in ml** | **Cost of treatment (Rs./ha)** | **Total cost** | **Yield per plot** | **Yield (q/ha)** | **Increase yield over control** | **Values of Increased yield** | **Net benefit** | **ICBR** | **Ranking** |
| **Pesticide charges** | **Labour+ Sprayer charges** |
| **1** | Neem oil 1500 ppm | 1500 | 960 | 1038.00 | 1998.00 | 6.93 | 77.00 | 42.44 | 38196 | 36198.00 | 18.12 | I |
| **2** | NSKE 5% | 7500 | 4875 | 1038.00 | 5913.00 | 6.77 | 75.22 | 40.66 | 36596 | 30683.00 | 5.19 | III |
| **3** | *Beauveria bassiana* | 7500 | 7500 | 1038.00 | 8538.00 | 4.93 | 54.78 | 20.22 | 18196 | 9658.00 | 1.13 | VII |
| **4** | *Metarhizium anisopliae* | 7500 | 7500 | 1038.00 | 8538.00 | 4.67 | 51.89 | 17.33 | 15596 | 7058.00 | 0.83 | VIII |
| **5** | *Bacillus thuringiensis* Var. *Kurstaki* | 7500 | 5625 | 1038.00 | 6663.00 | 5.45 | 60.56 | 26.00 | 23396 | 16733.00 | 2.51 | VI |
| **6** | Emamectin benzoate 5% SG | 1500 | 12900 | 1038.00 | 13938.00 | 8.37 | 93.00 | 58.44 | 52596 | 38658.00 | 2.77 | V |
| **7** | Spinosad 45% SC | 300 | 10500 | 1038.00 | 11538.00 | 9.35 | 103.89 | 69.33 | 62396 | 50858.00 | 4.41 | IV |
| **8** | Lambda cyhalothrin 5% EC | 3000 | 4080 | 1038.00 | 5118.00 | 8.13 | 90.33 | 55.77 | 50196 | 45078.00 | 8.81 | II |
| **9** | Control (Untreated) | - | - | - | - | 3.11 | 34.56 | - | - | - | - | IX |

**Table 3: Incremental Cost Benefit Ratio (ICBR) of different insecticides and bio-pesticides against brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenee) during *Kharif*, 2023**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S. No.** | **Name of Treatments** | **Qty. of Insecticides req./ha for 3 spray in ml** | **Cost of treatment (Rs./ha)** | **Total cost** | **Yield per plot** | **Yield (q/ha)** | **Increase yield over control** | **Values of Increased yield** | **Net benefit** | **ICBR** | **Ranking** |
| **Pesticide charges** | **Labour+ Sprayer charges** |
| **1** | Neem oil 1500 ppm | 1500 | 960 | 1038 | 1998 | 7.13 | 79.22 | 41.78 | 37604 | 35606 | 17.82 | I |
| **2** | NSKE 5% | 7500 | 4875 | 1038 | 5913 | 6.91 | 76.78 | 39.34 | 35404 | 29491 | 4.99 | III |
| **3** | *Beauveria bassiana* | 7500 | 7500 | 1038 | 8538 | 4.87 | 54.11 | 16.67 | 15004 | 6466 | 0.76 | VII |
| **4** | *Metarhizium anisopliae* | 7500 | 7500 | 1038 | 8538 | 4.77 | 53.00 | 15.56 | 14004 | 5466 | 0.64 | VIII |
| **5** | *Bacillus thuringiensis* Var. *Kurstaki* | 7500 | 5625 | 1038 | 6663 | 5.37 | 59.67 | 22.23 | 20004 | 13341 | 2.00 | VI |
| **6** | Emamectin benzoate 5% SG | 1500 | 12900 | 1038 | 13938 | 8.75 | 97.22 | 59.78 | 53804 | 39866 | 2.86 | V |
| **7** | Spinosad 45% SC | 300 | 10500 | 1038 | 11538 | 9.97 | 110.78 | 73.34 | 66004 | 54466 | 4.72 | IV |
| **8** | Lambda cyhalothrin 5% EC | 3000 | 4080 | 1038 | 5118 | 8.73 | 97.00 | 59.56 | 53604 | 48486 | 9.47 | II |
| **9** | Control (Untreated) | - | - | - | - | 3.37 | 37.44 | - | - | - | - | IX |

Note-

1. Labour charges for one spray/ha @ Rs. 237 labour /day, **four** labour required for each treatment
2. Sprayer pump hiring charge/ha @ Rs. 90 for each treatment
3. Sale value of brinjal @ Rs.900 /qtl.



**Figure 1: Comparison of Yield and ICBR of different treatments against brinjal shoot and fruit borer in Kharif 2022-23**