Efficacy of bio-rational pesticides for the management of *Leucinodes orbonalis* Guenee in Rupandehi, Nepal

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ARTICLE INFO

Keywords:
Bio-rational  
Brinjal  
Leucinodes orbonalis  
Management  
Monitoring

ABSTRACT

The field experiment was conducted from March to June of 2017 in field conditions at the Institute of Agriculture and Animal Science (IAAS), Paklihawa Campus, Rupandehi, Nepal to evaluate the efficacy of botanicals, microbial, and chemical insecticide against *Leucinodes orbonalis* Guenee. We assessed seven treatments including control in randomized complete block design with four replications and two sprays. The treatments evaluated for the management of *L. orbonalis* were i) Jholmal, 250 ml/l of water ii) *Beauveria bassiana* (Daman), 4 g/l water iii) *Abamectin* 5 % (Biotrine), 0.5 ml/l of water iv) *Bacillus thuringiensis* var. *kurstaki* (Mahastra), 4 g/l of water v) Emamectin benzoate (Cobra), 0.5 g/l of water vi) Azadirachtin 1500 ppm (Neem Kavach), 5 ml/l of water vii) Control (pure water application). All the treatments applied were found to be superior to the control. The results revealed that the lowest percentage of infested fruit i.e. 57.97% and 34.52% were found at 14 days after the first and second spray of Emamectin benzoate treatment respectively, as well as it was found to be significant over control in both sprays. The marketable yield of plot treated with Emamectin benzoate in eggplant was found to be the highest i.e.7.19 t/ha and 7.13 t/ha which was followed by Neem Kavach with the yield of 6.69 t/ha and 7.06 t/ha and that of control plots was 2.98 t/ha and 2.56 t/ha after first and second spray respectively. Further, our study concluded both marketable yield and Benefit-Cost (BC) ratio of brinjal fruit were the highest under the treatment of Emamectin benzoate followed by Jholmal and Neem Kavach. From this experiment, we concluded that Emamectin benzoate was the most effective treatment for the management of *L. orbonalis* while Jholmal and Neem Kavach proved to be the best alternative.

1. Introduction

Brinjal (*Solanum melongena* L.) also known as eggplant or Aubergine (in Europe), is one of the chief solanaceous vegetables rich in plenty of vitamins, phenols, and antioxidants grown throughout the world (Gürbüz et al., 2018). After tomato, brinjal secures its place as the second most grown vegetable belonging to family Solanaceae, in major parts of Nepal in all cropping seasons; except at very high altitudes (Singh and Bhandari, 2015). It is one of the most highly consumed vegetables in Nepal, India, and other South Asian countries (Thapa, 2010). It is cultivated in 8,732 ha of land with an average annual production of 126,475 tonnes with a productivity of 14.48 t/ha (MOALD, 2020) which is far behind global productivity of 29.87 t/ha (production: 55,197,878 tonnes, area cultivated: 1,847,787 ha) (FAO, 2019).

Different limiting factors such as insect pests, disease, and weeds, are associated with the declined production of brinjal. Brinjal is likely to be attacked by 140 species of insect pest (Sharma and Tayde, 2017). Among the plethora of insect pests that attack Brinjal, Brinjal Shoot and Fruit Borer (BSFB) *Leucinodes orbonalis* Guenee (Lepidoptera, Crambidae) is one of the most serious pests and crucial constraints of successful brinjal production. It damages all life stages of eggplant thereby shrinking the production of the crop (Gautam et al., 2019; Kalawate and Dethe, 2012). BSFB is the limiting factor for impairing both quantitative and qualitative harvest of the brinjal (Rahman et al., 2019). BSFB is regarded as one of the key pests of brinjal not only in Nepal but it is found to be equally dreadful in India, Bangladesh, Pakistan, Philippines, Cambodia, Thailand, Laos, and Vietnam (Mainali, 2014; Misra, 2008). The reduction in yield due to BSFB was reported to be as high as 70–92% (Dhandapani...
et al., 2003; Nair, 1986) but the study by Jagganavar et al. (2009) and Misra (2008) showed 85–90% yield loss due to BSFB.

Once the larva starts to bore tender shoots and buds, it causes a dead heart resulting in the wilting and death of the growing tips. Final instar larvae bore the fruits, characterized by small entrance holes closed by dried excrement which is not desirable for marketing (Atwal, 1986; CABI, 2018). Mostly, an infestation of the shoot and fruit borer coincides with the onset of the flowering stage and reaches its peak during the fruiting stage (Srinivasan, 2009).

Since L. orbonalis inhabits inside the bud, fruit, or shoot, it is not handy for their control. This leads to heavy crop loss which markedly causes a huge economic loss. The infestation is equally likely to occur all year round (Mannan et al., 2015). Reduction in brinjal yield due to L. orbonalis is significantly higher because of its prolific reproduction potential and quick turn over of its generation (Sharma and Tayde, 2017). Chemical pesticides are often primarily used by the farmers without considering a standard number of sprays per unit area to get rid of undesirable insect pests. Some study shows farmers rely heavily on pesticides for the management of pest associated with brinjal (Shetty, 2004). In order to get a high marketable yield, farmers apply chemical pesticides up to 7–8 times in most brinjal growing countries, which is exceptionally high in some Asian countries, like the Philippines and Bangladesh (Shukla et al., 2019). The practice of use of chemical pesticides, on one hand, increases the cost of production and on other hand, creates a toxic environment for the beneficial insects. The cost of pesticide to total cost of input requirement in brinjal was found to be 55%, which was high in comparison to cabbage with 49% and 31% in tomatoes in the Philippines (Orden et al., 1994). Similarly, irrational and unwise use of chemical pesticides results in pesticide resistance build-up in pests, formation of superbug, pest resurgence and secondary pest outbreak (Antwi and Reddy, 2015). The use of chemicals is discouraged by Atreya (2008) as brinjal fruits are harvested periodically at short intervals. It is therefore imperative to resort to non-chemical strategies to manage pests, which is eco-friendly and safe to human and environmental health. Therefore, this study was conducted to evaluate the efficient and eco-friendly approach of controlling BSFB using bio-rational products and the deterrent of the use of chemical pesticides.

2. Methodology

2.1. Site selection

The experiment was laid at a horticulture farm (27° 30’ N latitude and 83° 27’ E, 110 msl) of Paklihawa Campus, Rupandehi district, Lumbini Province, Nepal. Rupandehi is one of the major districts producing brinjal (MOALD, 2020).

2.2. Agronomic practices

Seedlings were raised in a solarized nursery bed (1 m, 1 m, and 0.15 m) in the first week of March 2017. Cultural practices were followed as suggested by Singh and Bhandari (2015). Thirty day old brinjal seedlings of variety F1 hybrid No 704 (Produced by Sungrow seeds) were transplanted by maintaining recommended spacing (PP*RR = 60 cm*60 cm), fertilizer requirement i.e. 20 t/ha of FYM and 200:180:80 kg NPK/ha (Singh and Bhandari, 2015). Nitrogen was incorporated in the form of urea in two split doses; first dose on 30 April 2017 and that second on 13 May 2017.

2.3. Experimental setup

The experiment was conducted in Randomized Complete Block Design (RCBD) design with seven treatments and four replications. One meter spacing was maintained between blocks and a 50 cm distance was maintained between individual plots within blocks.

2.4. Preparation of material for experiment

We evaluated seven treatments in our study. Table 1 shows the treatments deployed i.e. Jholmal, Daman, Biotrine, Mahastra, Cobra, Neem Kavach with different dosages and control.

Besides Jholmal, which was prepared at the research site, all other treatments were purchased from the Bhaarahawa market. Pure water was applied as a control treatment.

2.4.1. Preparation of Jholmal

Botanicals were collected from the premises of the research site and chopped into small pieces (5–10 cm). The next day, chopped botanicals were weighed as per the amount given in Table 2 and mixed with ten litres of fresh cow urine. One kilogram of fresh cow dung and one litre of effective microorganism (EM) was also added to the mixture and stirred for five minutes. The final mixture was kept in a plastic container (twenty litre capacity) and sealed with its cover and left for twenty one days to allow fermentation. After three weeks, the mixture was stirred for ten minutes and the liquid was separated using a strainer. The final solution (Jholmal) was diluted at the ratio of 1:4 with water and applied in the allotted field using a sprayer (ICIMOD, 2016). Table 2 shows the botanicals used for the preparation of Jholmal in our study.

2.4.2. Preparation and application of treatments

Treatments were prepared based on the instructions provided by the manufacturer company (Table 1). All the given treatments were applied with the help of a hand sprayer manufactured by Koval Classic Industries of a two-litre capacity. Treatment was sprayed during the late afternoon.
Table 1. Detail of treatments with trade name, active ingredients and doses.

| Treatments | Trade Name            | Manufacturer                                | Active Ingredients                                                                 | Dose (per litre of water) |
|------------|-----------------------|---------------------------------------------|------------------------------------------------------------------------------------|--------------------------|
| T1         | Jholmal               | N/A                                         | Cow urine, neem, mugwort, sweet flag, Sichuan pepper, garlic leaves.                | 250 ml                   |
| T2         | Daman                 | International Panaacea Limited             | B. bassiana spores 2% Wettable Powder (WP)                                        | 4 g                      |
| T3         | Biotrine              | Russell IPM Ltd., U K                       | Abamectin 5% w/w                                                                   | 0.5 ml                   |
| T4         | Mahatra               | International Panaacea Limited             | B. thuringiensis var. kurstaki Delta endotoxin 0.5% Wettable powder (WP)           | 4 g                      |
| T5         | Cobra                 | Global green Technologies                   | Emamectin benzoate 5% Water Dispersal Granules (WDG)                                | 0.5 g                    |
| T6         | Neem Kavach           | International Panaacea Limited             | Azadirachtin 1500 ppm (0.15 EC)                                                   | 5 ml                     |
| T7         | Control               | N/A                                         | Pure water                                                                         | N/A                      |

and two treatments were given during the experiment, one at fifty eight days after transplanting (DATG) and another at seventy three DATG. Ten percent damage on shoot and fruit was considered the economic threshold level for the application of treatments (Latif et al., 2009).

2.5. Data collection and statistical analysis

Observation parameters during the experiment were infested fruit and healthy fruit only and were recorded from four sample plants from each plot at three, seven, ten, and fourteen days after treatment (DAT). Marketable yield of brinjal fruit was also calculated but we did not record the data regarding shoot infestation because our concern was to record data related to healthy and infested fruit, the weight of marketable fruits of brinjal plant, percent fruit infestation and benefit to cost ratio of the eggplant. The collected data in this study was arranged in MS Excel 2016 and statistically analyzed with the help of the agricole package (de Mendiburu, 2016) RStat version 3.6.1 (The R Foundation, 2018). Means were separated using Duncan’s Multiple Range Test (DMRT) at a 5% level of significance (Gomez and Gomez, 1984).

2.5.1. Percent fruit infestation

Percent fruit infestation was calculated using Eq. (1).

\[
\text{Percent fruit infestation} = \frac{(\text{Number of infested fruit} \times 100)}{\text{Total number of fruits}}
\]  

(1)

2.5.2. Benefit - cost ratio calculation

The Benefit-Cost Ratio (BCR) is a relative measure for comparing benefits to per unit of costs. Benefit-Cost Ratio helps to analyze the financial efficiency of the vegetable crops and it was calculated using Eq. (2).

\[
\text{Benefit – Cost Ratio (BCR) = } \frac{\text{(Adjusted Net return)}}{\text{Total cost of production including plant protection cost}}
\]  

(2)

3. Results

The inclusion of biological methods in controlling pests is the mainstay of Integrated Pest Management (IPM) to overcome the hazardous effects due to the haphazard use of chemical pesticides. The result compared the mean percentage of infested fruit per sample plant at different DAT and the marketable yield harvested from tested plots.

Cobra was found to be the most effective treatment followed by Jholmal and Neem Kavach in reducing the pest infestation at all observed dates, both in the first and second spray. The highest attack of BSFB was recorded in the plot sprayed with water (control). The effect of treatments on reducing the pest infestation was statistically significant compared to control at all observed dates. Similarly, Biotrine, Mahatra, and Daman showed an average effect to reduce pest infestation on brinjal fruit on all observed days (Table 3). However, at 7 DAT of the second spray, Jholmal treated plot showed a statistically similar result with Cobra.

Our study revealed that the marketable yield of eggplant treated with Emamectin benzoate was the highest i.e. 7.19 t/ha and 7.13 t/ha which was followed by azadirachtin with the yield of 6.69 t/ha and 7.06 t/ha after the first and second spray respectively.

All the biorational pesticides seemed to significantly reduce the attack of BSFB. The control plot was heavily infested by the attack of BSFB. The effects of the biorational pesticides on the infestation of brinjal fruit are shown in Table 3.

BC (Benefit-Cost) ratio of brinjal fruit under seven different treatments was assessed (Table 4). The cost of brinjal production by applying Mahatra was the highest (580.76$) followed by Neem Kavach (550.67$) and Daman (550.13$). Similarly, the application of Cobra gave the highest gross return (1869.35$) followed by Neem Kavach (1794.62$) and Jholmal (1705.95$).

From our experiment, we found the highest BC ratio of brinjal treated with Cobra (2.19) having the marketable yield of 14.33 t/ha followed by Jholmal (1.96), Neem Kavach (1.94), Daman (1.38), Biotrine (1.33), Mahatra (1.28) and retaining the marketable yield of 13.07 t/ha, 13.75 t/ha, 11.41 t/ha, 11.08 t/ha and 11.27 t/ha, respectively. We analyzed the highest marketable yield of brinjal i.e. 14.33 t/ha from the plot treated with Cobra and the controlled plot gave the lowest brinjal yield 5.55 t/ha (Table 3). This clearly shows that the marketable yield of the brinjal was different with various treatments given to them. Although the marketable yield of Neem Kavach (13.75 t/ha) is higher than Jholmal (13.07 t/ha), the BC ratio of brinjal fruit under treatment of Jholmal is higher than that of Neem Kavach due to the low cost of production of Jholmal. The ingredients required for Jholmal preparation are locally available but Neem Kavach is not.

4. Discussion

From our experiment, we noted that the Emamectin benzoate was the most promising among tested bio-rational pesticides with the highest marketable yield (14.33 t/ha) while Neem Kavach (13.75 t/ha) and Jholmal (13.07 t/ha) could be used as next best alternatives after Emamectin benzoate. The result of our study is in agreement with the findings of Ghosal et al. (2013), Islam (2015), Shah et al. (2012), Sharma and Sharma (2010), and Sharma and Tayde (2017). Our results are in conformity with a study conducted by Pareet and Basavanagoud (2012) in India who concluded the yield of brinjal from the Emamectin benzoate treated plot was the highest compared to other treated plots. Islam et al. (2016) reported that 70.44% and 69.00% of fruits were protected when...
Table 2. Details of components of Jholmal.

| SN | Botanicals                        | Amount |
|----|-----------------------------------|--------|
| 1  | Neem leaves with seed (Azadirachta indica A. Juss) | 1.0 kg |
| 2  | Mugwort leaves (Artemisia vulgaris L.) | 0.5 kg |
| 3  | Sweet flag (Acorus calamus L.) | 0.5 kg |
| 4  | Sichuan pepper (Zanthoxylum armatum DC) | 0.5 kg |
| 5  | Garlic leaves (Allium sativum L.) | 0.5 kg |
| 6  | Effective microorganism (EM) | 1 L    |

Table 3. Effect of biorational pesticides on percentage of brinjal fruit infestation caused by Brinjal Shoot and Fruit Borer.

| Treatments | First spray | Second spray |
|------------|-------------|--------------|
|            | 3DAT        | 7 DAT        | 10 DAT | 14 DAT | 3DAT | 7DAT | 10DAT | 14DAT |
| Jholmal, 250 ml/l water | 68.58±1.28 | 60.55±1.40 | 64.63±1.90 | 65.61±1.33 | 44.84±2.00 | 40.62±1.73 | 44.36±1.84 | 43.61±4.24 |
| Daman, 4 g/l water | 69.56±3.68 | 70.44±2.92 | 65.95±1.58 | 65.43±1.69 | 62.12±0.42 | 66.98±1.52 | 66.80±1.58 | 66.14±1.31 |
| Biorine, 0.5 ml/l water | 76.14±0.67 | 67.75±1.50 | 67.99±1.26 | 69.32±1.72 | 43.96±1.71 | 50.60±0.96 | 44.64±2.21 | 43.75±1.17 |
| Mahatra, 4 g/l water | 74.32±3.02 | 72.09±3.63 | 71.03±2.08 | 68.29±3.94 | 73.41±0.76 | 72.62±2.38 | 73.16±2.89 | 73.28±1.02 |
| Cobo, 0.5 g/l water | 61.72±1.19 | 57.66±1.38 | 59.96±0.59 | 57.97±2.87 | 38.98±0.58 | 35.46±2.57 | 36.64±2.84 | 34.52±3.94 |
| Neem Kavach, 5 ml/l water | 67.14±1.66 | 66.80±1.98 | 67.21±0.74 | 64.09±2.86 | 42.22±0.90 | 48.29±1.02 | 47.58±2.33 | 43.41±0.57 |
| Control | 84.38±1.10 | 82.70±1.97 | 84.02±1.86 | 84.87±1.60 | 84.40±1.26 | 83.68±1.03 | 83.93±1.49 | 85.12±1.15 |

Mean in column with same superscript is not significant at 5% level of significance (P > 0.5). ** = 0.001 ‘*’ = 0.01 ‘*’ = 0.05, DAT = Days after Treatment, l = litre, g = gram, ml = millilitre.

Table 4. Effects of different treatments on total marketable yield and BC ratio of brinjal fruit.

| Treatments | First harvest (kg/ha) | Second harvest (kg/ha) | Total marketable yield (kg/ha) | Gross return (NRS) | Gross return of production (US$) | Adjusted net return (US$) | BC ratio |
|------------|-----------------------|-----------------------|-------------------------------|-------------------|-------------------------------|--------------------------|--------|
| Jholmal, 250 ml/l water | 6676.5 | 6402.43 | 13.07 | 196184 | 170595 | 500.51 | 981.28 | 1.96 |
| Daman, 4 g/l water | 5835.59 | 5575.58 | 11.41 | 171167.6 | 148841 | 550.13 | 763.75 | 1.38 |
| Biorine, 0.5 ml/l water | 5677.95 | 5407.56 | 11.08 | 166282.7 | 1445.94 | 540.54 | 721.27 | 1.33 |
| Mahatra, 4 g/l water | 5667.27 | 5609.24 | 11.27 | 169147.7 | 1470.85 | 580.76 | 746.19 | 1.28 |
| Cobo, 0.5 g/l water | 7192.01 | 7139.67 | 14.33 | 214975.2 | 1869.35 | 520.27 | 1144.69 | 2.19 |
| Neem Kavach, 5 ml/l water | 6693.05 | 7065.67 | 13.75 | 206380.8 | 1794.62 | 550.67 | 1069.96 | 1.94 |
| Control | 2988.02 | 2567.7 | 5.55 | 83335.8 | 724.65 | 400.32 | 594.22 | - |

L = litre, BC Ratio = Benefic Cost Ratio US$1 = NRS 115, wholesale price of brinjal fruit NRS 15 per kg; t = 1000 kg.
Coquillett), the 'Jholmal' treatment contributed to a total marketable fruit production of 62.8 t/ha. They also found the total number of marketable fruits harvested per plant in the 'Jholmal' treated plot was nearly double than in the control plot.

Entomopathogenic fungus, for eg. *B. bassiana* could be a potential biopesticide to control BSBF (Pal and Ghosh, 2014). Further, we found the gross return due to the application of Daman was about two times the of the controlled plot in our study. But according to Ghosh and Pal (2015) and Rahman et al. (2019), the yield of crops treated with *B. bassiana* was found to be 37.7% higher than that of the control. Also, the BC ratio of brinjal fruit under the treatment by Emamectin benzoate was superior to that of Neem Kavach which is supported by the result of Sharma and Tayde (2017). Similarly, our result is agreed with the findings of Yousaifi et al. (2016), who reported Emamectin benzoate as the most economical with the highest BC ratio than spinosad applied in the field for the management of BSBF.

5. Conclusion

All of the evaluated bio-rational insecticide-based management strategies of BSBF were successful in lowering the fruit infestation while also increasing marketable fruit production. From the experiment, it is clear that all the treatments were able to significantly lower the infestation of the obnoxious pest, BSBF in the field. We concluded that Emamectin benzoate was the best among the tested bio-rational pesticides, while Azadirachtin and Jholmal were equally efficacious for the management of BSBF. BC ratio of brinjal fruit was the highest under the treatment Emamectin benzoate followed by Jholmal and Neem Kavach. Thus, Neem Kavach and Jholmal could be the next best alternatives to manage *L. orbonalis* in field conditions. Considering the profitability and their non-deniable characters, like environmentally friendly reported in our findings, we can recommend to farmers, entomologists, and researchers in using Emamectin benzoate to control brinjal shoot and fruit borer. The benefits of using botanicals for the management of BSBF are economical and ecologically sound to the application of chemical pesticides. Due considerations to the development of alternatives of chemical pesticides for effective management of BSBF and their scientific validation should be prioritized.

6. Acknowledgements

The authors are grateful to Pakhiwara Campus, Institute of Agriculture and Animal Science (IAAS), Tribhuvan University for providing all the necessary inputs required for our study. The authors acknowledge Evelyn Platter from Iowa State University for assisting in English edit of the manuscript.

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Additional information

No additional information is available for this paper.

**Declarations**

**Author contribution statement**

Dipak Khanal: Conceived and designed the experiments;Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Radha Pandey; Radhika Dhakal; Nisha Neupane; Ankit Shrestha; Milan Nepali Joseph; Asmi Paudel: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Meena Pandey: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

**Funding statement**

This work was supported by Pakhiwara Campus, Institute of Agriculture and Animal Science (IAAS), Tribhuvan University.

**Data availability statement**

Data will be made available on request.

**Declaration of interests statement**

The authors declare no conflict of interest.
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Heliyon 7 (2021) e08286

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