INTEGRATED MANAGEMENT OF FRUIT BORER (*LEUCINODES ORBONALIS*) (PYRALIDAE: LEPIDOPTERA) IN SPRING BRINJAL CROP

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Abstract

Experiment on the effect of different management practices alone and in integration against Brinjal fruit borer (*L. orbonalis*) was carried out at Newly Developmental Form (Horticulture ection) The University of Agriculture Peshawar, Khyber Pakhtunkhwa during Spring, 2021. The experiment was comprised of 9 treatments including control. Treatments included (Hoeing, Clipping, Hoeing + Clipping, Flubendiamide (Belt 48SC), Chlorantraneiliprole (Coragen 20SC), Hoeing +Clipping + Flubendiamide (Belt 48SC), Hoeing + Clipping + Chlorantraneiliprole (Coragen 20SC), Hoeing + Clipping + Flubendiamide (Belt 48SC) + Chlorantraneiliprole (Coragen 20SC) and Control) followed Randomize Complete Block Design with three replications. Results revealed that tested treatment alone and in integration were found better than control in reducing the infestation of *L. orbonalis*. However, spray application of Belt in integration with Hoeing and clipping was found the most effective in managing *L. orbonalis*infestation with the lowest shoot infestation (14.06%), fruit infestation (5.92%) and highest Brinjal yield (3178.69 kg ha^{-1}). Results further yield that the application of Belt and Coragen used alone twice at 14 days interval was the most profitable with highest CBR 1:8.71 and 1:8.64 respectively. It is concluded that *L. orbonalis* can be well managed by integrating Hoeing+ Clipping with Flubendiamide (Belt 48SC) and Chlorantraneiliprole (Coragen 20SC) rather than these control methods used individually. Hence, it is recommended to integrate with other control strategies in IPM program for sustainable management of *L. orbonalis* in brinjal.

Keywords: *L. orbonalis*, Hoeing, Clipping of infested shoots and fruits, Pesticide

I. INTRODUCTION

Brinjal (*Solanum melongena* L.) is the 5th most economically crop after potato, tomato, pepper, and tobacco (FAO, 2014). It is an important source of nutrients, minerals, vitamins, dietary fiber and antioxidants (Rodriguez-Jimancz *et al.*, 2018; Naeem and Ozgen, 2000). In Pakistan, it is cultivated on 8,427 hectare with total annual production of 84,255 tons (FAO 2017; Rehman *et al.*, 2019).). In Khyber Pakhthunkhwa Province, it is cultivated area over the area of 1039 ha with a production of 9206 tons (Anonymous 2018).

In Pakistan, Brinjal growers does not achieve the required output of brinjal yield due to severe damage by insect pest particularly *Lucinodes orbonalis.* This pest is recognized the most devastating insect pest of brinjal in Asia (CABI, 2007) particularly in India, Pakistan, Sri Lanka, Nepal, Bangladesh, Thailand, Philippines, Cambodia, Laos, and Vietnam (CABI, 2021). Crop loses due to *L. orbonalis* in South-Asian countries, ranging between 20-88.7% have been reported by various researchers (Haseeb et al. 2009; Mishra et al. 2014; Kariyanna et al. 2020). In Bangladesh, fruit infestation ranged from 31- 90% (Rahman 1997), whereas in India 37-63% and 50-70% in Pakistan (Dhankar 1988; Alam *et al*., 2003, Latif *et al*., 2010). It is found to be more active throughout the year in moderate climate.

This pest in early stage of the crop bore into the shoots resulting in drooping, withering and drying of the affected shoots due to disruption of the vascular system and translocation of food materials (Atwal and Dhaliwal, 2007). At later stage of the plant growth, the larvae bore generally through calyx and later into the flower buds and fruits, by making small holes which are usually plugged with excreta (Alam *et al*., 2006) thus making brinjal fruit unfit for human consumption and their market value is also affected. (Gautam *et al.*, 2019). This type of interior feeding habit makes this pest much evasive from the reach of even the most powerful insecticides (*Krithika and Ananthanarayana*, 2017). A single larva can damage 4 to 6 healthy fruits. The brinjal growers in general used to resort frequent sprays of pesticides to kill the borer larvae (Rahman et al., 2006 and Yousafi et al., 2015). This results in increase costs of production, environmental pollution, outbreak of secondary pests, development of pesticide resistance in insect, adverse effects on beneficial insects, wild life and ultimately to human being through food chains (Pramanik et al., 2012). It has been reported that applications of toxic chemical twice a week is the common practice of farmers to control BFSB. Since these toxic chemicals have several health and environmental hazardous effects. Development of alternate pest management strategies is necessary to minimize the indiscriminate use of toxic pesticides in vegetables.

The researchers have been trying to develop IPM packages by integrating various control measures such as cultural, mechanical, pheromone, chemical etc. for the control of brinjal shoot and fruit borer (FAO, 2003; Sasikala et al., 1999; Islam et al., 1999; Maleque et al., 1998). Mechanical control such as collection and destruction of infested shoots and fruits in combination with insecticide treatments reduced BSFB infestation, increased yield of fruit and ensured the highest benefit cost ratio (Alam et al.,2003; FAO, 2003; Rahman et al., 2002). As the brinjal is consumed as fruits so development of eco-friendly and safe pest management strategy is very much essential. Keeping in view the above facts the present was carried out to evaluate non chemical control methods (hoeing, clipping of infested shoots alone and in combination with insecticides to develop an IPM strategy for the sustainable management of *L. orbonalis* in brinjal crop.

II. MATERIAL AND METHODS

Experiment was carried at Newly Developmental Farm (NDF), (Horticulture section), The University of Agriculture Peshawar during Spring 2021. Seeds of Brinjal variety (PUSA Purple Long) was sown in 45 cm earthen pots in Mid February. Healthy seedlings in the three to four true leaf stage were transplanted in the field by dibbling in 2nd week of March in well prepared field followed Randomize Complete Block Design (RCBD) with three replications. Each plot size was 3.048 m^2 having two rows, each row was consisted of ten plants, row to row and plant to plant spacing were 50 cm and 30 cm respectively. One meter of non cropped area was maintained between the replicates. Field was irrigated just after transplantation and Subsequent irrigations were given once or twice a week depend upon weather conditions Normal agronomic practices such as fertilizer, hoeing, weeding was applied uniformly to all experimental units. Treatments (Table 1) were applied to the whole plot, twice at 14 days interval but data was recorded on randomly selected five plants in each plot. Knaosack sprayer fitted with a hollow cone nozzle and operated at 16 bar pressure while spraying. Water was applied to control plots when insecticides were sprayed.

Parameters

1- Larval population:

Larval population was recorded on randomly selected 5 plants in all experimental plots after 7 and 14 days treatment application, then mean larval population was calculated

2- Percent Shoot / fruit Infestation:

Infested and un-infested shoots and fruits was recorded on randomly selected five plants in all experimental plots after 7 and 14 days of treatment application treatment application, then mean percent shoot/fruit infestation was calculated according to the method used by (Awal *et al.*, 2017)

$$\text{Percent Shoots / fruit Infestation} = \frac{\text{number of infested shoots / fruits}}{\text{Total number of shoots /fruits}} \times 100$$

3- Yield (kg ha^{-1})

Yield data was recorded at the time of picking by using electric balance. Total yield was calculated by adding the yield of all pickings and converted to kg ha^{-1} according to the method use by (Sajid *et al.*, 2012).

$$\text{Yield (kg ha}^{-1}) = \frac{\text{Yield per plot (kg)}}{\text{Plot area (m2)}} \times 10000$$

4- Economic Analysis:

Economic analysis was calculated according to the method used by (Usman *et al.*, 2015) to find out the most profitable treatment that gave maximum net return in Rupees.

Treatments

Treatments	Treatments Detail / combinations
T1	Hoeing @ 14 days interval.
T2	Clipping of infested shoots @ 14 days interval.
T3	Hoeing + Clipping of infested shoots @14 days interval.
T4	Flubendiamide (Belt 48 SC) @ 14 days interval.
T5	Sprays of Chlorantraniliprole (Coragen 20SC) @14 days interval.

T6	Hoeing + Clipping of infested shoots and fruits + Spray of Flubendiamide (Belt 48SC**)** @ 14 days interval
T7	Hoeing + Clipping of infested shoot + Spray of Chlorantraniliprole (Coragen 20SC) @ 14 days interval
T8	Hoeing + Clipping of infested shoots and fruits + First spray of Flubendiamide (Belt 48 SC) + Subsequent spray Chlorantraniliprole (Coragen 20SC) at 14 days interval.
T9	Control

Statistical Analysis:

Data recorded on different parameters were submitted to ANOVA, with the Treatments as main effect. When significant differences were found among treatments, the LSD test was used to statistically compare the values obtained for the treatments. All analyses were conducted using the Statistix V 8.1 software.

III. RESULTS AND DISCUSSION

Results regarding larval population of *L. orbonalis*recorded in different treatments show that all tested treatments found better than control in reducing larval population (**Table 1).** However, Hoeing in integration with Clipping and Belt was found the most effective with lowest larval population (1.21 and 1.07) after 7 days and (3.94 and 2.81) after 14 days in 1st and 2nd application respectively. Results further revealed that plots treated with hoeing and clipping in integration with insecticide (Belt/Coragen) had lowest larval population than plots where these treatments applied alone. The lowest mean larval population 2.27 was observed in plots where hoeing was used in combination with clipping and Belt 48SC followed by Hoeing +clipping + Belt 48 SC and Coragen 20SC (2.91) and Hoeing +clipping + Belt 48 SC (3.31).

Table 1.Effect of different management options on larval population of *L. orbonalis* plant^{-1} on brinjal crop

Treatments	1st Application		2nd Application		Mean larval population
	After 7 days	After 14 days	After 7 days	After 14 days	
Hoeing	4.41b	6.27ab	5.34b	6.67ab	5.67b
Clipping	3.81c	6.00bc	5.14b	5.81bc	5.19c
Hoeing + Clipping	3.00d	5.67bc	4.14c	5.47bc	4.57d
Belt (48 SC)	2.41e	4.41de	2.07d	4.74c	3.41e
Coragen(20SC)	3.07d	5.21cd	3.74c	5.34c	4.34d
Hoeing + Clipping + Belt (48 SC)	1.21f	4.00e	1.07e	2.81d	2.27g
Hoeing + Clipping + Coragen (20SC)	2.07e	4.54de	2.00d	4.61c	3.31e
Hoeing + Clipping + Belt (48SC)+ Coragen (20SC)	1.14f	3.94e	2.00d	4.54c	2.91f
Control	5.27a	7.00a	6.34a	7.26a	6.67a
$LSD_{(0.05)}$	0.570	0.803	0.457	1.330	0.403

Mean with different letters are significantly different from each other at P (0.05%) level of significance.

Tested treatments significantly reduced shoot infestation by *L. orbonalis* as compared to control in both applications (Table 2). Results revealed that after 7 days of 1st application, shoot infestation was minimum in plot where Hoeing and clipping of infested shoots was integrated with Belt 48 SC and Coragen 20SC (2.61%) while maximum shoot infestation was recorded in control 31.27%. Similarly 14 days post application results show that lowest shoot infestation (17.94%) was recorded in plot where only Belt was applied followed by plot where only Hoeing and clipping was applied 19.87% and 22.74% respectively. Results of shoot infestation 7 days after 2nd application show that Hoeing and clipping in combination with Belt and Coragen found better had lowest shoot infestation ranging from 5% - 6.87% than Hoeing and clipping applied alone 18.87% and 17.94% respectively. Similarly shoot infestation after 14 days revealed that plot treated with Coragen alone had lowest shoot infestation 16.81% followed by clipping and Hoeing alone. Mean shoot infestation shows that plot where Hoeing + clipping + Belt were applied had lowest shoot infestation (14.06%) and followed by Hoeing + clipping + Belt + Coragen where shoot infestation was 14.81%. Plots where Hoeing, Clipping was done alone and in combination remain less effective had higher shoot infestation (16.26% to 18.84%) than those plots where hoeing and clipping were done these in combination with pesticides.

Table 2. Percent shoot infestation of brinjal crops by *L. orbonalis* affected by different management options.

Treatments	1st Application		2nd Application		Mean % shoot infestation
	After 7 days	After 14 days	After 7 days	After 14 days	
Hoeing	13.81b	22.74cd	18.87b	19.94c	18.84b
Clipping	12.61b	19.87de	17.94b	17.21c	16.91c
Hoeing + Clipping	9.67c	27.94ab	9.81c	25.27b	18.17b
Belt (48SC)	6.94d	25.87abc	8.27c	23.94b	16.26cd
Coragen (20SC)	10.14c	17.94e	16.14b	16.81c	15.26de
Hoeing+ Clipping + Belt (48SC)	2.81e	24.74bc	5.00d	23.67b	14.06f
Hoeing + Clipping + Coragen (20SC)	5.27d	27.07ab	6.87cd	24.21b	15.86cde
Hoeing + Clipping + Belt (48SC) + Coragen (20SC)	2.61e	24.74bc	6.87cd	25.00b	14.81ef
Control	31.27a	29.27a	27.21a	31.27a	29.776a
$LSD_{(0.05)}$	2.184	3.950	3.087	3.432	1.162

Mean with different letters are significantly different from each other at P (0.05%) level of significance.

Fruits infestation by *L. orbonalis* larva affected by Hoeing, clipping of infested shoots and insecticides application are presented in **Table 3**. Result revealed that all the tested treatments significantly reduced the fruit damage compared to control. However, fruit damage was lowest (5.92%) where Hoeing and Clipping was integrated with Belt 48 SC, this was not significantly different from the treatment where hoeing was used in integration of weekly clipping of infested shoot and Coragen 20 SC (6.74%) and Hoeing + weekly clipping of infested shoots + Coragen 20SC and Belt 48SC (6.04%) damaged fruits. Results further revealed that Hoeing and Clipping applied alone were remained the least effective than used in integration (8.36%). Similarly Belt (7.19) and Coragen used alone was not as effective when used in combination with Hoeing and Weekly clipping of infested shoots.

Table 3. Percent fruit infestation of brinjal crops by *Leucinodes orbonalis* as affected by different management options during 2020

Treatments	Fruit infestation
Hoeing	10.09b
Clipping	9.36b
Hoeing + Clipping	8.36c
Belt (48SC)	7.19de
Coragen (20SC)	7.89cd
Hoeing+ Clipping +Belt (48SC)	5.92f
Hoeing + Clipping + Coragen (20SC)	6.74ef
Hoeing + Clipping + Belt (48SC) + Coragen (20SC)	6.04f
Control	13.11a
LSD(0.05)	0.953

Mean with different letters are significantly different from each other at P (0.05%) level of significance.

Marketable Yield (Kg ha^{-1})

All tested treatment alone and integration were better than Control in term of marketable yield (Table 4). However, the marketable yield was significantly higher recorded in plot where Hoeing + Clipping + Coragen + Belt were applied (3278.69 kg ha^{-1}) followed by plot where Belt was integrated with Hoeing + Clipping (3178. 69 kg ha^{-1}). While the yield was significantly lower in Control (1092.90 kg ha^{-1}). Hoeing, Clipping, and insecticide Belt, and Coragen yielded better when used in combination rather than alone.

Table 4. Effect of different management practices on brinjal Yield

Treatments	Yield (kg ha^{-1})
Hoeing	1311.48f
Clipping	1530.05e
Hoeing + Clipping	1980.21d
Belt (48SC)	2732.24b
Coragen (20SC)	2185.79c
Hoeing+ Clipping + Belt (48SC)	3178.69a
Hoeing + Clipping + Coragen (20SC)	2732.24b
Hoeing + Clipping + Belt (48SC) + Coragen (20SC)	3278.69a
Control	1092.90g
LSD(0.05)	144.80

Mean with different letters are significantly different from each other at P (0.05%) level of significance.

Economic analysis of different IPM modules

Economic analysis of the tested management options is presented in **Table 4**. CBR value indicated that all the tested were profitable having CBR value ≥ 1. However, the application of Belt was found the most profitable treatment bearing the highest CBR value (1: 8.71) followed Corangen (1: 8.64). Hoeing and Clipping alone and in combination were least profitable having CBR value lower than treatment where they were used in combination with Belt 48SC and Coragen 20SC.

Table 5. Economic analysis of different IPM modules

Treatments	Marketable yield (kg ha^{-1}) A	Gross income (Rs) B	Cost of control ha^{-1} (Rs.) C	Return over control (Rs. ha^{-1}) D	Estimated net benefit (Rs. ha^{-1}) E=(D-C)	C:B F=(D/C)
Hoeing	1311.48	52459	3200	8743	5543	2.73
Clipping	1530.05	61202	3200	17486	14286	5.46
Hoeing + Clipping	1980.21	79209	6400	35493	29093	5.55
Belt (48SC)	2732.24	109290	7528	65574	58046	8.71
Coragen (20SC)	2185.79	87432	5058	43716	38658	8.64
Hoeing+ Clipping + Belt (48SC)	3178.69	127148	12328	83432	71104	6.77
Hoeing + Clipping + Coragen (20SC)	2732.24	109290	9858	65574	55716	6.65
Hoeing + Clipping + Belt (48SC) + Coragen (20SC)	3278.69	131148	11093	87432	76339	7.88
Control	1092.90	43716	-	-	-	-

Where

Average market price of Brinjal kg^{-1} = Rs. 40/- ; Labor cost for Hoeing @ Rs. 3200 ha $^{-1}$; Labor cost for Clipping @ Rs. 3200 ha $^{-1}$; Labor cost for Hoeing + Clipping @ Rs. 6400 ha $^{-1}$; Labor cost of pesticide spray = Rs. 3200 ha^{-1} Pesticide cost ha^{-1}: Belt = Rs. 864; Coragen = Rs. 5058/; .

DISCUSSION

Sufficient work on control strategies have been done for the management of *L. orbonalis* but main dependency was made on chemicals. The indiscriminate use of insecticides to control *L. orbonalis* has disturbed natural balance of bio-control agents of *L. orbonalis* giving rise to resurgence of the pest (Baral*et al*., 2006). Likewise, non-availability of commercial eggplant cultivars resistant to *L. orbonalis* further aggravated the situation. For the control of *L. orbonalis* different management strategies have been used by some earlier researches such as resistant varieties, cultural practices, biological control, mechanical, chemical (Ramasamy, 2008, Latif et al . 2009, Bhushan et al 2011).

To reduce the dependency on the use of chemicals emphasis has been laid on the use of non-chemical and eco-friendly management strategies (Iqbal et al., 2014; Biradar et al. 2001). In the present study Hoeing, Clipping and insecticides of new chemistry Belt (40SC) and Coragen (20SC) was tested alone and in different combination to find out the effective treatment to reduce the damages by L. orbonalis and enhance the brinjal yield.

Results revealed that all the treatments though varied in their efficacies, caused significant reductions in L. orbonalis infestations and increased yield as compared to control. In general, combination of practices gave better results as compared to individual treatments with few exceptions.

In general, hoeing + clipping in combination with insecticide Belt and Coragen were found the most effective treatment in reducing pest infestations. Khorsheduzzamanet al. (1998) reported a remarkable decrease in fruit infestation when insecticides were integrated with other non-chemical approaches for the management of brinjal shoot and fruit borer. Application of Hoeing and clipping usedsingly was the least effective treatment but their efficiency increased when used in combination. Kumar et al. (2000; 2001),Biradaret al. (2001), Rashid et al. (2003),Alamet al. (2003) and Rahman et al. (2006) endorsed the effectiveness of insecticides in the control of the brinjal shoot and fruit borer and many other pest, but consider the integrated approach a better option. Findings of (Onekutu et al 2014) also revealed that the integration of different control techniques can significantly reduce damage by the eggfruit and shootborer.

Reduction in brinjal shoot and fruit infestations by periodic clipping of infested shoots and fruits is also documented by (Talekar, 2002 andSatpathyet al., 2005). This practice has also been reported to lower the incidence of pest on damaged fruits (Ducaet al., 2004 and Srinivasan, 2008). The reduction in brinjal shoot and fruit infestations by removal of infested shoots is attributed to prevention in the dispersal or dissemination of the pest (Neupane, 2000). These findings and those of Singh et al. (2005) and Rath and Maity (2005) related to mechanical clipping of infested shoots and leaves corroborated present results where clipping of damaged branches significantly reduced pest infestation and increased yield.

In the present study hoeing alone was also found better than control in reducing larval infestation, shoot and fruits infestation and increasing brinjal yield. Murthy and Nandihalli, 2003; Reddy and Kumar, 2004 revealed weedspresent in Brinjal field serve as alternative hosts for the survival and reproduction of brinjal shoot and fruit borer in addition to competing for nutrients, light etc. The removal of weeds through hoeing resulted in reduction in pest infestation as observed in our findings. Likewise, the pest pupates in the soil and by hoeing the pupae of the pest are exposed to sun and are destroyed or eaten by birds and caused reduction in pest infestation (Srinivasan, 2008). Shirale et al. (2012) highlighted that that Belt and Coragen was found the best among the tested insecticides had lowest shoot and fruit infestation and highest brinjal yield. Similarly (Latif et al. 2009) also found Flubendamide the most effective when integrated with mechanical control + field sanitation.

Variation yield of brinjal fruit was found among the tested treatments. It has been observed that the yield of brinjal may be affected due to feeding of larvae on tender shoots and flowers infestation. Results showed that plants with lowest shoot and fruit infestation yielded the highest. Results also revealed that treatments where Hoeing and Clipping was integrated with Belt and Coragen were proved the best had highest brinjal yield followed by the treatment where control measures was applied singly. Yield recorded in Hoeing and clipping used singly and in combined yielded lower brinjal yield, than those treatments where they both were used in integration with Belt and Coragen. The present finding is in agreement of (Latif et al. 2009) they found Flubendamide the most effective when integrated with mechanical control + field sanitation.

Cost benefit ratio is very crucial as it present the real picture of how much is gain by applying different management practices. Result shows that all the tested treatments found better and having positive CBR value. However, application of Belt twice at fortnight interval was found best, bears highest CBR value (1:8.71), followed by treatment where Coragen was used (1: 8.64) whereas the Hoeing bears the lowest CBR value (1:2.73) was found the least profitable treatment. Although the Belt was comparatively expensive than Coregen but Belt perform better had higher brinjal yield with highest net return than Coragen. The present findings cannot be compared with the findings of (Bhushan et al. 2011; Latif et al . 2009; Pandey et al. 2016) because of the differences in treatment combination, cost of the insecticide, net worth of produce and socio-economic conditions as it varies from region to region.

CONCLUSION AND RECOMMENDATION

It was concluded that all the tested treatments alone and in combination have the potential to manage *L. orbonalis* infestation as compared to Control. However, Hoeing and clipping and insecticides perform better used in combination rather than used alone. Belt and Coragen integration with Hoeing and Clipping were found the most effective in reducing *L. orbonalis* infestation and increased the brinjal yield. Application of Belt and Coragen used alone, twice at 14 days interval is the most profitable among the tested treatment having highest CBR value. Hoeing and clipping alone and in combination do affect the infestation level of *L. orbonalis.* But it is the least profitable as compared to other tested treatment therefore their use in combination with chemical pesticides is recommended to device integrated management strategy to combat *L. orbonalis* in Brinjal.

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