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Brinjal shoot and fruit borer: Bio-ecology and management

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Abstract
Shoot and fruit borer, *Leucinodes orbonalis* Guenee (Lepidoptera: Pyralidae) is the most destructive pest of brinjal at both vegetative and reproductive stages, of almost all regions of India causing significant reduction in the yield by 40 to 80 %. Incidence of this insect pest occurs either sporadically or in outbreak every year in the Indian subcontinent. Its infestation is responsible for both the qualitative and quantitative degradation of fruits round the year and attains the most serious stature during monsoon months. The small moth with dirty whitish wings and speckled markings, lays eggs on young leaves/ flowers/ calyx of the fruits. After hatching, the young larvae bore into the petioles/ midribs of leaves/ growing shoots/ flower buds/ fruits and close the bore holes with frass, after entering in them. The larvae feed inside the midribs/ flowers/ ovaries of flowers and in the pulp of fruit. The damaged shoots droop down and the damaged flowers drop away. The entry holes on the fruit are not visible as these are either recovered or covered with frass and the faded depressions of entry holes are seen. The large one or more round exit holes are visible on the fruits. Affected fruits get rotten from inside and such fruits loose their market value.

Keywords: *Leucinodes orbonalis*, brinjal, larva, infestation, shoot and fruit

Introduction
In 1854, brinjal shoot and fruit borer was first designated as *Leucinodes orbonalis* by Guenee (Capps, 1948) [13]. Whereas, in 1859, it was first selected as the type species of the genus by Walker (Capps, 1948) [13]. *Leucinodes orbonalis* Guenee is the most destructive pest of *Solanum gilo* (*Solanum aethiopicum*), *S. melongena*, *S. macrocarpon* and other related vegetables. It is considered as the most obnoxious and damaging pest of the eggplant, *S. melongena* (Butani and Jotwani, 1984; Chattopadhyay, 1987; Tewari and Sandana, 1987; AVRDC, 1995 and Rashid *et al*., 2008) [11, 15, 63, 10, 49], causing more than 80% loss in marketable yield (Ali *et al*., 1994; Dhankar, 1988 and Raju *et al*., 2007) [6, 19, 47]. Its incidence was first confirmed in India by Dhankar (1988) [19], which is considered the centre of origin and diversity of the eggplant, *S. melongena*. Larva is the only damaging stage of this pest which feeds inside the fruit and form large exit holes in the fruits for pupation after complete development, later decreasing the market value of the fruits and rendering them unfit for human consumption (Alam *et al.,* 2003) [3, 4]. The damage initiates at seedling stage and continues till the fruit harvesting. Larva bores into petioles and midribs of large leaves and young shoots, at the initial stages of plant growth, leads to closing the entry holes with their frass and feeding inside the shoot (Butani and Jotwani, 1984) [11], finally drooping and withering of the shoot occurs (Alam and Sana, 1962) [1]. In the later stages of fruit formation, the larva bores into the flower buds and fruits through the calyx, The entry holes on the fruit are not visible as these are either recovered or covered with frass and the faded depressions of entry holes are seen. The large one or more round exit holes are visible on the fruits. Affected fruits get rotten from inside and such fruits loose their market value.

Biology of *L. orbonalis*
Egg
Alam *et al.* (1982) [2] and Kavitha *et al.* (2008) [26] found that a single female could lay 5 to 242 eggs in her life time. Eggs were laid mostly singly and sometimes in the batches of 2 to 4 eggs. Females preferred to lay eggs on the lower surface of the tender leaves or the twigs of plant, flowers, calycies of the fruits. Eggs were oval or somewhat elongated in shape and creamy white in colour which changed to orange with prominent black spot before hatching (Harit and Shukla, 2005 and Singh and Singh, 2001) [23, 60]. The pre-oviposition, oviposition and post-oviposition period *viz.,* 1.1 to 2.1 days, 1.4 to 4.0 days and 1.0 to 2.0 days,

respectively had been reported by Ali and Sanghi (1962) [5]; Jat *et al.* (2003) [24]; Mehto *et al.* (1983) [35]; Raina and Yadav (2017) [44, 45] and Singh and Singh (2001) [60]. Whereas, incubation period was recorded as 3 to 4 days by Ali and Sanghi (1962) [5]; Alam *et al*. (1982) [2]; Lall and Ahmed (1965) and Muthukumaran and Kathirvelu (2007) [37]. However, Raina and Yadav (2017) [44, 45] reported that maximum hatching (38.2%) occurred on third day after oviposition followed by 27.0 and 0.6 per cent on fourth and fifth days, respectively.

Larva

According to Jat *et al.* (2003) [24]; Harit and Shukla (2005) [23]; Patial *et al.* (2007) [40]; Raina and Yadav (2017) [44, 45] and Singh and Singh (2001) [60], larvae passed through five instars before entering the pupal stage. They observed average duration of 1st, 2nd, 3rd, 4th and 5th larval instars *viz.*, 1-2, 2-3, 2-3, 2-4 and 2-4 days, respectively. Newly hatched larva was tiny, creamy or dirty white in colour with a prominent dark brown or light black head, three pairs of thoracic legs and five pairs of prolegs. Second instar larvae resembled the first instar larvae except larger in size and slightly darker colour. The third instar larvae were much longer and darker than the preceding instars, in which prothoracic shield had distinct markings, thoracic legs were dark brown in colour. Fourth instar was slightly pinkish in colour. Fifth instar was cylindrical in shape and pinkish brown in colour having three distict segments of thorax and five pairs of well-developed prolegs. But, Alam *et al.* (1982) [2] and Saxena (1965) [51] recorded six larval instars of shoot and fruit borer. Das and Patnaik (1970) [17] and Jat *et al.* (2003) [24] also reported that average larval period lasted for 12.3 to 14.0 days. Pupa

Butani and Verma (1976) [12] and Mehto *et al.* (1983) [35] reported pupal period varying from 7 to 10 days. They observed that pupae were dark brown in colour with wider cephalic lobe and narrow anal end with eight hook shaped fine spines at the posterior end of abdomen. Pupation took place on glass jars, soil, muslin cloth, on the fruits and sometimes on the leaves of plant (Alam *et al.*, 1982; Jat *et al.*, 2003 and Mathur and Jain, 2006) [2, 24, 33]. Whereas, according to Raina and Yadav (2017) [44, 45], pupal period varied between 6 to 8 days. They did not observe adult emergence upto 5th day after pupation. The emergence of adult started on 6th day after pupation and continued upto the 8th day. On an average 14 per cent, 30 per cent and 10 per cent adults emerged on 6th, 7th and 8th day after pupation and maximum emergence was observed on 7th day. Mean adult emergence was found to be 54 per cent.

Adult

Alam *et al.* (1982) [2]; Jat *et al.* (2003) [24] and Singh and Singh (2001) [60] reported that male moths lived for 1 to 3 days and female moths lived for 2 to 5.8 days. The moth was white in colour with blackish brown head and thorax. The whitish wings had pinkish brown markings which are bigger on the forewings. The males were smaller in size, lesser in wing- expanse and narrow/slender abdomen which tapered posteriorly while the females were bigger in size, more in wing expanse and broader abdomen with rounded posterior end (Jat *et al.*, 2003) [24]. However, according to Taley *et al.* (1984) [62] and Patial *et al.* (2007) [40] Patial sex ratio was found to be in favour of females 1.0:2.0 and 1.0:1.3, respectively. Raina and Yadav, 2017 [44, 45] reported that adults of *L. orbonalis* generally mate during night or early hours in the morning. Pre-mating period varied from 6-9 hours (avg 7.1 hours). The adults remained in mating position period for 30-49 minutes (avg 41.2 minutes). Post-mating period varied from 4-6 days (avg 5.0 days). Mehto *et al.* (1983) [35] and Yasuda and Kawashaki (1994) also observed that mating normally occurs during the early hours of the day lasted for 43 minutes. Lall and Ahmed (1965); Alam *et al* (1982) [2]; Atwal (1976) [9] and Mehto *et al* (1983) [35] recorded that brinjal shoot and fruit borer completes its life cycle in 19.0 to 43.0 days.

Population dynamics of *L. orbonalis*

Singh *et al.* (2009a) [54] from Kanpur noticed the initial infestation of shoot and fruit borer during 4th week of August at 47 days after transplanting and peak incidence was observed during 2nd week of September after 114 days of transplanting and thereafter declined gradually with rise in temperature. They recorded non-significant relationship between the shoot damage and the weather parameters. Singh *et al.* (2009b) [57] conducted experiment in the field of Manipur university and found that shoot and fruit borer infestation commenced first on shoots from the second week of April, 2003 and 2004 with 9.7 % and 11.6% damage. The peak infestation on shoot was observed during second week of June, 2003 and third week of May, 2004 with 25.8 % and 31.4 % infestation, resepctively. The per cent infestation of *L. orbonalis* was positively correlated with temperature (22.93-25.45ºC) and R.H (80.5-87.2%). Varma *et al.* (2009) [64] reported the positive correlation of brinjal shoot and fruit borer infestation with maximum relative humidity, rainfall and wind speed during 1st year of experiment and with maximum relative humidity and sunshine hours during the 2nd year. Singh *et al.* (2011) [59] studied the population incidence of brinjal shoot and fruit borer, *L. orbonalis* on *S. melongena* L c.v. Pusa Purple long during the two consecutive cropping seasons (2003 and 2004) at Manipur. They found that the incidence of shoot and fruit borer was started in the month of April and continued till the end of the June. The peak period of the pest on shoot was recorded in the first week of June (29.45%) and fourth week of May (25.24%) during the first and second cropping seasons, respectively. However, the incidence of this pest on fruit was highest during the second week of June, 2003 (67.16 %) and third week of June, 2004 (72.25%). The correlation studies revealed that the average temperature and R.H. showed significant positive association while average sunshine had significant negative association with the infestation of the pest on brinjal. Mathur *et al.* (2012) [32] studied the effect of abiotic factors on the seasonal incidence of shoot and fruit borer, *L. orbonalis* during rabi 2009 at Durgapur. It was found that the shoot damage was positively correlated with both maximum (18.1-37.88ºC) and minimum temperatures (4.6-20.84ºC), rainfall (0-2.6 mm) and wind speed (2.5-7.3 km/hr) while negatively correlated with mean relative humidity (21.8-75.3%). Whereas, per cent fruit infestation showed a non-significant correlation with maximum and minimum temperatures, rainfall and wind speed and negative correlation with mean relative humidity. Meena *et al.* (2012) [34] recorded that the peak period of shoot infestation was observed in 9th standard week (5.4%) and 7th standard week (4.6%) followed by 8th standard week (4.5%). The incidence of fruit borer started from 10th standard week and continued till last picking. Peak infestation of fruit borer was observed in 18th standard week (43.3%) and 17th standard week (40.1%). Kumar and Singh (2013) [29] from Kanpur revealed that seasonal incidence of shoot and fruit borer, *L. orbonalis* on shoot was more prevalent during vegetative phase of the crop up to the 3rd week of September. On the fruit initiation, there was a continuous decline in the infestation on shoots and it disappeared during fruiting stage of the crop in end of October, as the borer infestation shifted to the fruits in the 2nd week of October. It gradually declined with the advent of winter season and completely wiped out by the end of November. The role of temperature, rainfall, RH (morning) in increasing infestation and intensity on shoot and fruits was very conducive but RH (evening) responded negatively. Malik and Pal (2013) [31] studied the seasonal incidence of shoot and fruit borer, *L. orbanalis* on forty brinjal germplasm at Kalyanpur. The infestation of shoot borer appeared in 43rd standard week (18–24 October). Maximum temperature played positive role in multiplication of shoot borer of brinjal while minimum temperature and R.H was negatively correlated. The wind velocity and rainfall showed no correlation, while evaporation rate showed positive effect on the multiplication of infesting shoot. Kaur *et al.* (2014) [25] studied the population dynamics of brinjal shoot and fruit borer at Hisar during summer 2009-10 and reported a maximum number of larvae (10 larvae/ 90 plants) in the 39th and 40th standard weeks of the year. The lowest mean population (0.0 larvae/90 plants) was recorded in the 48th standard week. Correlation analysis revealed that larval population was positively correlated with temperature and negatively correlated with per cent R.H. Raina and Yadav, 2017 [44, 45] from Hisar conducted experiments from June to October during 2014, on brinjal (var. BR-112). They found that the infestation of *L. orbonalis* started appearing in shoots during June month, whereas, fruit infestation started appearing in July month. The peak incidence of shoot and fruit borer was observed in third week of September. Highest shoot damage (48.75%), fruit damage (40.00%) on number basis and maximum larval population (12 larvae/20 plants) was recorded in the third week of September, When temperature (max.) was 35.3°C and min.-25.0°C, relative humidity morning-87% and evening-45%. Incidence of *L. orbonalis* started declining afterwards in shoots as well as in fruits. Further, Correlation analysis showed non-significant relationship of abiotic factors with per cent shoot damage, fruit damage and mean larval population. Whereas, regression analysis showed 68 per cent variation in the population due to abiotic factors.

Management of *L. orbonalis*

Organic manure

Krishnamoorthy *et al.* (2001) evaluated the effect of application of neem and pongamia on various vegetables. In brinjal, it reduced the shoot and fruit borer incidence to 6-10 per cent as compared to 30-50 per cent in insecticide treated plots. However, the studies conducted by Sreenivasa Murthy *et al.* (2001) [61] revealed that the application of neem cake (250 kg/ha) decreased the incidence of borer to 8 per cent and increased the yield to nearly 68 per cent. Prakash *et al*. (2002) [42] reported lower percentage of fruit borer infestation in okra treated with FYM and vermicompost. Godase and Patel (2003) [22] observed the effect of organic manures and fertilizers on the incidence of brinjal shoot and fruit borer *L. orbonalis*. The lowest incidence of fruit borer was recorded in neem cake @ 1.700 kg per ha (6.08%). However, it was found at par with vermicompost @ 4000 kg per ha, double dose of K2O and half dose of FYM + half dose of fertilizer. Shobharani and Nandihalli (2004) reported that the single application of neem cake @ 240 kg/ha was effective in reducing *L. orbonalis* incidence in potato. Venkatesh *et al.* (2004) [65] studied the influence of the application of five organic manures *viz.*, neem cake, pongamia cake, castor cake (all @ 1.0 t/ha), farmyard manure and vermicompost (10.0 t/ha) on *L. orbonalis* in brinjal. Among all, neem cake was found as the most superior one.

Pheromone traps

Alam *et al.* (2003) [3] reported that, the marketable fruit yield was greater in pheromone-treated plots than in check plots. They also found that the number of insects trapped at the 0.5 m height was significantly greater than at the 1.5 m height. Cork *et al.* (2003) [16] reported that delta and wing traps baited with synthetic female sex pheromone of *L. orbonalis* were found to catch and retain ten times more moths than either *Spodoptera* or uni-trap designs. Locally produced water and funnel traps were also found as effective as delta traps, although ‘windows’ cut in the side panels of delta traps, significantly increased the trap catch from 0.4 to 2.3 moths per trap per night. Wing traps placed at crop height caught significantly more moths than traps placed 0.5 m above or below the canopy. However, Chatterjee (2009) [14, 41] stated that the setting of pheromone trap @ 75 numbers per hectare gave quite substantial protection from *L. orbonalis* in shoot damage (58.35%), fruit damage (33.73%) and yield (28.67%) in brinjal crop. Rani (2013) conducted field studies on brinjal shoot and fruit borer, *L. orbonalis* with sex pheromone trap at nine villages in and around Bangalore rural district during 2012-13. The four different trap heights were evaluated for optimum BSFB moth catches. The results revealed that traps at the greatest height of 0.6 m above crop canopy recorded with maximum number of moth catches (499 moths). Similarly five different trap densities (i.e., 8, 16, 24, 32 & 40 traps/acre) were also evaluated and they found that 16traps/acre recorded with maximum moth catches (1097 moths) and less fruit damage (6.48%).

Biopesticides and botanicals

Puranik *et al.* (2002) [43] evaluated different *B. thuringiensis* (*Bt*) formulations in comparison with neem and chemical insecticides against brinjal shoot and fruit borer. Among the different treatments, five sprays of Dipel 8L @ 0.2 per cent at 10 days interval resulted in minimum shoot (9.56%) as well as fruit (11.78%) infestation and maximum yield of marketable fruits (196.96 q/ha). Deshmukh and Bhamare (2006) evaluated newer insecticides in comparison with conventional insecticides against aubergine shoot and fruit borer, *L. orbonalis*. They found cartap hydrochloride at 0.1% as the most effective in reducing shoot infestation (4.20%) and fruit infestation (23.72% on number basis and 25.30% on weight basis) and in increasing fruit yield (78.73 q/ha) followed by spinosad at 0.01%. Patra *et al.* (2009) [41] during *kharif* season at West Bengal found that the lowest shoot as well as fruit infestation (7.47 and 9.88%) was recorded in the plots treated with spinosad 2.5 SC (50g a.i/ha). The highest marketable fruit yield (143.50 q/ha) was recorded by them in spinosad treatment followed by indoxacarb (126.90 q/ha) and emamectin benzoate (121.30 q/ha). Anil and Sharma (2010) studied bioefficacy of some insecticides on brinjal c. v Arka Nidhi against shoot and fruit borer, *L. orbonalis* during 2007 and 2008 at Palampur. They found that number of drooping shoots and fruit infestation was minimum in case of emamectin benzoate. But, cost-benefit ratio was found highest in agrospray oil T (0.2%). Wankhede *et al.* (2010) [66] evaluated that emamectin benzoate treatment was the most effective one with 5.0 & 4.8 % shoot damage in *kharif*, 2007 and 2008 trials, respectively. Minimum fruit infestation (11.51; 11.44 and 12.39; 12.44) on number and weight basis and highest yield of healthy fruits (24.06, 23.14 t ha^{-1}) was also recorded in emamectin benzoate, during the two cropping seasons. Gangwar *et al.* (2014) [21] conducted experiment at Meerut, Uttar Pradesh. They found spinosad 45 SC as the most effective one in reducing shoot and fruit damage with highest yield (253.30 q/ha) followed by novaluron 10EC (242.30 q/ha). But, they recorded maximum cost: benefit ratio in case of novaluron (1: 8.50) followed by carbosulfan (1:7.34).

Chemical control

Singh and Nath (2007) reported that the application of deltamethrin @ 25 g a.i./ha was effective in lowering the fruit damage on number and weight basis in brinjal and increased the yield of healthy fruits as compared to chlorpyriphos @ 500 g a.i/ha. Misra (2008) [36] evaluated two new insecticides, *viz.*, rynaxypyr 20SC and flubendiamide 480 SC in the field on brinjal cv. "Utkal Anushree" against shoot and fruit borer, *L. orbonalis* during winter, 2007 and summer, 2008 at Bhubaneshwar. Rynaxypyr 20SC @ 40 and 50g a.i./ha gave 95-97 per cent reduction in the 'shoot damage and 87-90 per cent reduction in-fruit damage on number basis and 88-90 per cent on weight basis at ten days after fourth spray as compared to untreated control. The healthy fruit yield was highest in plots treated with rynaxypyr 20SC @ 40 and 50g a.i.ha^{-1} during both the seasons. Naik *et al.* (2008) tested insecticides against shoot and fruit borer at Bapatla distt of Andhra Pradesh. They found that Profenofos (0.1%) produced the highest reduction (42.7%) of *L. orbonalis* shoot damage over control and increased the fruit yields (14312.05 Kg/ha) as against untreated control (6666.66 Kg/ha). Patial *et al.* (2009) [39] recorded the efficacy of ten insecticidal treatments against brinjal shoot and fruit borer during 2003 and 2004 at Palampur and observed that minimum shoot infestation and fruit infestation was registered in acetamprid with maximum profit and cost benefit ratio (Rs 24,146/ha and 1:13.24). Singh *et al.* (2009b) [57] conducted chemical control trial at Kanpur and observed that Profenofos @ 0.1% was the most effective insecticide in the reduction of shoot (39.91%) and fruit infestation (18.21 and 17.48%) of *L. orbonalis* on number and weight basis respectively as well as in giving higher fruit yield (310.50 q/ha). Kumar *et al.* (2010) reported a high efficacy of cypermethrin 0.0075% over endosulfan 0.05% for the control of *L. orbonalis* in brinjal which is more or less in consonance with the present studies. Singh and Kumar (2011) carried out the bioefficacy studies against *L. orbonalis* on brinjal at Pusa, Bihar and found Imidacloprid @ 0.025 kg a.i. ha^{-1} and fenvalerate @ 0.150 kg a.i. ha^{-1} as the most effective treatments and recorded the maximum fruit yield 290.25 q ha^{-1} and 268.5 q ha^{-1}, respectively. However, it was found that Fenvalerate @ 0.150 kg a.i. ha^{-1} gave highest ICBR (1:14.41) followed by cypermethrin (1:13.85) and imidacloprid (1:12.99). Shirale *et al.* (2012) [52] assessed that chlorantraniliprole 18.50SC and flubendamide 39.35SC proved their superiority over other insecticides in reducing infestation of *L. orbonalis* and resulted in higher yield efficacy on Mahyco brinjal hybrid MHB 39 during *kharif* 2009 and 2010 at Jalna. Saha *et al.* (2014) [50] from Sabour (Bihar) evaluated insecticides against shoot and fruit borer in *kharif* 2010-11 and *kharif* 2012-13. They recorded minimum shoot infestation (5.67%), fruit infestation (12.59%), number of larvae per plot (2.36) and holes per fruit (0.40) in plots treated with rynaxypyr 20 SC. They also noticed highest mean yield (346.69 q/ha) in case of rynaxypyr. Krishnamoorthy *et al.* (2014) [27] conducted supervised field trials at Coimbatore in two cropping seasons and found flubendamide 20 WG @ 75 g a.i/ha as the most effective insecticide in lowering down the shoot and fruit damage. Flubendamide attributed highest reduction in shoot damage (96.8 and 97.2%) and fruit damage (98.2 and 98.1%) and highest yield (21.7 and 26.3 ton/ha) in both the seasons. Raina *et al.* (2016) [46] showed that deltamethrin proved most effective in reducing shoot damage (60.40%) and fruit damage, on number basis (88.87%) and weight basis (88.89%) over control. Deltamethrin recorded the highest marketable fruit yield of 132.27q/ha and lowest was found in case of Nimbecidine (33.53 q/ha). Highest (1:8.7) cost to benefit ratio was recorded in deltamethrin followed by fenvalerate (1:8.5), cypermethrin (1:6.5), chlorpyriphos (1:4.5), Prempt (1:1.9), malathion (1:0.6) and Nimbecidine (1: -0.3).

Integerated pest management

Singh (2003) [56] reported the control of brinjal shoot and fruit borer with combination of plant products and insecticides. Among the different treatments tested, basal application of neem cake @ 20 q/ha + foliar spray of quinalphos 0.05 per cent was found effective in reducing the fruit borer incidence (20.63%). Asmita *et al*. (2006) [8] revealed that IPM module using spinosad 0.01% + *Metarhizium anisoplae* + chelating agent Fe-EDTA + cartap hydrochloride 0.1% was found as the most effective against shoot and fruit borer, *L. orbonalis* with minimum shoot infestation (7.47%) and highest yield (81.82 q/ha). Dutta *et al.* (2011) [20] noticed that among the different IPM modules evaluated, mechanical removal of infested fruits and shoots+ pheromone trap + neem was found as the most effective in reducing shoot damage (86.69%). This was immediately followed by pheromone trap + neem, mechanical removal of infested fruits and shoots + pheromone traps, and farmer's practices with reduction of shoot damage by 79.24%, 78.75% and 78.55% respectively. Whereas, lowest efficacy was recorded in neem with 54.46% of shoot infestation. In case of fruit infestation, the highest protection was recorded from mechanical removal of infested fruits and shoots + pheromone trap + neem with 59.36% reduction, followed by farmer's practices with 54.13% reduction and mechanical removal of infested fruits and shoots + pheromone trap with 52.77% reduction. These were followed by pheromone trap + neem, mechanical removal of infested fruits and shoots + neem and mechanical removal of infested fruits and shoots with protection of 47.70%, 43.69% and 42.93%, respectively. Whereas, installation of only traps provided least 38.17 per cent reduction in fruit damage.

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