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Management of brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenee) using biorational insecticide based IPM packages

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ABSTRACT

Brinjal shoot and fruit borer (BSFB) is a serious pest of brinjal which can cause up to 90% yield loss and very difficult to control. An experiment was conducted in the Entomology Field Laboratory, Bangladesh Agricultural University during December 2017 to April 2018 on the management of brinjal shoot and fruit borer using selected biorational insecticide based IPM Packages *viz.* spinosad + removal of infested shoot and fruit, abamectin + removal of infested shoot and fruit, emamectin benzoate + removal of infested shoot and fruit, cypermethrin + removal of infested shoot and fruit, spinosad + abamectin, spinosad + emamectin benzoate, spinosad + buprofezin, abamectin + buprofezin, emamectin benzoate + buprofezin, abamectin + emamectin benzoate along with an untreated control. The experiment was laid out in Randomized Complete Block Design with three replications. The effectiveness of IPM packages was evaluated based on following parameters *viz.* percent shoot and fruit infestation, percent protection of shoot and fruit over control, marketable and infested fruit yield (t ha^{-1}), percent increase or decrease of marketable or infested fruit over control. All the IPM packages significantly reduced percent shoot and fruit infestation and significantly increased/decreased the marketable/infested fruit yield, respectively over untreated control at 7 days after spraying (DAS). Among the packages the best results were found in case of spinosad + removal of infested shoot and fruit (73.13% and 72.72% shoot and fruit protection, respectively over control; marketable fruit yield of 5.70 t ha^{-1} and 65.07% reduction of infested fruit yield) and emamectin benzoate + buprofezin (82.72% and 57.70% shoot and fruit protection, respectively over control; marketable fruit yield of 5.71 t ha^{-1} and 43.88% reduction of infested fruit yield) treated plots whereas the lowest protection was obtained from abamectin + buprofezin (15.67% and 20.70% shoot and fruit protection, respectively over control; marketable fruit yield of 2.87 t ha^{-1} and 13.43% reduction of infested fruit yield). Therefore, spinosad + removal of infested shoot and fruit and emamectin benzoate + buprofezin could be recommended as the IPM programme for the sustainable management of BSFB.

Keywords: *Solanum melongena*, spinosad, abamectin, emamectin, buprofezin, removal, sustainable

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1 Introduction

Brinjal (*Solanum melongena* L.), also known as eggplant belongs to the family Solanaceae which occupies an important place in the world vegetable market for its taste and nutritional value. Composition per 100 g of edible portion of brinjal is calories 24.0, moisture content 92.7%, carbohydrates 4.0%, protein 1.4 g, fat 0.3 g, fiber 1.3 g, vitamin-A 124.0 I.U., oxalic acid 18.0 mg, iron 0.38 mg, vitamin C 12.0 mg (Anon, 2007). It is good for diabetic patients (Mahata et al., 2014). It is one of the widely used vegetable crops by most of the people and is popular in many countries *viz*., Central, South and South East Asia, some parts of Africa and Central America (Harish et al., 2011). In Bangladesh, brinjal is the second most important vegetable crop next to potato in respect of acreage and production (BBS, 2018). It covers about 12.57% of the total vegetable area of the Bangladesh with an average yield of 10.08 t ha^{-1} in 2017-18 (BBS, 2018). The total area of brinjal cultivation was 51.17 thousand hectare with total annual production of 516.00 thousand tons in 2017-18 (BBS, 2018).

More than 36 insect pests (Regupathy et al., 1997) infest brinjal from the time of its planting to harvest. The major insect pests are Jassid, *Amrasca biguttula biguttula* (Ishida), Aphid, *Aphis persicae* (Sulzer), White fly, *Bemisia tabaci* (Gennadius), Coccinelide beetle, *Epilachna* spp. and shoot and fruit borer (BSFB) (*Leucinodes orbonalis* Guenee) (Lepidoptera: Pyralidae) (Latif et al., 2010). BSFB is the most destructive pest of brinjal (Latif et al., 2010; Chakraborti and Sarkar, 2011; Saimandir and Gopal, 2012) and is found in all brinjal producing countries (Dutta et al., 2011). It is the first ranked pest of India, Pakistan, Srilanka, Nepal, Bangladesh, Thailand, Philippines, Cambodia, Laos and Vietnam (AVRDC, 1994). Its distribution is mostly higher in hot and humid climate like Bangladesh (Srinivasan, 2009). Female moths lay eggs on the lower surface of leaf, branches, flower bud and flower individually. Just after hatching young caterpillars bore into the young tender shoots and feed on the vascular tissue resulting in drooping, withering and drying of the affected shoots. Later, the older caterpillars bore into the flower buds and fruits resulting shedding and the bored holes are invariably plugged with excreta (Patra et al., 2016). Caterpillars feed on the mesocarp of fruit and the feeding and excretion result in fruit rotening (Neupane, 2001) that makes fruits unfit for human consumption and marketing. A single larva can infest 4 to 7 fruits during its life span (Jayaraj and Manisegaran, 2010). It causes severe damage in South Asia (Thapa, 2010), where yield losses may reach up to 85% to 90% (Misra, 2008; Jagginavar et al., 2009) and in Bangladesh up to 86% (Prodhan et al., 2018). Infestation also reduces Vitamin C content to an extent of 68% in the infested fruits (Anwar et al., 2015).

Generally, farmers of Bangladesh routinely spray broad-spectrum insecticides, often two to three times per week, and, in some cases, twice a day to control BSFB. Farmers lose anywhere from 30 to 60% of the crop yield to BSFB despite the high use of insecticides (Shelton et al., 2018). Though farmers are taking up 25-30 insecticidal sprays to manage this pest the result is not satisfactory (Sajjan and Rafee, 2015). Consequently, over 100 sprays per season may be applied, resulting in high residues on the fruit. The cost of insecticide treatments accounts for 35 to 40% of the total cost of cultivation of brinjal. Such an insecticide-dependent strategy poses both environmental and health concerns of farmers and consumers (Shelton et al., 2018). Besides, inappropriate application of insecticides is resulting development of pest resurgence, outbreak of secondary pests as well as destruction of natural enemies. To avoid these problems, development of alternate control measures for this pest is the present concern.

Among the several ways to overcome the insecticidal problem, replacement with new biorational insecticide is one of the important considerations. The role of biorational insecticides in lepidopteran insect pest management like BSFB is advantages in terms of effectiveness, specificity and safety to non-target organisms and other components related to biosphere (Kalawate and Dethe, 2012). Evaluation of newer biorational molecules for their efficacy against *L. orbonalis* is a continuous process as newer molecules having novel mode of action are being added every year. Therefore, some most promising biorational pesticides with greater selectivity and considerably lower risks to human, wildlife and the environment could be possible alternatives for managing BSFB. IPM strategy consists of combination of two or more control measures such as resistant cultivars, sex pheromone, cultural, mechanical, biological and chemical control methods. IPM in brinjal cultivation is superior to single control method. Again, the use of biorational insecticides is an important component of an IPM strategy. Unfortunately, almost no attempt has been taken to develop a suitable biorational insecticide based IPM approach for managing BSFB. Considering the fact the present study was conducted to manage the BSFB using selected biorational insecticide based IPM packages.

2 Materials and Methods

An experiment was conducted at the Entomology Field Laboratory of Bangladesh Agricultural University during December 2017 to April 2018 to evaluate the efficacy of different biorational insecticide based IPM packages for managing brinjal shoot and fruit borer using the plants of brinjal variety, BARI BEGUN-7 (Singnath). The experimental land was ploughed and cross-ploughed several times with a power tiller to obtain desirable tilth followed by laddering and spading. The stubbles of the crops and uprooted weeds were removed from the field and the land was properly leveled. Finally, the unit plots were prepared as 4 inch raised beds along with the addition of basal doses of manures and fertilizers. Cowdung and other chemical fertilizers were applied as recommended dose for eggplant cultivation (Rashid, 1993) at the rate of 15 tons of cowdung and 250, 150 and 125 kg Urea, TSP and MoP, respectively per hectare. The full dose of cowdung, TSP and a half of MoP was applied as basal dose during land preparation. One month old healthy and disease free brinjal seedlings were collected from the Department of Horticulture, BAU. The collected seedlings were transplanted in the experimental plots at the rate of 6 seedlings per plot. All the agronomic practices were done to have the healthy plants for conducting experiment. The entire dose of Urea and rest of MoP were applied as top dressing. The first top dressing with one third of Urea was made at 20 days after transplanting followed by second top dressing comprising one third of Urea and one fourth of MoP at the time of flower initiation followed by last top dressing comprising rest of Urea and MoP at the time of fruit initiation.

The experiment was laid out in the Randomized Complete Block Design with three replications of each treatment. The whole experimental field was divided into 3 equal blocks. Each block had 11 plots and finally a total of 33 plots were made in the specified area for conducting the experiment. The size of a unit plot was 4 ft $\times$ 2.5 ft. Two adjacent unit plots and blocks were separated by 0.5 ft apart. Plots were allocated randomly and they were separated in such way so that impact of every treatment could be quantified.

The experiment was conducted with 11 treatments (ten IPM packages + one untreated control). The IPM packages were as follows *viz*. T1 = Spinosad (Libsen 45SC @ 1 mL L^{-1} water) + Removal of infested shoot & fruit once/week, T2 = Abamectin (Ambush 1.8EC @ 1 mL L^{-1} water) + Removal of infested shoot & fruit once/week, T3 = Emamectin benzoate (Suspend 5SG @ 1 g L^{-1} water) + Removal of infested shoot & fruit once/week, T4 = Cypermethrin (Typer 10EC @ 1 mL L^{-1} water) + Removal of infested shoot & fruit once/week, T5 = Spinosad (Libsen 45SC @ 1 mL L^{-1} water) + Abamectin (Ambush 1.8EC @ 1 mL L^{-1} water), T6 = Spinosad (Libsen 45SC @ 1 mL L^{-1} water) + Emamectin benzoate (Suspend 5SG @ 1 g L^{-1} water), T7 =Spinosad (Libsen 45SC @ 1 mL L^{-1} water) + Buprofezin (Award 40SC @ 1 mL L^{-1} water), T8 = Abamectin (Ambush 1.8EC @ 1 mL L^{-1} water) + Buprofezin (Award 40SC @ 1 mL L^{-1} water), T9 = Emamectin benzoate (Suspend 5SG @ 1 g L^{-1} water) + Buprofezin (Award 40SC @ 1 mL L^{-1} water) and T10 = Abamectin (Ambush 1.8EC @ 1 mL L^{-1} water) + Emamectin benzoate (Suspend 5SG @ 1 g L^{-1} water. The eleventh treatment was untreated control (T11). Biorational insecticides from each IPM package was applied one first and after one day the other. A total of four sprayings were given at one week interval. Spraying was done within 9.00 to 11.00 am to avoid bright sun shine and drift caused by strong wind.

Data were collected at 7 days after providing each spray in case of shoot and fruit infestation, Pretreatment data were also collected before first spraying. To get marketable and infested fruit yield, fruits were picked at 7 days after 2nd and 4th treatments application and a total of two pickings were done. Percentage shoot and fruit infestation, yield (t ha^{-1}) of marketable and infested fruit were estimated from the collected data. Finally, percentage protection of shoot and fruit infestation over control, percentage increase of marketable fruit yield over control and percentage decrease of infested fruit yield over control was calculated from the data. Data were analysed using MSTT-C package programme (Russell, 1986) and means were separated using DMRT (Gomez and Gomez, 1984).

3 Results

3.1 Shoot infestation

The effect of all the biorational insecticide based IPM packages had significant ($p<0.01$) on the shoot infestation compared to the control (Table 1). The highest percentage of shoot infestation was observed in case of untreated control which was ranged from 11.87% to 14.98% where the cumulative mean shoot infestation was 13.66%. Shoot infestation caused by *L. orbonalis* increased very rapidly with increasing time at control plots whereas all other treatments significantly reduced the rate of shoot infestation over time as compared to control (Table 1). The lowest cumulative percentage of shoot infestation (2.36%) was observed from emamectin benzoate + buprofezin treated plots which were followed by spinosad + removal of infested shoot and fruit (3.67%), emamectin benzoate + removal of infested shoot and fruit (4.73%), spinosad + emamectin benzoate (4.83%) and spinosad + buprofezin (5.04%). Among the treatments (IPM packages), the moderate cumulative percentage of shoot infestation was obtained from the package composed of spinosad + abamectin (7.79%) which was followed by the packages of abamectin + removal of infested shoot and fruit (8.36%), cypermethrin + removal of infested shoot and fruit (9.86%), abamectin + emamectin benzoate (10.14%) and abamectin + buprofezin (11.52%) (Table 1). The results also indicated that the effect of chemical insecticide, cypermethrin against shoot infestation of brinjal caused by *L. orbonalis* was not strongly effective. This might be due to the development of to some extend resistance of *L. orbonalis* against cypermethrin. In case of percentage shoot protection over control, 82.72, 73.13,65.37, 64.64 and 63.10% were found when brinjal plants were treated with emamectin benzoate + buprofezin, spinosad + removal of infested shoot and fruit, emamectin benzoate + removal of infested shoot and fruit, spinosad + emamectin benzoate and spinosad + buprofezin, respectively (Fig. 1). From the moderately effective IPM packages percentage shoot protection over control were 42.97, 38.80, 27.82, 25.77, 15.67%, respectively.

3.2 Fruit infestation

Similar to shoot infestation (mentioned above), all the selected IPM packages significantly (P<0.01) reduced percent fruit infestation in comparison to control treatment (Table 2). The highest percentage of infested fruits after four sprays was obtained when brinjal plants were left untreated (91.67, 46.67, 67.86 and 75.48% after first, second, third and fourth spray, respectively) where the cumulative mean fruit infestation was found 70.42% (Table 2). The lowest cumulative percentage of fruit infestation (19.21%) was obtained from IPM package consisting of spinosad + removal of infested shoot and fruit treated plots which was followed by emamectin benzoate + removal of infested shoot and fruit (22.13%), spinosad + emamectin benzoate (25.56%) and emamectin benzoate + buprofezin (29.79%). The moderate percentage of fruit infestation after four sprays was obtained from abamectin + removal of infested shoot and fruit (47.80%) which was followed by spinosad + abamectin (48.41%), spinosad + buprofezin (51.38%), cypermethrin + removal of infested shoot and fruit (54.70%), abamectin + buprofezin (55.84%) and abamectin + emamectin benzoate (62.17%) treated plots among the treatments. In case of percentage fruit protection over control, 72.72, 68.57, 63.70, and 57.70% fruit was protected from larval infestation when brinjal plants were treated with spinosad + removal of infested shoot and fruit, emamectin benzoate + removal of infested shoot and fruit, spinosad + emamectin benzoate and emamectin benzoate + buprofezin, respectively (Fig. 2). Moderately effective packages contributed the percentage fruit protection were 32.12, 31.26, 27.04, 22.32, 20.70 and 11.72%, respectively (Fig. 2).

3.3 Yield of marketable fruits

The efficacy of selected biorational insecticide based IPM packages on marketable fruit yield (t ha^{-1}) was evaluated and the effects of all the IPM packages were significant (p<0.01) in comparison to control treatment (Table 3). The lowest marketable fruit yield after two pickings was obtained from control plots (0.87 and 1.34 t ha^{-1} after 1st and 2nd pickings, respectively) where total marketable fruit yield was only 2.21 t ha^{-1}. Among the treatments, the maximum marketable fruit yield was obtained from emamectin benzoate + buprofezin treated plots (5.71 t ha^{-1}) which was followed by spinosad + removal of infested shoot and fruit (5.70 t ha^{-1}), spinosad + emamectin benzoate (5.65 t ha^{-1}), emamectin benzoate + removal of infested shoot and fruit (5.48 t ha^{-1}) and spinosad + buprofezin (4.18 t ha^{-1}), respectively (Table 3). The moderate marketable yield was obtained from spinosad + abamectin (3.46 t ha^{-1}) treated plots which was followed by cypermethrin + removal of infested shoot and fruit (3.14 t ha^{-1}), abamectin + emamectin benzoate (2.99 t ha^{-1}), abamectin + removal of infested shoot and fruit (2.91 t ha^{-1}) and abamectin + buprofezin (2.87 t ha^{-1}) (Table 3). In case of percentage increase in marketable fruit yield over control, 61.30, 61.23, 60.88, 59.67 and 47.13% fruit was protected from larval infestation when brinjal plants were treated with emamectin benzoate + buprofezin, spinosad + removal of infested shoot and fruit, spinosad + emamectin benzoate, emamectin benzoate + removal of infested shoot and fruit and spinosad + buprofezin, respectively (Fig. 3). The moderate percentages increase in marketable fruit yield over control 36.13, 29.62, 26.09, 24.05 and 23.0%, was obtained from spinosad + abamectin, cypermethrin + removal of infested shoot and fruit, abamectin + emamectin benzoate, abamectin + removal of infested shoot and fruit and abamectin + buprofezin treated plots, respectively (Fig. 3).

3.4 Yield of infested fruits

It was observed that each of the treatments was significantly effective (p<0.05) against brinjal shoot and fruit borer infestation and also reduced infested fruit yield as compared to control (Table 4). Among the tested IPM packages, the lowest infested fruit yield was obtained from spinosad + removal of infested shoot and fruit treated plots (1.17 t ha^{-1}) which was followed by spinosad + emamectin benzoate (1.63 t ha^{-1}), emamectin benzoate + buprofezin (1.88 t ha^{-1}), spinosad + buprofezin (1.89 t ha^{-1}) and emamectin benzoate + removal of infested shoot and fruit (1.97 t ha^{-1}). Moderate amount of infested fruit yield was obtained from the plots treated with spinosad + abamectin (2.02 t ha^{-1}) which was followed by abamectin + removal of infested shoot and fruit (2.35 t ha^{-1}), cypermethrin + removal of infested shoot and fruit (2.62 t ha^{-1}), abamectin + buprofezin (2.90 t ha^{-1}) and abamectin + emamectin benzoate (2.95 t ha^{-1}). The highest amount of infested fruit yield (3.35 t ha^{-1}) was recorded from untreated control plots (Table 4). In case of percentage reduction in infested fruit yield over control, 65.07, 51.34, 43.88, 43.58 and 41.19% fruit was protected from larval infestation when brinjal plants were treated with spinosad + removal of infested shoot and fruit,

Table 1. Effects of biorational insecticide based IPM packages on mean (%) shoot infestation by BSFB after different sprays

Treatments †	Doses ‡	Pre-treated shoot (%)	Mean shoot infestation (%) by BSFB at 7 DAS				CM
			1st spray	2nd spray	3rd spray	4th spray	
Ss + Removal	1.0	10.52a	3.21b	3.37cd	4.03de	4.08e	3.67de
Am + Removal	1.0	8.81Am	5.74b	8.14b	9.51Amc	10.06Amc	8.36bc
Eb + Removal	1.0	7.44Amc	5.41b	4.27bcd	4.47cde	4.78de	4.73cde
Ss + Am	1.0 + 1.0	2.01c	6.67b	7.18bc	7.93bcd	9.37bcd	7.79bcd
Ss + Eb	1.0 + 1.0	5.73Amc	4.77b	4.63bcd	4.74cde	5.19cde	4.83cde
Ss + Bz	1.0 + 1.0	6.51Amc	4.00b	5.35bcd	5.39cde	5.41cde	5.04cde
Am + Bz	1.0 + 1.0	4.98Amc	8.24b	10.95Am	12.77Am	14.12Am	11.52Am
Eb + Bz	1.0 + 1.0	7.28Amc	2.85b	2.17d	2.10e	2.31e	2.36e
Am + Eb	1.0 + 1.0	4.03bc	8.23b	8.59b	11.28Am	12.45Am	10.14b
Cm + Removal	1.0	6.00Amc	8.00b	7.56bc	10.84Am	13.05Am	9.86b
Untreated control	–	2.08c	11.87a	13.77a	14.01a	14.98a	13.66a
Sig. level	–	*	**	**	**	**	**
CV (%)	–	48.79	47.6	32.18	34.76	30.47	31.96

† Ss = Spinosad (Libsen 45 SC), Am = Abamectin (Amubush 1.8 EC), Eb = Emamectin benzoate (Suspend 5 SG), Bz = Buprofezin (Award 40SC), Cm = Cypermethrin (Typer 10 EC), Removal = Removal of infested shoot and fruit; † mL L^{-1} water; In a column, means followed by similar letter (s) are not significantly different; DAS = Days after spraying; * and ** indicate 5% and 1 % level of significance, respectively; CM = cumulative mean

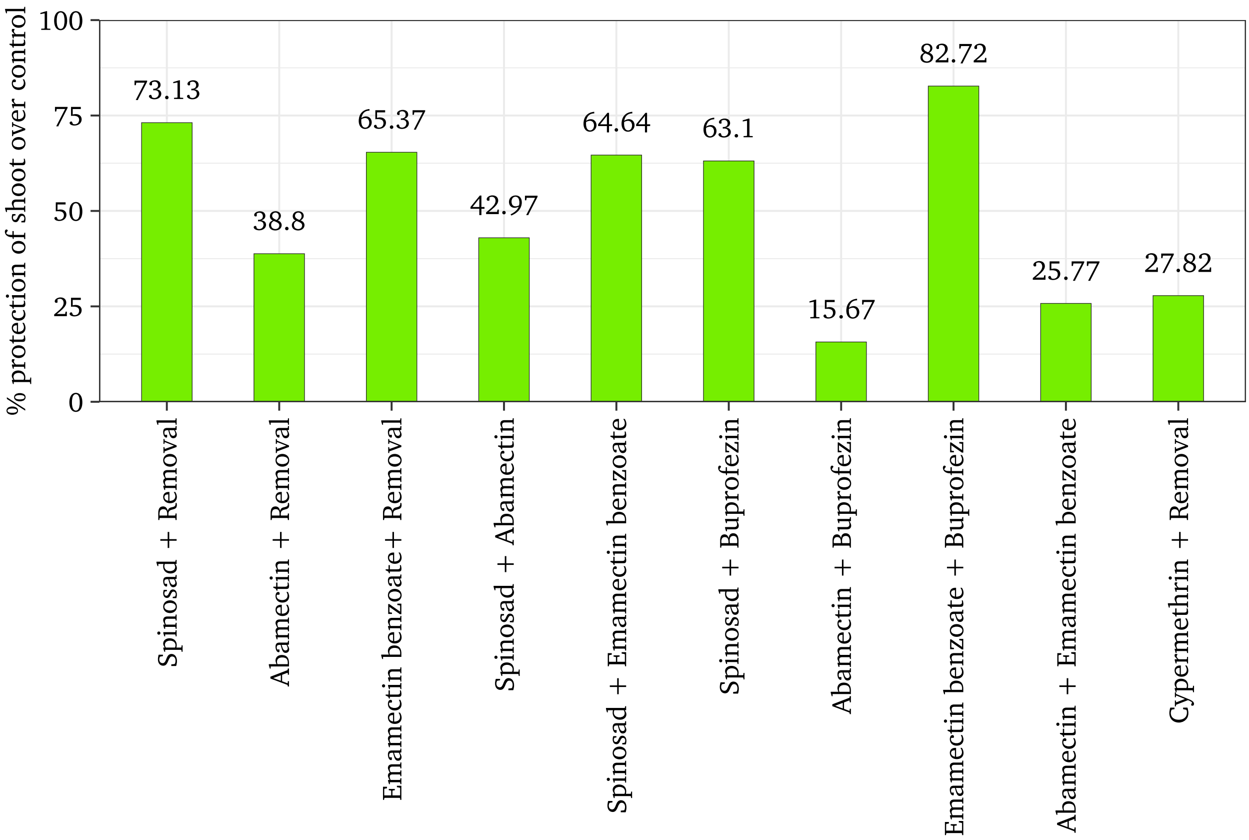

Figure 1. Protection of shoot (%) by different IPM packages over control

Table 2. Effects of biorational insecticide based IPM packages on mean (%) fruit infestation by BSFB after different sprays

Treatments †	Doses ‡	Pre-treated	Mean fruit infestation (%) by BSFB at 7 DAS				CM
		shoot (%)	1st spray	2nd spray	3rd spray	4th spray	
Ss + Removal	1.0	33.33	11.11de	21.67c	22.49c	21.57e	19.21d
Am + Removal	1.0	33.33	27.78cde	42.86ab	59.72ab	60.83bcd	47.80c
Eb + Removal	1.0	33.33	8.33e	27.78bc	22.62c	29.78e	22.13d
Ss + Am	1.0 + 1.0	44.44	55.56bc	43.91ab	46.03b	48.15d	48.41c
Ss + Eb	1.0 + 1.0	58.33	27.78cde	18.81c	24.52c	31.11e	25.56d
Ss + Bz	1.0 + 1.0	38.89	68.33ab	28.18bc	53.33ab	55.69cd	51.38bc
Am + Bz	1.0 + 1.0	44.44	60.00ab	43.33ab	61.13ab	58.89bcd	55.84bc
Eb + Bz	1.0 + 1.0	0	27.78cde	33.97abc	24.07c	33.33e	29.79d
Am + Eb	1.0 + 1.0	23.33	70.00ab	46.66a	65.56a	75.48a	70.42a
Cm + Removal	1.0	33.33	41.67bcd	36.19abc	68.69a	72.25ab	54.70bc
Untreated control	–	22.22	91.67a	46.67a	67.86a	75.48a	70.42a
Sig. level	–	NS	**	**	**	**	**
CV (%)	–	108.62	37.9	26.56	21.88	15.28	16.52

† Ss = Spinosad (Libsen 45 SC), Am = Abamectin (Amubush 1.8 EC), Eb = Emamectin benzoate (Suspend 5 SG), Bz = Buprofezin (Award 40SC), Cm = Cypermethrin (Typer 10 EC), Removal = Removal of infested shoot and fruit; † mL L^{-1} water; In a column, means followed by similar letter (s) are not significantly different; DAS = Days after spraying; * and ** indicate 5% and 1 % level of significance, respectively; CM = cumulative mean

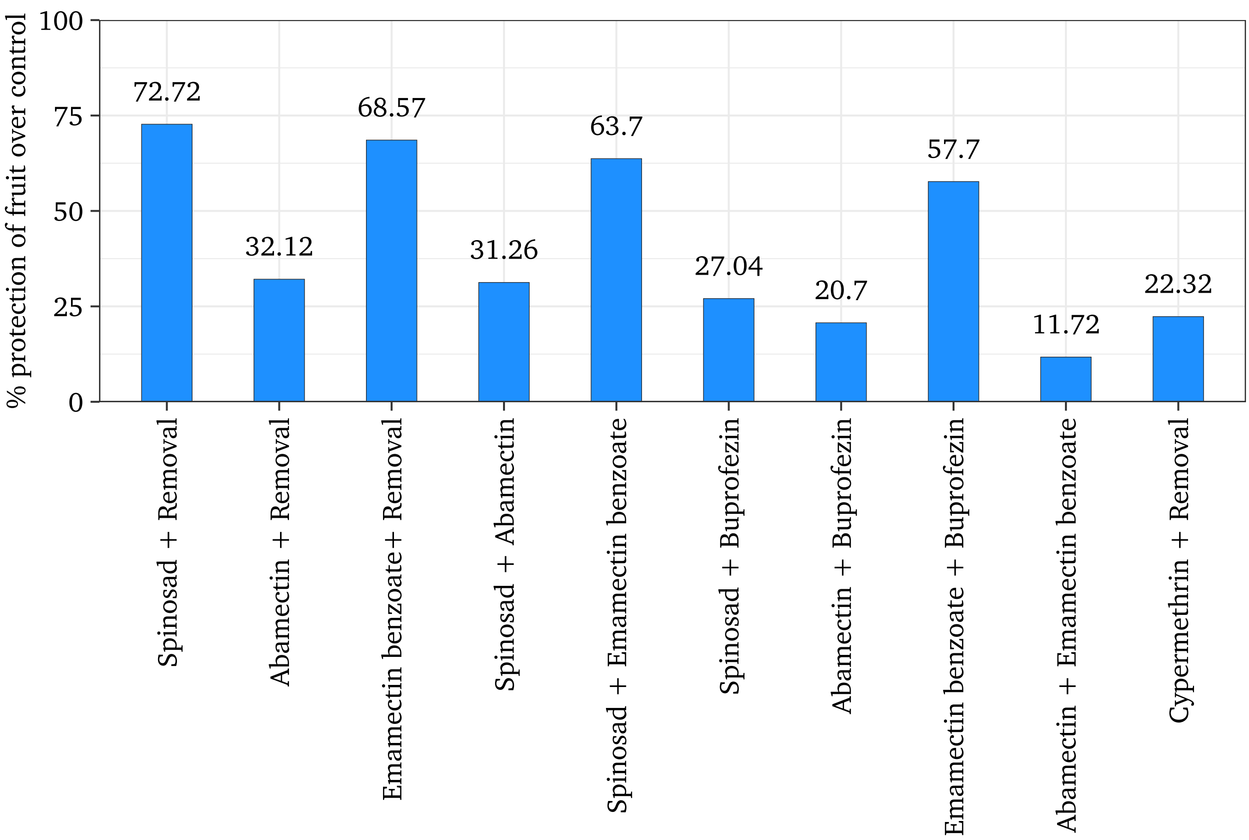

Figure 2. Protection of fruit (%) by different IPM packages over control

Table 3. Effects of biorational insecticide based IPM packages on the yield of marketable fruits

Treatments †	Doses ‡	Marketable fruit yield (t ha^{-1})		CM
		1st picking	2nd picking	
Ss + Removal	1.0	2.17ab	3.53ab	5.70a
Am + Removal	1.0	1.19cd	1.72cd	2.91bc
Eb + Removal	1.0	1.18cd	4.30a	5.48a
Ss + Am	1.0 + 1.0	1.47bcd	1.99bcd	3.46bc
Ss + Eb	1.0 + 1.0	2.40a	3.25abc	5.65a
Ss + Bz	1.0 + 1.0	1.78abc	2.40bcd	4.18ab
Am + Bz	1.0 + 1.0	1.47bcd	1.40d	2.87bc
Eb + Bz	1.0 + 1.0	2.41a	3.30abc	5.71a
Am + Eb	1.0 + 1.0	1.12cd	1.87cd	2.99bc
Cm + Removal	1.0	1.63abcd	1.51d	3.14bc
Untreated control	–	0.87d	1.34d	2.21c
Sig. level	–	**	**	**
CV (%)	–	27.91	34.84	22.67

† Ss = Spinosad (Libsen 45 SC), Am = Abamectin (Amubush 1.8 EC), Eb = Emamectin benzoate (Suspend 5 SG), Bz = Buprofezin (Award 40SC), Cm = Cypermethrin (Typer 10 EC), Removal = Removal of infested shoot and fruit; † mL L^{-1} water; In a column, means followed by similar letter (s) are not significantly different; DAS = Days after spraying; * and ** indicate 5% and 1 % level of significance, respectively; CM = cumulative mean

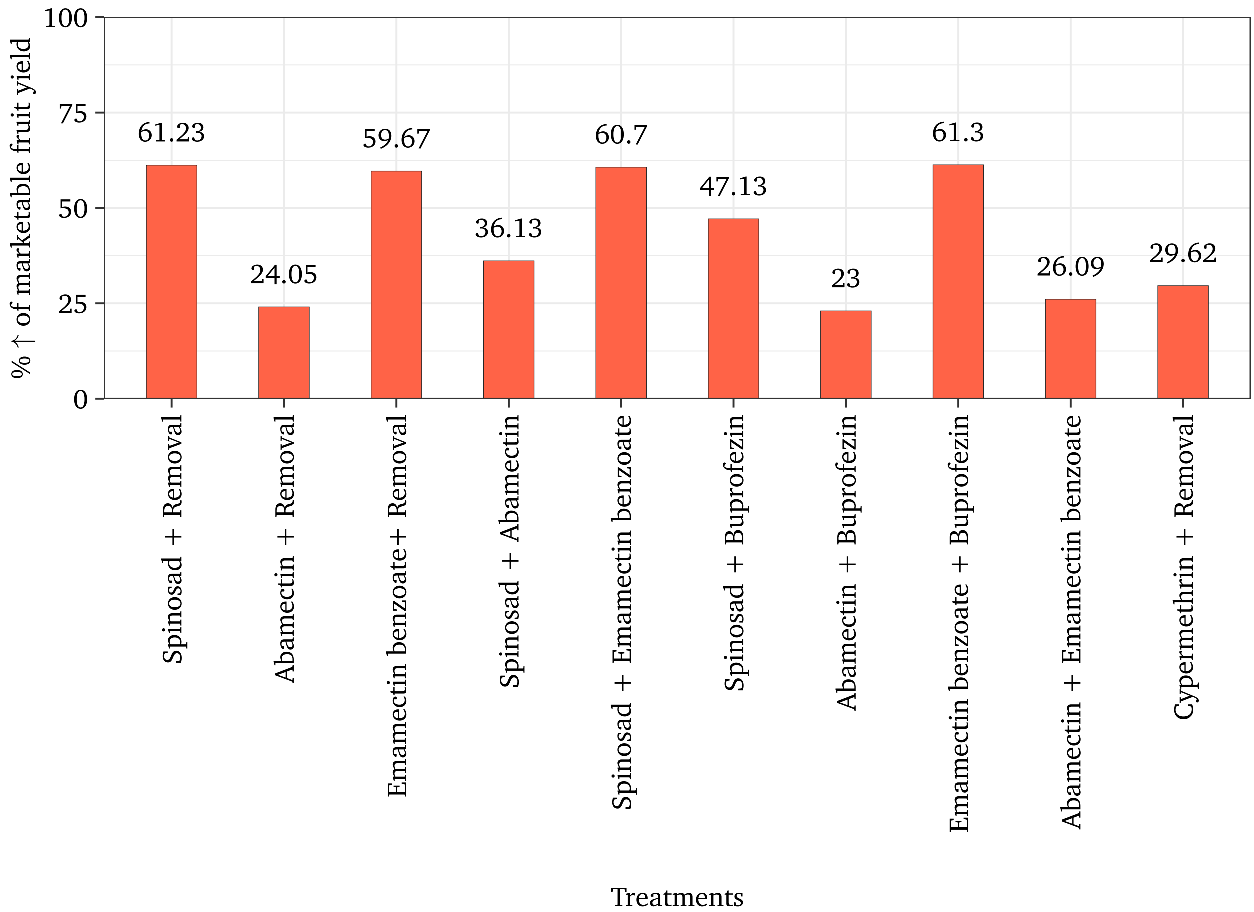

Figure 3. Increase (%) of marketable fruit yield by different IPM packages over control

Table 4. Effects of biorational insecticide based IPM packages on the yield of infested fruits

Treatments †	Doses ‡	Infested fruit yield (t ha^{-1})		CM
		1st picking	2nd picking	
Ss + Removal	1.0	0.16c	1.01bc	1.17g
Am + Removal	1.0	0.56bc	1.79ab	2.35bcdef
Eb + Removal	1.0	0.69ab	1.28abc	1.97defg
Ss + Am	1.0 + 1.0	0.72ab	1.30abc	2.02cdefg
Ss + Eb	1.0 + 1.0	0.77ab	0.86c	1.63fg
Ss + Bz	1.0 + 1.0	0.86ab	1.03bc	1.89efg
Am + Bz	1.0 + 1.0	1.07ab	1.83ab	2.90abcd
Eb + Bz	1.0 + 1.0	0.60bc	1.28abc	1.88efg
Am + Eb	1.0 + 1.0	0.92ab	2.03a	2.95abc
Cm + Removal	1.0	0.71ab	1.91ab	2.62abcde
Untreated control	–	1.22a	2.13a	3.35a
Sig. level	–	**	*	**
CV (%)	–	35.91	29.68	21.57

† Ss = Spinosad (Libsen 45 SC), Am = Abamectin (Amubush 1.8 EC), Eb = Emamectin benzoate (Suspend 5 SG), Bz = Buprofezin (Award 40SC), Cm = Cypermethrin (Typer 10 EC), Removal = Removal of infested shoot and fruit; † mL L^{-1} water; In a column, means followed by similar letter (s) are not significantly different; DAS = Days after spraying; * and ** indicate 5% and 1 % level of significance, respectively; CM = cumulative mean

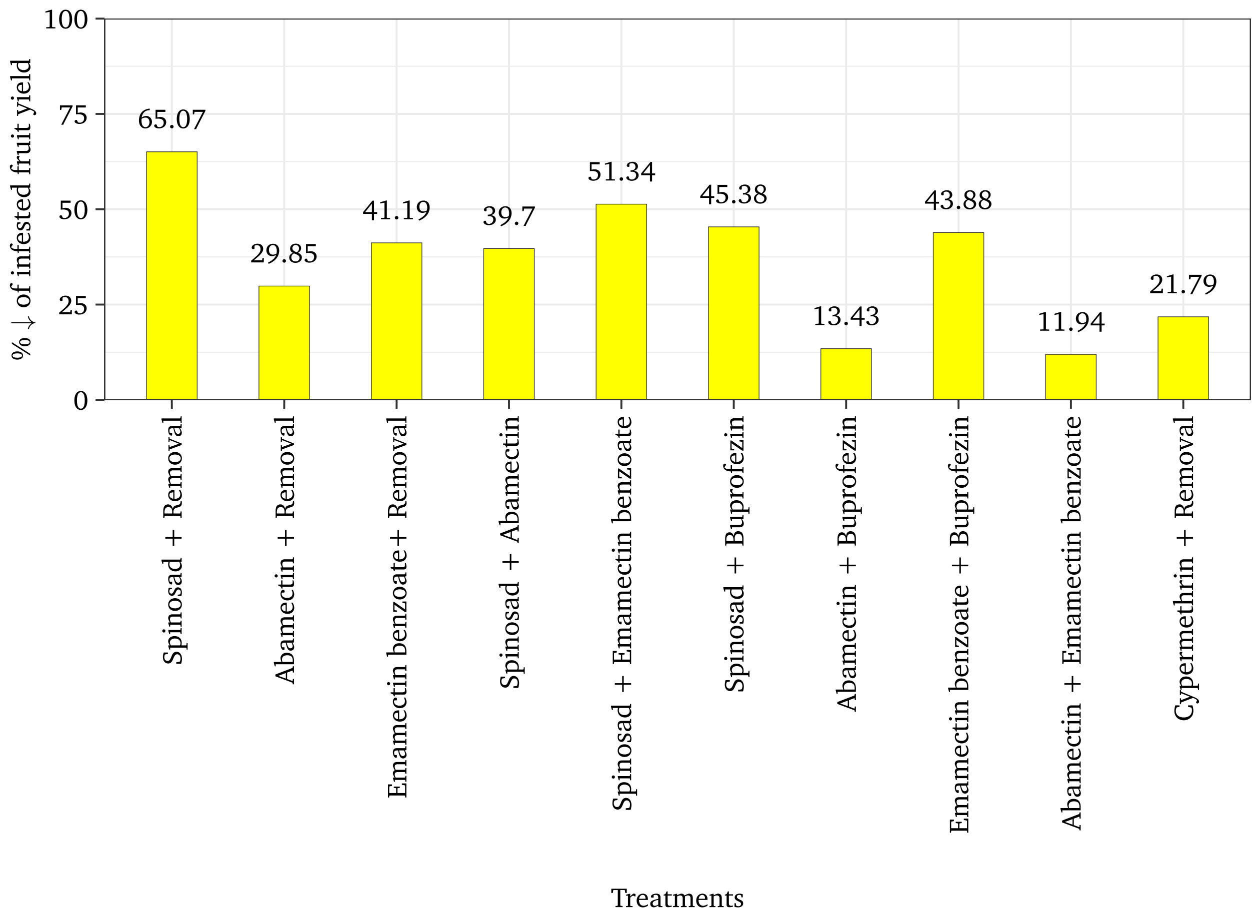

Figure 4. Decrease (%) of infested fruit yield by different IPM packages over control

spinosad + emamectin benzoate, emamectin benzoate + buprofezin, spinosad + buprofezin and emamectin benzoate + removal of infested shoot and fruit, respectively (Fig. 4). From the moderately effective IPM packages percentage reduction in infested fruit yield over control were 39.70, 29.85, 21.79, 13.43, and 11.94%, respectively (Fig. 4).

4 Discussions

The lowest cumulative percentage of shoot infestation (2.36%) was observed from emamectin benzoate + buprofezin treated plots which were followed by spinosad + removal of infested shoot and fruit (3.67%), emamectin benzoate + removal of infested shoot and fruit (4.73%), spinosad + emamectin benzoate (4.83%) and spinosad + buprofezin (5.04%). The highest percentage shoot protection over control was observed in emamectin benzoate + buprofezin treated plots (82.72%) which was closely followed by spinosad + removal of infested shoot and fruit (73.13). This present finding is mostly similar with other results reported by some other researchers in case of *L. orbonalis*. For example Islam et al. (2016) evaluated the efficacy of three bacterial fermented biopestcides *viz*., spinosad, emamectin benzoate and abamectin and one insect growth regulator, buprofezin in different combinations against the infestation of brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guen) and reported that the highest shoot protection (70.75%) was found from the treatment buprofezin + emamectin benzoate. Chakraborti (2001) reported that the effectiveness of biorational integrated approach in the management of brinjal fruit and shoot borer was highly effective showing only 4.92% mean shoot infestation whereas 20.42% shoot infestation was found in the conventional chemical insecticide treated plants. Pandey et al. (2016) reported that IPM programme consisting of cultural, mechanical and chemical components was proved to be an ideal management strategy against eggplant shoot and fruit borer. Therefore, these mentioned findings could be linked with the results of the present research where IPM packages consisting of mechanical, biorational and chemical components were significantly effective against BSFB.

In case of fruit infestation the lowest cumulative percentage of fruit infestation (19.21%) was obtained from IPM package consisting of spinosad + removal of infested shoot and fruit treated plots which was followed by emamectin benzoate + removal of infested shoot and fruit (22.13%), spinosad + emamectin benzoate (25.56%) and emamectin benzoate + buprofezin (29.79%). This result might be supported by the findings of the Chakraborti (2001) who studied the effectiveness of biorational integrated approach in the management of brinjal fruit and shoot borer and found only 5.32% mean fruit infestation where biorational IPM approach was also remarkably better than the conventional chemical method having 25.24% mean fruit infestation. Tiwari et al. (2009) found that removal and destruction of infested twigs/fallen leaves twice in a week + application of Bt @ 0.5 kg ha^{-1} showed minimum infestation of fruit (1.10 and 0.90%) in two consecutive years. The percentage fruit protection over control, 72.72, 68.57, 63.70, and 57.70% fruit was found from the IPM packages spinosad + removal of infested shoot and fruit, emamectin benzoate + removal of infested shoot and fruit, spinosad + emamectin benzoate and emamectin benzoate + buprofezin, respectively. Islam et al. (2016) mentioned that buprofezin + emamectin benzoate caused 63.99% brinjal fruit protection over control in the field. This finding clearly supports the result of the present research.

Among the treatments, the maximum marketable fruit yield was obtained from emamectin benzoate + buprofezin (5.71 t ha^{-1}) which was similar to the yield found from the spinosad + removal of infested shoot and fruit (5.70 t ha^{-1}) treated plots. Similar to marketable fruit yield the highest percentage increase in marketable fruit yield over control, was obtained from the IPM package emamectin benzoate + buprofezin (61.30%) which was similar to the yield increase found from the spinosad + removal of infested shoot and fruit (61.23%) treated plots. The present findings of the effect of biorational IPM packages on the marketable fruit yield are supported by the following reports. Islam et al. (2016) evaluated the combined efficacy of four biorational insecticides against the infestation of brinjal shoot and fruit borer and reported that the highest marketable fruit yield (9.94 t ha^{-1}) was obtained from the buprofezin + emamectin benzoate treated plots. Anil and Sharma (2010) studied the efficacy of spinosad and emamectin benzoate against BSFB and found that spinosad and emamectin benzoate was effective in increasing the marketable fruit yield by suppressing the fruit infestation by BSFB. Mandal et al. (2009) reported that the shoot and fruit damage was reduced in IPM module in which spinosad 45 SC @ 0.4 mL L^{-1} spray followed by azadirachtin 0.15% @ 2 mL L^{-1} spray along with clipping of infested shoots and removal of infested fruits at each harvesting, resulted in the highest yield of marketable fruits (160.24 q ha^{-1}).

The lowest infested fruit yield was obtained from spinosad + removal of infested shoot and fruit treated plots (1.17 t ha^{-1}) which was followed by spinosad + emamectin benzoate (1.63 t ha^{-1}) and emamectin benzoate + buprofezin (1.88 t ha^{-1}). Similarly, the highest percentage reduction of infested fruit yield over control was found from spinosad + removal of infested shoot and fruit (65.04%) followed by spinosad + emamectin benzoate (51.34%) and emamectin benzoate + buprofezin (43.88%) treated plots. The present result might be supported by the findings made by Chakraborti (2001) who studied the effectiveness of biorational integrated approach in the management of brinjal fruit and shoot borer and reported that biorational IPM approach was markedly superior to conventional chemical method having only 2% yield loss as compared to 50 and 45% in chemical control and untreated control, respectively.

5 Conclusions

It can be concluded all the tested biorational insecticide based IPM packages were effective in reducing shoot and fruit infestation and increasing of marketable fruit yield. But among the packages, spinosad + removal of infested shoot and fruit and emamectin benzoate + buprofezin were the most effective against infestation of BSFB resulting the highest marketable yield increase. Therefore, these two packages might be useful for sustainable management of brinjal shoot and fruit borer.

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Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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