Soybean is vulnerable to attack of many insect pests right from sowing to harvest of the crop and also in storage. Among the various pests infesting the crop, Leaf eating caterpillar, *Spodoptera litura* (Fabricius) and Gram pod borer, *Helicoverpa armigera* (Hubner) were the major pests that found the attacking the crop during *kharif* season of 2017. The available literature related to different aspects of present studies along with the same pests infesting other pulses in India and abroad has been reviewed and presented under following headings.

1. Seasonal incidence of defoliators on soybean
2. Bio-efficacy of insecticides against soybean defoliators under laboratory condition
3. Bio-efficacy of insecticides against soybean defoliators under field condition

### 2.1 Seasonal incidence of defoliators on soybean

#### 2.1.1 Tobacco leaf eating caterpillar, *S. litura* (Fabricius)

Shrivastava and Shrivastava (1989) observed the larvae of *S. litura* as a defoliator in soybean crop. The pest was active from August to October and the population varied from 5 to 6 larvae per ten plants, however, their activity was confined only to *kharif* season in Vindhyan Plateau in Madhya Pradesh. Similarly, Singh and Singh (1990b) observed that the *S. litura* attacks the soybean during August-October. It causes wide spread damage to soybean in September-October.

Singh *et al.* (1989) reported that the sporadic occurrence *S. litura* but when appears, if unattended, causes complete failure of crop. It has been reported as a pest of soybean from almost all the States wherever soybean is grown. Recently, it has been reported causing widespread defoliation in Orissa and Southern States. The young larvae are gregarious, while the old larvae are solitary. Infestation on soybean starts in August and continues till crop maturity. This is a serious and regular pest in Madhya Pradesh. This polyphagous pest has wide range of hosts feeding on paddy in Philippines and on Mulberry in Taiwan. It damages soybean in India from mid August to October in *kharif* and from November to March in *rabi*.
Sojitra (1990) reported that infestation of *S. litura* in soybean crop started from the 4th week of July and remained active up to mid September. The highest population was recorded in the first week of August. While during September, it showed two peaks of activity during the crop season. Among the different weather parameters, rainfall had negative correlation for the buildup of the pest population.

Kumar *et al.* (1998) observed that peak period of tobacco caterpillar during 2nd fortnight of October on soybean.

Choudhari *et al.* (1999) reported a positive correlation between *S. litura* population and bright sunshine hours, but negative association with rainfall, wind speed, minimum temperature, mean relative humidity and mean vapour pressure.

Kamala (2000) observed *S. litura* on soybean crop from 28 days after growth and caused severe defoliation in Bangalore.

Gopal (2001) recorded maximum activity of tobacco caterpillar in the first week of September (36 MW), second week of September (37MW) and fourth week of September (39MW) on soybean.

Negoyen (2001) reported that the incidence of *S. litura* was observed from 21 to 49 days after germination with less incidence (0.12 to 0.5 larvae/plant).

Singh (2001) studied the intensity of infestation of *S. litura* on soybean. The average plant, leaf damage and larval population ranged from 88 to 100 per cent, 72 to 98 per cent and 6.1 to 8.2 larvae per plant, respectively. The damaged plants were defoliated and had small and shrivelled pods with very small grains.

Chechani *et al.* (2002) reported that the tobacco caterpillar was noticed during 34th meteorological week (20 to 26 August, 1997) on soybean. There appeared two distinct peaks, the first peak was with a mean population of 1.53 larvae/plant in 36th meteorological week (3 to 9 September, 1997) and the second peak with a mean population of 1.53 larvae/plant during 38th meteorological week (17 to 23 September, 1997), when average temperature and relative humidity were 26.3°C and 26.65°C and 77 and 77.5 per cent, respectively. The pest population showed a positive correlation with temperature and relative humidity.
Jayappa et al. (2003) recorded the tobacco leaf eating caterpillar *S. litura* found during *kharif* season at vegetative stage from 30 to 60 days after germination. Its population ranged from 0.1 to 1.5 larvae per meter row length.

Meena and Sharma (2006) reported that the minimal larval population of 1.42 larvae/mrl in early sown soybean crop (25th June), followed by mid sown crop and late sown crop which recorded 1.67 and 1.87 larvae/mrl, respectively at Udaipur, Rajasthan.

Nandgopal et al. (2006) reported significant positive correlation between bright sunshine hours and population build up of *S. litura* in groundnut crop.

Choudhary and Shrivastava (2007) reported unusual severe attack of *S.litura* on soybean during August- September at Hoshangabad district of Madhya Pradesh.

Gedia et al. (2007) reported that male *S. litura* had significantly positive correlation with bright sunshine hours and significantly negative correlation with morning relative humidity and afternoon relative humidity.

Madrap et al. (2007) recorded the seasonal incidence of insect pests of soybean during *Kharif* season at Parbhani. However, infestation of *S. litura* was up to 6.8 per cent.

Padiwal et al. (2007) observed that the activity of defoliators initiated in the month of August and attained their peaks in the month of September and early October and showed positive correlation with mean temperature and mean relative humidity.

Paik et al. (2007) observed that *S. litura* occurred significantly in late August in soybean field. The peak activity of *S. litura* was observed during the third week of August.

Sreenivas et al. (2007) observed peak incidence of tobacco caterpillar during 35th MW (27th August to 2nd September, 2002).

Chaudhary (2009) reported the dispersion of *S. litura* on soybean crop from August to October.
Dhurgude (2010) reported that incidence of *S. litura* on soybean was observed throughout the crop growth period. The highest level of pest population was observed in 34th MW and also recorded that association of weather parameter rainy days with incidence of population of *S. litura* was negative but significant while with minimum temperature it was positive but significant.

Joshi and Patel (2010) observed non-significant relationship between the insect pest population of soybean crop and the ambient weather.

Netam (2010) reported that lepidopterous caterpillars were first observed on the crop during last week of July which was associated with 30.3°C and 25.6°C maximum and minimum temperatures, 91 and 78 per cent morning and evening relative humidity and 277.8 mm rainfall. Peak activity of lepidopterous larvae (5.0 larvae/m row) observed during last week of August was associated with minimum and maximum temperatures of 30.2°C and 25.2°C, morning and evening relative humidity of 94 and 82 per cent with 30.0 mm rainfall.

Kujur (2011) reported the peak activity of *S. litura* and was observed during last week of August with 31.2°C maximum temperature, 24.4°C minimum temperature, morning and evening relative humidity 93 per cent and 76 per cent, respectively with a rainfall of 62.8 mm.

Gaur *et al.* (2012) studied the population dynamics of insect-pest of soybean and their correlation with abiotic factors observed that all the weather parameters were non-significantly related to incidence of *S. litura*.

Prabhu *et al.* (2012) reported the maximum incidence of *S. litura* during kharif, 2010-11 on soybean in Belgaum district (4.43 larvae/meter row length at early vegetative phase).

Uttam *et al.* (2012) recorded population of *S. litura* per plant they observed 0.8 larvae at vegetative stage, 3.25 larvae at flowering stage and 2.75 larvae at pod stage.

Motaphale (2013) reported that incidence of *S. litura* was low (0 to 2.2 larvae/mrl) due to heavy rainfall during 2010-11 and from 6.80 to 26.2 larvae/mrl during 2011-12. The highest level of peak population was observed in 36th and 34th
MW. The correlation of weather parameters minimum temperature and evening relative humidity with larval population was negatively significant.

Naik et al. (2013) reported that soybean crop was infested by *S. litura* and *H. armigera* at twenty days after germination.

Punithavalli et al. (2014) studied in soybean, the first appearance of *S. litura* egg masses and larval populations were observed after the first appearance of male moths in early to mid-August, and were present in the growing season up to late September to mid-October. The peak appearance of egg masses and larval populations always corresponded with the peak activity of male moths recorded during mid-September in all years.

Ahirvar et al. (2014) reported that the first appearance and peak of larval population of tobacco caterpillar was observed 1.24 and 9.38 larvae/mrl at 31st and 37th MW with 71.6 per cent and 100 per cent foliage damage due to foliage feeders, respectively.

Yadav et al. (2014) found that the first attack of tobacco caterpillar was recorded in 33rd SMW in August, which continued up to 40th SMW. The peak activity (2.30 larvae/mrl) of the pest was observed during 37th MW and damaged leaves, flowers and pods. Correlation studies based on eight weekly paired values revealed that minimum temperature, rainfall, relative humidity (afternoon) and evaporation exhibited non significant negative correlation with tobacco caterpillar population, whereas maximum temperature and morning relative humidity were observed to have non significantly positive correlation.

Ahirwar et al. (2015) reported the peak activity of caterpillar *S. litura* (2.5 larvae/mrl) during second fortnight of August in soybean crop.

Matti and Deotale (2015) reported that the incidence of *S. litura* on soybean began during 35th standard week gradually attained maximum during 41st standard week. Multiple regression analysis revealed that decrease in 1 per cent of morning relative and evening relative humidity would lead to increase of 0.019 and 0.014 mean number of *Spodoptera* larvae per meter row length.
Ramesh Babu *et al.* (2015) carried out an investigation to study the effect of various weather parameters on the occurrence of larva and adult population of *S. litura* and their factors for outbreak of this pest in soybean in Banswara, Rajasthan. The moth populations of *S. litura* were active from August to mid-October and decreased sharply in late October. The peak appearance was observed during September-October months and corresponded with peak activity of egg masses and larval population in soybean contributed to the outbreak of this pest during the reproductive stage of the crop.

Kushram (2016) studied on effect of different weather parameters on seasonal incidence of lepidopterous caterpillars in soybean crop during last week of July. The peak activity of defoliator pests was observed during last week of August with 32.3°C maximum temperature, 25.9°C minimum temperature, 87 per cent morning and 65 per cent evening relative humidity, a rainfall of 23.6 mm and sunshine hours 6.5 lux.

### 2.1.2 Gram pod borer, *H. armigera* (Hubner)

*H. armigera* is a serious pest of cotton and pulse crops. Several workers have reported that it was a sporadic pest of soybean in Madhya Pradesh, Uttar Pradesh and Maharashtra States. At favorable conditions it appeared in serious form and caused heavy damage (Gangrade *et al.*, 1975).

Mehto *et al.* (1985) studied the incidence of *H. armigera* on soybean during 1983 reported that population had positive correlation with maximum, minimum and average temperature. They further stated that population build up under the influence of long duration of blight sunshine hours and attained a peak during pod formation stage by early March.

Sojitra (1990) studied the incidence and population dynamics of *H. armigera* on soybean and revealed that the pest was active during July to September, but the highest population was recorded in August. The population showed negative correlation with maximum temperature.

Rao *et al.* (1993) reported significant correlations could be established with weather factors such as maximum and minimum temperatures and relative humidity. Analysis of weather factors showed that rainfall is one of the key factors influencing
the incidence and damage levels of *H. armigera*. The fluctuations in the population of *H. armigera* corresponded to natural mortality factors in cotton field.

Jayaprakash (2000) reported that *H. armigera* and *S. litura* were noticed during July and September with peak incidence at 34 to 62 days after sowing.

Kumar *et al.* (2012) found that the activity of *H. armigera* started with flowering and continues up to harvesting stage of the crop. The peak populations noticed were 3 larvae/10 plants on Sidhauna village and 2 larvae/10 plants at Pandepurwa, Pithla and Jourium in 10th standard weeks at minimum temperature of 13.8°C, maximum temperature of 30.1°C, relative humidity 68.00 per cent. The larval population has positive correlation with minimum temperature, maximum temperature and relative humidity in village of Sidhauna.

Uttam *et al.* (2012) recorded population of *Helicoverpa* per plant on soybean they observed 0.2 larvae at vegetative stage, 0.8 larvae at flowering stage and 0.8 larvae at pod stage.

Motaphale (2013) conducted two research experiments at Parbhani during 2010-11 and 2011-12. During 2010-11 all weather parameters showed non significant association with population of *H. armigera* except rainy days which showed a positive and significant association. While during 2011-12, correlation between the population of *H. armigera* and evening relative humidity was positively significant while it was non significant with all other weather parameters.

Yeotikar *et al.* (2013) studied the incidence of *S. litura* (maximum 0.33 larvae/plant in 32nd and 35th MW) and *H. armigera* (maximum 0.66 larvae/plant in 32nd MW) was very low/negligible on soybean.

Pawar *et al.* (2015) observed that pod borer, *H. armigera* (Hub.), start infesting the pigeon pea during the reproductive stage i.e. 44th SW and 45th SW (0.01 eggs/plant and 0.35 larvae/plant) and population of the pests egg and larva available up to maturity stage i.e. 01st SW (1.8 eggs/plant and 0.15 larvae/plant).

Yeotikar *et al.* (2015) observed that correlation between all weather parameters and *H. armigera* was non-significant. The correlation of rainfall (*r* = -
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0.284), maximum temperature (r = -0.361) bright sunshine hours (r = -0.260) was negative.

2.2 Bio-efficacy of insecticides against soybean defoliators under laboratory condition

Mallik et al. (1993) reported that B. bassiana gave effective control of H. armigera from the 7th day after application under laboratory condition.

Gloriana et al. (2000) observed the Pathogenicity of two entomopathogenic microbes, B. bassiana and B. thuringiensis sub sp. kurstaki, by testing on different larval stages of S. litura. Laboratory studies showed that the early instars of S. litura was susceptible to B. bassiana and B. thuringiensis.

Rao et al. (2001) evaluated 14 insecticides at 3 doses under laboratory conditions for their relative efficacy against resistant Helicoverpa larval population. The results revealed that indoxacarb exhibited very high efficacy (100 per cent) even at recommended dose, whereas quinalphos was also promising at higher doses while acephate remained inferior.

Sood et al. (2001) evaluated the toxicity of wettable formulation of B. bassiana (Damen 2x10^9 cfu/g) against third instar larvae of S. litura. The larval mortality varied from 6.7 to 86.7 per cent under different treatments with mean larval mortality of 56.3 (2x10^7 cfu/g), 39.2 (1x10^7 cfu/g) and 26.3 per cent (5x10^6 cfu/g).

Dayakar and Kanaujia (2003) reported that conidial suspensions (10^4- 10^{10} conidia/ml) of the entomopathogenic fungi, B. bassiana and M. anisopliae were topically applied second to fourth instar larvae of S. litura infesting tobacco to determine the pathogenicity of the fungi to the pest. The results of the bioassays indicated that the susceptibility of the pest decreased with age of the larvae in terms of both LC_{50} and LD_{50}.

Wadyalkar et al. (2003) conducted pathogencity study of M. anisopliae against H. armigera with 10^8 spores/ml and noted that larval mortality was 100, 90, 76.67, and 56.67 per cent in 1st, 2nd, 3rd and 4th instars larvae of, respectively.

Sridevi et al. (2004) tested B. bassiana (1.6 x 10^5 to 2.5 x 10^5 spores/ml) against third instars larvae of H. armigera. Individual treatment resulted 60.4 to 75.3
per cent larval mortality and combination with Btk resulted in 60 to 86.4 per cent larval mortality.

Gupta et al. (2004) estimated the relative susceptibility of five day old larvae of *S. litura* (Fabricius) to certain novel insecticides. On the basis of LC<sub>50</sub> value, the order of toxicity of different insecticides was indoxacarb (1.62) > quinalphos (0.67).

Pandey and Kanaujia (2004) studied the pathogenicity of the entomopathogenic fungi *B. bassiana* and *M. anisopliae*, against *S. itura* were tested at 20 and 30°C in the laboratory. Higher LC<sub>50</sub> value, at higher temperature, indicated lower virulence of both funguses. Among the fungus, *B. bassiana* was more virulent over *M. anisopliae* against *S. litura* larvae at both temperature regimes.

Pandey and Kanaujia (2005) carried out a laboratory experiment to study the influence of different grain based media on the sporulation, germination and virulence of *B. bassiana* against third instar larvae of *S. litura*. The conidia produced from finger millet showed the highest virulence against the third instar larvae of *S. litura* with LC<sub>50</sub> value of 1.56 x 10<sup>6</sup> conidia/ml.

Punwar and Sochan (2005) studied the differential toxicity of *B. bassiana* and *M. anisopliae* against tobacco caterpillar, *S. litura* and found that the activity decreased with the advancement of age of larvae. On the basis of LC<sub>50</sub> and LT<sub>50</sub> values, reported that Pantnagar isolates of both fungi had more potency to kill *S. litura* than IMTECH, Chandigarh strains. In general, *B. bassiana* was more virulent than *M. anisopliae* to *S. litura*.

Saini et al. (2005) tested the different insecticides including indoxacarb against tobacco caterpillar, *S. litura* in laboratory and concluded that indoxacarb gives 73.3 per cent mortality at 72 hours.

In laboratory studies, LC<sub>50</sub> for chlorantraniliprole @ 0.1 ppm was significantly lower when compared to two standard insecticides indoxacarb @ 1.5 ppm and cypermethrin @ 13.5 ppm in insecticide treated diet assay on laboratory reared colony of tobacco budworm, *Heliothis virescens* (Anon., 2007).

Kaushik et al. (2008) reported that the virulence of *B. bassiana* against *H. armigera* (Hub.) and *S. litura* (Fab.) was assessed by bioassays under in vitro
conditions. Its conidial suspension showed concentration dependent activity. The highest concentration (2 x 10^{12} conidia/ml) caused maximum mortality of second and fourth instars of *H. armigera* and *S. litura* compared to the lowest concentration (2 x 10^3 conidia/ml) with 0 to 23.33 per cent mortality.

Ramanagouda and Srivastava (2009) tested the bioefficacy of different insecticides against 7 day old larvae of *S. litura* in soybean by contact and leaf dip methods and reported that indoxacarb was most toxic insecticide at 24 hr exposure.

Vijayavani et al. (2009) reported that pupae of *S. litura* (Fab) were treated with different isolates of conidia of an entomopathogenic fungi *B. bassiana* (SBT#1 and SBT#16) under laboratory conditions. This study indicates that dry conidia of both isolates are pathogenic to *S. litura* and could be used as potential biological control agent for the tested insect.

Kaur and Padmaja (2010) used the isolates of *B. bassiana* from different geographical regions and host ranges were evaluated for virulence against four larval stages of *S. litura* and *H. armigera* and virulent isolates against the two pests could be identified that may be useful for field applications and integrated pest management programs.

Malarvannan et al. (2010) reported that tobacco caterpillar, *S. litura* was reared in semi-synthetic diet and the different stages were maintained to conduct bioassay. Four different concentrations (2.4 x 10^7, 2.4 x 10^6, 2.4 x 10^5, 2.4 x 10^4 conidia/ml) of *B. bassiana* treated with larvae of *S. litura* and least pupation was observed in larvae treated with highest spore concentration (2.4 x 10^7) of *B. bassiana*.

Rajanikanth et al. (2010) carried out experiments to find the time mortality response of four strains and two local isolates of *B. bassiana* on third instar larvae of *S. litura*. The results showed decrease in LT_{50} values with increase in conidial concentration of all the strains.

Bhaduria et al. (2011) conducted study to determine the pathogenicity of a local isolate of *B. bassiana* against *S. litura*. Twelve local isolates of *B. bassiana* were collected from different mango orchards in Uttarakhand, India. *S. litura* larvae were treated with different *B. bassiana* spore concentrations (10^5, 10^6, 10^7, 10^8 and 10^9 conidia/ml) and results showed that *B. Bassiana* isolate PBB-02 caused 86.6 per
cent mortality of first instars, 73.3 per cent of second instars and 70 per cent of third instar *S. litura* larvae in vitro at 1 x 10^9 spores/ml concentration.

Gafnil *et al.* (2011) tested bio-efficacy of Avaunt (indoxacarb 15 per cent EC) on 2\(^{\text{nd}}\) and 4\(^{\text{th}}\) instar *S. litorallis* (Boisd.) larvae and concluded that 2\(^{\text{nd}}\) instars were more susceptible than 4\(^{\text{th}}\) instars as the LC\(_{50}\) and LC\(_{90}\) values were 0.63 and 3.1 ppm for 2\(^{\text{nd}}\) instar larvae and 2.0 and 18.75 ppm for 4\(^{\text{th}}\) instar larvae respectively. Percentage population and adult emergence was significantly less than their equivalent control.

Moorthi *et al.* (2011) evaluated the isolate of the *B. bassiana* against *S. litura* using leaf spray method. Mortality of 66.67, 73.33 and 80 per cent with respect to the isolates Bb 02, Bb 09 and Bb 10, respectively, was obtained four days after treatment.

Agarwal *et al.* (2012) studied the different formulation of *M. anisopliae* effective against larvae of *H. armigera* over chemical pesticides and reported that formulation of *M. anisopliae* can serve as an effective broad spectrum biocontrol agent for soybean and various other cash crops.

Baskar *et al.* (2012) studied the larvicidal and growth inhibitory activities of ten different isolates of *B. bassiana* from Pulney hills of Western Ghats of Tamil Nadu, India. They evaluated it at four different concentrations against the third instar larvae of *S. litura*. The *B. bassiana* (Bb10) isolate showed maximum larvicidal activity of 68.06 per cent, minimum pupal weight of 183 mg, low number of adult emergence (22.91 per cent) and 100 per cent abnormalities at 10^8 spore/ml concentration.

Su *et al.* (2012) conducted study to evaluate susceptibility of field populations of *S. litura* in China to chlorantraniliprole 18.5 SC by diet incorporation assay method and reported that the larvae were highly susceptible to chlorantraniliprole with LC\(_{50}\) value of 4.20 µg a.i./ml.

Asi *et al.* (2013) studied that the susceptibility of the insect to entomopathogenic fungi decreased with the advancement in age of larvae of the insect. The LC\(_{50}\) values for eggs were 2.45 x 10^7 conidia ml\(^{-1}\) in *B. bassiana*. The median lethal concentration (LC\(_{50}\)) for 3\(^{\text{rd}}\) instar larvae was 1.11 x 10^7 conidia ml\(^{-1}\) in
B. bassiana. Mortality of the larvae increased with increase in conidial concentrations and time elapsed after treatment.

Karuppaiah and Chitra (2013) estimated the relative susceptibility of third instar larvae of *S. litura* to certain novel insecticides. On the basis of LC$_{50}$ values, the order of toxicity of different insecticides was chlorantraniliprole 18.5 SC (37.75 ppm) > indoxacarb 15.8 EC (3.28 ppm) by direct spray method. The LC$_{50}$ obtained by leaf-dip method revealed that chlorantraniliprole 18.5 SC (0.0001 per cent) was most effective followed indoxacarb 15.8 EC (0.0012 per cent).

Chankapue *et al.*, (2014) reported that among the new insecticides, chlorantraniliprole 18.5 SC @ 0.006 per cent recorded 73.33, 80.00 and 90.00 per cent mortality of *H. armigera* at 24, 48 and 72 hours after spray, respectively. Indoxacarb 14.5 SC @ 0.007 per cent recorded 56.66, 73.33 and 76.66 per cent mortality of *H. armigera* at 24, 48 and 72 hours after spray, respectively. Quinalphos 25 EC @ 0.05 per cent found less effective among tested insecticides.

Gupta and Kumar (2014) studied that when the concentrations of spores were applied on 3$^{rd}$ instar larvae of *S. litura*, it increases the percentage of mortality. The fungal preparation *B. bassiana* @ 0.2×10$^8$ spore/ml caused 80 per cent mortality of *S. litura* followed *B. bassiana* 0.125×10$^8$ spore/ ml (73.3 per cent) and *B. bassiana* 0.1×10$^8$ spore/ml (46.6 per cent). The minimum mortality was observed under control i.e. 23.3 per cent. Thus, as the number of spore increased, per cent mortality also increased.

Neupane and Shrestha (2015) reported that, *B. bassiana* caused maximum mortality of *S. litura* (98.67 per cent), infection (80.00 per cent) with the least LT$_{50}$ value (5 days).

**2.3 Bio-efficacy of insecticides against soybean defoliators under field condition**

Yelshetty *et al.* (1999) reported that application of indoxacarb 15 SC @ 50 g a.i./ha considerably reduced the population of *H. armigera* and increased pigeonpea grain yield.

Gopalswamy *et al.* (2000) conducted a field experiment to evaluate the efficacy of certain insecticides against *H. armigera* on cotton during 1998-99 at Regional Agricultural Research Station, Lam, Guntur, Andhra Pradesh. The results
indicated that like indoxacarb was equally promising for control of *H. armigera* similar to that of commonly used quinalphos and cypermethrin.

Dhawan and Simwat (2000) evaluated indoxacarb for the control of bollworm complex of cotton. They reported that indoxacarb 60 g a.i./ha was most effective against *H. armigera* on cotton, when compared with chlorpyriphos 1000 g a.i./ha.

Purwar and Yadav (2003) reported that *B. bassiana* was more effective than NSKE and animal origin pesticides in controlling tobacco caterpillar, *S. litura* on soybean.

Punwar and Sachan (2005) reported that Panthagag isolates of *B. bassiana* and *M. anisopliae* had more potency to kill *S. litura* than IMTECH Chandigarh strains. In general, *B. bassiana* was more virulent than *M. anisopliae* to insect pests.

Rahman *et al.* (2006) reported that indoxacarb 150 EC was found effective against *H. armigera* with lowest number of larvae (0.33/plant) and highest larval mortality (97.38 per cent).

Shivankar *et al.* (2008) reported the quinalphos 25 EC @ 0.05 per cent was most effective insecticide showing 97.20 per cent larval mortality of *S. litura* with 75.5 t/ha yield of sugarbeet.

Greg *et al.* (2009) revealed that chlorantraniliprole is among the fastest acting insecticides available for control of lepidopteran pests and is faster than indoxacarb and is effective against insect populations that have developed resistance to other insecticide groups representing an attractive tool for integrated pest management programs.

Nishantha *et al.* (2009) assessed the bio-efficacy of chlorantraniliprole 18.5 per cent SC @ 10, 20, 30 and 40 g ai/ha against pod borer complex in pigeonpea. Chlorantraniliprole @ 40 g a.i./ha recorded significantly lowest pod and grain damage (15.00 per cent and 6.32 per cent), respectively by *H. armigera*, followed by lower dose of chlorantraniliprole @ 30 g a.i./ha (20 per cent and 8.95 per cent), respectively.

Chowdary *et al.* (2010) reported that, among the newer molecules tested against okra fruit borer, *H. armigera* the treatment with chlorantraniliprole 20 SC @ 30 g a.i./ha was found superior in recording less larval population, lower fruit damage and higher fruit yield.

Sahayaraj and Namachivayam (2011) used entomopathogenic fungi, *B. bassiana* (Balsam) against the *S. litura* (Fab.) in field conditions and reported that *B. bassiana* reduced 72 per cent of *S. litura* larval population.
Taggar et al. (2011) tested the bio-efficacy of different insecticides against S. litura infesting soybean, among them, indoxacarb 14.5 SC @ 500 ml/ha proved most effective in controlling the pest at 3 and 7 days after spray (4.84 and 2.14 larvae/m², respectively).

Agarwal et al. (2012) studied the different formulation of M. anisopliae against larvae of H. armigera over chemical pesticides at Bhopal and reported that formulation of M. anisopliae can serve as an effective broad spectrum biocontrol agent for soybean.

Gaur and Choudhary (2012) tested the efficacy of indoxacarb (40, 50, 60 or 70 g a.i./ha) against the population of tobacco caterpillar, S. litura on soybean. The insecticides were sprayed at 68 and 82 days after sowing. Indoxacarb @ 50, 60 and 70 g a.i./ha completely controlled the tobacco caterpillar.

Kambrekar et al. (2012) evaluated the bio-efficacy of indoxacarb 14.5 SC on H. armigera in chickpea. Indoxacarb 14.5 SC @ 75 g a.i./ha resulted in maximum larval reduction, lesser pod damage and higher yield.

According to Satpute and Barkhade (2012) chlorantraniliprole 20 SC was found most effective in reducing larval population as well as pod damage by H. armigera in pigeonpea.

Field trial was conducted by Ahirwar et al. (2013) during kharif season with different microbial insecticide against foliage feeders of soybean crop. B. thuringiensis var. kurstaki (4.26 larvae/mrl) was found to be most effective followed by B. bassiana (5.06 larvae/mrl), M. anisopliae (6.06 larvae/mrl). All the treatments exhibited significantly higher yield as compared to control. It was maximum in B. thuringiensis var. kurstaki (26.97 q/ha) followed by B. bassiana (24.04 q/ha), M. anisopliae (20.92 q/ha). The lowest grain yield was recorded in the control plot (14.88 q/ha).

Ghetiya et al. (2013) tested the efficacy of different insecticides against pigeonpea pod borer, H. armigera. Results revealed that lower larval population was recorded when crop treated with indoxacarb @ 0.007 per cent.

Landge et al. (2013) evaluated seven insecticides viz., spinosad 45 SC, indoxacarb 14.5 SC, endosulfan 35 EC, fenpropathrin 30 EC, pyridalyl 10 EC, flubendiamide 20 WDG, chlorantraniliprole 20 SC against pigeonpea pod borer, H. armigera. Among these insecticides, chlorantraniliprole 20 SC @ 40 g a.i./ha was most effective in reducing larval population.
Shali et al. (2013) tested the efficacy of insecticides against defoliators in soybean which revealed chlorantraniliprole 20 SC @ 100 ml/ha were significantly effective in reducing larval population of *S. litura*.

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 chlorantraniliprole @ 0.006 per cent and indoxacarb @ 0.0029 per cent were found to be most effective against *S. litura* and *H. armigera*.

Yadav (2013) studied efficacy of some botanicals and chemical pesticides against the major insect pests of soybean. On the basis of effectiveness of different chemicals and botanicals treatments against defoliators and grain yield obtained, it is concluded that indoxacarb 14.5 SC 500 ml/ha was the most effective when applied as foliar sprays at 45 and 60 days old crop.

Patel et al. (2014) studied that *B. bassiana* @ 10^{13} spores/ml were found effective treatments when applied as foliar sprays at 45 days old soybean crop. This treatment was effective in reducing the foliage feeder larval population.

Abbas et al. (2015) evaluated the different insecticides from the new chemistries, which were relatively safer to human and environment, i.e. coragen (chlorantraniliprole) and steward (indoxacarb), on tomato crop heavily infested by *H. armigera*. The mortality was compared after 4, 7 and 10 days and treatments were compared with control as well with one another. On the basis of damaged fruits and percent loss of yield pointed out that chlorantraniliprole and indoxacarb had resulted better as compared with others, although the difference was statistically non significant.

Acharya et al. (2015) revealed that chlorantraniliprole 0.006 per cent was found to be the most effective against *S. litura* on groundnut.

Bajya et al. (2015) reported that *B. bassiana* 1.15 per cent WP @ 3000 g/ha and 2500 g/ha was highly effective in controlling pod borer populations after two sprays of both the seasons, quinalphos 25 EC @ 1000 g/ha being a chemical pesticide was sprayed at pod formation stage and also effective against pod borer populations on both the seasons in chickpea.

Pandey and Das (2016) reported that *B. bassiana* @ 1 liter / ha (1 x 10^{12} spores/ml) was found most effective biopesticide as it recorded lowest larval population (6.68 larvae / 5 plants) in pigeon pea.
2.4 Yield increased and economics of insecticides used against soybean defoliators

Yelshetty et al. (1999) reported that application of indoxacarb 15 SC @ 50 g a.i./ha considerably reduced the population of *H. armigera* and increased pigeonpea grain yield.

Hosamani et al. (2008) found that chlorantraniliprole @ 40 g a.i./ha resulted minimum larval population of *S. litura* with highest yield of green chilli fruit 97.44 q/ha in comparison with other insecticides.

Khandwe et al. (2011) evaluated the bio-efficacy of new and recommended insecticides *viz.*., chlorantraniliprole 20 SC and quinalphos 25 EC against soybean defoliators. The highest mean yield of 1972 kg/ha was recorded with quinalphos 25 EC @ 1.5 lit/ha which was 636 kg (47.60 per cent) more than the untreated control. Spraying of quinalphos was economical and most remunerative recorded 1:6.2 ICBR.

Taggar et al. (2011) that the highest mean grain yield was recorded in the treatment indoxacarb 14.5 SC (1356 kg/ha).

Ahirwar et al. (2013) conducted field trial during *kharif* season with microbial insecticide against foliage feeders of soybean crop. Among these treatments *B. bassiana* (5.06 larvae/mrl) was found to be most effective followed by *M. anisopliae* (6.06 larvae/mrl). All the treatments exhibited significantly higher yield as compared to control. It was maximum in *B. bassiana* (24.04 q/ha) followed by *M. anisopliae* (20.92 q/ha). The lowest grain yield was recorded in the control plot (14.88 q/ha).

Prabhu Nayaka (2013) recorded highest B: C ratio for indoxacarb 14.5 SC @ 0.5 ml/l (1:3.59) and chlorantraniliprole 20 SC @ 0.2 ml/l00 g (1:3.41) in soybean.

Gadihya, et al. (2014) reported the highest cost benefit ratio 1:3.3 was observed in chlorantraniliprole @ 0.006 per cent followed by indoxacarb treatment in groundnut.

Manu et al. (2014) studied that among the new molecules indoxacarb 14.5 SC was found significantly superior in reducing the leaf eating caterpillar population and recorded highest seed yield 22.99 q/ha as compared to other treatments including
untreated check and reported highest benefit cost ratio was obtained from indoxacarb 14.5 SC @ 0.5 ml/l (4.26).

Patil et al. (2014) reported that chlorantraniliprole 18.5 per cent SC @ 30 g a.i./ha provide consistent protection from defoliation to soybean crop from S. litura with highest cost benefit ratio among the tested insecticides.

Matti et al. (2016) studied that, the application of indoxacarb 15.8 EC was found to be most effective treatment against soybean defoliator recorded higher yield of 20.10 q/ha.

Perini et al. (2016) reported that chlorantraniliprole 10 g a.i./ha had the highest soybean yield (2447 kg/ha) attributed to H. armigera control efficiency. The benefit cost ratio was higher for chlorantraniliprole (1:6.6) because of low cost of insecticide application and high soybean yield.