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Efficacy of Potassium Fertilizer and Certain Pesticides for the Management of Brinjal Fruit Infection by Shoot Borer [*Leucinodes Orbonalis* (Guenée)]

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Abstract: The research aims to evaluate the efficacy of different levels of potassium fertilizer (8 g/plant K_2O) as well as the insecticides neemix, spinosad, and imidacloprid at the rates of 6 ml, 0.33 ml, and 0.33 g/L water, respectively, for the management of brinjal fruits and shoot borer. The two-factor randomized complete block design with three replications was used. Significant minimum shoot damage was recorded in the plots treated with imidacloprid (0%), spinosad (1.67%) and neemix (5.0%) at 81 days after planting. Similarly, a significant minimum fruit infestation (2.90%) was recorded with imidacloprid, which was lower than those of spinosad (15.16%) and neemix (19.63%). The application of potassium fertilizer at a rate of 8 g/plant showed a significant reduction in shoot infestation (2.50%) 81 days after planting. The minimum percentage yield of infested fruit was reported with spinosad (1.03%), which was at par with other insecticidal treatments. Considering the negative impacts of chemical pesticides, neemix 6 ml/L water in combination with potassium fertilizer at 8 g/plant is recommended.

1 Introduction

Brinjal (*Solanum melongena*) is a commonly grown tropical and subtropical vegetable belonging to the family of Solanaceae. It is reported to be native to the Indo-Pak subcontinent and grown all over the world where hot and wet climates prevail (Dash et al 2020). It is the most common vegetable crop species grown annually for its fruit all over the world, except for areas with higher altitudes (Gotame et al 2020). It is a popular vegetable crop species in Nepal. A total of 149,075 Mt of brinjal was produced with a productivity of 13.20 Mt/ha in an area of 11,292 ha in the fiscal year 2021/22 (MOALD 2022). The productivity of brinjal varies all over Nepal, with 12.33 Mt/ha in the central region of Nepal, 13.3 Mt/ha in the western part of Nepal and 16.79 Mt/ha in eastern Nepal (MOALD 2022). Several pests attack the brinjal crop right from germination to harvest, *viz*., shoot and fruit borer (*Leucinodes orbonalis* (L.) Guen), jassid (*Amrasca biguttula biguttula*), aphid (*Aphis gossypii* Glover), lacewing bug (*Urentius echinus* Distant), Epilachna beetle (*Epilachna vigintioctopunctata* Fab) and stem borer (*Euzophera perticella* Ragonot)

(Prasad et al 2008). Shoot and fruit borer alone has been reported to cause more than 63% yield loss in brinjal (Omprakash and Raju 2014). Shoot and fruit borer (*Leucinodes orbonalis*) is one of the major pests, resulting in significantly higher damage to the crop during the early vegetative phase of crop development of the total pest infestation on the brinjal crop, fruit and shoot borer alone has been found to contribute losses as high as 89-90% in India (Prasad et al 2008). In one of the surveys, 50% of the total fruits damaged in brinjal were found to be caused by brinjal fruit and shoot borer in Nepal (Achhami et al 2013).

Shoot and fruit borer is active throughout the year and lays eggs one by one up to 250 eggs on the developing fruits and the shoots of the brinjal plant (Javed et al 2017), with an incubation period of 3.9 days (Ponnusamy 2021). The larva is pink in color and is covered with uniformly distributed hairs all over the body (Javed et al 2017). The monophagous insect is difficult to control as the larvae are often hidden in the fruits, which prevents direct contact with the chemical pesticide (Preedy et al 2016). There are five instar phases of larvae, with the latter one more damaging than the earlier one; the total larval period is 15.86 days (Ponnusamy et al 2021). Pupation takes place as a tough silken cocoon among the fallen leaves, while the pupal stage lasts for 5.76 days (Ponnusamy et al 2021). The total life duration of the brinjal fruit and shoot borer (BFSB) is 35.2 days (Ponnusamy et al 2021). The young larvae bore into the nearest tender shoot, flower or fruit, destroying fruit tissues and making them unfit for marketing (Yousafi et al 2015). Infected shoots wilt and dry as the pest continues tunneling inside the stems, consuming tissue and making the plant weak. The infection intensifies towards the fruit and reduces towards the shoot as the plant enters the reproductive phase from the vegetative phase (Kumar and Singh 2013 and Naqvi et al 2009).

The management of this pest is possible only through the calendar spraying of conventional insecticides, irrespective of pest incidence (Shirale et al 2012). Bio-pesticides, botanicals, chitin synthesis inhibitors and many new insecticides have previously been evaluated against BFSB (*L.orbonalis*) by many researchers to control the infestation of the pest under field conditions (Sharma and Kaushal 2010, Shirale et al 2012), these treatments are being used besides the conventional insecticides. However, the use of potassium fertilizer has been limited to a very short range of plant species to control insect pests. Amtmann et al (2008), Muhammad (2012) and Bajpai et al (2014), have shown that different potassium doses can alter the rate of infestation in different field crops. Sarwar (2012) reported that the application of K fertilizer recovered plant damage when attacked by larvae of borers in rice and also improved yield. Aziz et al (2018) reported that the use of potassium at a rate of 60 kg/ha reduced the infestation of yellow stem borer, leaf folder, rice hispa, grasshopper, brown planthopper, green leafhopper and rice bug insects in rice.

The haphazard and random pesticide application to control fruit and shoot borer can result in many problems e.g. pest resurgence, health hazards and high pesticide residue in fruits and soil (Shirale et al 2012). Moreover, as per our knowledge and available literature, the effect of potassium dose on pest infestation by BFSB on brinjal has not yet been evaluated. Thus, the objective of the study is to evaluate the level of infestation by BFSB on shoot, fruit and ultimately on the yield of brinjal by using different botanical and chemical pesticides and potassium fertilizer (K_2O) as the approach for integrated pest management.

2 Materials and Methods

2.1 Experimental site and experimental design

The study was carried out at the horticulture research field of Agriculture and Forestry University (AFU), Chitwan, Nepal. The experiment was carried out in field conditions during the summer season from June to September 2022. The location was 27.6505° N, 84.3503° E at an altitude of 385 m above sea level. The average monthly temperature was 32.5°C and the average monthly precipitation was 8 inches (Weather spark, 2022). The experiment was laid out in two factorials RCBD (Randomized Complete Block Design); the first factor was potassium fertilizer with three levels and the second factor was different pesticides with four levels. As the level of potassium in the soil was low, it was applied at a dose slightly higher than the recommended dose. However, all the insecticides were applied as permissible doses. The recommended dose of nitrogen and phosphorus was applied at the rate of N: P_2O_5, 100:50 kg/ha. There were eight treatments replicated 3 times in the experimental design (**Table 1**).

2.2 Seedling preparation and plantation

The brinjal seeds were planted on the tray for germination on 6th May 2022. The medium was prepared by mixing Coco-peat, vermiculite and perlite at a ratio of 3:1:1; the amount was set as required. The seedlings were transplanted in the main field on 18th June 2022 after 2-3 true leaves appeared on all the seedlings and attained a height of about 12-15 cm. The spacing of 75 cm × 55 cm was maintained on each plot with 12 plants. The plot-plot and block-block distance was maintained at 1m. The area of each plot was 4.3 m^2 (2.15 m × 2 m). Manual weeding was done three times at 20 DAP (Days after planting), 30 DAP, and 40 DAP. Irrigation was applied one day after each weeding.

Table 1. Details of the treatments used in the experiment

Treatment symbol	Description
T1 (K1M0)	K_2O @ 8 g/plant + no pesticide
T2 (K1M1)	K_2O @ 8 g/plant + Neemix (300 ppm) @ 6 ml/l water
T3 (K1M2)	K_2O @ 8 g/plant + Spinosad @ 1 ml/3l water
T4 (K1M3)	K_2O @ 8 g/plant + Imidacloprid @ 5 g/16l water
T5 (K0M0)	No K_2O + no pesticide
T6 (K0M1)	No K_2O+ Neemix (300 ppm) @ 6 ml/l water
T7 (K0M2)	No K_2O + Spinosad @ 1 ml/3l water
T8 (K0M3)	No K_2O + Imidacloprid @ 5 g/16l water

2.3 Spray of pesticides

Pesticides were sprayed at intervals of 60, 67 and 74 days after transplantation (DAP), by using an electric sprayer (model - HY-805, 16l capacity). Pre-spray refers to the collection of data just before the first spray of insecticides. The insecticides were mixed with the sticker “Tasin” before spraying. A sufficient amount of pesticides were sprayed on the shoot until runoff. The details of the pesticides are given in **Table 2**.

2.4 Data collection and analysis

Five plants in a plot out of 12 plants were randomly selected for data collection. The percentage of fruit infestation was calculated by using the following formula:

$$Fruit\ infestation\ (\%) = \frac{\text{Number of infested fruits}}{\text{The total number of fruits observed}} \times 100$$

Data on shoot infestation was collected from randomly tagged ten plants from the plot with infected and healthy shoots. Data were collected four times. One pre-treatment data was collected at 60 DAP. Afterward, three data were collected one week after each spray at 67 DAP, 74 DAP, and 81 DAP. The infested shoots from the selected plants were marked using a red ribbon tied around the shoot region to avoid recounting during the next data recording. Percent shoot infestation was calculated by using the following formula:

$$Shoot\ infestation\ (\%) = \frac{\text{Number of infested shoots}}{\text{Total number of shoots observed}} \times 100$$

Data entry was done in MS EXCEL and analysis was done in R-Studio version 4.1.2. The mean comparison was done by using Ducan’s Multiple Range Test (DMRT) at a 5% level of significance.

Table 2. Pesticides used during the experiment

S.N.	Common name	Trade name	Type of formulation	Conc.	Rate of used	Manufacturer country
1	Neemix (*Azadirachtin indica*)	Neem Raj	SC	300 ppm	6 (ml/L water)	India
2	Spinosad	Tracer	SC	45%	0.33 (ml/L water)	India
3	Imidacloprid	Guard	SC	30.5%	0.33 (g/L water)	India

3 Results and Discussion

3.1 Fruit infestation

Different pesticides had a significant impact on the percentage of fruit infestation at 74 DAP and 81 DAP (**Table 3**). The application of potassium fertilizer did not show any significant difference in the percentage of fruit infestation at all the dates of observation. At 74 DAP, the control plots showed maximum fruit infestation (32.84%). The lowest fruit infestation was observed in the plots sprayed with imidacloprid (5.91%) lower than neemix (16.79%) and spinosad (7.19%). At 81 DAP, the highest percentage of fruit infestation was observed with the control (29.44%), which was higher than neemix (19.63) and spinosad (15.16%). The minimum percentage of fruit infestation was observed with imidacloprid (2.90) lower than neemix (19.63) and spinosad (15.16).

3.2 Shoot infestation

The percentage of shoot infestation significantly differed with different pesticides used and potassium dose at 67 DAP, 74 DAP and 81 DAP (**Table 3**). At 67 DAP, spinosad showed a minimum percentage of shoot infestation (5.0%), compared to imidacloprid (6.67%) and neemix (11.67%). The maximum percentage of shoot infestation was found with the control (31.67%). Different pesticides showed a significant impact on the percentage of shoot infestation at 74 DAP at a 0.1% level of significance. The control plot showed a maximum percentage of shoot infestation (28.33%). The minimum percentage of shoot infestation was observed with spinosad (1.67%) followed by neemix (3.33%) and imidacloprid (3.33%) at 74 DAP. Similarly at 81 DAP, again the control plots showed a maximum percentage of fruit infestation (15.0%). The minimum percentage of shoot infestation was observed with imidacloprid (0%) which was less than those of spinosad (1.67%) and neemix (5.0%). Potassium fertilizer applied at the rate of 8 g/plant showed a lower percentage of shoot infestation at 67 DAP (7.50%), 74 DAP (6.67%), and 81 DAP (2.50%).

3.3. Yield loss

The effect of different pesticides was found to be significant on the percentage yield of infested fruits at 74 DAP and 81 DAP (**Table 3**). However, the application of potassium fertilizer did not show any significant impact on the percentage yield of infested fruits at all the dates of observation. At 74 DAP, spinosad showed the lowest percentage yield of infested fruits (6.41%) which was at par with imidacloprid (6.77%) but less than that of neemix (19.31%). The maximum percentage yield of infested fruits was observed with the control (31.54%), followed by neemix. As before, at 81 DAS, the control plots showed a maximum percentage yield of infested fruits (30.27%), followed by neemix (17.83%) and imidacloprid (13.64%). The lowest percentage yield of infested fruits was observed with spinosad (1.03%), which was at par with neemix and imidacloprid.

All three insecticides used in the study, neemix (300 ppm) at 6 ml/L water, spinosad at 1 ml/3L water and imidacloprid at 1 g/3L, showed a significant reduction in BFSB infestation on fruit, shoot, and yield of infested fruits as compared to the control treatment. Although imidacloprid was found to be most effective in reducing BFSB infestations on both shoots and fruits, spinosad was found to be most effective in improving yield. This result differs from the study conducted by Khare and Sneha (2021), who found that spinosad was (45% SC) most effective and imidacloprid was a moderately effective insecticide in controlling BFSB under field conditions. The findings also support the research conducted by Mollah et al (2022), who reported that spinosad 45% SC was effective in reducing BFSB infestation on both shoots and fruits. Machhindra et al (2022) also reported spinosad as the best insecticide, followed by imidacloprid and neemix, to reduce fruit infestation and improve yield. Warghat et al (2020) found spinosad (0.01%) to be an effective pesticide in managing the BFSB fruit infestation, producing a higher marketable fruit yield. Imidacloprid is a nicotinic acetylcholine receptor stimulator that works by blocking the nervous system of insects, resulting in their paralysis and eventually death (Pang et al 2020). Therefore, spinosad is considered an excellent pest control agent. Spinosad, as imidacloprid, is a systemic insecticide that mainly interferes with the nicotinic acetylcholine receptors

Table 3. Effects of different potassium doses and pesticides on the fruit and shoot infestation by *Leucinodes orbonalis*, and fruit yield

Treatment		Fruit infestation (%)				Shoot infestation (%)				Yield of infested fruits (%)			
		Pre-spray (60 DAP)	After 1st spray (67 DAP)	After 2nd spray (74 DAP)	After 3rd spray (81 DAP)	Pre-spray (60 DAP)	After 1st spray (67 DAP)	After 2nd spray (74 DAP)	After 3rd spray (81 DAP)	Pre-spray (60 DAP)	After 1st spray (67 DAP)	After 2nd spray (74 DAP)	After 3rd spray (81 DAP)
Potassium dose/plant	0 g	38.07	20.21	19.91	17.78	38.33	20.0^{a}	11.67^{a}	8.33^{a}	32.47	18.68	19.51	15.77
	8 g	30.75	22.23	11.46	15.79	32.5	7.50^{b}	6.67^{b}	2.50^{b}	32.03	23.39	12.49	15.61
	F-test	NS	NS	NS	NS	NS	**	*	*	NS	NS	NS	NS
	LSD	11.84	13.39	9.95	12.67	10.96	8.99	4.63	5.36	13.42	14.14	11.15	13.49
Pesticides	Control	37.63	35.06	32.84^{a}	29.44^{a}	40	31.67^{a}	28.33^{a}	15.0^{a}	34.81	30.11	31.54^{a}	30.27^{a}
	Neemix	29.33	19.31	16.79^{b}	19.63^{ab}	36.67	11.67^{b}	3.33^{b}	5.0^{b}	25.38	24.99	19.31^{ab}	17.83^{ab}
	Spinosad	40.56	16.41	7.19^{b}	15.16^{ab}	40	5.0^{b}	1.67^{b}	1.67^{b}	35.77	16.16	6.41^{b}	1.03^{b}
	IMI	30.13	14.11	5.91^{b}	2.90^{b}	25	6.67^{b}	3.33^{b}	0^{b}	33.05	12.87	6.77^{b}	13.64^{ab}
	F-test	NS	NS	**	*	NS	**	***	**	NS	NS	*	*
	LSD	16.75	18.94	14.07	17.91	15.49	12.71	6.55	7.58	18.98	20	15.77	19.08
	CV%	39.31	72.06	72.42	31.22	35.33	74.65	57.70	113.05	47.51	76.78	79.57	98.19
	Grand mean	34.41	21.22	15.69	16.79	35.42	13.75	9.16	5.42	32.25	21.04	16.0	15.69

DAP: Days after planting, CV: Coefficient of variation, LSD: Least significant difference, Means followed by the same letter in a column are not significantly different by DMRT at 5% level of significance, ***: significant at 0.001, **: significant at 0.01, *: significant at 0.05 level, NS: Not-significant. Neemix (6mL/L water), Spinosad (1mL/3L water), IMI (Imidacloprid) (5g/16L water).

(nAChRs) directly in the nervous system and γ-aminobutyric acid (GABA) receptors in insects, thereby
producing neuronal excitation that results in the paralysis of insects from neuromuscular fatigue after extended periods of hyperexcitation and eventually death (Santos and Pereira 2020). Neemix (Azadirachtin) was also found to be significantly effective in controlling fruit and shoot infestations and improving yield.

The effect of neemix was significantly at par with other chemical insecticides. Azadirachtin is the key active agent in neemix (d'Errico et al 2023) that interferes with the ability of an insect to mold by interfering with the synthesis of a molding hormone called "ecdysteroid" (Chaudhary et al 2017). Many scholars have found significant control of pests like Jassid and Aphid in cowpea (Dhakal et al 2019), fall armyworm *(Spodoptera frugiperda)* in corn, soybean caterpillar larva (*Anticarsia gemmatalis)* in soybean (Farder-Gomes et al 2022) and, root-knot nematode in tomato (d'Errico et al 2023) by the use of neemix solution.

The different insecticidal treatments did not show any significant difference in fruit infestation (%) one week after the first spray or at 67 DAP. This might be due to the uniform incidence of the pest on the fruits before spray and the indirect impacts of different insecticides on the pest residing on fruits within one week. As there was no significant difference among the different insecticides on fruit infestation after the first spray, there was also no significant impact of those treatments on yield loss (%) after the first spray. However, the insecticidal treatments showed a significant impact on the shoot infestation (%) after the first spray. This might be due to the direct impacts of insecticides on the pests residing on shoots. The use of potassium dose did not show any significant variation in fruit infestation (%) and yield of infested fruits. However, potassium fertilizer significantly reduced shoot infestations. The effects of potassium were observed more on shoots because potassium hardens the plant structure and cell wall, resulting in thicker and harder leaves and stems (PPA, 2023). Thicker stems and leaves prevent diseases and pests from penetrating the plant surface and causing infections (PPA, 2023). Sarker et al (2022) observed the highest grain yield and lowest incidence of wheat blast disease in wheat when potassium was applied at 125 kg/ha. Potassium has also been reported to significantly reduce field infestation by many diseases such as stem rust of wheat, gray leaf spot of corn (*Cercospora zeae-maydes*) and early blight of tomatoes (Devi et al 2022). A similar result was observed by Bhatt et al (2021), with the application of potassium at 80 kg/ha showing optimum growth, yield and quality parameters in sugarcane along with reduced pest infestation. Chatterjee and Mondal (2020) observed the lowest infection by dead heart disease and white ear head disease when potassium was applied at 40 kg/ha and the lowest infestation by leaf folder at 60 kg/ha under lowland rice in direct sowing and transplanted conditions. Aziz et al (2018) also reported that the use of potassium fertilizer at 60 kg/ha significantly reduced major pests in rice.

4 Conclusion

All the insecticidal treatments were proven to be significantly effective in controlling fruit and shoot infestation by BFSB and also showed significantly higher healthy fruit percentages as compared to untreated control. While potassium fertilizer (8 g/plant) showed its effectiveness only in controlling shoot infestation. Imidacloprid (5 g/16L water) showed the lowest percentage of fruit and shoot infestation but was at par with other insecticidal treatments. The treatment of spinosad (1 mL/3L water) is effective in producing the highest percentage yield of healthy fruits, which is also at par with the other two insecticidal treatments. Since the efficacy of all the insecticidal treatments is similar in controlling BFSB and increasing yield, considering the health hazards of chemical insecticides, neemix (6 mL/L water) and potassium fertilizer (8 g/plant) are recommended as an approach to integrated pest management (IPM) for the control of brinjal fruit and shoot borer.

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