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Field Evaluation of Different Pest Management Modules against Shoot and Fruit Borer (*Leucinodes orbonalis* Guenee.) Infesting Brinjal in Tripura

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Abstract

A field experiment was carried out to assess various pest management strategies for controlling shoot and fruit borer (*Leucinodes orbonalis* Guenee.) in Brinjal during 2019-20 and 2020-21. Seven Integrated Pest Management (IPM) modules were developed for use according to a calendar-based schedule and were compared to an untreated control in terms of their effectiveness in reducing shoot and fruit borer incidence. The results indicated that module M7 was superior to the untreated control (M8) as it resulted in lower percentages of shoot damage (10.63%), fruit damage on a number basis (12.34%), and fruit damage on a weight basis (11.44%), as well as higher yields. The optimal module (M7) comprised of the following components: (i) Soil incorporation of neem cake at a rate of 250 kg ha^{-1} (50% during the last plough and 50% at 3 weeks after transplanting); (ii) Installation of pheromone traps at a rate of 5 acre^{-1}, beginning from flower bud initiation (45 days old crop) until final harvest, with lures changed on a monthly basis; (iii) Mechanical clipping of drooped shoots and removal of infested fruits from the field at weekly intervals; (iv) Release of multiple insecticide tolerant *Trichogramma chilonis* at a rate of 1.25 lakh ha^{-1} at weekly intervals (4 times) from 30 days after planting (DAP); (v) Alternating spray of Chlorantraniliprole 18.5% SC at a rate of 0.3 ml L^{-1} and Novaluron 10% EC at a rate of 1.5 ml L^{-1} at fortnightly intervals beginning from 70 DAT was found to be the best module for brinjal growers.

Keywords: Brinjal, Field evaluation, *Leucinodes orbonalis*, Management, Pest management modules, Shoot and fruit borer

Introduction

Eggplant, also known as brinjal or *Solanum melongena* L., is a vegetable widely cultivated in tropical and subtropical regions of the world, with particular significance in countries such as India, Japan, Indonesia, China, Bulgaria, Italy, France, the USA, and several African nations. In India alone, eggplant is grown over a vast area of 7.49 lakh hectares, yielding a production of 128.74 lakh tonnes and a productivity of 18.6 tonnes ha^{-1} (Anonymous, 2018), making it the second-largest producer of brinjal after China. It is extensively grown in districts like Khowai, Sepahijala, South Tripura, and North Tripura, and is considered the "King of Vegetables," being the most popular and principal vegetable crop. However, the yield of the crop is significantly affected by various biotic and abiotic factors, with insect-pests being a major contributor to reduced yields by attacking the crop from the nursery stage until harvest (Deshmukh *et al.,* 2021).

Insects are a significant biotic factor that leads to substantial losses in brinjal crops throughout the year in India, with approximately 53 species of insect pests known to infest the vegetable (Nayar *et al.*, 1995). Insect pest infestation, particularly by the fruit and shoot borer (BSFB), *Leucinodes orbaonalis* Guenn. (Pyralidae: Lepidoptera), has caused a significant decrease in the productivity and quality of the fruits, seriously affecting the production of brinjal (Tewari and Sandana, 1990; Jat and Pareek, 2003). The damage caused by this pest is reported to reduce the yield of the crop by 20-30% (Bhargava *et al.*, 2008), 70% (Dhandapani

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et al., 2003; Srinivasan, 2009), 80% (Raju *et al*., 2007), and even 90% (Baral *et al*., 2006).

Shoot and fruit borer is the eggplant's most destructive and offensive pest and known for causing significant harm. The larva only causes damage, feeds inside the fruit, creating large exit holes before proceeding to pupate. This causes the infested fruits to lose value in the market and become unsuitable for human consumption (Alam *et al*., 2003). The damage process starts during the seedling stage and continues throughout fruit harvesting. During the initial stages of plant growth, the larva burrows into the petioles and midribs of large leaves and young shoots, obstructing the entry holes with their frass while feeding inside the shoot (Butani and Jotwani, 1984). This leads to drooping and wilting of the shoot at a later stage. In the fruit formation stage, the larva infiltrates the flower buds and fruits *via* the calyx. The entry holes on the fruit are usually invisible because they are either obscured or covered with frass, sometimes only the faded depressions of the entry holes may be visible. One or more large, round exit holes are present on the affected fruits. The fruits that have been impacted by rotting from the inside, resulting in a loss of market value (Raina and Yadav, 2018).

Although chemical control is a commonly employed method for pest management but due to the repeated use of synthetic chemicals which are broad-spectrum in nature results detrimental effects on the environment. This can lead to the contamination of the environment, the accumulation and biomagnification of chemical residues, and disturbance in the ecological balance (Dadmal *et al.*, 2004). Additionally, the excessive use of insecticides to manage the shoot and fruit borer of brinjal has resulted in the development of resistance and resurgence (Tripura *et al.*, 2017). Therefore, it is imperative to explore alternative and safer methods to replace the excessive use of chemical pesticides. Keeping in mind the economic importance of brinjal and to ensure the safe management, the present study was aimed to evaluate various pest management techniques for the shoot and fruit borer (*Leucinodes orbonalis* Guenee.) of brinjal.

Materials and Methods

During 2019-20 and 2020-21, an investigation was conducted in the farmers' field of Ramchandra Ghat, Khowai, Tripura (located at 24.025° N latitude and 91.617° E longitude) to assess various pest management techniques for the shoot and fruit borer (*Leucinodes orbonalis* Guenee.) in brinjal. The study involved the development of seven IPM modules for calendar-based operation, which were compared with an untreated check to determine their efficacy in reducing the incidence of fruit borer. The resulting package of eight modules is a comprehensive approach to pest management is as follows:

M_1: (i) 250 kg ha^{-1} of neem cake should be incorporated into the soil, with 50% added during the last plough and the other 50% three weeks after transplanting; (ii) Alneem, containing 1500 ppm of azadirachtin, should be sprayed at a rate of 3 ml L^{-1} of water. This should be done alternately with 10-day intervals twice during the vegetative stage, and six times starting at the fruiting stage; (iii) Weekly mechanical clipping of drooping shoots and removal of infested fruits from the field are recommended.

M_2: (i) Pheromone traps should be installed at a rate of 5 acre^{-1}, starting from flower bud initiation (45 days after planting) to final harvest, and the lures should be replaced on a monthly basis; (ii) Drooping shoots should be clipped mechanically and any infested fruits should be removed from the field on a weekly basis; (iii) At weekly intervals starting from 30 days after transplanting and continuing for four times, multiple insecticide tolerant *Trichogramma chilonis* should be released at a rate of 1.25 lakh ha^{-1}; (iv) Finally, an alternate spray of *Bacillus thuringiensis* at a rate of 2 ml L^{-1} and spinosad 45 SC at a rate of 0.5 ml L^{-1} should be applied twice at the vegetative stage and six times commencing with fruiting stage at 10-day intervals.

M_3: Alternate spray of following insecticides at fortnight interval starting from 30 DAT (Chlorantraniliprole 18.5% SC @ 0.3 ml L^{-1}, Novaluron 10% EC @ 1.5 ml L^{-1}, Flubendiamide 480 SC @ 0.3 ml L^{-1}, and Indoxacarb 14.5% SC @ 1.5 ml L^{-1}).

M_4 (Farmers Practice): Soil application of carbofuran and spraying of a variety of insecticides including cypermethrin, chloropyriphos, malathion, fenvalarate, chloropyriphos + cypermethrin, fipronil, and profenophos + cypermethrin on a weekly basis.

M_5: (i) Incorporation of neem cake into the soil at a rate of 250 kg ha^{-1} (50% during the last plough and the remaining 50% at 3 weeks after transplanting); (ii) Alneem, containing 1500 ppm of azadirachtin, should be sprayed at a rate of 3 ml L^{-1} of water. This should be done alternately with 10-day intervals twice during the vegetative stage, and six times starting at the fruiting stage; (iii) Clipping of drooping shoots mechanically and removing infested fruits from the field on a weekly basis; (iv) Pheromone traps should be installed at a rate of 5 acre^{-1}, starting from flower bud initiation (45 days after planting) to final harvest, and the lures should be replaced on a monthly basis; (v) Releasing *Trichogramma chilonis,* a multiple insecticide-tolerant species, at a rate of 1.25 lakh ha^{-1} at weekly intervals, four times from 30 days after planting (DAP).

M_6: (i) Incorporation of neem cake into the soil at a rate of 250 kg ha^{-1} (50% during the last plough and the remaining 50% at 3 weeks after transplanting); (ii) Alneem, containing 1500 ppm of azadirachtin, should be sprayed at a rate of 3 ml L^{-1} of water. This should be done alternately with 10-day intervals twice during the vegetative stage, and six times starting at the fruiting stage; (iii) Trim drooping shoots mechanically and remove infested fruits from the field weekly; (iv) Alternate spray Chlorantraniliprole 18.5% SC at a rate of 0.3 ml L^{-1} and Novaluron 10% EC at a rate of 1.5 ml L^{-1} every two weeks, starting from 70 days after transplanting.

M_7: (i) Incorporation of neem cake into the soil at a rate of 250 kg ha^{-1} (50% during the last plough and the remaining 50% at 3 weeks after transplanting); (ii) Pheromone traps should be installed at a rate of 5 acre^{-1}, starting from flower bud initiation (45 days after planting) to final harvest, and the lures should be replaced on a monthly basis; (iii) Trim drooping shoots mechanically and remove infested fruits from the field weekly; (iv) Releasing *Trichogramma chilonis*, a multiple insecticide-tolerant species, at a rate of 1.25 lakh ha^{-1} at weekly intervals, four times from 30 days after planting (DAP); (v) Apply Chlorantraniliprole 18.5% SC at a rate of 0.3 ml L^{-1} and Novaluron 10% EC at a rate of 1.5 ml L^{-1} alternately at fortnightly intervals, starting from 70 days after transplanting.

M_8 (Untreated control): The local germplasm Bholanath was utilized for the study with a spacing of 45 cm × 60 cm. The land was prepared through ploughing and laddering, and applied organic manure in the form of cow dung at a rate of 10 t ha^{-1}, 7 days prior to the final land preparation. Chemical fertilizers were applied in doses of NPK- 100:50:50 kg ha^{-1}, (50:50:50 applied as a basal dose and 50:00:00 at 30 days after transplanting). Cultural practices including irrigation were carried out as needed. A buffer zone was established between each module with a row of maize. The modules were subdivided into three regions to serve as replications for observations and statistical analysis.

Weekly observations were made at seven days interval on ten randomly selected plants in each micro plot of every module, starting from 30 days after transplanting (DAT) in case of shoot damage and 45 DAT in case of fruit damage. The modules were treated as the experimental treatments, while the blocks were considered as replications, thereby meeting the requirements for one-way ANOVA analysis.

Ten plants were randomly chosen and labeled from each net plot. The shoot infestation was recorded based on the number basis while the infestation of fruits was recorded separately based on the number and weight of infested fruits during each harvest. The infestation was recorded separately for each treatment, and the percentage of shoot and fruit infestation was calculated using the formula provided by Rahman *et al.* (2009).

Per cent shoot infestation = (Number of infested shoots / Total number of shoots) × 100 1

Per cent fruit infestation (Number basis) = (Number of infested fruits / Total number of fruits) × 100 2

Per cent fruit infestation (Weight basis) = (Weight of infested fruits / Total weight of fruits) × 100 3

The harvested yield was estimated and converted to yield $hectare^{-1}$ for further examination. The economic benefits were determined for each module after pooled analysis. The statistical analysis for mean performance followed the guidelines of Panse and Sukhatme (1989), with the treatment mean being separated using the least significant difference (LSD) at a 0.05% probability level, as outlined by Gomez and Gomez (1984).

Results and Discussion

Chakraborty *et al.* (2023) conducted an experiment utilizing the Bholanath local germplasm, which is extensively grown by farmers in Tripura. The results showed that this particular germplasm exhibits moderate to high vulnerability to Brinjal shoot and fruit borer. Consequently, there is a need for environmental friendly methods to manage the pest in order to achieve a higher yield.

Effectiveness of Different IPM Modules against L. orbonalis Infesting Brinjal Shoots

The results on the impact of IPM modules on shoot and fruit borer, *L. orbonalis* on shoot damage basis are illustrated in table 1. The results indicated that the shoot damage % varied between 10.63% and 28.76% $plant^{-1}$. Among the modules tested, M7 exhibited the lowest level of shoot damage (10.63%), followed by M6 (12.28%), whereas the untreated check (M8) had the highest percentage of shoot damage (28.76%). The module M7 also showed the highest percentage of reduction in shoot damage (62.35%), while M1 (Biorational pest management) had the lowest percentage of reduction (29.18%) when compared to the untreated check.

Table 1: Effectiveness of different IPM modules against *L. orbonalis* infesting brinjal shoots

Treatments	Shoot damage basis			
	2019-20	2020-21	Overall Mean	% reduction over control
M_1	20.46 (26.89)	19.51 (26.21)	19.98 (26.55)	29.18
M_2	18.39 (25.39)	17.09 (24.42)	17.74 (24.91)	37.13
M_3	14.58 (22.45)	13.36 (21.43)	13.97 (21.95)	50.50
M_4 (Farmers Practice)	17.38 (24.64)	15.09 (22.85)	16.23 (23.76)	42.47
M_5	18.34 (25.35)	16.04 (23.60)	17.19 (24.49)	39.09
M_6	12.19 (20.43)	12.36 (20.58)	12.28 (20.51)	56.50
M_7	10.28 (18.69)	10.97 (19.34)	10.63 (19.02)	62.35
M_8 (Untreated control)	30.49 (33.51)	27.02 (31.32)	28.76 (32.43)	-
SEM	1.31	1.29	1.30	-
CD (P=0.05)	4.39	4.31	4.34	-
CV	14.77	15.56	15.12	-

* Figures on parentheses are original values while those outside are arcsine transformed values; # Pooled data of corresponding SMW of 2019-20 and 2020-21

Effectiveness of Different IPM Modules against L. orbonalis Infesting Brinjal Fruits on Number Basis

The results on the % fruit damage on the basis of number by shoot and fruit borer, *L. orbonalis* in the two field experiments are presented in table 2. The overall mean % fruit damage ranged from 12.34 to 43.94%, with the lowest

Table 2: Effectiveness of different IPM modules against *L. orbonalis* infesting brinjal fruits

Treatments	Number basis				Weight basis			
	2019-20	2020-21	Overall mean	% reduction over control	2019-20	2020-21	Overall mean	% reduction over control
M_1	37.68 (37.87)	33.97 (35.65)	35.83 (36.77)	16.81	34.52 (35.98)	32.81 (34.95)	33.67 (35.47)	21.82
M_2	26.34 (30.88)	22.80 (28.52)	24.57 (29.72)	42.94	23.76 (29.17)	20.67 (27.04)	22.22 (28.12)	48.41
M_3	19.66 (26.32)	18.68 (25.61)	19.18 (25.97)	55.48	20.48 (26.91)	18.90 (25.77)	19.70 (26.35)	54.26
M_4 (Farmers Practice)	27.52 (31.64)	26.94 (31.27)	27.24 (31.46)	36.76	25.93 (30.61)	25.80 (30.52)	25.87 (30.57)	39.94
M_5	31.99 (34.44)	29.82 (33.10)	30.91 (33.78)	28.24	29.91 (33.15)	28.27 (32.12)	29.09 (32.64)	32.45
M_6	14.54 (22.41)	14.13 (22.08)	14.34 (22.25)	66.71	15.72 (23.35)	15.94 (23.53)	15.83 (23.45)	63.24
M_7	12.89 (21.03)	11.78 (20.07)	12.34 (20.56)	71.35	11.95 (20.22)	10.93 (19.31)	11.44 (19.77)	73.43
M_8 (Untreated control)	45.12 (42.20)	42.75 (40.83)	43.94 (41.52)	-	43.90 (41.49)	42.24 (40.53)	43.07 (41.02)	-
SEM	1.94	2.17	1.99	-	1.76	2.21	2.12	-
CD (P=0.05)	6.50	7.27	6.67	-	5.92	7.41	7.10	-
CV	16.87	20.22	17.96	-	16.03	21.34	19.65	-

* Figures on parentheses are original values while those outside are arcsine transformed values; # Pooled data of corresponding SMW of 2019-20 and 2020-21

level of damage recorded in module M7 (12.34%), which was comparable to M6 (14.34%), and the highest level of damage in the untreated check module M8 (43.94%). The module M7 showed a higher percent reduction (71.35%) in fruit damage, while the module M1 (Biorational pest management) showed a lower percent reduction (16.81%) compared to the untreated check.

Effectiveness of Different IPM Modules against L. orbonalis Infesting Brinjal Fruits on Weight Basis

The fruit damage caused by shoot and fruit borer, *L. orbonalis*, on the basis of weight is presented in table 2. The results indicated that module M7 had the lowest fruit damage percentage (11.44%), followed by M6 (15.83%), while M8 (untreated check) had the highest percentage of fruit damage (43.07%). The treatment in M7 demonstrated a greater reduction in percentage (73.43%), whereas the module M1 (Biorational pest management) had a lower reduction percentage of 21.82% compared to the untreated check.

Effectiveness of Different IPM Modules on Yield (tones ha^{-1}), Yield Increase over Control (%) and BCR

Table 3 (pooled data) presents the results of field experiments conducted in 2019-20 and 2020-21, indicating the yield trends (tones ha^{-1}) for different modules. The highest yield trend was observed in module M7 (17.52 tones ha^{-1}), followed by M6 (16.09 tones ha^{-1}) and M3 (Newer molecules) (13.88 tones ha^{-1}), while the lowest yield trend was found in M1 (Bio-rational Pest Management Module) (8.71 tones ha^{-1}) followed by M2 (Bio-intensive Pest Management Module) (9.45 tones ha^{-1}). The maximum increase in yield (tones ha^{-1}) was found in M7 (73.87%), followed by M6 (71.54%) and M3 (Newer molecules) (67.00%), while the lowest yield trend was observed in M1 (Bio-rational Pest Management Module) (47.41%) followed by M2 (Bio-intensive Pest Management Module) (51.54%). Furthermore, the BC ratio was high in M7 (1:3.86 and 1:3.52) and low in M1 (1:1.74 and 1:1.65) during 2019-20 and 2020-21, respectively.

During the 2019-20 and 2020-21 field experiments, as well as the analysis of pooled data, it was noted that the shoot and fruit borer, *L. orbonalis*, caused less damage in module M7 and M6 compared to the untreated check M8. Among the modules tested, module M7 exhibited the highest percentage reduction in damage, while module M1 (Biorational pest management) showed the lowest percentage reduction in damage compared to the untreated check. Therefore, it can be concluded that module M7, which demonstrated a higher percentage reduction of damage and obtained higher yield with a favorable benefit-cost ratio, is more advantageous to farmers than the other modules against *L. orbonalis*.

The study at hand received significant support from various sources including Islam *et al.* (2004), Prabhat and Johnsen (2000), Bajpai *et al.* (2005), Rahman *et al.* (2009), Mandal *et al.* (2009), and Dutta *et al.* (2011). The research found

Table 3: Effect of different IPM modules on yield and BCR of brinjal (2018-19, 2019-20 and Pooled data)

Treatments	Yield (tonnes ha^{-1})			Yield increase over control (%)			BCR	
	2019-20	2020-21	Pooled data	2019-20	2020-21	Pooled data	2019-20	2020-21
M_1	8.87	8.54	8.71	44.77	50.15	47.41	1.74	1.65
M_2	9.64	9.26	9.45	49.17	54.01	51.54	2.00	1.95
M_3	14.18	13.58	13.88	65.45	68.63	67.00	2.89	2.75
M_4 (Farmers Practice)	12.35	11.82	12.08	60.34	63.95	62.11	2.55	2.28
M_5	10.45	9.45	9.95	53.13	54.93	53.99	2.10	1.98
M_6	16.90	15.28	16.09	71.01	72.12	71.54	3.25	3.00
M_7	18.28	16.77	17.52	73.19	74.60	73.87	3.86	3.52
M_8 (Untreated control)	4.9	4.26	4.58	-	-	-	-	-
SEM	1.43	1.38	1.41	-	-	-	-	-
CD (P=0.05)	4.79	4.63	4.71	-	-	-	-	-
CV	20.38	20.45	20.39	-	-	-	-	-

that chlorantraniliprole was the most effective insecticide for controlling the brinjal shoot and fruit borer, which aligns with the findings of Saha *et al.* (2014) and Devi *et al.* (2015). Moreover, the study demonstrated that all the modules had a noticeable impact on reducing shoot and fruit infestation while increasing fruit yield compared to the untreated control, which is consistent with the work of Sinha (2021), and Abhishek and Dwivedi (2021).

Conclusion

From both the field experiments it was noted that the shoot and fruit borer, *L. orbonalis* caused less damage in module M7 and M6 compared to the untreated check M8. Among the modules tested, module M7 exhibited the highest percentage reduction in damage, while module M1 showed the lowest percentage reduction in damage compared to the untreated check. Therefore, it can be concluded that module M7, which demonstrated a higher percentage reduction of damage and obtained higher yield with a favorable benefit-cost ratio, is more advantageous to farmers than the other modules against *L. orbonalis*.

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