

MANAGEMENT OF EGGPLANT SHOOT AND FRUIT BORER (*Leucinodes orbonalis* Guenee) BY INTEGRATING DIFFERENT NON-CHEMICAL APPROACHES

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Eggplant shoot and fruit borer (ESFB), *Leucinodes orbonalis* Guenee, a destructive pest of eggplant (*Solanum melongena* L.), adversely affects quality and yield of eggplant fruit throughout the world. Currently, its management is mainly relied on insecticides which are inimical to humans, livestock and environment. To get rid of the pernicious consequences of chemicals, use of alternative non-chemical approaches has been emphasized. Ergo, in the present study non-chemical methods viz. hoeing, clipping of damaged fruits and shoots and weeding at weekly intervals and a biocontrol agent *Trichogramma chilonis* individually and in combination were assessed for the management of ESFB. All the treatments though varied in their efficacies, caused significant reductions in infestation of ESFB and increased yield as compared to control. Combination of practices gave better results as compared to individual treatments with few exceptions. In general, the combined treatment (*T. chilonis* + hoeing + clipping) was found to be the most effective in reducing pest infestations and increasing yield followed by another combined treatment where hoeing, clipping and weeding were applied conjointly. Application of *T. chilonis* singly was the least effective treatment; however, incorporation of *T. chilonis* with other practices gave good results. Similarly, integration of hoeing with clipping of infested shoots and fruits at weekly intervals also proved satisfactory in reducing pest infestation and enhancing yield. It is concluded that integration of non-chemical approaches will help reduce infestation of ESFB significantly and will make a major contribution to both climate-change mitigation and sustainable crop production systems.

Keywords: *Leucinodes orbonalis*, *Solanum melongena*, *Trichogramma chilonis*, hoeing, weeding, pruning.

INTRODUCTION

Eggplant (*Solanum melongena* L.) also known as brinjal and aubergine is an important solanaceous vegetable and is extensively cultivated in South Asia (Bangladesh, India and Pakistan) which constitutes about 50% of the total area under eggplant cultivation in the world (Alam *et al.*, 2003). Among all the summer grown vegetables with semi-perennial nature, eggplant is almost available throughout the year and is consumed in various forms by all classes of people. It has high nutritive value and contains all the essential minerals, vitamins and amino acids. In Pakistan, eggplant is cultivated on large scale, but it lags behind many countries in terms of productivity.

Several factors are responsible for low productivity of eggplant in Pakistan (Hussain *et al.*, 2014, 2016; Iqbal and Mukhtar, 2014; Kayani *et al.*, 2017; Mukhtar *et al.*, 2013a,b; 2014, 2017a,b; Shahbaz *et al.*, 2015; Tariq-Khan *et al.*, 2017). Among biotic factors, eggplant shoot and fruit borer (ESFB) (*Leucinodes orbonalis* Guenee) is considered by far the most damaging pest of eggplant (Taylo *et al.*, 2016). The pest is active in moderate climates throughout the year. The females lay approximately 250 eggs one by one on developing fruits

and young shoots of eggplant. The caterpillar is pink in color and is covered with sparsely distributed hairs all over the body. Fully grown larva measures about 20 mm long and pupates in a tough silken cocoon. The entire life cycle is completed in 3-6 weeks. There are five overlapping generations of the pest in a year.

Severe damage to fruits and shoots is caused by the larvae of the pest. The petioles, midribs of large leaves and young tender shoots are bored by newly hatched larvae. Due to larval activity, translocation of nutrients towards shoots is affected. This causes withering and drooping of shoots, resultantly the growth of eggplant and size and number of fruits are significantly reduced (Atwal and Dhaliwal, 2007). The larvae then enter into young fruits, make tunnels and start feeding on internal tissues. The tunnels are clogged with frass and render the fruits unmarketable (Alam *et al.*, 2003; Mainali, 2014). Sometimes, secondary infection by bacteria causes rotting of fruits and further deteriorates the quality of fruits.

The pest is a serious threat due to its high reproduction, fast turnover of generations and tremendous damage. A single larva is enough to damage 4-6 healthy fruits (Jayaraj and Manisegaran, 2010). The infestations and losses caused by the pest vary from location to location and season to season

depending upon environmental factors, cultivars sown and plant age. In Bangladesh, the fruit infestation ranged from 31 to 90% (Rahman, 1997), in India 37–63% (Dhankar, 1988), and in Pakistan 50–70% (Saeed and Khan, 1997). The pest is responsible for reducing crop yield up to 90% (Misra, 2008; Jagginavar *et al.*, 2009).

For the management of ESFB several management tactics have been formulated and advocated. The conventional methods involve the use of chemicals, pheromone traps or cultural practices. The pheromone traps have shown promising results; however, these traps lose their effectiveness quickly and have to be replaced. The cultural practices are either not easily applicable in all the growing areas or are labor intensive. Pruning and prompt disposal of infested eggplant shoots at regular intervals up to the first harvest is an important component in the ESFB IPM strategy (Srinivasan and Huang, 2009). The scarcity of natural sources of resistance in *Solanum* species against ESFB has been a major challenge to breed cultivars resistant to ESFB (Yousafi *et al.*, 2013). Farmers mainly rely on synthetic pesticides to manage this devastating pest (Rahman *et al.*, 2006; Yousafi *et al.*, 2015) and over forty sprays of chemicals have been applied per growing season (Alam *et al.*, 2006). The indiscriminate and injudicious application of synthetic insecticides has given rise to the problems of increased production costs, residual toxicity, pesticide resistance, resurgence, secondary pest outbreak, potential health and environmental threats and lethality towards beneficial organisms (Gaur and Chaudhary, 2009). To dispense with the pernicious consequences of chemicals, use of alternative non-chemical approaches has been emphasized. Therefore, in the present study non-chemical methods viz. hoeing, clipping of damaged fruits and shoots and weeding at weekly intervals and a biocontrol agent *Trichogramma chilonis*, individually and in combination, have been used for the management of ESFB.

MATERIALS AND METHODS

Raising of eggplant nursery: The nursery of eggplant cv. Nirala was raised in sterilized potting mixture in germination trays at greenhouse of Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi. The daily temperature of the greenhouse ranged 25-27°C. The trays were watered when required.

Experimental lay out: The experiment on the efficacy of various management strategies (alone and in combinations, making 14 treatments) was carried out at the experimental area of Pir Mehr Ali Shah, Arid Agriculture University, Rawalpindi. The geographical characteristics of the region have been described by Kayani *et al.* (2013) and the description of treatments is given in Table 1. The experiment comprised four blocks, each block serving as a replication. Within each block, 14 plots each measuring 4.25 m × 3.5 m

were prepared, separated by a strip of 0.5 m. The treatments were assigned randomly to each plot. A non-experimental area of 0.25 m was left from the four sides of each plot. A plant-to-plant distance of 0.60 m and row-to-row distance of 0.75 m were maintained in each plot making a plant population of 36 per plot. Four-week-old seedlings of eggplant cv. Nirala raised in sterilized soil in germination trays were transplanted to each plot. All the agronomic practices were followed as per recommendations.

Table 1. Description of treatments.

Treatment	Description
T1	<i>Trichogramma chilonis</i> at the rate of 1 card/plot at weekly interval (2500 eggs per card)
T2	Hoeing at weekly interval
T3	Clipping of damaged fruits and shoots at weekly interval
T4	Weeding at weekly interval
T5	<i>T. chilonis</i> at the rate of 1 card/plot at weekly intervals + Hoeing at weekly interval
T6	<i>T. chilonis</i> at the rate of 1 card/plot at weekly intervals + Clipping of damaged fruits and shoots at weekly interval
T7	<i>T. chilonis</i> at the rate of 1 card/plot at weekly intervals + Weeding at weekly interval
T8	Hoeing at weekly interval + Clipping of damaged fruits and shoots at weekly interval
T9	Hoeing at weekly interval + Weeding at weekly interval
T10	Clipping of damaged fruits and shoots at weekly interval + Weeding at weekly interval
T11	<i>T. chilonis</i> at the rate of 1 card/plot at weekly intervals + Hoeing at weekly interval + Clipping of damaged fruits and shoots at weekly interval
T12	<i>T. chilonis</i> at the rate of 1 card/plot at weekly intervals + Hoeing at weekly interval + Weeding at weekly interval
T13	Hoeing at weekly interval + Clipping of damaged fruits and shoots at weekly interval + Weeding at weekly interval
T14	Control

Data collection: For estimation of population of ESFB per leaf and percentage infestation of shoots, buds, flowers and fruit, ten plants from each plot were selected at random and tagged. The larvae of ESFB were counted from upper, middle and lower leaves of each randomly selected plants on weekly basis during the entire growing season. The average larvae per leaf were calculated by dividing total larvae by ten. The total numbers of healthy and infested shoots, buds and flowers of ten randomly selected plants were counted and percentage infestation of shoots, buds, and flowers were determined. For

the estimation of fruit infestation, infested as well as healthy fruits were counted from each plot after each picking throughout the cropping season and percentage of infested fruits was calculated. Fruits with holes made by the larvae of ESFB were identified as infested. For yield assessment, fruits were picked on weekly basis from each plot during the entire growing period, weighed and the cumulative per plot yield of all the pickings was transformed into total yield in tons per hectare.

Statistical analysis: All the data were subjected to Analysis of Variance (ANOVA) using GenStat package 2009 (12th Ed.), version 12.1.0.3278 (www.vsni.co.uk). The means were compared by Fisher's protected least significant difference test at ($P \leq 0.05$).

RESULTS

Larval population: All the treatments though varied in their efficacies, caused significant reductions in larval population of ESFB as compared to control. T13 (hoeing + clipping of damaged shoots and fruits + weeding) was found to be the most effective treatment in reducing larval population per leaf followed by T5 (*T. chilonis* + hoeing) and T6 (*T. chilonis* + clipping of damaged shoots and fruits) which were statistically at par with T13. The treatment (T3) in which only damaged shoots and fruits were clipped was statistically equally effective as compared to T8, T10 and T11 where clipping was done along with other strategies. Application of *T. chilonis* singly was the least effective treatment (Table 2).

Shoot infestation: The percent shoot infestation due to ESFB

larvae was the lowest in T11 (4.21%) where *T. chilonis*, hoeing and clipping of damaged shoots and fruits were applied conjointly. The combined treatment (T13) where weeding was done instead of *T. chilonis* application, was the second best treatment, although percent shoot infestation as a result of this treatment was significantly higher than T11 and had no significant differences with treatments T3, T6 and T8. *T. chilonis* (T1) proved to be the least effective in controlling ESFB while other treatments had intermediate effects on the pest (Table 2).

Bud, flower and fruit infestation: Minimum bud infestation of 5.21% was found with T11 followed by an infestation of 10.3% with T13 which was significantly higher than T11. Maximum infestations were recorded with treatments T1, T2, T3 and T4 which were found at par with each other. The other treatments were moderate in reducing bud infestation as shown in Table 2.

Similarly, the lowest flower and fruit infestation was observed with treatment T11 followed by T13 resulting in 6.73 and 8.77% decreases in flower infestation and 6.94 and 7.13% decreases in fruit infestation respectively. T1, T4 and T7 were the least effective treatments in reducing flower and fruit infestations. The rest of the treatments caused intermediate reductions (Table 2).

Yield: Of all the treatments, T11 was the most effective as it increased maximum yield as compared to control followed by T13. The minimum increase in yield was obtained with treatment T1 followed by T2 and T7. The rest of treatments resulted in inter a mediate increase in yield (Table 2).

Table 2. Effect of treatments on infestation of ESFB on eggplant.

Treatment	Larval population per leaf	Percent shoot infestation	Percent bud infestation	Percent flower infestation	Percent fruit infestation	Yield in tons
T1	0.1783fg	21.90h	18.24ef	27.98ef	19.04g	2.283b
T2	0.1617ef	20.15fgh	17.36ef	24.24d	16.23f	2.558c
T3	0.1125bc	16.79bcd	17.37ef	20.36c	13.06de	3.040e
T4	0.1567ef	21.41gh	18.57f	28.57f	19.35g	2.363b
T5	0.0933ab	18.25cdef	17.19e	21.02c	14.34e	2.857d
T6	0.0942ab	17.00bcd	12.22c	13.32b	10.81c	2.901d
T7	0.1783fg	20.41fgh	17.58ef	25.84de	18.59g	2.524c
T8	0.1125bc	16.21bc	11.74c	9.22a	8.93b	3.304f
T9	0.1408de	19.45efg	14.91d	13.43b	12.50d	2.826d
T10	0.1108bc	18.67def	14.56d	12.85b	12.42d	2.838d
T11	0.1117bc	4.21a	5.21a	6.73a	6.94a	3.794h
T12	0.1267cd	17.82cde	17.18e	18.49c	13.05de	2.861d
T13	0.0708a	14.85b	10.30b	8.77a	7.13a	3.620g
T14	0.1967g	27.82i	38.17g	37.23g	21.87h	1.981a

Each value is an average of four replications.

Mean values in each column with similar letters do not show significant statistical difference at $P < 5\%$ when tested by Fisher's protected LSD test.

DISCUSSION

A number of control strategies have been applied for the management of ESFB but main reliance was made on chemicals. Up to 50 sprays of insecticides on eggplant during 5-6 month crop season have been applied by farmers (AVRDC 1994) and the number is still increasing. However, the undue application of insecticides to control ESFB has disturbed natural balance of bio-control agents of ESFB giving rise to resurgence of the pest (Baral *et al.*, 2006). Likewise, non-availability of commercial eggplant cultivars resistant to ESFB further aggravated the situation.

To minimize the reliance on the use of chemicals emphasis has been laid on the use of non-chemical and eco-friendly management strategies (Mukhtar *et al.*, 2013c, d; Iqbal *et al.*, 2014; Shahzaman *et al.*, 2015). Hence, in the present study various cultural methods and a biocontrol agent individually and in combination have been used for the management of ESFB. All the treatments though varied in their efficacies, caused significant reductions in ESFB infestations and increased yield as compared to control. Combination of practices gave better results as compared to individual treatments with few exceptions. In general, the combined treatment T11 (*T. chilonis* + hoeing + clipping) was found to be the most effective treatment in reducing pest infestations followed by T13 (hoeing + clipping + weeding). Application of *T. chilonis* singly was the least effective treatment.

A gradual reduction in ESFB infestations by periodic removal of infested and damaged twigs, shoots or branches is well documented (Talekar, 2002; Arida *et al.*, 2003; Satpathy *et al.*, 2005). This practice has also been reported to lower the incidence of pest on damaged fruits (Duca *et al.*, 2004; Srinivasan, 2008). The reduction in ESFB infestations by pruning of damaged branches and 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. Periodical pruning and removal of lateral branches and older leaves from the lower portions for proper lightening and circulation of air within the canopy are recommended for production of high quality and bright colored fruit (Chen *et al.*, 2002). Duca *et al.* (2004) reported that hebdomadal removal and destruction of infested shoots and fruits resulted in the production of healthy and highest weight fruits which showed that pruning did not adversely affect the growth and yield of eggplant (Talekar, 2002).

Similarly, a number of weeds have been reported to infest eggplant fields which serve as alternative hosts for the survival and reproduction of ESFB in addition to competing for nutrients, light etc. (Murthy and Nandihalli, 2003; Reddy and Kumar, 2004). The removal of weeds 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).

Scores of parasitoids and entomopathogenic nematodes (Rahoo *et al.*, 2017) have been reported as natural enemies of ESFB throughout the world and are responsible for keeping the pest populations under reasonable control. Among these, the egg parasitoid *T. chilonis* has been proved to be the most effective (Krishnamoorthy, 2012) and caused increase in yield. The biocontrol agent can also be integrated with other pest management tactics to increase crop yield (Gonzales, 1999). This parasitoid has been reported to be present in India (Naresh *et al.*, 1986), Bangladesh (Alam and Sana, 1964) and Nepal (Kafle, 1970) however; its contribution to pest control has hardly been documented and does not appear to be significant. As in developing countries, ESFB is mainly controlled by synthetic insecticides which also adversely affected the populations of this parasitoid. In the present study *T. chilonis* did not prove effective in controlling the pest. These findings are in conformity with those of Singh *et al.* (2005) and Ghananand *et al.* (2009) who reported that *T. chilonis* did not show significant impact on the population density of *L. orbonalis*. In the present study, the yield of eggplant did not increase significantly by this treatment as compared to control and the findings are in agreement with those of Prasad *et al.* (2005) and Rath and Bijayeeny (2005) who also reported that release of *T. chilonis* alone did not yield valuable increase in production.

It is, therefore, concluded that ESFB can be well managed by a combination of cultural methods like weeding, hoeing and removal of infested plant parts. These practices can also be integrated with other strategies in integrated pest management programs. The approach will help reduce infestation of ESFB significantly and will make a major contribution to both climate-change mitigation and sustainable crop production systems.

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