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Research article

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

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A R T I C L E I N F O

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A B S T R A C T

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

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et al., 2003; Nair, 1986) but the study by Jagginavar 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 it's 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 and 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 ecofriendly and safe to human and environmental health. Thus, there is a dire need to come out with contrivance, which is both environmentally safe and ecologically sound pest control methods such as the use of biopesticides (Shukla et al., 2019).

The use of botanicals has shown a greater promise in Integrated Pest Management (IPM), which has been a part of agriculture since time immemorial (Roger, 1997). Jholmal, a natural bio-fertilizer and bio-pesticide is prepared using different botanicals having pesticidal values, preferably having a pungent smell like Neem along with cow urine, dung, etc (FAO, 2017). Apart from pesticide properties, Jholmal also acts as a source of fertilizer. Thus, it is preferred for its low cost of production, highly repulsive and has nutritious quality in Nepalese agriculture.

Microbial pesticides based on *Bacillus thuringiensis* Berliner, entomopathogenic fungus-like *Beauveria bassiana* (Balsamo) can be effective for the management of BSFB and incorporated as a component of IPM programs for successful control of insect pests of brinjal (Nawaz et al., 2020; Singh and Kaur, 2020; Wraight et al., 2000). Similarly, Abamectin, extracted from the soil bacterium *Streptomyces avermitilis* Kim and Goodfellow (Agarwal, 1998), which is a macrocyclic lactone disaccharide, is extensively used in agriculture (Nasr et al., 2016) for checking insect pest in various crops ranging from fruits and vegetables to ornamental crops (Lankas and Gordon, 1989). Abamectin was found to be effective to suppress BSFB infestation in brinjal fields where yield was significantly higher compared to control (Islam et al., 2019). Likewise, Emamectin benzoate is a novel macrocyclic lactone insecticide derived from naturally occurring avermectin isolated by fermentation from the soil microorganism, *Streptomyces avermitilis* (Ishaaya et al., 2002). Emamectin benzoate may be considered a valuable tool for the control of lepidopteran pests (Ioriatti et al., 2008). Azadirachtin, a tetranortriterpenoid, isolates of neem and other related plants, inhibits the metabolism of lactase dehydrogenase and is an important glycolytic enzyme present in all animals including insect tissues (Nathan et al., 2006). Azadirachtin was found to be efficacious against numerous insects (Jat and Pareek, 2001). The application of neem oil beneficially reduced pest population in fruit and spice crops (Adnan et al., 2014; Stanley et al., 2014). As brinjal is a vegetable crop meant to be consumed as a part of human food, the use of chemical insecticides is strongly discouraged to prevent contamination of toxic residue of chemical pesticides to human 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 masl) 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 Bhairahawa 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, mug wort, 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	Mahastra	International Panaacea Limited	*B. thuringiensis* var. *kurstaki* Delta endotoxin 0.5% Wettable powder (WP)	4 g
T5	Cobra	Global green Technologies	Emamectic 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 agricolae 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).

$$\text{Percent fruit infestation} = \frac{(\text{Number of infested fruit})*100}{\text{Total number of fruits}} \tag{1}$$

2.5.2. Benefic -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).

$$\text{Benefit} - \text{Cost Ratio (BCR)} = \frac{(\text{Adjusted Net return})}{\text{Total cost of production including plant protection cost}} \tag{2}$$

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, Mahastra, 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 Mahastra 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), Mahastra (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 (*Artemesia vulgaris* L.)	0.5 kg
3.	Sweet flag (*Acorus calamus* L.)	0.5 kg
4.	Sichuan pepper (*Zanthoxylem armatum* DC)	0.5 kg
5.	Garlic leaves (*Allium sativum* L.)	0.5 kg
6	Effective microorganism (EM)	1 L

treated with Emamectin benzoate 5 SG, 1 g/l and Abamectin 1.8 EC, 1 ml/l, respectively.

In contrast to our study, Sharma and Sharma (2010) found the bio efficacy of Emamectin benzoate was the lowest (0.002%) as compared to endosulfan (0.05%) and novaluron (0.01%). However, in consideration of the detrimental effects of endosulfan, these are banned for use. Similarly, Tracer 45 SC (Spinosad) was found to be an effective pesticide over Emamectin Benzoate, which could be used to control the brinjal shoot and fruit borer in brinjal production (Islam et al., 2019). According to the findings of Satpathy and Mishra (2011), the response of *L. orbonalis* towards Neem seed kernel extract (4%) and the neem-based product Neemarin® was detrimental than that of ash dust. Furthermore, the past results of the experiment by Noor et al. (2017); Satpathy and Mishra (2011); and Sharma and Tayde (2017) proved the use of Neem Kavach protected brinjal fruit significantly from BSFB infestation. Likewise, in a separate study conducted by Ullah et al. (2021), it was reported that Neem oil 5% had the lowest shoots and fruits infestation, the most flowers per plant and the maximum brinjal yield of various botanical extracts tested.

In the experiment conducted by Noor et al. (2017), among biopesticides, *Beauveria bassiana* showed efficient treatments against BSFB, with mean shoot infestations of 12.38% compared to 24.20 % in control plots. However, in our study, we found Cobra followed by Jholmal and Neem Kavach to be comparatively effective in the management of BSFB. The majority of studies on the application of insecticides showed that Emamectin benzoate was the most effective control measure for the management of BSFB which was also successful in destroying 4th instar larvae of BSFB significantly (Awal et al., 2014; Gautam et al., 2019).

From our study, it is demonstrated that the plot treated with Emamectin benzoate harbored less BSFB and the least percentage of infested fruits, and the highest marketable yield. Our findings were consistent with research conducted by Anwar et al. (2015); Patra et al. (2009) and Shah et al. (2012) who reported Emamectin benzoate as the most beneficial in controlling and present the crop damage and subsequent increment in brinjal production which was also found by Sharma and Sharma (2010). Our findings are supported by Kameshwaran & Kumar (2015) who concluded that shoot and fruit damage was significantly reduced by the application of Emamectin benzoate 25 WG, 11 g a.i./ha which gave a considerable yield of brinjal fruit, according to the research conducted in India. Spinosad 45 SC and Emamectin benzoate 5 SG, 0.002% was found to be equally efficacious for lowering the infestation of BSFB (Warghat et al., 2020). Our research findings illustrated that foliar application of *Bacillus thuringiensis* (Bt) effectively reduced the damage of BSFB which is in consistent with the result of Krishna et al. (2002) and Nawaz et al. (2020). In addition, Bt is recommended as a major component of IPM against BSFB (Akter et al., 2018).

In our study, Jholmal was found to be efficacious after Emamectin Benzoate with the highest BC ratio. It is mentioned that by the use of Jholmal, the farmer saved up to NRs 25,000 (US$ 217.39) in a year, which they used to spend on synthetic pesticides and fertilizers for managing the pests in their vegetables (Dhungana, 2016). According to the results of the field experiment conducted by Sapkota & Thapa (2009) for the field management of cucurbit fruit fly (*Bactrocera cucurbitae*

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	$68.53^{cd} \pm 1.28$	$60.55^{cd} \pm 1.40$	$64.63^{c} \pm 1.90$	$65.61^{bc}\pm1.33$	$44.85^{d} \pm 2.00$	$40.62^{e} \pm 1.73$	$44.36^{c} \pm 1.84$	$43.61^{c} \pm 4.24$
Daman,4 g/l water	$69.56^{cd} \pm 3.68$	$70.44^{b} \pm 2.92$	$65.95^{bc}\pm1.58$	$65.43^{bc}\pm1.69$	$62.12^{c} \pm 0.42$	$66.98^{c} \pm 1.52$	$66.80^{b} \pm 1.58$	$66.41^{b} \pm 1.31$
Biotrine, 0.5 ml/l water	$76.14^{b} \pm 0.67$	$67.75^{b} \pm 1.50$	$67.99^{bc}\pm1.26$	$69.32^{b} \pm 1.72$	$43.96^{d} \pm 1.71$	$50.60^{d} \pm 0.96$	$44.64^{c} \pm 2.21$	$43.75^{c} \pm 1.17$
Mahastra,4 g/l water	$74.32^{bc}\pm3.02$	$72.00^{b} \pm 3.63$	$71.03^{b} \pm 2.08$	$68.29^{b} \pm 3.94$	$73.41^{b} \pm 0.76$	$72.62^{b} \pm 2.38$	$73.16^{b} \pm 2.89$	$73.28^{b} \pm 1.02$
Cobra,0.5 g/l water	$61.72^{e} \pm 1.19$	$57.68^{d} \pm 1.28$	$59.90^{d} \pm 0.59$	$57.97^{c} \pm 2.87$	$38.98^{e} \pm 0.58$	$35.46^{f} \pm 2.57$	$36.64^{d} \pm 2.84$	$34.52^{d} \pm 3.94$
Neem Kavach,5 ml/l water	$67.14^{de} \pm 1.66$	$66.80^{bc}\pm1.98$	$67.71^{bc}\pm0.74$	$64.09^{bc}\pm2.86$	$44.22^{d} \pm 0.90$	$48.29^{d} \pm 1.02$	$47.58^{c} \pm 2.33$	$44.31^{c} \pm 0.57$
Control	$84.38^{a} \pm 1.10$	$82.70^{a} \pm 1.97$	$84.02^{a} \pm 1.86$	$84.87^{a} \pm 1.60$	$84.40^{a} \pm 1.26$	$83.68^{a+}\pm1.03$	$83.93^{a} \pm 1.49$	$85.12^{a} \pm 1.15$
Grand mean	71.68	68.27	68.74	67.94	55.99	56.89	56.73	55.86
$LSD_{0.05}$	5.75***	6.44***	4.71***	7.4***	3.75***	4.85***	6.93***	6.97***
CV	5.40	6.35	4.61	7.33	4.51	5.74	8.22	8.40
F value	14.30	14.19	22.71	11.12	6.39	10.68	21.77	22..03

Mean in column with same superscript is not significant at 5% level of significance ($P \geq 0.5$). '***' 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(t/ha)	Gross return (NRS)	Gross return (US$)	Total cost of production (US$)	Adjusted net return (US$)	BC ratio
Jholmal, 250 ml/l water	6676.5	6402.43	13.07	196184	1705.95	500.51	981.28	1.96
Daman, 4 g/l water	5835.59	5575.58	11.41	171167.6	1488.41	550.13	763.75	1.38
Biotrine, 0.5 ml/l water	5677.95	5407.56	11.08	166282.7	1445.94	540.54	721.27	1.33
Mahastra, 4 g/l water	5667.27	5609.24	11.27	169147.7	1470.85	580.76	746.19	1.28
Cobra, 0.5 g/l water	7192.01	7139.67	14.33	214975.2	1869.35	520.7	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	5.555	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 BSFB (Pal and Ghosh, 2014). Further, we found the gross return due to the application of Daman was about two times that 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 Yousafi 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 BSFB.

5. Conclusion

All of the evaluated bio-rational insecticide-based management strategies of BSFB 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, BSFB 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 BSFB. 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 BSFB 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 BSFB and their scientific validation should be prioritized.

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; Ankita 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.

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Data availability statement

Data will be made available on request.

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The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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