Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2020; 9(5): 2874-2881
Received: 22-07-2020
Accepted: 26-08-2020

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Study on management of damage caused by *Henosepilachna vigintioctopunctata* in brinjal

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Abstract
H. vigintioctopunctata is a stern pest of solanceous crops all over the world and is one of the major defoliators of eggplant leading to heavy economic yield loss. It is a polyphagous pest, having a wide host range, with brinjal as the most preferred one. Both grubs as well as adults feed voraciously on the green matter of the leaf and skeletonize it leaving the upper epidermal tissue. The growth and development of the plants are greatly hampered and the yield is markedly reduced. The percent infestation starts from one week after transplanting. Population dynamics of the pest species is associated with environment. The infestation and multiplication of insect have correlation with different prevailing weather parameters such as maximum and minimum temperature, wind velocity, minimum and maximum relative humidity, sunshine and rainfall which influencing insects both directly and indirectly. The studies on its biology indicated that female laid eggs in batches during her life span and the larvae pass through four moults. The duration of different stages of life cycle like premating period, pre oviposition period, oviposition period, incubation period, larval period, pre pupal period, pupal period and adult vary for each stage of its life cycle. Due to its multiple host range pests occurred throughout the year. When number of pest managing application increases, profit decreases. IPM is a system that utilizes all suitable techniques and methods in a compatible manner as possible and maintains pest populations at levels below those causing economic injury. Intelligent selection and use of pest control tactics will ensure favorable economic, ecological and sociological consequences. There is a need for further study over the effects of the ecological factors on different life stages of *H.vigintioctopunctata* so that they could be exploited in devising IPM strategy for effective management.

Keywords: *Henosepilachna vigintioctopunctata*, symptoms and nature of damage, management, brinjal

Introduction
Vegetables play a vital role in providing essential protective nutrients like vitamins and minerals and are used as selective diets by everybody. Brinjal is a widely grown crop of Asia, Africa and some parts of Europe. It is a common popular worldwide vegetable crop grown in sub-tropical and tropical areas (Sarker *et al*., 2006) [86] including India, which is the largest producer and original habitat among the tropical and sub-tropical nations (Behra *et al.,* 1997) [4] grown under diverse agro-climatic conditions as one of the chief vegetable crops (Prasad UK *et al*., 2008) [61].

Being a succulent crop with high plant canopy, it is susceptible to many insect-pest attacks. Forty four species of insect pests reportedly damage this crop in India (Lal, 1975) [42]. Among these Epilachna beetle, *Henosepilachna vigintioctopunctata* (Coleoptera: Coccinellidae) which is known as Mexican beetle in Europe and locally known as hadda beetle, is also one of the most destructive pests extensively found all over India and in other countries (Anam *et al*., 2006; Rahaman *et al*., 2008; Sreedevi *et al*.,1993) [3, 70, 95]. In India it has also been recorded from the regions of Jammu and Kashmir, Punjab, Himachal Pradesh, Uttar Pradesh, Bengal and Karnataka etc. (Shankar *et al.,* 2010) [90]. In some areas of the world it is regarded as being a troublesome insect to control.

Lefroy (1909) [45], Fletcher (1914) [16], Subramaniam (1924) [97] and Krishnamurthi (1932) [40] had reported it as a very common pest found feeding on solanceous and cucurbitaceous plants in various parts of India. It causes considerable economic loss to many crops including brinjal next to BSFB depending on place and season for variations of prevailing environmental conditions (Rajagopal and Trivedi, 1989; Bhagat and Munshi, 2004; Islam *et. al*., 2011) [74, 75, 6, 28].

It is a common pest which attacks many cultivated and wild crops belonging to Solanaceae, Cucurbitaceae, Fabaceae, Convulvulaceae and Malvaceae (Thomas *et al.,* 1969; Ramzan *et al.*,1990; Richards and Filewood, 1990; Kalra, 1997; Rajendran and Gopalan, 1997; Ahmad *et al.,* 2001; Rath, 2005) [102, 80, 83, 34, 77, 2, 81] that has turned out as destructive pest having a wide host range with brinjal as the most preferred one (Ghosh SK and Senapati SK. 2001; Pandey

and Shankar 1975) [21, 58] which is distributed around South Canada, USA, Mexico, Guatemala, Africa and South East Asia Australia, Africa, Asia, Afghanistan, America, China, Middle East, Siberia and Sri Lanka (Jamwal *et al.*, 2013) [33].
Redtenbacher (1843) [42] was the first person to draw the attention epilachnae for their phytophagous habits. They are generally considered as polyphagous but also considered as oligophagus (Pandey and Shankar, 1975; Mandal and Mandal, 2003) [58] on the plants belonging to the family Solanaceae. They are specialist feeders of various plant species of family Solanaceae which can vigorously feed tomato and brinjal within 5 minutes continually to cause severe losses (Shinogi T. 2005) [92, 93].
The genus *Hensoepilachna* is a serious pest of many agricultural crops including potato, eggplant, tomato, tobacco, bitter gourd, sweet gourd, ribbed gourd, snake gourd, cucumber, pumpkin, zucchini, beet, sugar beet, marrow, cotton melon, rock melon, squash, cowpea, peanut, okra, alfalfa, vetch, clover, cotton, banana, many weeds and grasses (Schaefer, 1983) [89] *Amaranthus viridis* (Wilson, 1989) some medicinal plants such as *Datura innoxia* Mill., *D.stromonium*, *Solonum nigrum* L., *Physalis minima*, *Withania sominfera* (Jamwal *et al.*, 2013; Sudan, 2008) [33, 99] Chinese cabbage, *Arabidopsis*, kidney bean, and its feeding efficacy is varied (Shinogi *et al*., 2005) [92, 93].
Kapur (1950) [35] first studied the biology and external morphology of the larvae of epilachna in India and also described nine species genus Epilachna. *H. vigintioctopunctata* is one of a group of closely related herbivorous ladybird beetles that have diversified greatly in external morphology and host plant use in and around Indian sub-continent.

Seasonal incidence and occurrence

The amount of infestation by *H. vigintioctopunctata* and its occurrence on brinjal crop depends on the existing biotic and abiotic factors. The ecological factors existing in the crop eco-system play an important role in bionomics, distribution of the pest. The activities of beetles are severely affected by various ecological factors such as maximum and minimum temperature, wind velocity, minimum and maximum relative humidity, sunshine and rainfall, etc. The peak period of infestation varies with regions and kind of variation is due to date of planting, seasonal variations and other biotic factors. Several workers like Prasad and Logiswaran (1997) [62]; Ghosh and Senapati (2001) [21]; Muthukumar and Kalyanasundrum (2003) [55]; Varma and Anandhi (2008) [110]; Ghosh and Senapati (2001) [21]; Tiwari *et al.*, (2012) [106]; Putta Raju, (2008) [64]; Raghuraman and Veeravel (1999) [69, 72]; Haseeb *et al.*, (2009) [25, 65] recorded the relationship of beetles with the environmental factors and concluded that environmental factors played a major role in the activity of beetles. Sometimes their population gives positive correlation with the environmental factors while sometimes gives negative correlation.
Beetles are active throughout the crop season and starts damage from first week after transplanting. They hibernate in winter in the heaps of dry plants, cracks and crevices or in the soil. Due to its polyphagous nature survivability is more in both on and off seasons. The population of beetle depends on the abundance of food availability and the activity of the pest is more prevailing during the when the average temperature and humidity are about 20 °C-30 °C and 80 percent respectively (Mall *et al.*, 1992; Iftekhar and Khan, 1980; Suresh *et al.*,1996; Grewal,1988) [49, 26, 100, 22].
Behavioral, genetic, and ecological determinants of oviposition behavior persuade preference for plants and plant parts in insects (Thompson and Pellmyr, 1991) [103]. Food plays a very indispensable role in oviposition as it provides nourishment to the ovarioles that eventually results in egg laying. Both oviposition and feeding of the adults as well as the larvae is distressed by the temperature (Bind, 1998; Pervez and Omkar, 2004; Tilavov, 1981) [7, 59, 105].
Resemblance in size and appearance results in overlapping distribution of these beetles and sometimes their feeding habits also baffle the researchers (Froggatt, 1923) [17]. The crest period of infestation of these beetles generally varies with the regions involved. In general the peak activity of this species has been noticed from July to August where both the imago and the larvae energetically feed on the epidermal tissues of the host plants (Khan *et al*., 2000).

Symptoms and nature of damage

Brinjal is highly prone to hadda beetle infestation and is one of the most favourable host plants of hadda beetle (Dhamdhere *et al.*, 1990) [13, 14] which have huge economic impact on the crop which sometimes may go up as high as 100 % (Butani DK and Jotwani MG., 1984) [8]. Different species of hadda beetle have been reported to attack brinjal of which *H. vigintioctopunctata* is the most predominant species. It seems to inflict considerable damage to plant foliage (Butani and Verma, 1976; Kalra, 1997; Shankar *et al*, 2010) [9, 34, 90]. It is highly destructive at both, adult and larval stages, which feed on the epidermal tissue of leaves, flower and fruits by scraping the chlorophyll content and cause a big yield loss (Imura and Ninomiya, 1978; Srivastava and Butani, 1998; Ghosh and Senapati, 2001) [27, 96, 21].
All the stages of beetles can found on the plant foliage which are mandibulated having chewing type of mouthparts which scrap the chlorophyll in between the veins and lower epidermis of leaves in characteristic manner leaving behind stripes of uneaten areas. They don't swallow solid food material. Both larvae and adults chew of leaf, masticate it and suck the plant juice (Robert, 1978) [84] as a result skeletonisation of the leaves will happened which present a lace like appearance, later dry up and gradually fall from the plants (Rajagopal and Trivedi, 1989; Kalra, 1997) [74, 75, 34]. In severe infestation, even the calyx of the fruits may also be infested (Varma and Anandhi, 2008) [110] and all leaves may be eaten off leaving only the veins intact.
In grub-infested leaves of eggplant, fully damaged epidermis, parenchyma cells and phloem cells of vascular bundles are generally noticed (Mohanchander *et al*., 2013) [53]. The grubs confine their attack mostly on the lower surface while adult beetles usually feed on both lower and upper surface scrapping the green matter leaving behind only a network of veins (Prodhan *et al.*, 1990; Khan *et al*., 2000) [63]. This characteristic scraping made the leaves papery and the infested leaves exhibited inter venal damage or holes. Sometimes they also cause characteristic injuries on the fruits (Rai and Gopal, 1975) [73]. Due to its infestation during every crop season, both quality and quantity of crop output are adversely affected.

Biology

Mating

With the onset of warm weather, the adult beetles can be seen in the fields flying and feeding. Mature adults start mating after 2-3 days of emergence. A pair copulates several times and each copulation lasts for approximately 1-3 minutes.

Egg

Female lays about 200-450 eggs in 5-40 batches during her life span and each cluster contains 15-50 eggs on the underside of the leaf (Tyade and Simon, 2013; J. S. Tara and Sonia Sharma, 2017; Qamar *et al*., 2009) [107, 30, 65]. Freshly laid individual egg is stalked & shiny and cigar-shaped, tapering at top end, pointed distally and clustered vertically. Bright yellow colour changed into yellow (Kaur and Mavi, 2005; Varma and Anandi, 2008) and ultimately to creamy yellow at hatching. The egg hatches within 2-9 days (2-3 days in summer, 4-9 days in winter). The average incubation period of eggs is shortest on brinjal and development of grubs is quickest (Dhamdhere SV *et al*., 1990) [13, 14]. Because of these reasons brinjal are the best oviposition choice for the beetles (Jamwal VVS *et al*., 2013) [33].

Larva

Newly hatched fleshy larvae are creamy white or light yellow or dull blackish-green in color elongated and oval with six rows of long branched spines on thoracic and abdominal segments (Kaur and Mavi 2005; Qamar *et al*., 2009) [37, 65]. At first the spines are yellow, but later become darken on the tips, and thus more conspicuous. The larval period lasts for 9-18 days during which it passes through four different stars. First instar larval stage generally did not move and feed on tender foliage. Second instar larvae are well chitinised. This stage moves on the under surface of leaves and scraped the green matter in patches in a characteristic manner. Third instar stage is swift in movement and fed on green matter from both the surfaces of the leaves and even the twigs of the foliage. Fourth instar stage is voracious feeder of the foliage, completely scrap the green matter and skeletonized the leaves. The full grown fourth instar grub stop feeding and the color of the grub gradually faint and the body shrinks (Qamar *et al*., 2009) [65] at the time of pupation. During their earlier stages the grubs are gregarious in nature but as they grow older they tend to split into smaller groups.

Pupa

The fully grown fourth instar grubs stop feeding and attach to the underside of the leaves or stem by the posterior end of their bodies by means of sticky secretion and spend about 1-2 days in pre-pupal stage (Varma and Anandi 2008; Qamar *et al*., 2009) [109, 110, 65]. Pupa is hemispherical (Kaur and Mavi, 2005) [37] or oval in shape and dark in colour. The newly formed pupa is shining yellow or orange but turned creamish brown with spots on the dorsal surface. Its anterior portion is smooth while posterior region is spinous. Pupa resembles the grub but is mostly darker in colour, although it sometimes is yellowish in colour. Pupa bears spiny hairs on the posterior, but not on the anterior part. The pupal period lasts for 3-6 days (Verma and Anandhi 2008 and Qamar *et al.*, 2009) [110, 65] but in certain cases it may extend further after which adult beetle emerges out.

Adult

The newly emerged adult is shiny yellow in color later changed to copper brown color (Kaur and Mavi, 2005) [37] with a bronze tinge mottle with black spots (Varma and Anandi, 2008) [109, 110]. Body is spherical with convex dorsal surface and flat ventral surface and gives appearance of 'D' when viewed from side (Qamar *et al*., 2009) [65]. Adults are 6-7 mm in length and 5-6 mm wide with black head and the whole body is covered with fine short hairs. Beetles have 28 black spots on the elytra. Beetles with 14, 16, 18, 20, 22, 24 or 26 spots can also be observed due to mating between females of *H. dodecastigma* and males of *H. vigintioctopunctata.* Adult males are slightly smaller in size than adult females.

There are 7-8 generations of the epilachna beetles during March-October in plains and 1-2 generations in hills. During hot summer days their population declines considerably, whereas in winter the beetle hibernates inside soil or in the heap of dry leaves around the field. The adults are voracious eaters and survive for 4 weeks to 6 months. Life cycle is completed in 17-18 days in summer but in winter it may prolong up to 60 days.

IPM

The management of beetle was based on synthetic pesticides due to their quick and knock down action (Jagan Mohan, 1985; Ghosh, 1986; Samanta *et al.*, 1999; Das *et al.*, 2002; Liu *et al.*, 2003) [31, 19, 85, 11, 46]. Frequent and indiscriminate use of pesticides in the vegetable fields for insect pest management results in various environmental and ecological problems such as widespread development of pest resistance, undesirable effects on non-target organisms, presence of toxic residues in food, outbreak of secondary pests ((Subramanyam and Hagstrum, 1995; Kranthi *et al*., 2002; Hagen and Franz 1973) [98, 39, 24], long persistence, bioaccumulation, health hazards (Bhaduri *et al*., 1989) [5] and environmental pollution (Devi *et al*., 1986; Fishwick 1988) [12]. These problems have highlighted the need for development of new, safer and eco-friendly pest control measures.

The insect pest management is the application of technology, in the context of biological knowledge, to achieve a satisfactory reduction of insect pest numbers or effects and to maintain the pest population below levels that cause economic damage. Insect pest management may be grouped into physical, mechanical, cultural, biological, chemical, hormonal, genetical and legal practices. Few tactics are preventive such as physical and mechanical measures, cultural practices and legal control that prevent the insect to attain a pest status while others are curative such as biological, biopesticidal and chemical control that reduce the number of insects infesting the crop or human belongings.

Integrated Pest Management strategies are totally safe to non-target organisms, millions of untrained users, consumers and eco-system. It also helps to increase the biotic factors and thus maintains a natural pest control in a sustainable way Since IPM involves close observation on population dynamics, growth and related decisions about the correct control measures which are to be used for managing the pest population for sustainable crop production (Kumar, 1987) [41].

Physical methods

Collecting and destroying the adult beetles, grubs and pupae. Shake plants to dislodge grubs, pupae and adults in a pail of kerosenated water early in the morning.

Cultural methods

Management practices during cropping season may reduce the beetle population in the fields but again the population rebuild in a certain period from the alternate hosts to the main crop. For effective management of pests, alternate hosts and its interaction should be known and the fields should be kept clean.

Mechanical methods

By using mechanical methods *H. vigintioctopunctata*

population can be maintained at levels below the economic injury level (Karmakar and Bhattacharya, 2000) [36].

Resistance varieties

Rajendran and Gopalan, (1998) [78] screened the brinjal seed samples for resistance to *H. vigintioctopunctata* and reported that among 103 accessions only 9 entries were rated as resistant, 17 as moderately resistant and 77 as susceptible. Of the hybrids tested, only EP24/ 65 alone was moderately resistant, but all the wild accessions were resistant except *S. macrocarpum* (BE-046/EP154), which was rated as moderately resistant.

Natural enimies

Using parasitoids is a large potential tool in IPM. Natural enemies contribute to a significant levels of immature stage mortality of Hadda beetle and are potentially important in pest management in commercial vegetable cultivation. The increasing pest status and abundance of hadda beetle has raised a number of questions regarding the factors responsible for its development, its natural enemy complex and management under natural conditions. The interacting components between natural enemies and prey should clearly be understood to enhance or augment the effect of natural enemies in a prey population (Rabb, 1974) [68].

The larval parasitoid, *P. foveolatus* and egg parasitoid *Tetrastichus* sp. had been reported as parasites of *H.vigintioctopunctata* by various workers (Jain and Bhargava, 2007) [32]. Immature stages of beetles are subjected to attack by number of parasitoids *viz*. *Pediobius foveolatus* Crawford, *Pleurotropis epilachnae* Rhower, *Tetrastichus ovulorum* Ferriera, *Achrysocharis appannai*, etc. (Lall, 1964) [43].

The parasitoids *T. ovulorum*, *P. foveolatus, Uga menoni* and *Bracon* sp. parasitizing *H. vigintioctopunctata* remain active in the fields from August (Venkatesha, 2006) [111] to December (Kaur and Mavi, 2002; Raju and Maheshwari, 2004; Dhamdhere and Dhingra, 1990; Rajendran and Gopalan 1997) [38, 79, 13, 17, 77] and also from February (Varma and Anandhi, 2008) [109, 110] to April (Raghuraman and Veeravel 1999) [69, 72] parasitized the eggs, grubs and pupae, respectively. The parasitization is highest in the fourth stage instar and the adult parasitoids emerged from the grubs by making holes in the posterior region.

Botanicals

The use of natural plant products with microbes and less hazardous pesticides is considered to be an eco-friendly proposition. Substitutes are being strongly conceived whereby researchers are now paying much emphasis on the biologically active indigenous plant products because they are environmentally safe, biodegradable and cost effective (Saxena *et al*., 1983; Ghani, 1998) [88, 18]. Plant extracts contain botanical insecticides or phytochemicals that can be used to repel, deter feeding, or limit reproduction and survival of various insect pest species including coccinellid ladybird beetles.

Naturally occurring plant products play an important role to replace or minimize the excessive use of pesticides as they constitute a rich source of bioactive components (Wink, 1993) [114]. A number of researchers have reported various properties like larvicidal, antifeedant, reproductive and growth inhibitory properties against different insects of economic importance (Singh and Saratchandra, 2005; Rahman and Talukdar, 2006; Sharma and Rajguru, 2009) [94, 71, 91]. As these botanicals possess more than one active component, there will be less chance of development of resistance and easily biodegradable in the environment.

Plant products like leaf extracts of *Azadirachta indica*, *Calotropis gigantea*, *Prosopis juliflora*, *Vitex negundo*, *Pongamia pinnata*, *Lantana camara*, *Allium sativum* extracts, neem cake extract, neem oil, and Nimbecidine can bring reduction in population (Murugesan and Murugesh, 2008) [54]. *Azadirachta indica* products *viz*. Neem oil, Neemark, Bioneem, Nimbicidin, Neem Gold, Achook, neem leaf extract, neem seed kernel extract (NSKE) can bring reduction in pest population (Mane and Kulkami, 2010) [52].

Biopesticides

Rajendran and Gopalan (1997) [77] evaluated the biopathogens viz. *Bacillus thuringiensis* var. *kurstaki* and the white muscardine fungus, *Beauveria bassiana* on different stages *of E. vigintioctopunctata* and reported that *Bt* used as a leaf dip caused maximum mortality in the first instar grubs while the adults were less susceptible to *Bt* whereas direct spraying of *Bassiana* killed maximum first instar grubs and pre-pupal stage grubs. The adults were less susceptible to fungus. The mortality of beetles can be observed from the first day after application of mycopathogen, *Beauveria bassiana* in the field (Thurkathipana and Mikunthan, 2008) [104]. Green muscardine fungus, *Metarrhizium anisopliae* has the ability to suppress both grubs and adults (Rajendran, 2002) [76].

Chemical control

The management of beetle is mainly based on synthetic pesticides due to their quick and knock-down action (Liu *et al.*, 2003) [46]. Insect growth regulators like diflubenzuron, teflubenzuron and flufenoxuron has the ability to inhibit complete egg hatching in adults of *H. vigintioctopunctata* (Mala *et al*, 1992) [47, 48] while Teflubenzuron also has the ability to make eggs sterile. Diflubenzuron applied at micro quantity level is effective as potent larvicidal compounds interfering with the moulting process besides affecting egg hatchability and fecundity (Gupta and Dogra, 1994) [23] which invariably reduces the population by nearly 95% in field. Fipronil is the best chemical in controlling the beetle in the fields and control both adults and larvae (Panda *et al.*, 2005; Qing and Hong, 2004; Qing *et al.*, 2003) [57, 67, 66] while Cypermethrin is best in reducing pest population at all stages of plant growth (Umapathy and Baskaran, 1991; Mandal and Kumar, 2001) [108, 51]. Spraying insecticides like etofenprox, quinalphos and cypermethrin has the ability to show good ovicidal effect (Mala *et al*, 1992) [47, 48]. Insecticides like dimethoate, fenpropathrin and fluvalinate are effective against larvae whereas quinalphos, cypermethrin, deltamethrin and fenvalerate are effective against both larvae and adults (Nagia *et al*, 1992) [56].

Conclusion

Chemical control has its own limitations due to inherent character of the pest to resurge at a very faster rate on one hand and the problem of residual toxicity on the other due to the frequent plucking of edible fruits. Environmental pollution with insecticides has become a matter of great concern. Highly residual insecticides can pass well beyond their intended targets and may reduce populations of beneficial insects and wildlife. Another major problem associated with the use of insecticides is the development of insecticide resistance in strains of several pest species. There are more than 500 species of insects that have developed resistance to insecticides. In addition, unfortunately, natural enemies of

insect pests are more susceptible to insecticides than the insect pests and are easily eliminated from the agro ecosystem. Evidences of pesticide threats to human health and economic effects have been documented in several studies (A. C. Rola, P.L. Pingali, 1993 and J. M. Antle, P.L. Pingali, 1994) [1, 29]. So there is every need to develop new IPM strategies in which using the chemical pesticides is of least priority. Conservation of natural enemies will help in suppressing the *E. vigintioctopunctata* population in brinjal. Research is still needed to critically evaluate the interaction studies between pest and natural enemies and also new IPM tools that safeguard the natural enemies. Keeping these in view, more studies have to be conducted to determine the pesticide natural enemies' relation and parasitism intensity of associated natural enemies. A number of plant products or botanicals with a series of important properties such as; insecticidal, antifeedant, repellent, growth inhibitory, chitin synthesis inhibitor property and environmental friendly nature attracted the attention of researchers in the direction of pest control programme (Satpathi and Ghatak, 1990; Chitra *et al.*, 1992; Venkataramireddy *et al.*, 1993; Prajapati *et al.*, 2003; Lee *et al.*, 2004; Murugesan and Murugesh, 2008; Swaminathan *et al.*, 2010; Ghosh and Chakraborty, 2012) [87, 10, 112, 60, 44, 54, 101, 20]. Research should be focused on the bio pesticides which contain the extracts of pant parts having active components that suppress the pest. There is a need for further study over the effects of the ecological factors on different life stages of *H. vigintioctopunctata* so that they could be exploited in devising IPM strategy for effective management. This will help to construct the life table and biology of *H. vigintioctopunctata* to delineate and quantify the role of bio-mortality factors.

References

1. Rola C, Pingali PL. Pesticides, Rice Productivity, and Farmers Health: An Economic Assessment, International Rice Research Institute, The Philippines and World Resources Institute, Washington DC, USA, 1993.
2. Ahmad M, Ahmad MJ, Afroze S, Mishra RK. First record of Coccinellid beetles (Coleoptera: Coccinellidae) on Poplar, *Populus deltoides* from North India. Indian Forest. 2001; 127(8):891-897.
3. Anam M, Ahmad M, Haque MA. Efficacy of neem oil on the biology and food consumption of epilachna beetle, *Epilachna dodecastigma* (Weid.). Journal of Agriculture and Rural Development, 2006; 4(1, 2):83-88.
4. Behra TK, Singh TS, Kalda TS. Breeding for resistance to shoot and fruit borer *Leucinodes orbonalis* Guen. in eggplant (Solanum melongena). In: Symposium on Integrated Pest Management for Sustainable Crop Production. Indian Agricultural Research Institute, New Delhi. 1997, 39-40.
5. Bhaduri M, Gupta DP, Ram S. Effect of vegetable oils on the ovipositional behaviour of *Callosobruchus maculatus* (Fab.). Proc. 2nd Int. Symp. On Bruchids and Legumes (ISLB-2) held at Okayama, Japan; 1989, 81-84.
6. Bhagat KC, Munshi SK. Host preference of spotted leaf-eating beetle, *Henosepilachna vigintioctopunctata* (Fabr.) on different brinjal varieties. Pest Management and Economic Zoology, 2004; 12(1):77-81.
7. Bind RB. Bioecology and behaviour of a ladybird beetle *Cheilomenes* (*Menochilus*) *sexmaculata* (Fabricius) (Coleoptera: Coccinellidae). PhD thesis, University of Lucknow, Lucknow, 1998.
8. Butani DK, Jotwani MG. Insects of Vegetables. P S Periodical Export Book Agency, New Delhi. 1984.
9. Butani DK, Verma S. Pests of vegetables and their control in brinjal. Pesticides, 1976; 11(1):33-35.
10. Chitra KC, Reddy PS, Rao PJ, Goel SC. Efficacy of petroleum ether extracts of certain plants in the control of brinjal spotted leaf beetle, *Henosepilachna vigintioctopunctata* (Fabr.). In: Proceedings of National Symposium on Growth, Development and Control Technology of Insect Pests, 1992, 175-178.
11. Das G, Islam KS, Saha KC. Effectiveness of three chemical insecticides in controlling epilachna beetle, *Epilachna dodecastigma* Muls. Journal of Biological Sciences. 2002; 2(10):679-681.
12. Devi DA, Mohandas N, Vistakshy A. Residues of Fenthion, Quinphos and Malathion in paddy grains following surface treatment of gunny bags. Agric. Res. J Kerala 1986; 24(2):222-224.
13. Dhamdhere SV, Dhingra MR. Natural enemies of *Epilachna ocellata* Redtenbacher at Jabalpur, India. Journal of Entomological Research, 1990; 14(2):192-193.
14. Dhamdhere SV, Koshta VK, Rawat RR. Effect of food plants on the biology of *Epilachna vigintioctopunctata* Fabr. (Coleoptera: Coccinellidae). Journal of Entomological Research. 1990; 14(2):142-145.
15. Fishwick RB. Pesticide residues in grain arising from post-harvest treatments. Aspects Appl. Biol. 1988; 17(2):37-46.
16. Fletcher TB. Some South Indian Insects. Govt. Press, Madras. 1914, 292.
17. Froggatt W. Insect pests of cultivated cotton plant. No. 4.Cutworms and leaf-eating beetles. Agri. Gaz. N.S.W. 1923; 34:343-348.
18. Ghani A. Medicinal Plants of Bangladesh: Chemical Constituents and Uses. Asiatic Society of Bangladesh, Dhaka. 1998, 238.
19. Ghosh MR. Results of preliminary trial on control of pest complex of brinjal. Pestology. 1986; 10(1):25.
20. Ghosh SK, Chakraborty G. Integrated field management of *Henosepilachna vigintioctopunctata* (Fabr.) on potato using botanical and microbial pesticides. Journal of Biopesticides, 2012; 5:151-154.
21. Ghosh SK, Senapati SK. Biology and seasonal fluctuation of *Henosepilachna vigintioctoctopunctata* Fabr. On brinjal under terai region of West Bengal. Indian Journal of Agricultural Research. 2001; 35:149-154.
22. Grewal GS. Seasonal fluctuation in population *of Epilachna vigintioctopunctata* on brinjal (*Solanum melongena)* crop. Bulletin of Entomology, 1988; 29(1):73-75.
23. Gupta PR, Dogra GS. Sensitivity of stages of development of *H. vigintioctopunctata* to tropical application of diflubenzuron and penfluron. Journal of Insect Science, 1994; 7(2):143-147.
24. Hagen KS, Franz JM. A history of biological control. In: *History of Entomology* (eds. Smith RF, Mittler TE and Smith CN) pp. 433-467. Annual Rev. Inc., California. 1973, 872.
25. Haseeb M, Qamar M, Sharma DK. Seasonal Incidence of Brinjal Hadda Beetle, *Henosepilachna vigintioctopunctata* (F.) (Coleoptera: Coccinellidae) in Aligarh, Uttar Pradesh. Trends in Biosciences, 2009; 2(1):31-32.

26. Iftekhar B, Khan NH. Effect of temperature and relative humidity conditions on the occurrence of certain coccinellids on brinjal plants. Journal of Environmental Research. 1980; 1(11):38-41.
27. Imura O, Ninomiya S. Quantitative measurement of leaf area consumption by *Epilachna vigintioctopunctata* (Fabricius) (Coleoptera: Coccinellidae) using image processing. Applied Entomological Zoological. 1978; 33(4):491-495.
28. Islam, Kamrul, Islam M, Saiful, Ferdousi, Zennat. Control of *Epilachna vigintioctopunctata* Fab. (Coleoptera: Coccinellidae) using some indigenous plant extracts. Journal of Life and Earth Science, 2011; 6:75-80.
29. Antle JM, Pingali PL. Pesticides, productivity and farmer health: A Filipino case study, American Journal of Agricultural Economics, 1994; 76:418-430.
30. Tara JS, Sonia Sharma. Biology and life cycle of *Henosepilachna vigitioctopunctata* fabricius, a serious defoliator of bitter gourd (*momordica charantia*) in Jammu region (Jammu & Kashmir) India. Indian J.Sci. Res. 2017; 13(1):199-203,
31. Jagan Mohan N. Control of *Epilachna* and fruit borer on brinjal. *Pesticides*, 1985; 19(7):32-33.
32. Jain PC, Bhargava MC. Entomology: Novel Approaches. New India Publishing Agency, New Delhi, India. 2007, 510.
33. Jamwal VVS, Ahmad H, Sharma D. Host biology interactions of *Epilachna vigintioctopunctata* Fabr. The Bioscan., 2013; 8(2):513-517.
34. Kalra VK. Insect pest management in brinjal and cabbage/ cauliflower. In: Advanced Training Course on Insect Pest Management. Indian Council of Agricultural Research, Centre for Advanced Studies, CCS. H.A.U., Hissar. 1997, ll0-117.
35. Kapur AP. The biology and external morphology of the larvae of *Epilachninae* (Coleoptera: Coccinellidae). Bull. Ent. Res. 1950; (41):161-208.
36. Karmakar K, Bhattacharya B. Performance of a local brinjal variety (*Solarium melongena* L.) and its pest management under terai agro-ecological conditions. Environment and Ecology. 2000; 18(2):344-346.
37. Kaur R, Mavi GS. Biology of *Epilachna vigintioctopunctata* (Fabricius) (Coleoptera: Coccinellidae) on brinjal in Ludhiana, Punjab. Crop Research. 2005; 29(1):141-144.
38. Kaur R, Mavi GS. New record of hymenopterous parasitoids from *Epilachna vigintioctopunctata* (Fabricius) at Ludhiana, Punjab. Insect Environment. 2002; 8(2):77-78.
39. Kranthi KR, Jadhav DR, Kranthi S, Wanjari RR, Ali SS, Russell DA. Insecticide resistance in five major insect pests of cotton in India. *Crop Protection*, 2002; 21:449-460.
40. Krishnamurti B. The potato Epilachna beetle *Epilachna vigintioctopunctata* (Fabr.) bulletin department of agriculture mysore State, Entomological 1932; 9:16.
41. Kumar R. Principal and Philosophy of Integrated Pest Management for Tropical Root and Tuber Crops, ppl 10-115. Ill A, Ibadan, Nigeria, 1987.
42. Lal OP. A compendium of insect pests of vegetables in India. Bulletin of Entomology. 1975; 16:52-88.
43. Lall BS. *Vegetable*. Indian Journal of Entomology. Silver Jubilee Number. 1964, 187-211.
44. Lee BH, Annis PC, Tumaalii F, Choi WS. Fumigant toxicity of essential oils from the Myrtaceae family and 1, 8-cineole against 3 major stored grain insects. Journal Stored Products Research. 2004; 40(5):553-564.
45. Lefroy HM. Indian insect life. Thacker Spink & Co. Calcutta & Simla. 1909, 792.
46. Liu DQ, Wang SM, Xin SR, Li SY. A study on efficacy of different insecticides on control of eggplant *Henosepilachna vigintioctopunctata* (Fab). Acta Agricultural Universitatis Jeangxiensis. 2003; 25(4):574-576.
47. Mala SR, Peter C, David BV. Effect of insect growth regulators on reproduction of the spotted leaf beetle, *Henosepilachna vigintioctopunctata* F. Pesticide Research Journal. 1992; 4(2):99-102.
48. Mala SR, Peter C, David BV. Activity of certain insecticides on eggs of the spotted leaf beetle, *Henosepilachna vigintioctopunctata* F. on brinjal. Indian Journal of Plant Protection. 1992; 20(1):95-98.
49. Mall NP, Pandey RS, Singh SV, Singh SK. Seasonal incidence of insect pests and estimation of the losses caused by shoot and fruit borer on brinjal. Indian Journal of Entomology, 1992; 54(3):241-247.
50. Mandal A, Mandal SK. Host plant range of Epilachnine beetles in West Bengal. Indian J Ecology. 2003; 30(2):252-257.
51. Mandal SK, Kumar B. Evaluation of certain new insecticides against *Epilachna* beetle (*Epilachna vigintioctopunctata* Fab.) on brinjal. Environment and Ecology. 2001; 19(2):483-484.
52. Mane PD, Kulkami SN. Bio-efficacy of neem products against *Epilachna vigintioctopuncatata* Fab. on brinjal. Green Farming, 2010; 1(3):330.
53. Mohanchander P, Reegan AD, Rahman MAU, Raveen RS. Effect of Hadda beetle, *Epilachna vigintioctopunctata* Fab. (Coleoptera: Coccinellidae) infestation on eggplant leaf (*Solanum melongena* L.) and biocontrol potential of essential oil formulations. Pakistan Journal of Biological Sciences. 2013; 16:991-997.
54. Murugesan N, Murugesh T. Efficacy of Some Plant Products against Spotted Leaf Beetle (Hadda beetle), *Henosepilachna vigintiooctopunctata* (F.) in Brinjal. Journal of Biopesticides. 2008; 1(1):67-69.
55. Muthukumar M, Kalyanasundram. Influence of abiotic factors on the incidence of major insect pests in brinjal (*Solanum melongena* L.). South Indian Horticulture. 2003; 51(1-6):214-218.
56. Nagia DK, Kumar S, Sharma P, Meena RP, Saini ML. Laboratory evaluation of insecticides for the control of *Henosepilachna vigintioctopunctata* Fabricius on brinjal (*Solanum melongena* L.) (Coleoptera: Coccinellidae). Bio-ecology and Control of Insect Pests, 1992, 188-191.
57. Panda SK, Nayak SK, Behera UK. Bio-efficacy of some newer group of insecticides against insect pests of brinjal (*Solanum melongena* Linn.). Journal of Plant Protection and Environment, 2005; 2(2):123-125.
58. Pandey ND, Shankar U. Studies on the host preference of *Henosepilachna vigintioctopunctata* Fabr. Indian Journal of Entomology. 1975; 37(3):321-324.
59. Pervez A, Omkar. Temperature dependent life attributes of an aphidophagous ladybird beetle, *Propylea dissecta* (Mulsant). Biocont. Sci., Tech. 2004; 14:665-673.
60. Prajapati, Veena, Tripathi AK, Khanuja SPS, Kumar Sushil. Anti-insect Screening of Medicinal Plants from

Kukrail Forest, Lucknow, India. *Pharmaceutical Biology*, 2003; 41(3):166- 170.
61. Prasad UK, Prasad R, Prasad D. Integrated management of *Epilachna* beetle (*Henosepilachna vigintioctopuncta* Fabricious) infesting brinjal. J Res. BAU. 2008; 20(1):77-82.
62. Prasad G, Logiswaran G. Influence of weather factors on population fluctuation of insect pests on brinjal at Madurai, Tamil Nadu. Indian Journal of Entomology. 1997; 59(4):385-388.
63. Prodhan S, Jotwani MG, Prakash S. Comparative toxicity of insecticides to the grub and adult of *Epilachna vigintioctopunctata* Fab. (Coleoptera: Coccinellidae). Indian Journal of Entomology. 1990; 24(4):223.
64. Putta Raju B. Seasonal occurrence of major insect pests and their natural enemies on brinjal. *Current Biotica*, 2008; 2(1):63-73.
65. Qamar, Muntha, Haseeb M, Sharma DK. Biology and Morphometrics of *Henosepilachna vigintioctopunctata* (Fab.) on brinjal. Ann. Pl. Protec. Sci., 2009; 17(2):303-306.
66. Qing DL, Min SW, Rong SX, SuYing L. A study on efficacy of different insecticides on control of eggplant *Henosepilachna vigintioctopunctata* (Fabricius). Acta Agriculturae Universitatis Jiangxiensis. 2003; 25(3):574-576.
67. Qing WYLD, Hong ZS. Controlling effects of different insecticides on *Henosepilachna vigintioctopunctata*. *China Vegetables*, 2004; 4:39-40.
68. Rabb RL. Naturally occurring biological control in the eastern United States, with particular reference to tobacco insects. In : Huffaker, C.B. (ed.). Biological control. Plenum Publ. Co. New York, 1974, 294-309.
69. Raghuraman M, Veeravel R. Influence of abiotic factors on the incidence of spotted leaf beetle, *Henosepilachna vigintioctopunctata* (F.) in brinjal. Pest Management in Horticultural Ecosystems. 1999; 5(1):17-20.
70. Rahaman MA, Prodhan MDH, Maula AKM. Effect of botanical and synthetic pesticides in controlling *Epilachna* beetle and the yield of bitter gourd. International Journal of Sustainable Crop Products, 2008; 3(5):23-26.
71. Rahman A, Talukder FA. Bioefficacy of some plant derivatives that protect grain against the pulse beetle, *Callosobruchus maculatus*. 10pp. Journal of Insect Science 2006; 6:03, available online: insectscience.org/6.03
72. Rahuraman M, Veeravel R. Seasonal incidence of *Pediobius foveolatus* Craw.(Hymenoptera: Eulophidae), a parasitoid of spotted leaf beetle, *Henosepilachna vigintioctopunctata* F. in brinjal. *Shashpa*, 1999; 6(1):89-90.
73. Rai PS, Gopal RD. Feeding activity of *Epilachna vigintioctopunctata* Fabricius on Brinjal (*Solanum melongena* L.) fhiits. Indian Journal of Entomology, 1975; 37(1):84.
74. Rajagopal D, Trivedi TP. Status, bio ecology and management of Epilachna beetle, *Epilachna vigintioctopunctata* (Fab.) (Coleoptera: Coccinellidae) on potato in India: A review. Trop. Pest Management 1989; 35(4):410-413.
75. Rajagopal D, Trivedi TP. Status, bioecology and management of Epilachna vigintioctopunctata (Fabr.) (Coleoptera: Coccinellidae) on potato in India: A review. Tropical Pest Management. 1989; 6:410-413.
76. Rajendran B. Preliminary studies on the effect of green muscardine fungus, *Metarrhizium Anisopliae* (Metsch) Sorokin on eggplant spotted beetle, *Henosepilachna vigintioctopunctata* (Fabr.) (Coleoptera: Coccinellidae). Pest Management in Horticultural Ecosystems, 2002; 8:127-130.
77. Rajendran B, Gopalan M. *Pediobius foveolatus* Craw. (Eulophidae: Hymenoptera) a potential parasitoid on the grubs of eggplant spotted beetle *Henosepilachna vigintioctopunctata* Fab. *Entomon*, 1997; 22(2):147-149
78. Rajendran B, Gopalan M. Screening and grading of Brinjal (*Solanum melongena)* accessions for resistance to spotted beetle (*Henosepilachna vigintioctopunctata*). Indian Journal of Agricultural sciences, 1998; 68(4):224-225.
79. Raju K, Maheswari TU. Natural enemies associated with spotted leaf beetle *Henosepilachna vigintioctopunctata* Fab. on brinjal. Insect Environment, 2004; 10(4):168-169.
80. Ramzan M, Singh D, Singh G, Mann GS, Bhalla JS. Comparative development and seasonal abundance of hadda beetle, *Henosepilachna vigintioctopunctata* (Fabr.) on some solanaceous host plants. Journal of Research, 1990; 27(2):253-262.
81. Rath LK. Antibiosis mechanism in eggplant against *Epilachna* beetle, *Henosepilachna vigintioctopunctata* (Fabr.). Indian Journal of Plant Protection, 2005; 33(1):82-84.
82. Redtenbacher L. Tentamen dispositionis generum et specierum *Coleopterorum pseudotrimerorum*. Archducatus Austriae, Dissert, Vindobonae, 1943.
83. Richards A, Filewood LW. Feeding behavior and food preferences of the pest species comprising the *Epilachna vigintioctopunctata* (F.) complex (Coleoptera: Coccinellidae). Journal of Applied Entomology, 1990; 110(5):501-515.
84. Robert EP. Vegetable crop insects, Fundamentals of applied entomology, McMillan publishing Co., Inc. New York. 1978, 418-421.
85. Samanta A, Roy P, Das AK, Majumdar D, Somchoudhary AK. Bioefficacy of a new formulation of quinalphos against insect pests of brinjal. Journal of Interacademicia. 1999; 31(1):49-52.
86. Sarker RH, Yesmin S, Hoque MI. Multiple shoot formation in eggplant (*Solanum melongena* L.). Plant Tissue Culture Biotechnology. 2006; 16:53-61.
87. Satpathi CR, Ghatak SS. Evaluation on the efficiency of some indigenous plant extracts against *Henosepilachna vigintioctopunctata* (Coleoptera: Coccinellidae), a pest of brinjal. Environment & Ecology, 1990; 8(4):1293-1295.
88. Saxena RC, Epino PB, Cheng-Wne TU, Puma BC. Neem, chinaberry and custard apple: Antifeedant and insecticidal effects of seed oils on leaf hoppers and plant hopper pests of rice. *Proc. 2nd Int. Neem Conf*. held on 25- 28 May 1983. Rauisch-Holshausen, FRG. 1983, 391-402.
89. Schaefer PW. Natural enemies and host plants of species in the Epilachninae (Coleoptera: Coccinellidae) - a world list. University of Delware. Agricultural Experiment Station Bulletin. 1983; 445:409.
90. Shankar U, Kumar D, Gupta S. Integrated pest management in brinjal. Technical Bulletin Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu. 2010; 4:l6.

91. Sharma AN, Rajguru, Monika. Efficacy of a herbal formulation against *Spodoptera litura* Fab. Soybean Research, 2009; 7:102-105.
92. Shinogi T. Role of induced resistance in interactions of *Epilachna vigintioctopunctata* with host and non-host plant species. Plant science. 2005; 168(6):1477-1485.
93. Shinogi T, Hamanishi Y, Otsu Y, Wang YQ, Nonomura T *et al*., Role of induced resistance in interactions of *Epilachna vigintioctopunctata* with host and non-host plant species. Plant Sci. 2005; 168:1477-1485.
94. Singh RN, Saratchandra B. The development of botanical products with special reference to seri-ecosystem. Caspian J Env Sci. 2005; 3(1):1-8.
95. Sreedevi K, Chitra KC, Rao PK. Effect of certain plant products against brinjal leaf beetle, *Henosepilachna vigintioctopunctata* Fab. under greenhouse conditions. *Indian Journal of Entomology*, 1993; 55:329-331.
96. Srivastava KP, Butani D. Pest management in vegetable. Research Periodical and Book Publishing House, 1998, 197-225.
97. Subramaniam TV. Some coccinellids of South India. Rep. Proc. Fifth Ent. Meet. Pusa. 1924, 108-118.
98. Subramanyam B, Hagstrum DW. Resistance Measurement and Management. In: Integrated management of insects in stored products. (Subramanyam, B. and Hagstrum D.W. eds.), Marcel Dekker, New York, 1995, 331-397.
99. Sudan M. Survey of insect pests infesting some medicinal plants in district Rajouri (J&K). M.phil. Dissertation submitted to University of Jammu, Jammu, 2008.
100. Suresh M, Bijaya P, Prasad B, Singh TK. Seasonal incidence of insect pests on brinjal and a note on the biology of *Leucinodes orbonalis* Guen. (Lepidoptera: Pyraustidae) in Manipur. Uttar Pradesh Journal of Zoology, 1996; 16(3):151-155.
101. Swaminathan R, Manjoo S, Hussain T. Anti-feedant activity of some biopesticides on *Henosepilachna vigintioctopunctata* (Fab.) (Coleoptera: Coccinellidae). Journal. Biopesticides. 2010; 3(1):77-80.
102. Thomas MJ, Jacob A, Nair MR GK. Host-biology relations of *E.vigintioctopunctata.* Agriculture Research Journal of Kerala, 1969; 7(1):31- 33
103. Thompson JN, Pellmyr O. Evolution of oviposition behavior and host preference in Lepidoptera. Annu. Rev. Entomol. 1991; 36:65-89.
104. Thurkathipana N, Mikunthan G. Eco-friendly management of hadda beetle using *Beauveria bassiana* in brinjal. Communication in Agriculture and Applied Biological Sciences. 2008; 73(3):597-602.
105. Tilavov TT. The daily and seasonal feeding rhythm of the adult of the cucumber beetle, *Epilachna chrysomelina* Fab.Uzbek. Biol. Zhur. 1981; 8(5):40-61.
106. Tiwari G, Prasad CS, Kumar A, Nath L. Influence of weather factors on population fluctuation of pest complex on brinjal. Ann. Pl. Protec. Sci. 2012; 20(1):68-71.
107. Tyade AR, Simon S. Studies on biology and morphometrics of hadda beetles, *Epilachna vigintioctopunctata* (Coleoptera:Coccinellidae) a serious pest of bitter gourd, *Momordica charantia*, in eastern Uttar Pradesh, India. International Journal of Agricultural Science and Research. 2013; 3(4):133-138.
108. Umapathy G, Baskaran P. Bio-efficacy of certain synthetic pyrethroids against major pests of brinjal. Madras Agricultural Journal. 1991; 78(1-4):8-10.
109. Varma S, Anandhi P. Seasonal incidence of brinjal hadda beetle, *Henosepilachna vigintioctopunctata* (Fab.) and its natural enemies. Indian Journal of Entomology, 2008; 70(1):31-39.
110. Varma S, Anandhi P. Assessment of mortality factors, biology and morphometries of hadda beetle, *Henosepilachna vigintioctopunctata* (F.) on brinjal. Annals of Plant Protection Sciences, 2008; 16(1):119-123.
111. Venkatesha MG. Seasonal occurrence of *Henosepilachna vigintioctopunctata* (F.) (Coleoptera: Coccinellidae) and its parasitoid on ashwagandha in India. Journal of Asia-Pacific Entomology. 2006; 9(3):265-268.
112. Venktaramireddy P, Chitra KC, Rao PK. Efficacy of the plant extracts in the control of brinjal spotted leaf beetle, *Henosepilachna punctata*. Botanical Pesticides in IPM: 1993, 225-227.
113. Wilson RL. Studies of insects feeding on grain amaranth in the Midwest. Journal of the Kansas Entomological Society, 1989; 62(4):440-448.
114. Wink M. Production and application of phytochemicals from an agricultural perspective. In: *Phytochemistry and agriculture*, (Van Beek, T. A. and Breteler, H. eds.), vol. 34, Clarendon, Oxford, UK, 1993, 171- 213.