Larvicidal toxicity of various insecticides against Tobacco caterpillar, *Spodoptera litura*, Fabricius (Lepidoptera: Noctuidae)

Shyamli, Kiranjot Kaur, Gurleen Kaur, Shushant Tuteja and Randeep Singh  

DOI: https://doi.org/10.22271/j.ento.2020.v8.i6b.7846

Abstract

The present study was envisaged to check the toxic effect of certain insecticides (chlorpyriphos, spinosad, novaluron, acetamiprid and thyme oil) on third instar larvae of *Spodoptera litura* by using three different bioassays i.e. topical treatment, leaf dip and artificial diet method at different concentrations viz., 5, 25, 125 and 625 ppm. Observations on larval mortality were recorded from each treatment at 24, 48 and 72 hours intervals. Spinosad was found to be most toxic on the basis of larval mortality followed by chlorpyriphos, novaluron, thyme oil and acetamiprid in topical bioassay. But in leaf dip bioassay, thyme oil at 5 ppm caused 100 percent larval mortality. Acetamiprid proved as poor insecticide against this pest causing 26.66, 16.66 and 10 percent mortality after 72 hours of treatment in topical, leaf dip, and artificial diet bioassay at highest concentration, respectively. In artificial diet method, highest mortality percent was recorded in chlorpyriphos and spinosad i.e. 86.66 percent after 48 and 72 hours of treatment, respectively.

Keywords: Insecticides, *Spodoptera litura*, spinosad, chlorpyriphos, novaluron

Introduction

The tobacco caterpillar, *Spodoptera litura* Fabricius is ubiquitous, polyphagous, multivoltine, lepidopterous insect pest of agricultural crops in the Asian tropics [23]. It is also known as cluster or tobacco caterpillar, common cutworm, cotton leaf worm, grey streaked moth and tropical armyworm [24]. It is widely distributed throughout tropical and temperate Asia, Australasia and the Pacific Islands [22, 25]. Due to its migration ability over long distances and high reproductive capacity, *S. litura* has an enormous potential to invade new and wide range of ecological niches. More than 389 species belonging to 109 families of economically important plants including corn, peanut, soybean, castor, sunflower, mash, moong, eggplant, tobacco, cabbage and so on are host of this pest, making it one of the most damaging agricultural pests in Asian countries [31, 3]. The host plant range for *S. litura* can vary due to their higher level of feeding on almost all parts of plants and on different species of plants. Based on the crop stage and its infestation level in the field, it causes economic losses ranging from 25.8 to 100% [3].

From the insect control point of view, various strategies were implemented such as use of insecticides, chemosterilants, cultural and environmental practices, growing resistant varieties, pheromone-based tactics (mating disruption, lure and kill, mass trapping, attractants) and genetic control methods etc. [17]. Use of insecticides for controlling major insect pest was the most efficient and inexpensive way during past years. These chemicals are used primarily to control disease-carrying insects or to control pests that infest plants in specific areas. Complete reliance control on various insecticides (chemical control) of this pest was due to higher multiplication rate of *S. litura*.

Synthetic organic insecticides are now the leading agents in insect control having different mode of actions. The organophosphates (OPs) work by inhibiting acetylcholinesterase of the nervous system which results in the accumulation of acetylcholine (ACh) at the neuromuscular junctions or synapses, causing disruption of nervous activity [14]. Neonicotinoids are the synthetic versions of nicotine and interact with nicotinic acetylcholine receptors (nAChR) at the central and peripheral nervous systems, resulting in excitation and paralysis and finally death of the organism [44].
Among alternative to the conventional insecticides, some novel insecticides are there like Spinosad, IGR and botanicals. Spinosad is a bacterial formulation which is a mixture of the two most active naturally occurring metabolites (spinosyns A and D) produced by Saccharopolyspora spinosa \[31\]. It is having primary target binding site nAChRs and secondary binding site as GABA \[31\] causing excitation of the insect nervous system, further leads to involuntary muscle contractions, prostration with tremors and paralysis. IGRs are new class of bio-rational compounds for insect pest control. These compounds cause abnormal morphogenesis of insect’s integument by imitating juvenile hormone and moulting hormone or by interfering with chitin synthesis \[28\]. Extracts derived from plants are currently one of the most promising methods \[29\]. Plants are great sources of natural substances possessing pesticidal properties that can be used in the development of environmentally safe methods for insect control \[33\]. Therefore, in the present study we investigated the toxicity of different insecticides against 3rd instar larvae of *S. litura*.

Materials and Methods

The egg masses of *S. litura* and larvae were collected and reared in the Insect culture laboratory of Plant Protection Division, PG Department of Agriculture, Khalsa College Amritsar. The larvae of *S. litura* were reared in the laboratory on castor (*Ricinus communis*) leaves in sterilized glass jars (20cm x 15cm) at 25±2 °C and 65±5% RH in B.O.D incubator \[26\]. The leaves were used after sterilization by sodium hypochlorite solution and air dried. The freshly laid egg batches were placed on these leaves. Eggs hatched into larval instars which when fully grown starts to pupate. Then the pupae were transferred to glass jars containing thick layer of moist sterilized sand covered with filter paper. The moths so emerged were collected and transferred to clean jars wrapped with filter paper from inside and containing suspended cotton swabs soaked with 10% honey solution.

### Insecticides Tested

Following insecticides were tested for their efficacy against 3rd instar larvae of *S. litura*:

| Class of Insecticides | Name of Insecticides | Trade name |
|-----------------------|----------------------|------------|
| Organophosphate (OPs) | Chlorpyriphos         | Aldrin 20 EC |
| Neonicotinoid         | Acetamiprid           | HEME 20 SP |
| Spinosyn              | Spinosad              | Tracer 45 SC |
| IGR                   | Novaluron             | Rimon 10 EC |
| Botanical             | Thyme oil             | Allin exporters |

Four concentrations of each insecticide i.e. 5, 25, 125 and 625 ppm were used. Untreated larvae were included as a control to assess the natural mortality rates of the test insect species. The different bioassay methods viz. topical bioassay, leaf dip bioassay and artificial diet bioassay were used to evaluate the toxicity of these insecticides against larvae of *S. litura*.

Topical method

The toxicity of selected chemicals was tested using micropipette. 3rd instar larvae were placed in petri dish and placed in the spray tower and sprayed with the insecticides at different concentrations mentioned before. In control, no treatment was given to larvae. After application, the larvae were allowed to dry for 10 minutes and transferred to artificial diet in rearing containers individually. Each treatment was replicated three times with 10 larvae/replication. The observations were recorded after 24, 48 and 72 hours on larval mortality.

### Leaf Dip Bioassay

Fresh castor leaves were washed, sterilized and air dried. Afterwards, the leaves of uniform size (approx. 6 cm in size) were dipped for 10 minutes in different insecticidal concentrations. Leaves were again air dried and placed in petri plates having moist cotton swab so as to avoid desiccation of leaves. The 3rd instar larvae were released on the treated leaves subsequently. Each treatment was replicated three times with 10 larvae/replication. The mortality was recorded after 24, 48 and 72 hours of treatment for each insecticidal treatment at each concentration.

### Artificial Diet Bioassay

The artificial diet was prepared as per methodology given by \[19\] and was supplemented with different concentrations of each insecticide. Diet without insecticide served as control. The 3rd instar larvae from culture maintained on artificial diet were selected and fed on treated as well as untreated diet. Each treatment was replicated thrice with 10 larvae/replication. The mortality count was taken after 24, 48 and 72 hours of treatment.

### Statistical analysis

The larval mortality was analyzed by using ANOVA at different intervals to find out the significant difference if any in the observations obtained from different treatments at p<0.05 for variance.

### Results

**Toxicity of test insecticides against *S. litura* using topical bioassay**

The larvicidal toxicity of different insecticides using topical bioassay is presented in (Table-1). The toxicities of chlorpyriphos and spinosad were higher than the other insecticides (novaluron, acetamiprid and thyme oil). It is evident from the results that as the time interval increased, the mortality also increased and maximum mortality was observed after 72 hours of treatment in all concentrations. Highest mortality (80 percent) was observed at 625 ppm after 72 hours of treatment in spinosad and 73.33 percent when treated with chlorpyriphos and as compared to control, significant results in treated larvae was observed at highest concentrations of 125 and 625 ppm after 24 and 48 hour of treatment in both chlorpyriphos and spinosad whereas all the treatments found to be significant after 72 hours of treatment. In treatment with novaluron, at every concentration and interval, significant results were obtained with highest percent mortality of 63.33 percent after 72 hours of treatment. In the case of acetamiprid, only highest concentration was significant at 24 hours after treatment and at 125 and 625 ppm was found to be significant after 48 and 72 hours of treatment. Lastly in thyme oil, at highest concentration, 60 percent mortality was recorded also compared to control and results were significant at all concentration after 72 hours of treatment.
Table 1: Larvicidal toxicity of different insecticides against *S. litura* (3rd instar larvae) under laboratory conditions by topical application bioassay.

| Insecticide used | Control | 5ppm   | 25ppm   | 125ppm  | 625ppm  | CD (0.05%) |
|------------------|---------|--------|---------|---------|---------|------------|
|                  |         | 0°     | 10°     | 20°     | 50°     | 100°       |
|                  |         | 6.60±3.33 | 13.33±3.33 | 20±5.77 | 50±5.77 | 100±5.77   |
| Chlorpyriphos   |         | 24 HAT | 48 HAT  | 72 HAT  |         |            |
| Spinosad         |         | 43.33±8.81 | 33.33±8.81 | 60±20.81 | 80±11.34 |            |
| Novaluron        |         | 13.33±3.33 | 16.66±3.33 | 20±5.77 | 46.66±8.81 |            |
| Acetamiprid      |         | 3.33±3.33 | 6.66±3.33 | 13.33±3.33 | 26.66±3.33 |            |
| Thyme oil        |         | 23.33±3.33 | 36.66±3.33 | 46.66±3.33 | 63.33±8.81 |            |

All values are given as Mean±SE, CD-Critical Difference, HAT-Hours after treatment Variables (~,b,c,...) significantly differ from each other at 5% level of Significance.

**Toxicity of insecticides against *S.litura* using leaf dip bioassay**

Third instar larvae of *S. litura* were fed on castor leaves dipped in insecticides at different concentrations. Spinosad at higher concentrations and thyme oil even at lowest concentration of 5 ppm gave complete kill of the larvae (Table 2). Also mortality of 90 and 83.34 percent was reported after 72 hours of treatment with chlorpyriphos and novaluron, respectively. Significant results with control were recorded at all concentrations after 24, 48 and 72 hours after treatment with chlorpyriphos whereas in novaluron only after 48 and 72 hours of treatment results were proved to be significant at all concentrations. However acetamiprid showed very minimal toxicity via this method as no mortality was observed after 24 hours of exposure at all concentrations and at lower concentrations (5 and 25 ppm) even after 48 hours of treatment. Thyme oil after 24 hours of exposure showed larval mortality of 50 percent at highest concentration of 625 ppm and then further to 100 percent after 48 and 72 hours of treatment.

Table 2: Larvicidal toxicity of different insecticides against *S. litura* (3rd instar larvae) under laboratory conditions by leaf dip bioassay.

| Insecticide used | Control | 5ppm   | 25ppm   | 125ppm  | 625ppm  | CD (0.05%) |
|------------------|---------|--------|---------|---------|---------|------------|
|                  |         | 0°     | 10°     | 20°     | 50°     | 100°       |
|                  |         | 6.60±3.33 | 13.33±3.33 | 20±5.77 | 50±5.77 | 100±5.77   |
| Chlorpyriphos   |         | 24 HAT | 48 HAT  | 72 HAT  |         |            |
| Spinosad         |         | 50±5.77 | 60±20.81 | 80±11.34 |         |            |
| Novaluron        |         | 50±5.77 | 80±11.34 |         |         |            |
| Acetamiprid      |         | 30±5.77 | 40±5.77 | 60±5.77 | 80±5.77 |            |
| Thyme oil        |         | 23.33±3.33 | 36.66±3.33 | 46.66±3.33 | 63.33±8.81 |            |

All values are given as Mean±SE, CD-Critical Difference, HAT-Hours after treatment Variables (~,b,c,...) significantly differ from each other at 5% level of Significance.

**Toxicity of insecticides when fed via artificial diet bioassay to *S.litura***

The mortality data of different chemicals at different concentrations given through artificial diet incorporation method are presented in (Table-3). Data showed significant dose-dependent mortality. In chlorpyriphos and spinosad, significant results were found after 24 hours of treatment at highest concentration whereas in chlorpyriphos, spinosad and...
novaluron significant results was seen at 125 and 625 ppm after 72 hours of treatment. Chlorpyriphos and spinosad @ 625 ppm was significantly superior to all the treatment with highest mortality (86.66 percent) followed by novaluron in which up to 80 percent mortality was recorded (72 HAT). In acetamiprid and thyme oil, mortality of only 10 and 13.33 percent was noted at highest concentration after 72 hours of treatment, respectively.

Table 3: Larvicidal toxicity of different insecticides against S. litura (3rd instar larvae) under laboratory conditions by artificial diet bioassay.

| Insecticide used | Control | 5ppm | 25ppm | 125ppm | 625ppm | CD (0.05%) |
|------------------|---------|------|------|--------|--------|------------|
| **Chlorpyriphos** |         |      |      |        |        |            |
| 24 HAT           | 0       | 0    | 3.33±3.33 | 13.33±8.81 | 66.66±6.66 | 1.458       |
| 48 HAT           | 0       | 3.33±3.33 | 10±0 | 20±5.77 | 86.66±6.66 | 1.479       |
| 72 HAT           | 0       | 16.66±6.66 | 26.66±16.66 | 40±10 | 86.66±6.66 | 3.342       |
| **Spinosad**     |         |      |      |        |        |            |
| 24 HAT           | 0       | 0    | 3.33±3.33 | 10±0 | 3.33±3.33 | 0.595       |
| 48 HAT           | 0       | 0    | 6.66±3.33 | 20±5.77 | 36.66±12.01 | 2.228       |
| 72 HAT           | 0       | 0    | 40±10 | 36.66±17.63 | 43.33±18.55 | 4.328       |
| **Novaluron**    |         |      |      |        |        |            |
| 24 HAT           | 0       | 0    | 6.66±3.33 | 6.66±3.33 | 6.66±3.33 | --          |
| 48 HAT           | 0       | 0    | 6.66±3.33 | 6.66±12.01 | 63.33±8.81 | 2.293       |
| 72 HAT           | 0       | 0    | 13.33±3.33 | 16.66±3.33 | 43.33±14.52 | 4.328       |
| **Acetamiprid**  |         |      |      |        |        |            |
| 24 HAT           | 0       | 0    | 0    | 3.33±3.33 | 3.33±3.33 | --          |
| 48 HAT           | 0       | 0    | 0    | 3.33±3.33 | 3.33±3.33 | --          |
| 72 HAT           | 0       | 0    | 0    | 6.66±3.33 | 10±5.77 | --          |
| **Thyme oil**    |         |      |      |        |        |            |
| 24 HAT           | 0       | 0    | 0    | 0    | 0 | --          |
| 48 HAT           | 0       | 0    | 0    | 3.33±3.33 | 3.33±3.33 | --          |
| 72 HAT           | 0       | 0    | 0    | 3.33±3.33 | 13.33±3.33 | 0.595       |

All values are given as Mean±SE, CD-Critical Difference, HAT-Hours after treatment Variables (~,b,c,...) significantly differ from each other at 5% level of Significance.

**Discussion**

Chlorpyriphos was proved to be toxic in the current study. As chlorpyriphos belongs to OPs, it acts by inhibiting the activity cholinesterase enzyme. When Ahmad et al. [4] checked the toxicities of cholinesterase inhibitors, chlorpyriphos showed high toxicity. Overstimulation of the nervous system leads to the insect’s death. Toxicity of this insecticide on Spodoptera spp. has been reported by several workers [22, 34, 39]. In the field conditions also, Bhadane et al. [8] reported upto 70 percent mortality of S. litura larvae after 5 days of spray. High toxicity may be due to the low level of resistance against chlorpyriphos as Ahmad and Arif [2] also reported very low level of resistance in another species of Spodoptera (S. exigua) against chlorpyriphos. Using leaf dip method, mortality of 90 percent was seen when treated with this chemical. Similar results were reported by Saini et al. [36] when they observed 90 percent mortality in larvae fed on treated after 48 hours of treatment.

Spinosad was also proved to be highly toxic insecticide during this experimentation. Larvae treated with spinosad showed full mortality after 48 hours of treatment. Santis et al. [38] tested efficacy of spinosad against S. exigua and concluded spinosad as most toxic to the 3rd instar larvae. In current study, spinosad is more toxic than chlorpyriphos in 24 HAT. In contradiction with Srivastava et al. [42] who observed the high toxicity, high susceptibility and no resistance for emamectin benzoate and spinosad against S. litura. Also, no cross-resistance of spinosad was noticed when Rehan and Shaiba [32] tested spinosad with few other insecticides. This implies that spinosad can be used in IPM Programmes.

The main reason for the effectiveness of IGRs is that they disturb the development and metamorphosis of an insect. Application of novaluron to S. litura larvae gave higher mortality in leaf dip bioassay then all other bioassays in this study. Also when Tallikoti et al. [45] evaluated the toxicity of IGR’s, highest toxicity was shown by novaluron after 72 hours of treatment. High mortality was also observed by Dhawan et al. [10] using topical application method with LC50 value of 0.002%. In topical treatment at 625 ppm, mortality of 63.33 percent was observed. Similar results were scored by Shaia et al. [40] at 600 ppm where up to 70 percent mortality was reported. Toxicity of novaluron to some extent is in agreement with reported toxic effects of novaluron on other insects, such as on mosquito, Culex pipiens [11], beetles, Tribolium castaneum [18], Leptinotarsa decemlineata [9] and Moth, Palpita unionalis [13]. There has been increase in the mortality of the larvae as time increases and these results are in agreement with Barrania [7] who also observed increase in mortality of S. littoralis larvae with increase in time. Toxicity of novaluron is slightly low than spinosad and chlorpyriphos. The results regarding this chemical were also comparable to Sahar et al. [35] who reported the order of effectiveness (LC10, LC25 and LC50) against third instar larvae of S. litura was chlorfluazuron> chlorpyriphos > novaluron > λ- cyhalothrin. Acetamiprid showed low level of toxicity in the current study. Same results were scored by Ahmed [6] who studied toxicity of some neonicotinoids and found that acetamiprid and thiamethoxam showed lowest level of toxicities. Also when El-Sheikh et al. [12] tested efficiency of some neonicotinoids, Acetamiprid was found as least toxic. However, this study is in contradiction with Srivastava et al. [42] who observed the order of toxicity as flubendiamide> acetamiprid> spinosad> lufenuron> propaconazole> carbendazim> azoxystrobion> mancozeb> ridomil.

Insects are showing resistance to various synthetic insecticides, thus natural products and plant extracts used as...
herbal pesticides seem to resolve the insecticidal resistance development and environmental problems caused by the use of synthetic pesticides. Thyme oil was found toxic in topical and leaf dip bioassays in the current study and seems to be non-toxic in artificial diet bioassay. Jiang et al. [10] reported that *T. vulgaris* and *Syzygium aromaticum* was the most active in contact and residual toxicity bioassays against *Trichoplusia ni* (Semilooper). Similar results were reported by Hummelbrunner and Isman [15] and Koul et al. [20] when they tested plant essential oils through topical application with highest toxicity was being observed with thyme oil. Also, Pavela [30] tested antifeedant and larvicidal effects of some phenolic components of essential oils against *S. littoralis* in which thymol was most effective. Among thyme, neem and bitter oil, Abdel-Aziz et al. [1] found thyme oil as most toxic against 2nd instar larvae of *S. littoralis*.

The results clearly indicated that these chemical insecticides showed different level of toxicity against 3rd instar larvae of *S. litura* in all the bioassays. The botanical (thyme oil) had also shown great results in leaf dip bioassay. Thus, further research is required to find more botanicals which show greater mortality rate in *S. litura*. Moreover, check their insecticidal properties and resistance studies of these eco-friendly insecticides so that they can be efficiently incorporated in IPM programmes.

References-

1. Abdel-Aziz HS, Osman HH, Sayed SZ, El-Gohary EGE. Effect of certain plant oils on some biological and biochemical aspects on the cotton leaf worm *Spodoptera littoralis*. Egyptian Academic Journal of Biological Sciences. A, Entomology 2013;6(3):69-80.

2. Ahmad M, Arif MI. Resistance of beet armyworm *Spodoptera exigua* (Lepidoptera: Noctuidae) to endosulfan, organophosphorus and pyrethroid insecticides in Pakistan. Crop Protection 2010;29(12):1428-1433.

3. Ahmad M, Ghaffar A, Rafiq M. Host plants of leaf worm, *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae) in Pakistan. Asian Journal of Agriculture and Biology 2013;1:23-28.

4. Ahmad M, Saleem MA, Ahmad M, Sayyed AH. Time trends in mortality for conventional and new insecticides against Leaf worm, *Spodoptera litura* (Lepidoptera: Noctuidae). Pakistan Journal of Biological Sciences 2006;9(3):360-364.

5. Ahmad M, Saleem MA, Ahmad M. Time-oriented mortality in leafworm, *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae) by some new chemical insecticides. Pakistan Entomologist 2005;27(1):67-70.

6. Ahmed MA. Evaluation of novel neonicotinoid pesticides against Cotton leafworm, *Spodoptera littoralis* (Boisd.) (Lepidoptera:Noctuidae) under laboratory conditions. Advances in Environmental Biology 2014;8(10):1002-1007.

7. Barrania AA. Antifeedant, growth inhibitory and toxicity effects of chlorantraniliprole, thiamethoxam and novaluron against the cotton leaf worm, *Spodoptera littoralis* (Boisd.) (Lepidoptera:Noctuidae) in cotton fields. Egyptian Journal of Agricultural Research 2013;91:903-911.

8. Bhadane M, Kumar NN, Acharya MF. Bioefficacy of Modern Insecticides against *Spodoptera litura* Fabricius on Castor. International Journal of Agriculture Innovations and Research 2016;4(4):789-795.

9. Christopher Cutler G, Scott-Dupree CD, Tolman JH, Ronald Harris C. Acute and sublethal toxicity of novaluron, a novel chitin synthesis inhibitor, to *Lepinotarsa decemlineata* (Coleoptera: Chrysomelidae). Pest Management Science 2005;61(11):1060-1068.

10. Dhawan AK, Saini S, Mohindru B Singh K. Susceptibility of *Spodoptera litura* (Fabricius) to some novel insecticides. Pesticide Research Journal 2007;19(2):169-171.

11. Djeagher NEH, Aissaoui L, Amira K, Boudjelida H. Impact of a chitin synthesis inhibitor, Novaluron, on the development and the reproductive performance of mosquito *Culex pipiens*. World Applied Sciences Journal 2014;29(7):954-960.

12. El-Sheikh ESAM, El-Saleh MA, Aioub AA, Desuky WM. Toxic Effects of Neonicotinoid Insecticides on a Field Strain of Cotton Leafworm, *Spodoptera littoralis*. Asian Journal of Biological Sciences 2018;11:179-185.

13. Ghoneim K, Hamadah K, Mansour AN, Abo Elsoud AA. Toxicity and disruptive impacts of Novaluron, a chitin synthesis inhibitor, on development and metamorphosis of the olive leaf moth *Palpita unionalis* (Hubner) (Lepidoptera: Pyralidae). International Journal of Trend in Research and Development 2017;4(3):184-193.

14. Haynes KF. Sublethal effects of neurotoxic insecticides on insect behavior. Annual Review of Entomology 1988;33(1):149-168.

15. Hummelbrunner LA, Isman MB. Acute, sublethal, antifeedant, and synergistic effects of monoterpenoid essential oil compounds on the tobacco cutworm, *Spodoptera litura* (Lepidoptera:Noctuidae). Journal of Agricultural and Food Chemistry 2001;49(2):715-720.

16. Jiang ZL, Akhtar Y, Zhang X, Bradbury R, Isman MB. Insecticidal and feeding deterrent activities of essential oils in the cabbage looper, *Trichoplusia ni* (Lepidoptera: Noctuidae). Journal of Applied Entomology 2012;136(3):191-202.

17. Knipling EF. The basic principles of insect population suppression and management. No. 512 US Department of Agriculture, United States 1979, 1-15.

18. Kostyukovsky M, Trostanetsky A. The effect of a new chitin synthesis inhibitor, novaluron, on various developmental stages of *Tricholium castaneum* (Herbst). Journal of Stored Products Research 2006;42(2):136-148.

19. Koul O, Shankar JS, Mehta N, Taneja SC, Tripathi, AK, Dhar KL. Bioefficacy of crude extracts of *Agava* species (Meliaceae) and some active fractions against lepidopteran larvae. Journal of Applied Entomology 1997;121:245-248.

20. Koul O, Singh R, Kaur B, Kanda D. Comparative study on the behavioral response and acute toxicity of some essential oil compounds and their binary mixtures to larvae of *Helicoverpa armigera*, *Spodoptera litura* and *Chilo partellus*. Industrial Crops and Products 2013;49:428-436.

21. Kranz J, Schmutterer H, Koch W. Diseases, pests, and weeds in tropical crops. Soil Science 1978;125(4):272.

22. Kumar BV, Regupathy A. Generating Base Line Data for Insecticide Resistance Monitoring in *Spodoptera litura* (Fabricius). Pesticide Research Journal 2000;12(2):232-234.
23. Mallikarjuna N, Kranthi KR, Jadhav DR, Kranthi S, Chandra S. Influence of foliar chemical compounds on the development of *Spodoptera litura* (Fabricius) in interspecific derivatives of groundnut. Journal of Applied Entomology 2004;128(5): 321-328.

24. Meagher RL, Brambila J, Hung E. Monitoring for exotic *Spodoptera* species (Lepidoptera: Noctuidae) in Florida. Florida Entomologist 2008;91(4):517-523.

25. Monobrullah M, Shankar U. Sub-lethal effects of Spl MNPV infection on developmental stages of *Spodoptera litura* (Lepidoptera: Noctuidae). Biocontrol Science and Technology 2008;18(4):431-437.

26. Narvekar PF, Mehendale SK, Desai SD, Karmarkar MS, Golvankar GM. Host preference and digestibility indices of *Spodoptera litura* (Fab.) on different host plants under laboratory condition. International Journal of Chemical Studies 2018;6(6):1657-1661.

27. Natikar PK, Balikai RA. Relative toxicity of newer insecticide molecules against tobacco caterpillar, *Spodoptera litura* (Fabricius). International Journal of Agricultural and Statistical Sciences 2015;11(1).

28. Oberlander H, Silhacek DL. Mode of action of insect growth regulators in Lepidopteran tissue culture. Pesticide Science 1998;54(3):300-302.

29. Pavela R. Acute, synergistic and antagonistic effects of some aromatic compounds on the *Spodoptera littoralis* Boisd. (Lepidoptera:Noctuidae) larvae. Industrial Crops and Products 2014;60:247-258.

30. Pavela R. Antifeedant and larvicidal effects of some phenolic components of essential oils lasp lines of introduction against *Spodoptera littoralis* (Boisd.). Journal of Essential Oil Bearing Plants 2011;14(3):266-273.

31. Qin H, Ye Z, Huang S, Ding J, Luo R. The correlation of the different host plants with preference level, life duration and survival rate of *Spodoptera litura* Fabricius. Chinese Journal of Eco-Agriculture 2004;12(2):40-42.

32. Rehan A, Freed S. Selection, mechanism, cross resistance and stability of spinosad resistance in *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae). Crop Protection 2014;56:10-15.

33. Sadek MM. Antifeedant and toxic activity of *Adhatoda vasica* leaf extract against *Spodoptera littoralis* (Lepidoptera:Noctuidae). Journal of Applied Entomology 2003;127(7):396-404.

34. Saeed Q, Saleem MA, Ahmad M. Toxicity of some commonly used synthetic insecticides against *Spodoptera exigua* (Fabricius) (Lepidoptera: Noctuidae). Pakistan Journal of Zoology 2012;44(5):1197-201.

35. Sahar E, Samah MH, Doaa AF. Toxicity of certain IGRs and conventional insecticides against cotton leafworm and their effects on the development and haemocyte counts. Alexandria Journal of Agricultural Sciences 2019;63(2):93-103.

36. Saini RK, Kumar S, Sharma SS. Evaluation of insecticides against *Spodoptera litura* (Fab.) attacking cotton. Journal of Cotton Research and Development 2005;19(2):273-276.

37. Salgado VL. Studies on the mode of action of spinosad: insect symptoms and physiological correlates. Pesticide Biochemistry and Physiology 1998;60(2):91-102.

38. Santis EL, Hernandez LA, Martinez AM, Campos J, Figueroa JI, Lobit P, et al. Long-term foliar persistence and efficacy of spinosad against beet armyworm under greenhouse conditions. Pest Management Science 2012;68(6):914-921.

39. Shad SA, Sayyed AH, Fazal S, Saleem MA, Zaka SM, Ali M, et al. Field evolved resistance to carbamates, organophosphates, pyrethroids, and new chemistry insecticides in *Spodoptera litura* Fab. (Lepidoptera: Noctuidae). Journal of Pest Science 2012;85(1):153-162.

40. Shaila O, Rao SRK, Babu RT. Chemical compatibility of avermectins and chitin synthesis inhibitors with common fungicides against *Spodoptera litura*. European Journal of Zoological Research 2013;2(4):116-23.

41. Sparks TC, Thompson GD, Kirst HA, Hertlein, MB, Larson LL, Worden TV, et al. Biological activity of the spinosyns, new fermentation derived insect control agents, on tobacco budworm (Lepidoptera: Noctuidae) larvae. Journal of Economic Entomology 1998;91(6):1277-1283.

42. Srivastava K, Sharma S, Sharma D, Ahmad H Ganai, SA. Base line toxicity of fungicides and insecticides to *Spodoptera litura* (Fab.). Bangladesh journal of Botany 2016;45(1):39-46.

43. Stanley J, Chandrasekaran S, Regupathy A, Jasmine RS. Base line toxicity of emamectin and spinosad to *Spodoptera litura*. Annals of Plant Protection Sciences 2006;14(2):346-349.

44. Taillebois E, Cartereau A, Jones AK, Thany SH. Neonicotinoid insecticides mode of action on insect nicotinic acetylcholine receptors using binding studies. Pesticide Biochemistry and Physiology 2018;151:59-66.

45. Talikoti LS, Sridevi D Ratnasudhakar T. Relative toxicity of insect growth regulators against tobacco caterpillar, *Spodoptera litura* (Fabricius). Journal of Entomological Research 2012;36(1):31-34.

http://www.entomoljournal.com