Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
www.entomoljournal.com
JEZS 2020; 8(4): 2111-2118

Received: 13-05-2020
Accepted: 16-06-2020

Lalita
Department of Entomology, MM University, Ambala, Haryana, India

Suman Devi
Department of Entomology, CCS Haryana Agricultural University, Hisar, Haryana, India

Lokender Kashyap
Department of Entomology, MM University, Ambala, Haryana, India

Corresponding Author:
Lalita
Department of Entomology, MM University, Ambala, Haryana, India

Biology and mechanisms of resistance to brinjal shoot and fruit borer: A review

Lalita, Suman Devi and Lokender Kashyap

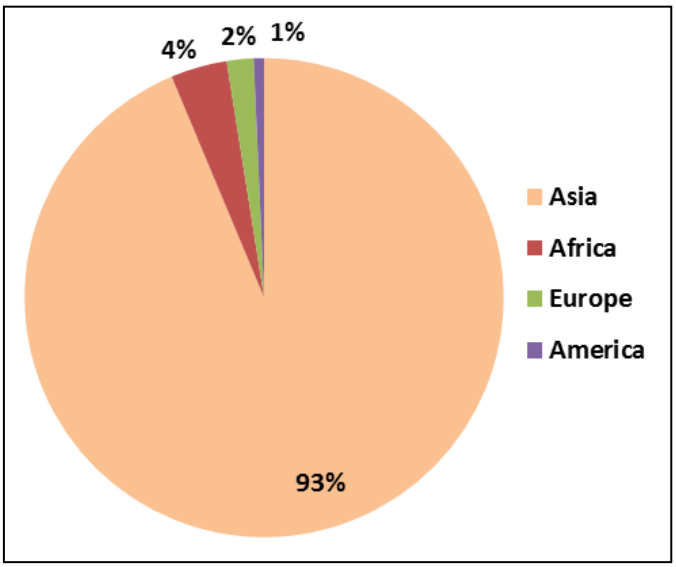
Abstract
Brinjal, *Solanum melongena* Linnaeus belongs to family solanaceae also known Eggplant or Baingan and it is the most important widely grown vegetable both for raw and cooked purpose and attack by the major and serious pest known as brinjal shoot and fruit borer [*Leucinodes orbonalis* Guenee (Lepidoptera: Pyralidae)] which is responsible for causing up to 37-100% damage as well as quality and quantity loss in brinjal due to its regular occurrence from the nursery to till harvesting. In order to manage this problem, farmers still depends on the pesticides, but excessive (140-180 time more) use of pesticides has resulted residues in the food chain, phytotoxicity, pesticide resistance, pest resurgence, bioaccumulation and secondary pest outbreak, in addition to causing harmful effect on the environment and non-targeted beneficial organisms. Here, we reviewed the host plant resistant approaches by use of resistant varieties to reduce the incidence of brinjal shoot and fruit borer to achieve sustainability in brinjal production technology. This review highlights examples of successful management approaches from the past studies that were implemented in experimental trials and farmers' fields and these practices can be explored as reproducible practices for management the pest in different locations.

Keywords: Brinjal, host plant resistance, resistant varieties, shoot and fruit borer

Introduction
Brinjal (S. melongena L.) is most important vegetable crop and tender perennial plant grown worldwide for its edible fruit belongs to family Solanaceae/Nightshade, solanoideae subfamily. In South-East Asia and South Africa it is known as *brinjal*, *Eggplant* in USA, Australia, New Zealand and Canada, *Aubergine* or *Guinea squash*, *Melongene* and *Garden egg* in UK, Ireland and Quebec, respectively. Owing to its popularity and versatile nature, it is widely use in Indian cuisine not only in everyday but also in festival occasions, brinjal (baingan) leads to described as the "King of vegetables". Brinjal fruits are widely used in various culinary preparations viz., sliced bhaji, stuffed curry, bertha, chutney, vangnibath, and pickles etc. Commercially grown brinjal fruit can varies in tastes, colour (purple, green, white, yellow and striated shades), size (small to large) and shape (pendulous, cylindrical, egg-shaped and oblong to round) with smooth and glossy skin [30]. Brinjal is a major source of supplements, minerals, vitamins, proteins cancer prevention agents, dietary fiber and weight training variables and ranked among the top 10 vegetables in term of oxygen radical absorbance capacity [11]. Nutritionally, 100grams of cooked fruit contains; very low caloric value (25.0), moisture 92.7%, carbohydrates 8.29g (of which 3.04 are sugar), fat 0.2 gram, protein 1 gram, β carotene 21.1 µg and fiber content of 3.4 grams [56,]. Other element like 0.7mg iron, 13.0mg sodium, 10.6mg magnesium, 213.0mg potassium 12.0mg calcium, 26.0mg phosphorus, 8.93mg choline, 13.4g folate, 5.0mg ascorbic corrosive and 27 International Units of vitamin A, 0.89mg vitamin B, 2.2mg vitamin C, 0.30mg vitamin E and 3.5 µg vitamin K [79] are also found in the 100g ripened fruit. The peel of deep blue or purple colored varieties of brinjal has significant amounts of phenolic flavonoid phytochemicals called as anthocyanins which help to fight against cancer, aging, and neurological diseases [73]. Brinjal has been reported as Ayurvedic medicine for curing diabetes; beside it also used as a good appetizer, aphrodisiac, cardiac tonic, laxative and reliever of inflammation [48] and found as an excellent remedy for those who suffering from liver complaints.

Brinjal has been cultivated in the country for the last 4,000 years, although it is often thought of as a Mediterranean or mid-Eastern vegetable. Brinjal is a warm weather crop grown in subtropical regions of the world. However, it is widely cultivated in temperate region (grown mainly during warm season) and tropical regions (widely cultivated) of the globe [63].

Two other cultivated eggplant species, the Scarlet eggplant (*S. aethiopicum* L.) and Gboma eggplants (*S. macrocarpon* L.), are less known but have local importance in Sub-Saharan Africa [15]. Brinjal is grown in every country of the world in outdoor fields, polyhouses, net houses, kitchen and commercial gardens in both Rabi and Kharif season and it is the world's 5th most economically important solanaceous crop after potato, tomato, pepper and tobacco [25]. In Asia and the Mediterranean, eggplant ranks among the top five most important vegetable crops [26]. Brinjal is also exported in the fresh or frozen form. Globally, eggplant is grown over an area of 1864556 hectares with a production of 54077210 tons and productivity of 29 tons per hectare [24]. Region wise, production share of eggplants is highest in Asia accounting for over 93.6% of production followed by Africa (3.8%), Europe (1.8%), America (0.7%) and Ocenia (0%). India rank second after China in area and production of brinjal at global level. In India, eggplant is cultivated over an area of 736000 hactare and production of 12826000 tons with productivity of 17.43 tons/hectare [24].



Source:http://www.eppo.int/QUARANTINE/Pest_Risk_Analysis/PRAdocs_insects/12-17840_PRM_Leucinodes_orbonalis.docx

Fig 1: Major brinjal- producing region in the world and in
Fig 2: Brinjal producing states in India

Eggplants are attacked by several insect pests and mites right from the nursery stage to till harvesting including *L. orbonalis* (Guenee); whitefly, *Bemicia tabaci* (Gennadius); Leafhopper, *Amrasca biguttula biguttula* (Ishida); Hadda beetle, *Henosepilachna vigintioctopunctata* (Fab.); Blister beetle, *Mylabris pustulata;* Thrips, *Thrips palmi* (Karny); Leafroller, *Eublemma olivacea* (Walker) and non insect pest includes; red spider mite, *Tetranychus macfarlanei* (Baker and Pritchard) and *Tetranychus urticae* (Koch) [47].

In India, this notorious pest is considered a limiting factor in brinjal cultivation causing losses are 37–63% [18], up to 90% as high as 70-92% [54] and may cause 100% damage if no control measures are connected [62]. In Bangladesh losses has been recorded up to 67% [17], 31 to 90% [60] and in Pakistan, reported losses are 50-70% [68]. That's why many farmers hesitate to grow brinjal because of heavy infestation of this borer and lower returns. The losses in reduction of crop yield caused by pest vary from season to season and from location to location because of moderate temperature and high humidity favor the population build-up and cause heavy losses during hot and humid condition [28]. Unpredictable weather with extreme temperatures, drought or flooding can also reduce yield and fruit quality. Farmers are presently using countless insecticide nearly 140 times or more in one cropping season, during 6-7 months and 32% of total cost is contributed to crop production [2]. According to report of insecticide survey, 180 times insecticides were used within a year to protect the brinjal against BFSB in Bangladesh [31]. Economic threshold level of brinjal for shoot and fruit borer is 0.5% shoot, 5% fruit damage and 8-10 moths/ day/ trap [16].

Dispersion of brinjal shoor and fruit borer

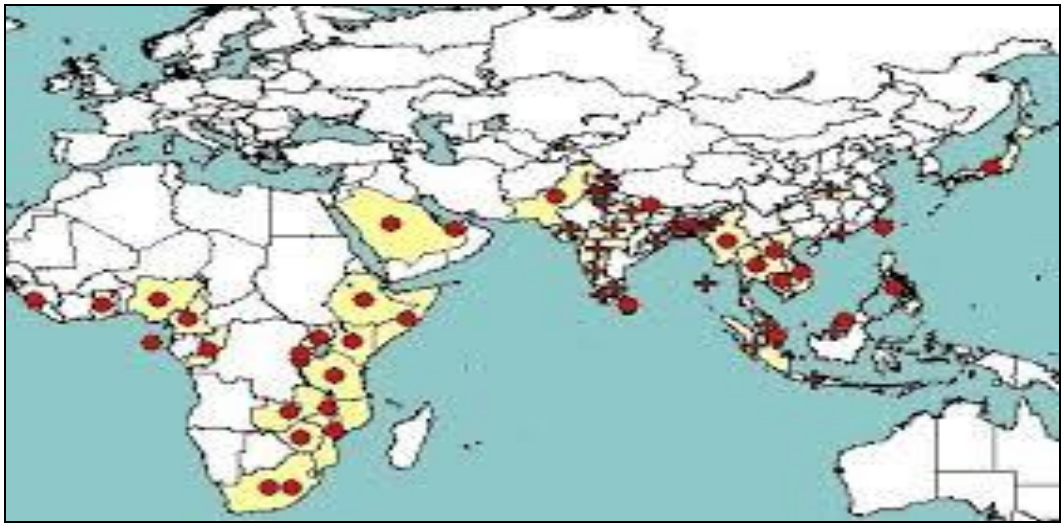
Dispersion of *Leucinodes arbonalis* have been reported in Africa, South of the Sahara and South-East Asia, including China and the Philippines [10]. In Asia, it is the most dangerous and found to be primary positioned insect of India, Pakistan, Srilanka, Nepal, Bangladesh, Germany, Malaysia, East Africa Thailand, Philippines, Cambodia, Laos and Vietnam [6]. Its dispersion is accounts for the most part, but higher in those regions having hot and humid atmosphere.

3. Taxonomy

The favored logical name of eggplant fruit and shoot borer is the *Leucinodes orbonalis* Guenee was portrayed by Guenee in 1854 and Walker assigned it as the types species of the genus Leucinodes in 1859 [10]. The systematic position of brinjal [80] and *Leucinodes orbonalis* is indicated by CABI [10] is given below in the table 1:

Table 1: Systematic position of Brinjal and Brinjal shoot and fruit borer

	Brinjal (Plant)	**Brinjal shoot and fruit borer (Pest)**
Domain	Eukaryota	Eukaryota
Kingdom	Plantae (Angiosperms)	Animalia
Phylum	Spermatophyta: (Mangoliophyta)	Arthropoda
Class	Magnoliopsida (Dicotyledons)	Insecta
Order	Solaneles	Lepidoptera
Family	Solanaceae	Crambidae (Syn: Pyralidae)
Subfamily	Solanoideae	Spilomelinae
Tribe	Solaneae	Lineodini
Genus	*Solanum*	*Leucinodes*
Species	*Melongena*	*Orbonalis*
Scientific name	*Solanum melongena* Linnaeus	*Leucinodes orbonalis* Guenee



Source: Image courtesy
of http://www.cabi.org/cpc/?compid=1&dsid=26757&loadmodule=datasheet&page=868&site=161

Fig 3: Distribution map of *Leucinodes arbonalis*

Biology of brinjal shoot and fruit borer

Like other members of the order Lepidoptera, life cycles of *L. orbonalis* includes four stages; eggs, larvae, pupa, and adult are given below in Fig. 4. Longest period of growth found for larval stage, followed by pupal stage and incubation period [51]. Oviposition takes place during the night and lasts for 2-3 days. In the early morning hours, female lay 80- 253 eggs singly or in the batches on the lower/ventral surface of the young leaves, green stems, flower buds, and calyx of the fruits [10]. Eggs are oval or somewhat elongated in shape and creamy white in colour [29], turns to orange with prominent black spot before hatching [64]. The pre-oviposition, oviposition and post-oviposition period ranging from 1.1 to 2.1 days, 1.4 to 4.0 days and 1.0 to 2.0 days [33] [64]. The egg incubation period depends on temperature and varies between 3 to 5 days in summer and 7-8 days in winter and hatch into dark white larvae. The larval period lasts 12 - 15 days during summer and 14 - 22 days during winter season [61]. Larva passes through at least five instars before entering the pupal stage [5] and there are reports of six larval instars existence also [23].

Newly hatched larva is 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. Jat *et al*. (2003) [33] also reported that average larval period lasted for 12.3 to 14.0 days. Caterpillars hibernate in the winter and pupate early in the spring [6].

Pupal period ranging from 7 to 10 days and 6-8 days [64]. Pupae are of 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 takes place on glass jars, soil, muslin cloth, on the fruits and sometimes on the leaves of plant [33].

Life span of male (1-3 days) and female moths (2-5.8 days) are reported by many workers [33]. Female moths are white in colour with blackish brown head and thorax having whitish wings with pinkish brown markings which are bigger on the forewings. Females were bigger in size, more in wing expanse and broader abdomen with rounded posterior end while the males were smaller in size, lesser in wing- expanse and narrow/slender abdomen which tapered posteriorly [33]. Adults of *L. orbonalis* generally mate during night or early morning hours and it lasted for for 43 minutes [64]. Brinjal shoot and fruit borer completes its life cycle in 19.0 to 43.0 days. *L. orbonalis* is active throughout the year at places having moderate climate but its activity is adversely affected by severe cold [5]. There are five overlapping generations in a year [6].

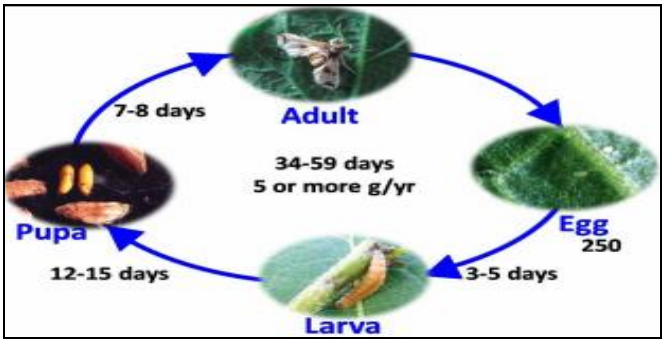


Fig 4: Life cycle of brinjal shoot and fruit borer

Nature of damage

Brinjal shoot and fruit borer is practically monophagous in nature and primarily feeds on eggplant *Solanum melongena* however, in many cases, different plants of solanaceae family are considered to be hosts of this pest. Major host are *S. melongena* (L.) and *S. tuberosum* (L.) and minor and alternate host includes, Tomato (*Lycopersicon esculentum* Mill), Sweet potato (*Ipomoea batatas* L.), Nightshades (*S. indicum* L. and *S. myriacanthum* Dunal) [56], green pod of Austrian winter pea (*Pisum sativum* var. *arvense* L.), Dark nightshade (*S. nigrum* L.), Turkey berry (*S. torvum* Swartz) [28] and Gilo (*S. gilo* Raddi) [10]. Black nightshade (*S. anomalum* Thonn), African egg plant (*S. macrocarpon* L.), Tropical soda apple (*S. viarum* Dunal), Indian nightshade or Kantakari (*S. xanthocarpum* Schrad), Cape gooseberry (*Physalis peruviana* L.), Pygmy ground cherry (*Physalis minima* L.) and Forest bitter berry (*Solanum anguivi* Lam.) [22] are account for wild

host of *L. orbonalis*.

Shoot and Fruit Borer (FSB) is the most noxious and internal feeder pest of brinjal. It not only cause reduction in yield (quantity and quality) by making holes in shoots as well as in fruits but also reduce the content of vitamin C in fruit up to 80% [70] and aesthetic value of the fruits. Initially, just after hatching larva immediately bore into the nearest tender shoot, petioles, developing bud, and flower while later, when the fruits are formed; larvae bore into the fruit and feed inside on mesocarp of fruit [52] by making tunnel results in destruction of fruit tissue. Boring into fruits resulted formation of dead heart by the larva and they often plug the entrance bore holes and feeding tunnel with their excreta or frass. The entry holes on the fruit are not visible as holes are either recovered or covered with frass but faded depressions of entry holes are seen. The large one or more circular exit holes are also visible only on the damaged fruits. Affected fruits get rotten from inside, become out of shape and such fruits are unfit for consumption and marketing [65]. One fruit contains up to 20 larvae [35], a single larva may destroy 4-7 healthy fruits. Fruit feeding by the larva is the major cause of damage and bore into tender shoots of the plant as a result, the affected twigs, flower and fruits dries up, wither, becoming flaccid type and may drop off and ultimately cause of wilting of young shoot and dieback of the branch terminals which reduces the fruit-bearing capacity of plant [9]. This reduces plant growth, which in turn, reduces fruit number and size. New shoots can arise but this delays the crop maturity and the newly formed shoots are also subject to larval damage. Larval feeding in flowers results in failure to form fruit from damaged flowers.

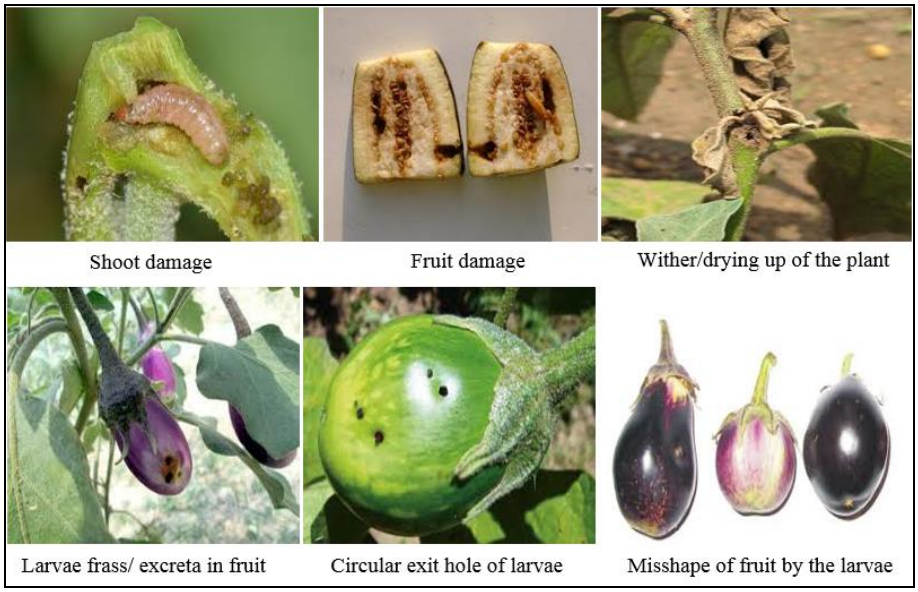


Fig 5.

Resistant varieties

The use of resistant varieties is one of the safest methods which are compatible with other pest control strategies considered as farmer's first line of defense against pests. Several attempts have been made to cultivate resistant genotype South Asia but after 40 years of efforts, no commercial cultivars have been developed with appreciable level of resistance. Although the resistance in some varieties/cultivars and hybrids to some extent was also reported by number of worker indicated in the table 2.

Table 2: Sources of resistance to shoot and fruit borer *L. orbonalis* in brinjal

Location/ Country	Tolerant genotype(s)	Reference
	Katrain-4	Mishra *et al.* (1987) [45]
	Doli-5, Pusa Purple Cluster and Junagarh Long	Jyani *et al.* (1995) [36]
	Arka Kusumakar, Nischintapur, Brinjal Long Green, Altapati, Arka Shirish, Manjpur, Makra and Chikon Long	Gangopadhyay *et al.* (1996) [27]
	Pusa Kranti and Nurki	NARC (1998) [50]
	Pusa Purple Cluster, Bhagyamathi, Annamalai, Nurki and Singhnath	Behera *et al.* (1999) [8]
	Pusa Puple Long - 74 and Navkiran	Mathur *et al.* (2012) [44]
	IC136347	Ramesh *et al.* (2015) [67]
	IGB-92	Netam *et al.* (2018) [51]
	DS-407 and Ganesh	Sharma *et al.* (2017) [69]
	Pant Samrat	Chaudahry *et al.* (2018) [14]
	Green long-183, Swarna, shyamli, Navkiran and Utsav	Supriya and Singh (2019) [74]
	EG058	(AVRDC 1999) [7]
	VI047451	Ramasamy 2009[66]
	Arka Keshva	Sharma *et al.* (2001) [71]
Nepal	Nurki, Neelam Long and Pusa Purple Long	Thapa *et al.* (2007) [78]
Bangladesh	Katabegun WS and Marich begun S	Ahmed *et al.* (2008) [1]
	EG075	Alam *et al.* (2003) [3]
	Jumki-1, Jumki-2, Islampuri-3, BL-34, Singhnath-4 and Singhnath long	Mannan *et al* (2003) [43]

Pakistan	Shilpa, Nirala and Hybrid 3715	Thangamani *et al*. (2011) [76]
Thailand and Taiwan	Turbo (a commercial F1 hybrid), BL009 and ISD006	Alam *et al*. (2003) [3];

Host plant resistance

Several studies have been conducted by many scientists on screening of brinjal genotypes to shoot and fruit borer, *L. orbonalis* through host plant resistance includes antixenosis, antibiosis and tolerance mechanism. Many morphological and biochemical factors are known to be associated with insect resistance in brinjal plants. The mechanisms of host plant resistance to brinjal are given below in table 3.The susceptible varieties showed higher shoot infestation as compared to resistant varieties (Kale *et al*. 1986) [53]. Antixenosis character includes, presence of thin stem, more branches, lower third leaf length and width, more spines, rough leaf surface area, heavily lignified thick cuticle, broad and thick hypodermis, closely packed vascular bundle and small pith area may be responsible for lower infestation and vice-versa in case of higher infestation. Antixenosis mechanism of different character of plant studied by many worker and studies indicated that the reductions in pest population of shoot and fruit borer due to biophysical characters are given in table 4.

Table 3: Characters with different resistance mechanisms in brinjal

Mechanism (s)	Character (s)
Antixenosis (non-preference)	Fruit colour, shape and diameter, size, Calyx size, pericarp thickness, surface wax, glandular and non glandular trichomes, leaf size
Antibiosis	Total phenol , sugar content, polyphenol oxidase and peroxidase enzyme, solasodine contents, flavonols and potassium,
Avoidance (escape)	Earliness with cold tolerance

Table 4: Antixenosis characters which shows the resistance/ reduction to brinjal shoot and fruit borer

S. No	Biophysical Varietal Characters	Reference
1	Long narrow fruited variety	Chandha (1993) [13]
2	Dense pubescent varieties with long tuft erect trichomes	Panda and Das (1974) [53]
3	Erect trichomes, dense pubescent, longer tuft, high silica and crude fiver contents and less ash and crude fat protein	Kale *et al*. (1986) [37]
4	Short and lower number of calyx with lower diameter and thin shoot	Malik *et al*. (1986) [42]
5.	Leaf trichomes, stem thickness and stem hair density	Javed *et al*. (2011) [34]
6	Leaf thickness and trichome density	Naqvi *et al*. (2008) [49]
7.	Number of shoots per plant, spines of leaves, branches, petioles, calyx of fruits, fruit skin thickness, shoot thickness and long fruited varieties	Shaukat *et al*. (2018) [72]

Pubescent varieties with dense and long tuft erect hairs on the surface cause interference to adult in oviposition and hatching of eggs [53]. Varieties (wild type and other resistant varieties) having high silica and crude fiber contents and comparatively less ash and crude fat protein in the shoot create hindrances to the larval feeding and digestion [37]. Genotypes bearing thin fruits with short calyx and lower number of calyx with lower diameter and thin shoot are being considered tolerant to *L. orbonalis* attack [42].

It is obvious that the biochemical factors are more important than morphological and physiological factors in conferring non-preference and antibiosis. Many biochemical factors are known to be associated with insect resistance in crop plants [41]. Some biochemical constituents may act as feeding stimuli for insects. Occurrence at lower concentration or total absence of such biochemical leads to insect resistance. The biochemical constituents like glycoalkaloid (solasodine), phenols, phenolic oxidase enzymes namely polyphenol oxidase and peroxidase are available in brinjal and these biochemical constituents possess insect resistant properties [38] are given in table 5. Complete borer resistance would be difficult and thought of development of tolerant genotypes [59] that while selecting genotypes for shoot and fruit borer resistance, apart from their performance, consideration may also be given on the quantity of biochemical constituents and isozyme banding pattern.

Table 5: Antibiosis characters which shows the resistance/ reduction in brinjal to brinjal shoot and fruit borer population

S. No.	Biochemical Characters	Reference
1	Solanine content and total phenols	Asati *et al*. (2002) [4]; Preneetha (2002) [59]; Jat and Pareek (2003) [32]; Thangamani (2003) [75]; Prabhu *et al*. (2009) [57]
2	Higher glycoalkaloid (solasodine) content, total phenols and polyphenol oxidase activity	Doshi *et al*. (1998) [32]
3	Polyphenol oxidase activity, total phenol content and solasodine content	Prabhu *et al*. (2009) [57]
4	High silica and crude fiver contents and less ash and crude fat protein	Kale *et al* (1986) [37]
5	Phenolics content	Elanchezhyan *et al*. (2009) [21]; Prasad *et al*. (2014) [58]
6	Polyphenol oxidase (PPO), Phenylalanine ammonium lyase (PAL) and Lignin	Khorsheduzzaman *et al*. (2010) [39]

Conclusion

Eco-friendly management of brinjal shoot and fruit borer can be done by integrated pest control measure tactics such as breeding resistant cultivars are optimal for getting high yields beside with eco-friendly management of the pest. The present review concluded that the use of IPM options, along with growing resistant varieties reduce the unenthusiastic force of insecticides on the natural enemies, beneficial insect,

pollinators, animal and human being that are present in the appropriate ecological niche and will defend the flora and fauna and the atmosphere from toxicological hazards contents.

References

1. Ahmad H, Rahman MH, Haque MA, Ahmed KS. Screening of brinjal varieties/lines resistance to brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee. J Agrofor Environ. 2008; 2(2):131-133.
2. Alam S, Hossain M, Rouf F, Jhala R, Patel M, Rath L *et al*. Implementation and promotion of an IPM strategy for control of eggplant fruit and shoot borer in South Asia. Technical Bulletin No. 36. 2006, AVRDC publication number 06-672. AVRDC- The World Vegetable Center, Shanhua, Taiwan.
3. Alam SN, Rashid MA, Rouf FMA, Jhala RC, Patel JR, Patel S *et al*. Development of an integrated pest management strategy for eggplant fruit and shoot borer in South Asia. AVRDC-The World Vegetable Center Shanhua, Taiwan, Technical Bulletin No. 28. 2003, AVRDC Publication No. 2003; 3(548):56. ISBN 92-9058-126-3
4. Asati BS, Sarnaik DA, Thakur BS, Guhey A. Shoot and fruit borer incidence as influenced by total phenol and total chlorophyll content in round fruited varieties. Orissa J Hort. 2002; 30(2):100-104
5. Atwal AS. Agricultural pests of India and Southeast Asia. Kalyani Publishers. New Delhi, India, 1976, 529
6. Atwal AS, Dhaliwal GS. Agricultural pest of South Asia and their management. Kalyani publisher, New Delhi, 2008, 332
7. AVRDC. Annual Report. Asian Vegetable Research and Development Center, Shanhua, Taiwan. AVRDC Publication No. 99-492, 1999, 148
8. Behera TK, Singh N, Kalda TS, Singh N. Genetic diversity in eggplant for resistance to shoot and fruit borer. Indian J Hort. 1999; 56(3):259-261.
9. Butani DK and MG Jotwani Insects in vegetables. New Delhi: Periodical Expert Book Agency, 1984, 356
10. CABI. Crop protection compendium. CAB International, 2007 (Available at: http://www.cabicompendium.org/cpc Retrieved on March 15, 2012).
11. Cao G, Sofic E, Prior RL. Antioxidant capacity of tea and common vegetables. J Agr Food Chem. 1996; 44(11):3426-3431. doi.org/10.1021/jf9602535.
12. Chakraborty S, Sarkar PK. Management of *Leucinodes orbonalis* Guenee on eggplant during the rainy season in India. J Plant Prot. Res. 2011; 51(4):325-328.
13. Chanda ML. Improvement of brinjal. In: Chandha KL and Kallo G (eds.) Advances in Horticulture: Vegetable Crops. Malhotra Publishing House. New Dehli, India, 1993, 105-135
14. Choudhary RS, Rana BS, Kumar A, Murdia A, Singh B. Screening of brinjal varieties against, *Leucinodes orbonalis* (Guenee) infestation. J Entomol Zool Stud. 2018; 6(2):194-198
15. Daunay MC, Hazra P. "Eggplant" in Handbook of Vegetables, eds Peter KV and Hazra P (Houston, TX: Studium Press), 2012, 257-322
16. Dhaliwal GS, Arora R, Dhawan AK. Crop loss due to insect pest and determination of economic threshold lavel. In: Singh A, Trivedi TP, Sardana HR, Sharma OP and Sabi N (eds) Recent advance in integrated pest management. National Centre for Integrated Pest Management, New Delhi, 2003, 12-20
17. Dhandapani N, Shelkar UR Murugan M. Bio-intensive pest management in major vegetable crops: An Indian perspective. J Food Agric Environ. 2003; 1(2):330-339
18. Dhankar DS. Progress in resistance studies in eggplant (*Solanum melongena* L.) against shoot and fruit borer of brinjal (*Leucinodes orbonalis* Guen.) infestation. Trop Pest Manage. 1988; 34:343-345
19. Docimo T, Francese G, Ruggiero A, Batelli G, Palma MD, Bassolino L *et al*. Phenylpropanoids accumulation in eggplant fruit: characterization of biosynthetic genes and regulation by a MYB transcription factor. Front Plant Sci. 2015; 6:1233.
20. Doshi KM, Bhalala MK, Kathiria KB. Correlation and path analysis for yield, fruit borer infestation, little leaf incidence and quality traits in brinjal (*Solanum melongena* L.). Capsicum-Eggplant News Letter. 1998; 17:84-87.
21. Elanchezhyan K, Murali Baskaran RK, Rajavel DS. Biochemical basis of resistance in brinjal genotypes to shoot and fruit borer, *Leucinodes orbonalis* Gen. J Entomol Res. 2009; 33:101-104
22. Elekofehinti OO, Kamdem JP, Bolingon AA, Athayde ML, Lopes SR, Waczuk EP *et al*. African eggplant (*Solanum anguivi* Lam.) fruit with bioactive polyphenolic compounds exerts in vitro antioxidant properties and inhibits Ca (2+) induced mitochondrial swelling. Asian Pac J Trop. Biomed. 2013; 3(10):757-66. doi:10.1016/S2221-1691(13)601525.
23. FAO. Eggplant integrated pest management an ecological guide. FAO inter-country programme for integrated pest management in vegetables in South and Southeast Asia. Bangkok, Thailand, 2003, 177.
24. FAO. FAOSTAT data 2018 (Available at: http://www.fao.org)
25. FAO. FAOSTAT Production Databases. 2014 Available online at: http://www.faostat.fao.org (Accessed January 30), 2017.
26. Frary A, Doganlar S, Daunay MC. Eggplant, in Vegetables SE -9, Genome mapping and molecular breeding in plants, ed. Kole C. (Berlin: Springer), 2007, 287-313. 10.1007/978-3-540-34536-7_9
27. Gangopadhyay C, Maity TK and Mandal SK. Screening of brinjal germplasms against fruit and shoot borer *Leucinodes orbonalis* Guenee. Environ Ecol. 1996; 14(4):834-836.
28. Gautam M, Kafle S, Regmi B, Thapa G, Paudel S. Management of brinjal fruit and shoot borer (*Leucinodes orbonalis* Guenee) in Nepal. *Acta* Sci Agron. 2019; 3(9):188-195. doi 10.31080/ASAG. 2019.03.0632
29. Harit DN, Shukla GR. Laboratory biology of brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee (Lepidoptera). J Exp Zool. 2005; 8(24):307-311
30. Herbst ST. The new food lover's companion: Comprehensive definitions of nearly 6,000 food, drink, and culinary terms. Barron's cooking guide. Hauppauge, NY: Barron's educational series. 2001; ISBN 0764112589.
31. Islam MS, Choudhury MAR, Maleque AM, Mondal MF, Hassan K, Khan AU *et al*. Management of brinjal shoot and fruit borer (*Leucinodes orbonalis* Guen.) using selected bio-rational insecticides. Fundam Appl Agric. 2019; 4(4):1025-1031 doi: 10.5455/faa.55331

32. Jat KL, Pareek BL. Biophysical and biochemical factors of resistance in brinjal against *Leucinodes orbonalis*. Indian J Entomol. 2003; 65: 252-258.
33. Jat KL, Pareek BL, Singh S. Biology of *Leucinodes orbonalis*: An important pest of brinjal in Rajasthan. Indian J Entomol. 2003; 65:513-517.
34. Javed H, Mohsin A, Aslam M, Naeem M, Amjad M, Mehmood T. Relationship between morphological characters of different aubergine cultivars and fruit infestation by *Leucinodes orbonalis* Guenee. Pak J Bot. 2011; 43(4):2023-2028.
35. Jayaraj J, Manisegaran S. Management of fruit and shoot borer in brinjal, The Hindu: Sci-Tech Agri College and Res Instt Madurai, 2010, 32-34.
36. Jyani DB, Patel NC, Ratanpara HC, Patel JR, Board PK. Varietal resistance in brinjal to insect-pest and disease. Deptt. of Entomology, B. A. College Agric Univ Res J. 1995; 21:59-63.
37. Kale PB, Mohod UV, Dod VN, Thakare HS. Screening of brinjal germplasm (*Solanum* spp.) for resistance to fruit and shoot borer (*Leucinodes orbonalis* Guenee) under field conditions. In: proceedings of national symposium on new horizons in resistant breeding of vegetable crops, February 14-16, Jabalpur, India. Veg Sci. 1986; 13(2):376-382.
38. Kalloo G. Biochemical basis of insect resistance in vegetables. Vegetable Breeding Vol. II, CRC Press Inc Boca Raton, Florida, 1988.
39. Khorsheduzzaman AKM, Alam MZ, Rahman MM, Mian MAK, Mian MIH. Biochemical basis of resistance in eggplant (*Solanum melongena* l.) to *Leucinodes orbonalis* Guenee and their correlation with shoot and fruit infestation. Bangladesh J Agril Res. 2010; 35(1):149-155
40. Kumar NKK, Sadashiva AT. *Solanum macrocarpon*: a wild species of brinjal resistant to brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guen.). Insect Environ. 1996; 2(2):41-42.
41. Mainali RP. Biology and management of eggplant fruit and shoot borer, *Leucinodes orbonalis* Guenee (Lepidoptera: Pyralidae): a review. Int J Appl Sci Biotechnol. 2014; 2(1):18-28 doi: 10.3126/ijasbt.v2i1.10001
42. Malik AS, Dhankhar BS and Sharma NK .Variability and correlation among certain characteristics in relation to shoot and fruit borer, (*Leucinodes orbonalis* Guen.) infestation in brinjal. Haryana Agriculture University J Res. 1986; 16(3):259-265
43. Mannan MA, Begum A, Rahman MM, Hossain MM. Screening of local and exotic brinjal varieties/ cultivars for resistance to brinjal shoot and fruit borer, *Leucinodes orbonalis* Guen. Pakistan J biol Sci. 2003; 6:488-492. doi:10.3923/pjbs.2003.488.492
44. Mathur A, Singh S, Singh NP, Meena M. Field evaluation of plant products and microbial formulations against brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee under semi-arid conditions of Rajasthan. J Biopest. 2012; 5(1):71-74
45. Mishra PN, Singh Y, Nautiyal MC. Screening of eggplant (*Solanum melongena* Linn.) varieties for resistance to shoot and fruit borer (*Leucinodes orbonalis* Guen.) (Lepidoptera: Pyralididae). 11th Int Congr Plant Protec Manila (Philippines). 1987; 5:5-9.
46. Mishra PN, Singh YV, Nautiyal MC. Screening of brinjal varieties for resistance to shoot and fruit borer (*Leucinodes orbonalis* Guen.) (Lepidoptera: Pyralidae). South Ind Hort. 1988; 36:188-192.
47. Muhammad AS, Mustafa AM, Ahmad A, Maqsood S, Hayat U, Mustafa F *et al*. Life aspects and mode of damage of brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenee) on eggplant (*Solanum melongena* Linnaeus):A review. Int J Entomol. 2018; 3(2):28-33.
48. Nandi C, Narabenchi G, Jakatimath S, Prafulkumar MV. Seasonal incidence of brinjal shoot and fruit borer, *Leucinodes orbonalis* Guene, (Lepidoptera: Crambidae) during kharif season. Int J Curr Microbiol App Sci. 2017; 6(12):1088-1093. doi: https://doi.org/10.20546/ijcmas.2017.612.123
49. Naqvi AR, Pareek BL, Nanda US, Mitharwal BS. Leaf morphology and biochemical studies on different varieties of brinjal in relation to major sucking insect pests. Indian J Plant Prot. 2008; 12:243-248.
50. NARC. NARC Research Highlights 1989/1990 to 1994/1995. Nepal Agricultural Research Council, Khumaltar Lalitpur, Nepal, 1998.
51. Netam M, Lakra R, Koshta VK, Sharma D, Deole S. Screening of shoot and fruit borer (*Leucinodes orbonalis* Guenee.) for resistance in brinjal (*Solanum melongena* L.) germplasm lines. Int J Curr Microbiol App Sci. 2018; 7(02):3700-3706. doi: https://doi.org/10.20546/ijcmas.2018.702.439
52. Neupane FP. Crop pest and their management (4th ed.) (Nepali language). Sajha Prakashan, Pulchwok, lalitpur, Nepal, 2001, 582.
53. Panda RN and Das RC. Ovipositional preference of shoot and fruit borer (*Leucinodes orbonalis* Guen.) to some varieties of brinjal. South Indian Horti. 1974; 22(1-2):46-50.
54. Patil PD. Technique for mass rearing of brinjal shoot and fruit borer, *Leucinodes orbonalis* Guen. J Entomol Res.1990; 14:164-172.
55. Plazas M, Prohens J, Cunat AN, Vilanova S, Gramazio P, Herraiz FJ *et al*. Reducing capacity, chlorogenic acid content and biological activity in a collection of scarlet (*Solanum aethiopicum*) and gboma (*S. macrocarpon*) eggplants. Int J Mol Sci. 2014; 15:17221-17241. doi: 10.3390/ijms151017221
56. Poonam S, Manmeet BB, Kaur P. Biological studies on brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee. J Entomol Zool Stud. 2018; 6(1):161-165
57. Prabhu M, Natarajan S, Veeraragavathatham D, Pugalendhi L. The biochemical basis of shoot and fruit borer resistance in interspecific progenies of brinjal (*Solanum melongena*). Eur Asia J Bio Sci. 2009; 37:50-57. doi:10.5053/ejobios.2009.3.0.7
58. Prasad TV, Rakesh Bhardwaj KK, Gangopadhyay M, Arivalagan MK, Bag BL, Dutta M *et al*. Biophysical and biochemical basis of resistance to fruit and shoot borer (*Leucinodes orbonalis* Guennee) in eggplant. Indian J Hort. 2014; 71(1):67-71.
59. Preneetha S. Breeding for shoot and fruit borer (*Leucinodes orbonalis* G.) resistance in brinjal (*Solanum melongena* L.). Ph.D. Thesis, Tamil Nadu Agricultural University, Coimbatore, 2002.
60. Rahman AKMZ. Screening of 28 brinjal lines for resistance/tolerance against the brinjal shoot and fruit borer. Annual Report. Entomology Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Bangladesh, 1997.

61. Rahman MM. Vegetable IPM in Bangladesh. Department of Entomology. Bangabandhu Sheikh Mujibur Rahman Agricultural University Gazipur, Bangladesh, 2006. (http://ipmworld.umn.edu/chapters/rahman).
62. Rahman MM. Vegetables 1PM in Bangladesh. In: Redcliffe's 1PM World Textbook, University of Minnesota, 2007, 457-462.
63. Rai AB, Vora VT, Patel CV. Investigations on the integrated control of *Tetranychus urticae* (Acari: Tetranychidae) infesting brinjal in South Gujarat. Abstract presented in 5th national symposium on acarology, Bangalore, 20-22, September, 1995, 76-77.
64. Raina J, Yadav GS. Studies on biological parameters of *Leucinodes orbonalis* Guenee on brinjal under laboratory conditions. J Exp Zool India. 2017; 20(2):795-800.
65. Raina J, Yadav GS. Brinjal shoot and fruit borer: Bio-ecology and management. Int J Pharmacogn Phytochem. 2018; 7(4):444-449.
66. Ramasamy S. Insect and mite pests on eggplant: A field guide for identification and management. AVRDC- The World Vegetable Center, Shanhua, Taiwan, 2009. AVRDC Publication No. 09-729.
67. Ramesh K, Sivaraj N, Babu BS, Chakrabarty SK. Screening brinjal genotypes for resistance to shoot and fruit borer, *Leucinodes orbonalis* and analysing the geographic divergence of resistance through divagis. Int Quaterly J Life Sci. 2015; 10:923-928.
68. Saeed MQ, Khan IA. Population abundance and chemical control of brinjal fruit borer *Leucinodes orbonalis* Guenee (Lepidoptera: Pyralidae). Sarhad J Agric. 1997; 13:399-402.
69. Sharma A, Rana RS, Sharma KC, Kumar A, Singh S. Screening of brinjal cultivars resistance against brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenee). Int J Entomol Res. 2017; 2(5):69-75.
70. Sharma DR. Bio-efficacy of certain insecticide and biopesticides against major pest of brinjal under field condition. M.Sc. (Ag.) Thesis, Indian Agriculture Research Institute, New Delhi, India, 2002, 160
71. Sharma V, Lal R, Choudhary A. Screening of brinjal (*Solanum* spp.) germplasm against shoot and fruit borer, *Leucinodes orbonalis* Guenee. Insect Environ. 2001; 7 (3):126-127.
72. Shaukat A, Ahmad A, Mustafa F. Evaluation of resistance in brinjal (*Solanum melongena* L.) against brinjal shoot and fruit borer (*Leucinodes orbonalis* Guen.) infestation: A review. Int. J. Appl. Sci. Biotechnol. 2018; 6(3):199-206. doi: 10.3126/ijasbt.v6i3.19187
73. Stommel JR, Whitaker BD, Haynes KG, Prohens J. Genotype × environment interactions in eggplant for fruit phenolic acid content. Euphytica. 2015; 205: 823-836. doi: 10.1007/s10681-015-1415-2
74. Supriya D, Singh KM. Screening of brinjal varieties resistant to brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guenee) H. Indian J Hill Farming (Special Issue), 2019; 68-71.
75. Thangamani C. Evaluation of F_1 brinjal (*Solanum melongena* L.) for yield and quality. M.Sc. thesis, Tamil Nadu Agricultural University, Coimbatore. 2003.
76. Thangamani C, Jansirani P, Sumathi T. Association of certain biometrical and biochemical characters on fruit borer tolerance in brinjal (*Solanum melongena* L.). Plant Arch. 2011; 11(1):315-318.
77. Thapa RB. Integrated management of brinjal fruit and shoot borer, *Leucinodes orbonalis* Guen: An overview. J Inst Agric Animal Sci. 2010; 30(32):1-16.
78. Thapa RB, Achhami B, Tiwari S, Dhakal SC. Field screening of selected brinjal genotypes against shoot and fruit borer, *Leucinodes orbonalis* Guenee (Pyralidae: Lepidoptera) in Eastern Terai of Nepal. J Inst Agric Anim Sci. 2007; 30:173-177.
79. .Tindall D. Commercial vegetables growing. ELBS & Oxford University Press, London, 1978, 711.
80. USDA. Classification, Plants Database, Natural Resources Conservation Service, http:// plants. 2008. usda.gov/java/ClassificationServlet?source=display&classid=SOME