INTERNATIONAL JOURNAL OF PLANT PROTECTION
VOLUME 10 | ISSUE 1 | APRIL, 2017 | 193-202
● e ISSN-0976-6855 | Visit us : *www.researchjournal.co.in*

IJPP

A REVIEW

DOI : 10.15740/HAS/IJPP/10.1/193-202

Present status on bio-ecology and management of tobacco caterpillar, *Spodoptera litura* (Fabricius) – An update

■ P. K. NATIKAR* AND R. A. BALIKAI[1]

Department of Agricultural Entomology, College of Agriculture, University of Agricultural Sciences, DHARWAD (KARNATAKA) INDIA
[1]College of Agriculture (U.A.S.), Hanumanamatti, HAVERI (KARNATAKA) INDIA (Email: rabalikai@gmail.com)

ARITCLE INFO

Received : 14.02.2017
Accepted : 29.03.2017

KEY WORDS :
Tobacco caterpillar, *Spodoptera litura*, Damage, Biology, Management

***Corresponding author:**
shanthunatikar@gmail.com

ABSTRACT

The tobacco caterpillar, *Spodoptera litura* (Fabricius) is one of the economically important and regular polyphagous pests on the field and horticultural crops and distributed in Indo-Australian tropics. The larvae feed on a wide range of plants and have been recorded from over 40 mostly dicotyledonous plant families. It is a major pest of tobacco, cotton, rice, maize, soybean and groundnut. The present article focuses on literature generated on various aspects of tobacco caterpillar *viz*., pest status and their distribution, biology, damage, losses, seasonal incidence, host range and ecology and different management strategies such as, cultural and mechanical, host plant resistance, role of natural enemies and need based chemical control besides integrated pest management strategies employed against this pest.

How to view point the article : Natikar, P.K. and Balikai, R.A. (2017). Present status on bio-ecology and management of tobacco caterpillar, *Spodoptera litura* (Fabricius) – An update. *Internat. J. Plant Protec.*, **10**(1) : 193-202, **DOI : 10.15740/HAS/IJPP/10.1/193-202**.

INTRODUCTION

The tobacco caterpillar, *Spodoptera litura* (Fabricius) is one of the economically important and regular polyphagous pests on the field and horticultural crops (Shankara Murthy *et al*., 2006). It is considered as one of the major threats to the present-day intensive agriculture and changing cropping patterns worldwide, next only to *Helicoverpa armigera* (Hubner). *Spodoptera litura* is reported to feed on 150 species of plants (Rao *et al*., 1993) causing 26-100 per cent yield loss under field conditions (Dhir *et al*., 1992); more than 180 crops (Isman *et al*., 2007). It is polyphagous pest, reported damaging more than 112 species of plants belonging to 44 families, of which 40 species are known from India (Chari and Patel, 1983) and many other countries (Shivayogeshwara *et al*., 1991). Among the main crop species attacked by *S. litura* in the tropics are *Colocasia esculenta*, cotton, flax, groundnuts, jute, lucerne, maize, rice, soyabeans, tea, tobacco, vegetables (aubergines, *Brassica*, *Capsicum*, cucurbit vegetables, *Phaseolus*, potatoes, sweet potatoes, *Vigna* etc.). Other hosts include ornamentals, wild plants, weeds and shade trees (e.g. *Leucaena leucocephala*, the shade tree of cocoa plantations in Indonesia).

Nature of damage and damage symptoms :

The larvae attack the crop normally in the month of August and September during late vegetative and early, reproductive stages of the crop. The newly hatched larva, scrape the chlorophyll content and feed voraciously. This gives the appearance of yellowish white web on the leaves. As the caterpillar matures, they completely defoliate the leaves leaving only midribs and stalks. Larval feeding is vigorous as it advances in age. The soft pods are chewed by the larvae and the thick pods are bored and feed on grain. The habit of larvae is to hide under the plants, cracks and crevices of soil debris during the day time and feeds during night hours. The incidence could be noticed by the faecal pellets left on the leaves (Punithavalli and Balaji Rajkumar, 2014). On most crops, damage arises from extensive feeding by larvae, leading to complete stripping of the plants. On cotton, Leaves are heavily attacked and bolls have large holes in them from which yellowish-green to dark-green larval excrement protrudes. On tobacco leaves develop irregular, brownish-red patches and the stem base may be gnawed off. On maize the stems are often mined and young grains in the ear may be injured. The common signs of infestation include (1) Presence of an egg mass (4-7 mm in diameter) covered with hair scales on the underside of young leaves. (2) Larvae on leaves, stems, buds, flowers and fruits. (3) Leaves with holes or skeletonised leaves.

Extent of losses :

Spodoptera litura is reported to feed on 150 species of plants (Rao *et al.*, 1993) causing 26-100 per cent yield loss under field conditions (Dhir *et al.*, 1992). During 2008-09, there was severe outbreak of *S. litura* coupled with *Helicoverpa armigera* and other leaf eating caterpillar pest on soybean crop in Marathwada and Vidarbha regions of Maharashtra State. Crop over an area of 14.64 lakh hectares (48% of area under soybean) was infested out of that 10.44 lakh hectares was having more than 50 per cent infestation level. As such, the crop was almost devastated. Monetary losses due to pest outbreaks were estimated to the tune of Rs.1392 crores (CROPSAP, 2008-09).

Biology of *Spodoptera litura* :

A female moth lays masses of eggs on the undersurface of young leaves. After egg hatch, caterpillars feed on leaves. They are first gregarious and later solitary. They also may feed on stems, buds flowers and fruits. Pupation occurs in soil several centimeters deep without a cocoon. A life cycle completes on average of 25 days.

Egg :

Latha *et al*. (2014) reported that eggs were flat and hemispherical in shape. Each eggmasses had 300-350 eggs which were arranged in rows upto 3 layers. The incubation period ranged from four to five days with an average of 4.10 ± 0.32 days. The egg measured 0.2 to 0.4 mm in length with an average of 0.31 ± 0.06 mm. The freshly laid eggs were pale green in colour, eggs become pearly white after 24 hours and turned yellow on second day. Eggs were covered by brown scales from the body of the female (Cardona *et al.*, 2007). According to CABI/EPPO (1990) *S. litura* eggs are spherical, somewhat flattened, 0.6 mm in diameter, laid in batches and covered with hair scales from tip of the abdomen of the female moth. Usually pale orange-brown or pink in colour.

Larva :

Latha *et al*. (2014) reported that caterpillar during its developmental period undergone five moults and six larval instars. The total larval period ranged from 15 to 23 days with an average of 19.90 ± 2.33 days. The newly hatched larva is cylindrical in shape. The head is prominently big, bigger than any part of the body. As the larva advances to second instars, the body grows faster and as a result the body turns wider than the head (Cardona *et al.*, 2007). CABI/EPPO (1990) reported that larva attains 40-45 mm in length; hairless, variable in colour (blackish-grey to dark green, becoming reddish-brown or whitish-yellow); sides of body with dark and light longitudinal bands; dorsal side with two dark semilunar spots laterally on each segment, except for the prothorax; spots on the first and eighth abdominal segments later than others, interrupting the lateral lines on the first segment. Though the markings are variable, a bright-yellow stripe along the length of the dorsal surface is characteristic of *S. litura* larvae.

First instar larva :

The newly hatched latvae were initially sluggish in nature which become active later. The length of first instar larva varied from 1.1 to 1.7 mm with an average of 1.33 ± 0.18 mm. The duration of first instar larva ranged from 3 to 4 days with mean of 3.80 ± 0.42 days (Latha *et al.,* 2014). Almost similar observations were reported by Cardona *et al*. (2007).

Second instar larva :

As the larva advanced to second instar, the body grew faster and as a result the body turned wider than head. Longitudinal light brown stripes (4) found on the sub-dorsal and lateral side of abdomen. The length of second instar larva ranged from 2.4 to 3.9 mm with an average of 3.28 ± 0.46 mm with duration range of 2.00 to 3.00 days (Latha *et al.,* 2014). Almost similar observations were reported by Cardona *et al*. (2007).

Third instar larva :

Latha *et al*. (2014) reported that the third instar larva measured 7.6 to 8.5 mm and larval period varied from 2 to 3 days with an average of 2.80 ± 0.42 days. The body was elongated and longer than second instar. The larva was yellowish green in colour with many scattered black spots on the body. Three thin yellow lines were present in the middle and each side. The three pairs of prothoracic legs were distinct and pro legs were situated on the sixth, seventh, eighth and ninth segments of abdomen. During the third instars, the body length of the larva measures 11.71 + 0.33 mm while the body width was 2.45 + 0.23 mm as reported by Cardona *et al*. (2007).

Fourth instar larva :

Latha *et al*. (2014) reported that the body length of fourth instar larvae ranged from 20 to 24 mm (Av. 22.45 ± 1.19 mm) and duration period was 2 to 3 days. The larva was dark green in colour with many yellow and green longitudinal stripes. Head and prothorax shield were dark green and crochets on prothorax were distinct. Cardona *et al*. (2007) reported that the body length measures 26.97 + 1.77 mm and a body width of 4.73 + 0.26 mm.

Fifth instar larva :

Cardona *et al*. (2007) reported that the body length of full grown larva was 46.91 + 2.25 mm and a body width of 6.87 + 0.16 mm. Latha *et al*. (2014) reported that the head was reddish brown and the tubercles and thoracic legs were black in colour. The spiracles were very prominent. The length of fifth instar larva ranged from 31 to 35 mm with duration of 4 to 6 days.

Total larval period :

Latha *et al*. (2014) reported that the total larval life period lasted for 15 to 23 days with an average of 19 ± 2.33 days.

Pupa :

Cardona *et al*. (2007) reported that the body length of pupae measures 22.29 + 0.71 mm and a body width of 7.51 + 0.36 mm. The pupa is elongated oval in shape and of shiny red colour. The eyes and the antennal case are prominent. The abdomen has movable incisures with dark spiracles. Latha *et al*. (2014) reported that the length of pre-pupa ranged from 17 to 22 mm with an average of 19.10 ± 1.58 mm. The duration of pre-pupal period ranged from 1 to 2 days with an average of 1.10 ± 0.32 days and pupal characters were similar to the findings of Cardona *et al*. (2007). The pupal period ranged from 9.00 to 14.00 days. CABI/EPPO (1990) reported that pupa is of 15-20 mm long, red-brown: tip of abdomen with two small spines.

Adult :

The length of male and female moth varied from 15 to 17 mm (average 16.20 ± 0.84 mm) and 17 to 20 mm (average 18.60 ± 1.14 mm). The adult females and males were hairy and brown in colour. The head, thorax and abdomen were distinct. The antennae and legs were dark brown. It has a very prominent rounded bluish black eyes occupying almost 1/3 of the facial head. Two long segmented antennae are located dorsally on the head and close to the compound eyes (Latha *et al*. 2014). Almost similar observations were also drawn by CABI/ EPPO (1990); Cardona *et al*. (2007) and Robert *et al*. (2003).

Total life cycle :

Latha *et al*. (2014) reported that the total life span of male and female cut worm varied from 43 to 48 days with an average 45.50 ± 1.58 days and 45 to 52 days with an average of 48.20 ± 2.10 days, respectively.

Behavioural studies :

Feeding :

The young larva is less mobile few minutes after hatching from the egg. It feeds by scraping the surface of the leaves. As the caterpillar matures, they produce regular holes on the leaves leaving the veins. Feeding is more active as it advances in age and at night time. The larva hides in the soil at daytime and return damaging the plants at night. This characteristic of the larva was observed upon reaching the third until the fifth instars. The larva cease on feeding few minutes before molting. The presence of exuviates manifest that the insect has undergone molting. Food consumption generally increased as the insect developed to fifth instars (Cardona *et al.*, 2007).

Pupation :

Few hours before pupation, the larva is immobile and cease on feeding. Later, the larva moves down and borrows into the soil that was provided into the rearing cage. The larva is more or less 1cm below the soil. Before it finally developed to pupa, the larva was active by its manner of moving the body with reversible C-shape position (Cardona *et al.*, 2007).

Mating behaviour :

Latha *et al*. (2014) reported that the average pre-mating period was 1.24 ± 0.15 days and mating period ranged from 0.25 to 0.37 days with an average of 0.30 ± 0.06 days. Prior to mating, courting was observed. The male actively initiates the mating. It flies several times above the female. When it stops flying, it lands close to the female. The male gradually moves by walk- ing close to the female. Using the antennae, the male touches the female. The male quickly mounts the female and soon there is a downward movement of the insect antennae. Before a successful mating, the male courts the female for a period of 10 to 20 minutes. The male coiled proboscis is straightened during mating but returns to its original form as soon as the copulation is finished. Copulation lasts for 2-3 hours and usually done early morning at between 2:00 to 5:00 AM (Cardona *et al.*, 2007).

Oviposition :

The oviposition site is first located by the female. After the site was identified, the insect cleans the leaf surface area by wip- ing using the tip of the abdomen. Oviposition takes place immediately after. The egg is laid in mass under the shade near the petiole. The egg is deposited in layers of 2-3 as reported by Cardona *et al*. (2007). Latha *et al*. (2014) reported that the pre-oviposition period varied from 1 to 2, ovipositional period 3 to7 and post-oviposition period 1 to 2 days, respectively.

Fecundity :

The egg is laid in mass instead of the singly egg laying as behaved by some insects. As a way probably of protecting the egg from possible predators and adverse weather factors, the mass of egg is covered by scales which according to Paris (1968) come from the mother abdomen during the act of oviposition. An average egg mass of 8.7 is laid. The insect's life span is 12 days egg laying as the shortest and 14 days as the longest. The peak of oviposition is 6 days. Oviposition abruptly declined 7 and 8 days after and descends gradually thereafter until the insect dies. There are 874.9 individual eggs in one egg mass (Cardona *et al.*, 2007).

Host range :

The host range of *S. litura* covers at least 120 species. Among the main crop species attacked by *S. litura* in the tropics are*Colocasia esculenta*, cotton, flax, groundnuts, jute, lucerne, maize, rice, soybeans, tea, tobacco, vegetables (*Brassica*, *Capsicum*, cucurbit vegetables, *Phaseolus*, potatoes, sweet potatoes and species of *Vigna*. Other hosts include ornamentals, wild plants, weeds and shade trees (for example, *Leucaena leucocephala*, the shade tree of cocoa plantations in Indonesia).

Seasonal incidence and influence of weather parameters :

Soybean :

Activity of *S. litura* in relation to weather factors have been investigated in soybean cropping systems (Prasad *et al*., 2013 and Punithavalli *et al*., 2013). The activity of defoliators (*S. litura* and *T. orichalcea*) was found throughout the cropping season. However, lowest incidence of *S. litura* was noticed on early sown crop 16-06-2007 (5.37 and 3.98 larvae per meter row length (l/mrl), respectively) compared to the crop sown on 03-07-2007 (7.31 and 5.51 l/mrl, respectively) and on 15-07-2007 (8.44 and 6.03 l/mrl, respectively) as reported by Santhosh (2008). Pheromone traps can be used for the prediction of numbers of *S. litura* eggs and larvae in soybean fields. Thus, it is clear from the results that the rainfall pattern (Surplus than Normal RF during the current year), moth catches in pheromone trap during September and October, sudden rise in temperature and sunshine hours would decide the outbreak of *S. litura* in soybean crop. It may conclude that *S. litura* out breaks are more likely to occur during rainy seasons in soybean and coupled with moth catches during September October months (Ramesh Babu *et al*., 2015).

Cotton :

Selvaraj *et al*. (2010) reported that the highest incidence of *S. litura* was recorded during 18th MSW which was corresponding to the period when maximum temperature ranged from 32.0^{o} to 35.0^{o}C, minimum temperature from 24.0^{o} to 26.0^{o}C, morning relative humidity from 89 to 92 per cent, evening relative humidity from 62 to 64 per cent, wind speed 6.2 kmph and zero rainfall.

Castor :

Thanki *et al*. (2003) reported that the minimum temperature, evening relative humidity, morning and evening vapour pressure showed negative effect on oviposition behaviour and larval development of *S. litura*, whereas correlation analysis showed non-significant difference between various abiotic factors and leaf damage.

Present status of resistance in *Spodoptera litura* :

Field collected population *of S. litura* showed significantly higher resistance to cypermethrin, deltamethrin, chlorpyrifos and profenofos (Munir Ahmed *et al*., 2005). A high level of resistance is found against organophosphates, carbamates, synthetic pyrethroids and abamectin (Hong Tong *et al.*, 2013). *S. litura s*howed high resistance to profenofos and profenofos exposed strains of this moth showed high cross-resistance to chlorpyrifos (Naeem Abbas *et al.*, 2014). The resistance to spinosad in *S. litura* increased 3921-fold after eleven generations of selection with spinosad (Rehan and Freed, 2014). In the insect bioassay conducted, field collected strains of *S. litura* showed high level of resistance to synthetic pyrethroids (Anbalagan *et al*., 2014).

Management practices :

The various aspects of *S. litura viz*., toxicity, ovicidal action, oviposition deterrent activity, ovipositional preference, management and screening of different varieties of soybean have been reviewed by Natikar and Balikai (2015).

Cultural control :

Deep ploughing is required during summer months to expose the pupae. Avoid pre-monsoon sowing. Sowing resistant or tolerant varieties. Use optimum seed rate as per recommended for particular crops (Punithavalli and Balaji Rajkumar, 2014).

Resistant varieties :

Hareesha *et al*. (2011) reported that the inter-specific cotton hybrids, Kashinath BG-II and Namcot BG-II were found to be resistant to *S. litura* as they recorded lowest number of live larvae per plant. Natikar and Balikai (2015a) reported that the soybean varieties *viz*., DSb 1, DSb 21 and KHSb 2 were not preferred by *Spodoptera* to lay eggs as evidenced by no egg masses on their leaves under laboratory tests. While under field conditions, out of ten soybean varieties, DSb-1, KHSb-2, DSb-21 and DSb 23-2 were identified as resistant ones against *S. litura* as they recorded 0.00, 0.00, 0.33 and 0.33 egg masses per meter row length. The least pod damage was noticed in DSb-1 (5.15%), KHSb-2 (6.72%), DSb-21 (7.73%), DSb 23-2 (9.14%) which were on par with MACS-1394 with 11.46 per cent pod damage (Natikar and Balikai, 2015b). Taware *et al.* (2007) conducted screening of soybean lines for resistance against *S. litura* and found that none of them were highly resistant to *S. litura*, but twelve lines like MACS 754,756 757 etc. were found to be moderately resistant. Seven genotypes were screened for resistance against *S. litura* in groundnut. Among them the genotypes ICGV-86699 Tan and Mutant –III were at par with each other in causing highest larval mortality at 5, 10 and 15 days after harvesting. Thus, these two genotypes were resistant to *Spodoptera litura* (Rashmi *et al.*, 2011). Harish *et al.* (2009) conducted screening of different soybean genotypes for resistance against major defoliators, mainly *S. llitura.* Their results revealed that among eleven genotypes screened, DSb-1, Bragg and KHSb-2 were found to be highly resistant to the tobacco caterpillar. Also, four genotypes were found to be moderately resistant.

Mechanical control :

Collect and destroy egg masses and gregariously feeding early stage larvae. Install one light trap (200 W mercury vapor lamp) / ha in the field to catch the adults. Install pheromone traps @ 8-10/acre at a distance of 50 m interval for early detection/ mass trapping. Erection of bird perches @ 10-12/ha. Use of Castor as trap crop (Punithavalli and Balaji Rajkumar, 2014).

Biological control :

Release egg parasitoid *Telenomus remus* @ 50000/ ha. Spray *Spodoptera litura* NPV (Nuclear Polyhedrosis Virus) @ 250 LE. Spray NSKE @ 5% to manage early stage larvae. Spray biopesticide *Nomuraea rileyi* @ 2 g/lit. Spray *Bacillus thuringiensis var. kurstaki* @ 0.75-1.0 g/ha (Punithavalli and Balaji Rajkumar, 2014). Sharma *et al.* (2014) reported three egg parasitods like *Trichogramma chilonis*, *Tetrastichus* sp. and *Telenomus* sp. on *S. litura.* Three larval parasitoids *Ichneumon promissorius, Carcelia* spp, *Diglyphus isaea* were also reported. Efficacy of entomopathogenic nematodes *Heterorhabditis indica* and *Steinernema glaseri* was studied against *S. litura* on black gram by Umamaheshwari *et al.* (2006). They found that *H. indica* at 5 x 10^9 IJ / ha was the most efficient one in causing highest mortality and also lowest pod damage. The next best treatment was found with *S. glaseri* at 5 x 10^9 IJ / ha. Narasimhamurthy *et al.* (2012) evaluated the efficacy of *Sl*NPV with plant extracts against *S. litura* under field conditions. Their results revealed that *Sl*NPV + NSKE (5%) was the best treatment in recording highest larval reduction. This was followed by the treatment with SlNPV+ *Neem* oil (0.1%). The highest efficacy among biopesticides against *S. litura* in urdbean was observed in treatment imposed with *Sl*NPV @ 250 LE/ha followed by NSKE @ 5% (Kumar *et al.*, 2007). Natural parasitisation of *S.litura* larvae by parasitoids *Campoletis chloridae* and *Apantales* spp. recorded highest per cent parasitisation in groundnut + lucerne (17.00%) intercropping at 45 DAS followed by groundnut + foxtail millet (16.00%), groundnut + bajra (14.00%), groundnut+sorghum (13.00%). Groundnut + cowpea and groundnut + lucerne intercropping system recorded higher percentage of larval mortality and lower per cent defoliation after spray of *N.rileyi* (Girija, 2014). Percentage mortality of *S.litura* larvae infesting soybean was assessed by spraying with different phytoextracts like *Acarus calamus*, *Acacia concinna*, *Terminalia chebula* and *Terminalia belerica*. Among these, phytoextracts of *Acacia concinna* recoded highest larval mortality followed by *T. chebula* extracts (Patil and Chavan, 2010). Among different IPM modules against defoliators in castor, the module consisting of erecting bird perches + NSKE 5% + *Sl* NPV + mechanical control, was the best treatment in recording lowest populations of *S. litura* and also highest yield. The next best treatment was found to be the module consisting of mechanical control+ monocrotophos 0.05 per cent (Suganthy, 2010).

Chemical control :

Lakshmi Narayanamma *et al.* (2013) reported that among different newer insecticide molecules tested against *S. litura*, Flubendiamide 480 SC and Chlorantraniliprole 18.5 SC were found to be at par with each other in reducing the larval populations. Gedia *et al.* (2008) studied the efficacy of different insecticide combinations on larval population of *S.litura* and yield on castor. They reported that the treatment with Btk @ 1 kg/ha + Chlorpyriphos 0.025 per cent was found to be superior over all other treatments in causing larval mortality and also recording highest yield. Vinaykumar *et al.* (2013) evaluated the newer insecticides against *S. litura* and *H. armigera* in soybean field experiment at Instructional Farm, College of Agriculture, Junagadh during *Kharif* 2009 and reported that among eleven different insecticides tested, spinosad @ 0.025%, rynaxypyr @ 0.006%, thiodicarb @ 0.15%, indoxacarb @ 0.0029% and flubendiamide @ 0.05% were found to be most effective against *S. litura* and remaining treatments were moderately effective in managing *S. litura.* Hanumantharaya *et al.* (2013) reported that mean fruit borer population in tomato was significantly lower in flubendiamide 24 SC @ 0.2 ml/lit treated plot (0.10 larva/plant) which was on par with chlorantraniliprole 20 EC @ 0.2 ml/lit with 0.14 larva/plant followed by profenophos 50 EC @ 2 ml/lit with 0.20 larvae/plant and spinosad 45 EC @ 0.2 ml/lit with 0.30 larvae/plant. Natikar and Balikai (2015c) reported that highest per cent mortality of *S. litura* eggs in case of thiodicarb 75 WP @ 1 g/lit (88.43%) treated eggs followed by flubendiamide 480 SC @ 0.2 ml/lit (65.95%) and emamectin benzoate 5 SG @ 0.25 g/lit (63.98%). Natikar and Balikai (2015d) documented that maximum reduction in egg laying was recorded with thiodicarb 75 WP @ 1 g/lit (78.11%) which was on par with chlorantraniliprole 18.5 SC @ 0.2 ml/lit (74.37%), chlorpyriphos 20 EC @ 2 ml/lit (74.33%), flubendiamide 480 SC @ 0.2 ml/lit (73.18%) and cyantraniliprole 10 OD @ 0.2 ml/lit (72.38%). Shali Raju *et al.* (2013) tested the efficacy of insecticides against defoliators in soybean which revealed that spinetoram 12 SC and rynaxypyr 20 SC @ 100 ml/

ha were significantly effective and at par with commonly recommended insecticides *viz*., profenophos 50 EC @ 1250 ml/ha, triazophos 40 EC @ 800 ml/ha, quinalphos 25 EC @ 1500 ml/ha and thiamethoxam 25 WG @ 100 g/ha. Manu *et al*. (2014) studied efficacy of novel insecticides and biorationals in the management of *S. litura* and reported that flubendiamide 480 SC @ 0.2 ml/lit was the most efficient chemical in managing *S. litura* by giving highest larval reduction followed by the spraying of indoxacarb14.5 SC @ 0.5 ml/lit which proved to be the second best treatment among all and among the biorationals *Sl*NPV @ 250 LE/ha was found to be superior with larval reduction of 55.49 per cent followed by *Nomuraea rileyi* 2 x 10^8 conidia @ 2 g/lit and nimbecidine (FS) @ 3 ml/lit. Natikar and Balikai (2015e) reported that among the various insecticides tested, emamectin benzoate 5 SG was found to be most toxic with LC_{50} value of 0.50 ppm followed by cyantraniliprole 10 OD (0.63 ppm), indoxacarb 15.8 EC (1.44 ppm), chlorantraniliprole 18.5 SC (2.26 ppm), spinosad 45 SC (8.41 ppm), chlorfenapyr 10 SC (9.33 ppm), flubendiamide 480 SC (14.02 ppm) and chlorpyriphos 20 EC (143.84 ppm). While Natikar *et al*. (2016) reported that, among the new molecules flubendiamide 480 SC @ 0.2 ml/lit was found significantly superior in reducing the larval population in soybean crop and recorded highest grain yield of 2382.00 kg/ha followed by indoxacarb 15.8 EC @ 0.3 ml/lit (2217.33 kg/ha) and cyantraniliprole 10 OD @ 0.2 ml/lit (2053.33 kg/ha).

Remya Kolarath *et al*. (2015) evaluated newer insecticides for the management of pod borers of field bean and found that novaluron 10 EC @ 0.7 ml/lit, emamectin benzoate 5 SG @ 0.2 g/lit, spinosad 45 SC @ 0.1 ml/lit, flubendiamide 20 SC 0.2 g/lit and diflubenzuron 25 WP @ 1.0 ml/lit were effective in reducing the larval population as well as pod damage by *Maruca vitrata* (Fabricius). Rynaxypyr 10 SC @ 0.1 ml/lit was found least effective as compared to other newer insecticides. Joshi and Patel (2011) conducted trail with eco-friendly approach for the management of *S. litura* on soybean and the results revealed that, the data on mortality of leaf eating caterpillar indicated that triazophos @ 0.06% gave highest mortality (93.44 %) followed by spinosad @ 0.01%, quinalphos @ 0.05% and endosulfan @ 0.007% (91.65, 87.41 and 87.13% mortality, respectively). The treatment with NSKE @ 5%, *Beauveria bassiana* @ 5 g/lit, neemazol @ 2.00 ml/lit and ememectin benzoate @ 0.5 g/lit were the next effective treatments as they recorded 79.55, 79.06, 78.11 and 72.04 per cent mortality, respectively. Mutkule *et al*. (2009) conducted field experiment to evaluate some new molecules against *S. litura* in groundnut and the results revealed that, the application of spinosad 45 SC (0.018 %) was found to be superior in the suppression of larval population and was at par with emamectin benzoate 5 WSG @ 0.001% and thiodicarb 75 WP @ 0.0075%. The highest pod yield of 1998 kg/ha was recorded with the treatment of spinosad 45 SC (0.0018%) and it was at par with all the insecticides evaluated whereas bio-agents stood at second position. Patil *et al*. (2008) evaluated flubendiamide 480 SC @ 24, 36 and 48 g a.i./ha, indoxacarb 14.5 SC @ 75 g a.i./ha and spinosad 45 SC @ 84.375 g a.i./ha for their efficacy against pod borers in black gram. The minimum larval population of 1.13 and 0.50 larvae per five plants was recorded with the treatment of flubendiamide 480 SC @ 48 g a.i./ha followed by indoxacarb 14.5 SC @ 75 g a.i./ha (1.19 and 0.63 larvae/ 5 plants) at 3 and 7 days after spraying, respectively which were at par with each other. The lowest pod damage of 9.98 per cent was recorded in flubendiamide 480 SC @ 48 g a.i./ha followed by indoxacarb 14.5 SC (10.22%). The maximum seed yield of 793 kg/ha was obtained by the treatment of flubendiamide 480 SC @ 48 g a.i./ha followed by indoxacarb 14.5 SC @ 75 g a.i./ha (777 kg/ha).

Effect of insecticides on natural enemies of soybean pests :

Indoxacarb 15.8 EC @ 0.3 ml/lit, chlorpyriphos 20 EC @ 2.00 ml/lit and flubendiamide 480 SC @ 0.2 ml/lit were found highly toxic to coccinellids as compared to safer chemicals like spinosad 45 SC @ 0.2 ml/lit, emamectin benzoate 5 SG @ 0.25 g/lit, chlorantraniliprole 18.5 SC @ 0.2 ml/lit and novaluron 10 EC @ 1.00 ml/lit. For *Chrysoperla* spp., spinosad 45 SC @ 0.2 ml/lit and emamectin benzoate 5 SG @ 0.25 g/lit were found to be at par with untreated check with least toxic effects. Similarly, spinosad 45 SC @ 0.2 ml/lit and emamectin benzoate 5 SG @ 0.25 g/lit were safer to spiders. Among different chemicals used, highest soybean yield was registered in spinosad 45 SC @ 0.2 ml/lit (2354 kg/ha) followed by chlorantraniliprole 18.5 SC @ 0.2 ml/lit (2304 kg/ha) (Natikar *et al*., 2016a).

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