
Review Article

Biology and integrated management of tobacco caterpillar, *Spodoptera litura* Fab.: A systematic review

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Abstract

Tobacco caterpillar (*Spodoptera litura*) has damaged in great extent in different cultivated crops. Mainly it affects solanaceous crops. It feeds on the leaves of the crop and crops seems as it is fed by the animals. In later stage it damages whole plant causing rotting of plant. Commercial farmers are normally relying on chemical pesticides. Integrated Pest Management (IPM) strategy is suggested as a best option of pest management. Using respective trap crop of major crops has been found most effective method as trap has multiple advantages for the small-scale farmers. Handpicking can be effectively used for the fourth and fifth instar of the larva. This systematic review aims to collect the general biology of tobacco caterpillar and related species as well as various IPM measures of pest management. The details pest biology, ecology, host distribution and integrated pest management are reviewed systematically and presented in review section. Reviews were carried out citing different journal articles, books, conference proceedings, thesis, reports, books sections etc. This review can be useful for the researchers, academicians and extension workers to develop an IPM protocol for the tobacco caterpillar.

Introduction

Wide range of cultivated crops (more than 112 species of crops) are affected by polyphagous pest, Tobacco caterpillar (*Spodoptera litura*) worldwide (Ramaiah & Maheshwori, 2018). Meagher et al. (2008) reported that there are about 30 different species of genus *Spodoptera* worldwide. According to Taludker et al. (2018) have tobacco caterpillar (*S. litura*) is a devastating pest of cabbage, cauliflower

and many other cultivated crops resulting a great loss in yield and quality similarly Kumar & Ray (2007) reported that tobacco caterpillar is main pest of tobacco, it also affects cole crops, cotton, solanaceous crops etc and some weed hosts most favored include *alternanthera* (alligator weed), *Euphorbia*, *Echhornia*, *Ipomoea*, *Parthenium* and *Rumex*.

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Zoological classification (Nishida, 2002):





Kingdom: Animalia
 Subkingdom: Bilateria
 Infrakingdom: Protostomia
 Superphylum: Ecdysozoa
 Phylum: Arthropoda
 Subphylum: Hexapoda
 Class: Insecta
 Subclass: Pterygota
 Infraclass: Neoptera
 Superorder: Holometabola
 Order: Lepidoptera
 Family: Noctuidae
 Subfamily: Noctuinae
 Latreille, 1809
 Tribe: Prodeniini
 Latreille, 1809
 Genus: *Spodoptera*
 Latreille, 1809
 Species: *S. litura*
 Fabricius, 1775


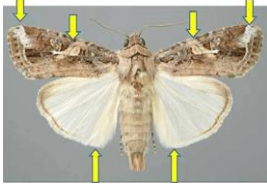


Aim of this review research was to disseminate knowledge about the highly destructive pest tobacco caterpillar which is voracious and polyphagous in nature and feeds on leaves causing great decline in crop production.

Morphology of *Spodoptera* and other common species

About 30 different species of genus *Spodoptera* are reported worldwide (Meagher et al., 2008), important species are *Spodoptera litura* Fab., *Spodoptera mauritia* Boisduval, *Spodoptera exempta* Walker, *Spodoptera frugiperda* J. E. Smith, *Spodoptera eridania* Stoll, *Spodoptera littoralis* Boisduval, *Spodoptera exigua* Hubner, *Spodoptera ornithogalli* Guenee (Brown & Dewhurst, 1975; Msr & Vankateshalu, 2017). Eggs of *Spodoptera* species are laid on single layer (usually) or on two layers (occasionally) covered with creamy white or brown colored hairs while the color pattern of larvae varies among the species with common four abdominal prolegs (pseudolegs) present (European and Mediterranean Plant Protection Organization, 2015). Pupa is dark reddish brown of 15-22 mm length with two spines and ring of pits on dorsal abdominal segments (Brown & Dewhurst, 1975). Adult of different species differ in a wing color pattern (Pogue, 2002). Morphological variations of common *Spodoptera* species are mentioned in the table below.

Table 1. Morphological variations of common *Spodoptera* species

| Life stages | <i>Spodoptera litura</i> | <i>Spodoptera frugiperda</i> | <i>Spodoptera littoralis</i> | <i>Spodoptera exuiga</i> |
|-------------|---|---|--|--|
| |  |  |  |  |
| | Source: Cardona et al., 2007 | Source: Hardke et al., 2015 | Source: European and Mediterranean Plant Protection Organization (2015) | Source: Mau & Martin, 1991 |
| Egg | Eggs are round and dirty white or pale orange (5 days duraion) (Cardona et al., 2007) | Eggs are ovlate spherical which are greenish grey initially (Hardke, et al., 2015) | Eggs are whitish yellow covered by yellowish hair (European and Mediterranean Plant Protection Organization, 2015) | Eggs are round pearl white in color covered with yellowish brown hair (Mau & Martin, 1991) |

| | | | | |
|-------|---|--|---|--|
| Larva | Larvae are greenish brown with dark markings. Body has rows of dark markings with longitudinal or transverse grey lines or bands. (Garad et al., 1985) | White to yellow color with black head of first instar larva which finally become brown or black color in final stage. Larva has four square dots on eight abdominal segment. Prominent inverted Y shape on head capsule. (Hardke et al., 2015) | Newly hatched larva has white body with dark head and tapering towards end. Dark light longitudinal bands are present on lateral side with two dark semilunar spots on each segment except in prothorax region. (Ulrich et al., 2008) | Larvae are green in early instars. Later it changes to brownish color with interrupted lines (Azidah, & Sofian-Azirun, 2006). |
| Pupa | Posterior segment of abdomen is less tapering in comparison to <i>S. littoris</i> and Mesothoracic leg terminate around the lower margin of wing (Pinhey, 1975) | Pupation takes place in loose oval cocoon by tying together soil particles and silk (Food and Agriculture Organization, 2018) | Pupa is more tapering towards posterior segment of abdomen and mesothoracic leg extend beyond the lower margin of wings (Pinhey, 1975) | Pupa has extra pair of spines present dorsally to the long caudal spine (European and Mediterranean Plant Protection Organization, 2015) |
| Adult |  |  |  |  |
| | Source: European and Mediterranean Plant Protection Organization, 2015 | Source: Curz, 2018 | Source: Goergen et al., 2016 | Source: Capinera, 1999 |
| | Wings are brown with creamy colored criss-cross markings. Males have prominent white band as compared to females. (Ramaiah & Maheshwori, 2018). | Forewing has triangular white patch in apical region while centre of wing has circular spot. Hind wings are silver white with dark border (Bhavanani et al., 2019) | Forewings are grey to reddish brown in color having pale lines in veins. (European and Mediterranean Plant Protection Organization, 2015) | Fore wings are mottled grey and brown with light colored bean shaped spots. (Capinera, 1999) |

Description of *Spodoptera litura*

Tobacco caterpillar (*S. litura*) is a devastating pest of cabbage, cauliflower and many other cultivated crops resulting a great loss in yield and quality (Taludker et al., 2018). It is distributed in tropical and temperate Asia, Australasia and Pacific Island (Fand et al., 2015). *Spodoptera* belonging to the second largest insect family i.e. Noctuidae (Mudassar, 2017) and has capability to lay egg on various host plants and has greater host finding ability (Fand et al., 2015). These caterpillars also familiar with other common names such as the cluster

caterpillar, tobacco cutworm, tropical armyworm (Brambila et al., 2008) that consists of more than 30 species (Pogue, 2002). Tobacco caterpillar lays brown spherical shaped eggs (Ramaiah & Maheshwori, 2018). Color of larvae changes from pale green to dark green with dorsal black spot on the third instar which eventually changes to dark blackish brown with three lines on dorsal surface of body (Natiker & Balikai, 2017). Initially color of pupa is yellowish that later becomes reddish brown. Fore wings of adult are brown colored with crisscrossed markings while hind wings are

silvery colored without markings. Female adults have dull colored in comparison to male adults (Gupta et al., 2015).

Host range

Spodoptera litura is polyphagous pest invading more than 112 species of crops

(Ramaiah & Maheshwori, 2018). Though tobacco caterpillar is major pest of tobacco, it also affects cole crops, cotton, solanaceous crops etc. According to Kumar and Ray, (2007) *alternanthera* (alligator weed), *Euphorbia*, *Echhornia*, *Ipomoea*, *Parthenium* and *Rumex* are the most favored weed hosts. Common *S. litura* host plants along are in Table 2.

Table 2. Host range of *Spodoptera litura* in various cultivated crops and weeds

| Host family | Plant name | Citations |
|--------------|---|-------------------------------|
| Fabaceae | Peanut, <i>Arachis hypogea</i> L. | (Zong et al., 2012), |
| | Chick pea, <i>Cicer arietinum</i> L. | (Natarikar & Balikai, 2017) |
| | Soyabean, <i>Glycine max</i> L. | (Punithivali & Sharma, 2013), |
| | Sweet pea, <i>Lathyrus odoratus</i> L., Alfa Alfa <i>Medicago sativa</i> L., French Bean <i>Phaseolus</i> L., Black gram <i>Vigna mungo</i> L., Green gram <i>Vigna radiata</i> L. | (Bragard, et al., 2019), |
| | Cauliflower, <i>Brassica oleracea</i> var. <i>botrytris</i> , | (Tuan et al., 2016) |
| Brassicaceae | Cabbage, <i>Brassica oleracea</i> var. <i>capitata</i> , | (Taludker et al., 2018) |
| | Mustard, <i>Brassica rapa</i> L., Radish, <i>Raphanus sativa</i> L. | (Hamzah & Norsyazwina, 2019) |
| Malvaceae | Cotton, <i>Gossypium hirsutum</i> L. | (Selvaraj et al., 2010) |
| Solanaceae | Chilly, <i>Capsicum frutescens</i> L. | (Negal et al., 2016) |
| | Tobacco, <i>Nicotiana tabacum</i> L. | (Natarikar & Balikai, 2017) |
| | Tomato, <i>Solanum lycopersicum</i> L., Potato, <i>Solanum tuberosum</i> L., | (Bragard, et al., 2019) |
| | Eggplant, <i>Solanum melongana</i> L., | (Zong et al., 2012) |
| Poaceae | Rice, <i>Oryza sativa</i> L., Sorghum, <i>Sorghum bicolor</i> L., Maize, <i>Zea mays</i> L. | (Hamzah & Norsyazwina, 2019) |
| Theaceae | Tea, <i>Camellia sinensis</i> L. | (Bragard, et al., 2019), |
| Moraceae | Mulberry, <i>Morus alba</i> L. | (Zong et al., 2012) |

Life Cycle

Egg

Tobacco caterpillar lays brown spherical shaped eggs in a group covered with yellowish brown hairs (Ramaiah & Maheshwori 2018; Cardona et al., 2007). Incubation period of egg ranges from 4-5 days. An egg is 0.2-0.4 mm in length. Female lays 890.50 ± 16.26 eggs during night in mass which are sorted in 3 layers in rows (Mudassar, 2017).

Larva

Newly emerged *Spodoptera* larvae are cylindrical in shape having wide head size and tapering abdomen towards caudal region

(Cardona et al., 2007). They have five larval instars with larval periods of 15-22 days (Latha et al., 2014). Patil et al., (2014) reported period of larvae was longer (22-31 days) in GTH-1 variety of tobacco.

Newly hatched larvae are slow moving pale green color with average length of 1.4 mm (Latha et al., 2014). Cardona et al. (2007) reported that first instar larvae had tapering abdomen and wider head than second instar larvae.

As larvae reaches to second instar its abdomen turns wider than head Cardona et al. (2007) with longitudinal brown stripes on lateral and dorsal side of abdomen (Natarikar &

Balikai, 2017). Length of second instar larvae is approx 3.15 mm with instar duration of 2-3 days (Latha et al. 2014).

Third instar is elongated and longer (7.6-8.5 mm) (Latha et al. 2014) with yellowish green color and black spots on body (Natiker & Balikai, 2017).

Fourth instar is dark green in color (Natiker & Balikai, 2017) having length of average 22.45mm with duration of 2-3 days (Latha et al., 2014) with yellow and green stripes with spots Cardona et al. (2007).

Fifth instar has reddish brown head and black legs with time period of 4-6 days (Latha et al., 2014).

Pupa

Pupa is reddish brown measuring 22.29 ± 0.71 mm length and 7.51 ± 0.36 mm breadth

Cardona et al. (2007) with eminent antennal and eye case (Natiker & Balikai, 2017). Latha et al. (2014) reported average length of pupa 19.5 mm with pupal duration of 9-14 days. Pupation occurs in soil or under the residues (Gupta et al., 2015)

Adult

Adult female is larger than male with short abdomen while color of male is brighter than female Cardona et al. (2007). According to Hopper & Ahmed, (1980) adult emerges after 23.4 days at 28°C. Fore wings have dark grey patterns while hind wing is silvery colored without any patterns. Head is protruding covering 33 % of of facial region (Natiker & Balikai, 2017).

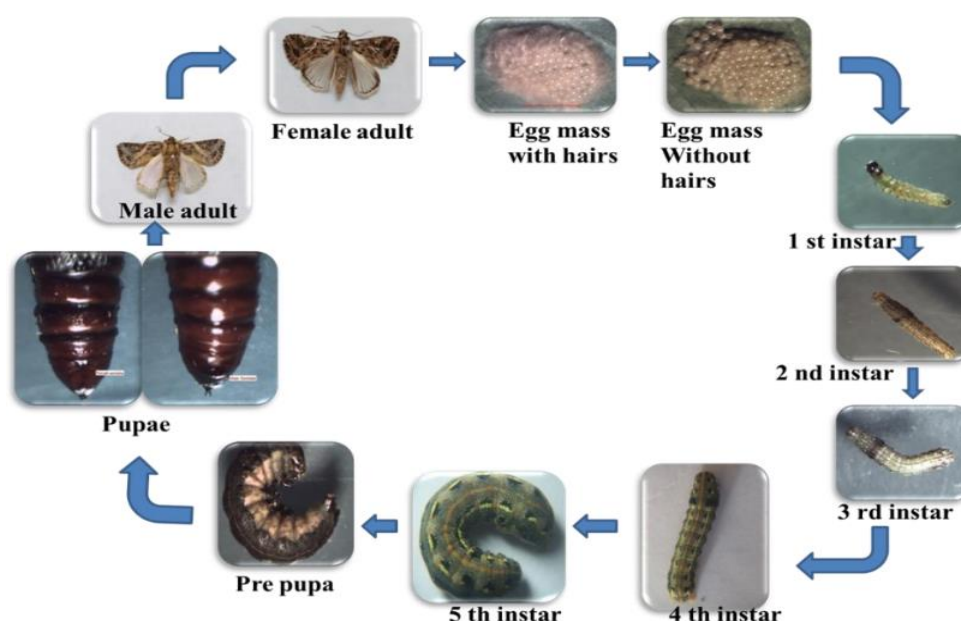


Figure 1. A general life cycle of tobacco caterpillar (*Spodoptera litura*)

Source: Adopted from Maheshwori & Ramaiah, 2018

Ecology

Range of 23-25°C is considered the optimum temperature for the growth and development of different instars of larvae (Xue, 2000). It damages head of cabbage causing rotting of head. Peak feeding season of *S. litura* is February in Pakistan and activity is reduced after March (Maree, et al., 1999). Babasaheb et al., (2015) observed suitable temperature range for oviposition is 25°C to 30 °C. Study of Xue,

(2000) observed that temperature requirements for the eggs, different larval instars and pupae were 26.7 °C, 24.7 °C, 24.9 °C and 25.8 °C respectively. Increase in temperature affected indirectly in growth and development of second larval instars of tobacco caterpillar (Pham & Shaw, 2020). Female cannot ovulate below 15 °C and above 35°C temperature (26-35 °C), relative humidity (89%), wind velocity (6.2 km/hr) and zero rainfall (Selvaraj et al., 2010).

Crop Damage

Spodoptera litura is prominent phytophagous leaf feeding insect causing significant loss in crop production (Natiker & Balikai, 2015). Larvae is voracious feeder and feeds gregariously commencing from leaves and eventually feeding whole plant parts in a severe condition (Ahmad et al., 2013). Tuan et al. (2016) reported that exhaustion rate on cabbage was thrice than that of taro (*Colocasia esculenta* L.) though rate of population increase was not significantly different. Similarly, Maung (2016) reported 65 % of adult's exposure on cabbage followed by 60 % on cauliflower (*Brassica oleracea* var. *botrytis*) and 56.6% on broccoli

(*Brassica oleracea* var. *italica*). Results of Shekhawat et al. (2018) were contrary to (Maung, 2016) which showed increase in pest population was faster on cauliflower (3.78 days) than on cabbage (3.71 days). *Spodoptera litura* infestation caused more than 75 % yield loss in hot pepper (*Capsicum annum* L.) (Moekasan et al., 2020) and about 100 % in bell pepper (*Capsicum frutescens* L.) (Negal et al., 2016). According to Sarwar (2017) larvae scratches leaves and bolls of cotton as if gazed by livestock. Fourth and fifth instar of tobacco caterpillars are the most damaging larval stage (Mainali et al., 2014).



Spodoptera litura larvae in cabbage leaves

Source: Singh et al., 2018



Spodoptera litura larvae on *Ricinus communis* (castor) leaves

Source: Arivoli & Tennyson, 2020

Figure 2: Damage of *Spodoptera* spp. in cabbage and *cummunis* leaves

Integrated pest management

Integrated pest management focuses all possible management strategies to keep the pest below the economic threshold level. IPM not only reduces the pesticide consumption in agricultural fields but also reduces pest problems caused by pesticides. In this integrated pest management strategy, all possible *S. litura* management strategies are described thoroughly.

Cultural strategy

Pest management with manipulating the crop habitat is the successful pest management strategy for many cultivated crops. Trap cropping, cover cropping, intercropping are the

common habitat manipulation strategies for the pest management. These strategies are relying on natural enemies' hypothesis and resource concentration hypothesis for pest management that can help to keep the pest away from the main crop or increase the fitness of biocontrol agents for promoting conservation biological control (Tiwari et al., 2020) among them, trap cropping is a suitable cultural technique of pest management. Shekhawat et al. (2018) reported that cauliflower (*Brassica oleracea* L. var *Botrytis*: Brassicaceae), cabbage (*Brassica oleracea* L. var *Capitata*: Brassicaceae) plants can be protected from *S. litura* if castor, *Ricinus communis* L. (Euphorbiaceae) plants are deployed in cabbage and cauliflower

fields. Planting Chinese cabbage as trap crop in crucifer field is another trap management strategy (Sireesha et al., 2014). In practice, castor should be grown along the field border 15 days before cabbage plantation for egg laying. Planting crops between March to April can reduce the *S. litura* infestation rate (Insect and Plant Disease Control Manual, 2018). Trench digging around infested fields (Natiker & Balikai, 2017), promoting organic farming (Taludker et al., 2018), planting late maturing cabbage varieties (Punithivali et al., 2013) and planting cabbage crops in a pest exclusion Nets (Singh et al., 2018) are other common cultural pest management practices. Trap cropping is widely adapted method for the management of tobacco caterpillar in Nepal. Trap crop not only manages insect pest but also increases income by extra production. Similarly management of insects by changing the time of plantation and harvesting has been increasing nowadays.

Physical method of management

Hand picking of larvae is economic and traditional method of larvae management. Pheromone trap (spodo lure) is effective monitoring tool for management of tobacco caterpillar (Aivelu & Duraimurugan 2018). Yellow color night lighting trap can successfully control *Spodoptera litura* population effectively (Ishikura et al., 2010). Handpicking is mostly applied for large sized insects and for the insects which feed in groups. It is mostly used in caterpillars of tobacco caterpillar, fall armyworm, hairy caterpillars etc.

Biological based management

Biological management approach refers to the administration of beneficial entomopathogenic organisms and use of biopesticides and bio stimulants (Baker et al., 2020). Application of *Steinernema carpocapsae* in field can give reduction of *Spodoptera* population in Chinese cabbage field (Kim et al., 2008). Aqueous extraction from leaves of *Lantana camara* L. (Verbenaceae) and spray at the concentration of 40 % caused 96.6 % mortality in cabbage field (Desmukhe et al., 2011). Hexane extract from *Piper nigrum* showed excessive toxicity (LD50; 1.8mg/g) within 48 hr. of treatment on tobacco caterpillar (Loh et al., 2011). Similarly, Treatment of eggs of *Spodoptera litura* with 2% neem seed extract (*Azadirachta indica* A. juss) along with release of *Telonomus remus* Nixon controlled *S. litura* effectively in nursery crops (Natiker & Balikai, 2015). Efficiency in utilization of host was reduced by 32% in comparison to control condition by using sesame (*Sesamum indicum* L. Pedaliaceae) extract (Sintim et al., 2009). Mukherjee, (2003) also found similar result which reported that midgut activity of insect was influenced by sesame extract. Lacewing, ladybird beetle, spiders, red ant, dragonfly, robber fly, reduviid bug, praying mantis are natural enemies of tobacco caterpillar. Mainly *Trichogramma* is used in different research works in field for management of different caterpillars. Common biocontrol agents are mentioned below table.

Table 3. Common biocontrol agents of *Spodoptera litura* Fab

| Natural enemy, Authority (Family: Order) | Type | References |
|--|-------------------|---|
| <i>Apanteles colemani</i> Forster (Braconidae: Hymenoptera) | Parasite (larvae) | (Maheshwori & Ramaiah, 2018) |
| <i>Aspergillus flavus</i> Link (Trichomaceae: Eurotiales) | Pathogen | (Kaur et al., 2020) |
| <i>Bacillus thuringiensis</i> Berliner, (Bacillaceae: Bacillales) <i>Bacillus subtilis</i> Cohn (Bacillaceae: Bacillales) | Pathogen | (Revathi et al., 2014; Natiker & Balikai, 2015) |
| <i>Bracon brevicornis</i> Fabricius (Braconidae: Hymenoptera) | Parasite (larvae) | (Ghosh et al., 2020) |

| Natural enemy, Authority (Family: Order) | Type | References |
|---|-------------------|-------------------------------|
| <i>Cotesia glomerata</i> Linnaeus (Braconidae: Hymenoptera) | Parasite (larvae) | (Ahuja et al., 2012) |
| Granulosis virus | Pathogen | (Gupta et al., 2010) |
| <i>Metarhizium anisopliae</i> Sorokin (Clavicipitaceae: Hypocreales) | Pathogen | (Sarwar, 2017) |
| <i>Telonomus remus</i> Nixon (Platygastridae: Hymenoptera) | Parasite (egg) | (Mani & Krishnamoorthy, 1986) |
| <i>Trichogramma chilonis</i> (Trichogrammatidae: Hymenoptera) | Parasite (egg) | (Shivankar et al., 2008) |

Chemical method of management

Chemical methods are another popular pest management strategy. However, this method are not sustainable practices as they can create adverse effect in human health and biodiversity. Application of Novaluron 10% EC at the rate of 1ml/liter or Chlorantraniliprole 18.5% SC at the rate of 1ml/10litre per ha was effective against *Spodoptera litura* (Bhandari et al., 2015). Treatment of newly moulted fifth instar larvae with Chlorofluradan on either male or female of *Spodoptera* reduced both number of eggs lying and hatching of laid eggs (Perveen, 2005). According to Narayanamma et al. (2013), larval population found per plant for 3 days was 0.3 and 0.4 due to the application of Flubendiamide and Chlorantraniliprole. Similarly, application of Flubandiamide 480 SC was effective against *Spodoptera litura* at rate of 40 g a.i. per ha and 60 g a.i. per ha (Reddy et al., 2014). LD50 of Cypermethrin was highest (14.699) in bioassay of insects done in Tamilnadu and Kerala (Kumar et al., 2014). Differing from this, Ahmad et al., (2007) reported 9 and 5 resistance ratios of Deltamethrin and Chlorpyrifos respectively when compared with susceptible lab strain. Chlorantraniliprole is widely used in field. Since use of chemical pesticides is decreasing, these pesticides are focused least in integrated pest management approaches.

Future research recommendations

Defoliators are considered as a crop limiting factor in cabbage and cauliflower fields.

Ecological study is suggested to understand pest life cycle and habitat that can guide to develop a IPM protocol. Potential trap crops should be assessed from a wide range of crop and non-crop species. Trap crop deployment strategies, their stages, time of deployment etc. are the other future research recommendation for successful pest management by trap cropping. Study of potential caterpillar resistant varieties are other options for future study. Testing of a wide range botanical to repel the pest along with practicing conservation biological control are some idea for future pest management strategy. Organic farming and biological pest management programs including trap cropping are suitable management practices to be recommended for future management strategies.

Conclusion

Tobacco caterpillar (*Spodoptera litura*) is a highly destructive pest which feeds on leaves causing great decline in crop production. Caterpillars are voracious and polyphagous in nature that can damage more than 112 cultivated and weed species. Temperature below 15 °C and above 35 °C are deleterious for the growth and development of insect. Integrated pest management is an alternative approach for pest management. Field sanitation, trap cropping strategy and use of botanicals along with use of pheromones are the common IPM strategies. Pesticide can be used as a last resort but these practices are not eco-friendly.

Author's declaration and contribution

SS carried out idea, reviewed literature worked in writing phase. US helped in searching literature online and editing phase after completion of writing phase. TS helped in editing total manuscript and added some important points which should not be missed. All the authors have a great contribution in bringing the manuscript in this phase. All the authors read and approved the final manuscript.

References

- Ahmad, M., Ghaffar, A., & Rafiq, M. (2013). Host plants of leaf worms, *Spodoptera litura* in Pakistan. *Asian Journal of Agriculture Biology*, 1(1), 23-28. [Direct Link](#).
- Ahmad, M., Sayyed, A., Crickmore, N., & Mustaq, A. (2007). Genetics and mechanism of resistance to deltamethrin in a field population of *Spodoptera litura* (Lepidoptera: Noctuidae). *Society of Chemical Industry*, 63(10), 1002-1010. doi: [CrossRef](#)
- Ahuja, D. B., Ahuja, U. R., Srinivas, P., Singh, R. V., Malik, M., Sharma, P., & Bamawale, O. M. (2012). Development of farmer-led integrated management of major pests of cauliflower cultivated in rainy season in India. *Journal of Agricultural Science*, 4(2), 79.
- Alivelu, K., & Duraimurugan, P. (2018). Determination of an action threshold for tobacco caterpillar, *Spodoptera litura* based on pheromone catch in castor. *Journal of Entomological Research*. 42(2), 189 doi: [CrossRef](#)
- Arivoli, S., & Tennyson, S. (2020). Antifeedant activity of leaf extracts against *Spodoptera litura* Fabricius 1775 (Lepidoptera: Noctuidae) highlighting the mechanism of action. *London Journal of Research in Science: Natural and Formal*. 20(4).
- Azidah, A. A., & Sofian-Azirun, M. (2006). Life history of *spodoptera exigua* (Lepidoptera: noctuidae) on various host plants. *Bulletin of Entomological Research*, 96 (6), 613–18, doi: [CrossRef](#)
- Babasaheb, B., Nitin, T., Shantanu, K., & Minhas, P. (2015). Temperature impacts the development and survival of common cutworm (*Spodoptera litura*): Simulation and visualization of potential population growth in India under warmer temperatures through life cycle modelling and spatial mapping. *PLoS ONE* 10(4). doi: [CrossRef](#)
- Baker, B. P., Green, T. A., & Loker, A. J. (2020). Biological control and integrated pest management in organic and conventional systems. *Biological Control*, 140, 104095. [CrossRef](#)
- Bhandari, N. R., Subedi, R. K., & Thapa, R. B., (2015). Pest management decision guide: green and yellow list. Tobacco caterpillar (*Spodoptera litura*), Nepal. CABI Wallingford UK [Direct Link](#).
- Bhavani, B., Chandra, S., Varma, K., Bharatha, L., Jamuna, P., & Swapna, B. (2019). Morphological and molecular identification of an invasive insect pest, fall army worm, *Spodoptera frugiperda* occurring on sugarcane in Andhra Pradesh, India. *Journal of Entomology and Zoology Studies*, 7(4), 12-18. [Direct Link](#).
- Bragard, C., Dehnen-Schmutz, K., Di Serio, F., Gonthier, P., Jacques, M. A., Miret, J. A., Jaques-Miret, J. A., Justesen F. A., Magnusson, S. C., Milonas, P., Navas-Cortes, A. J., Roel-Potting, P. S., Reignault, L. P., Thulke, H. H., Werf, V. W., Civera, V. A., Yuen, J., Zappala, L., Malumphy, C., Czwienczek, E., and MacLeod, A. (2019). Pest categorisation of *Spodoptera litura*. *European Food Safety Authority (EFSA) Journal*, 17(7). doi: [CrossRef](#)
- Brambila, J. (2013). Identification notes for *Spodoptera litura* and *Spodoptera littoralis* (Lepidoptera: Noctuidae) and some native *Spodoptera* moths. Animal and Plant Health Inspection Service U.S. Department of Agriculture 1-12
- Brambila, J., Hung, E., & Meagher, R. (2008). Monitoring for exotic *Spodoptera* species (Lepidoptera: Noctuidae) in florida. *Florida Entomologist*. 91, 517-522. [Direct Link](#).
- Brown, E., & Dewhurst, C. (1975). The genus *spodoptera* (Lepidoptera, Noctuidae) in Africa and the Near East. *Bulletin of Entomological Research*, 65(2), 221-262. [CrossRef](#)
- Capinera, J. L. (1999). Beet armyworm, *Spodoptera exigua* (Hübner) (Insecta: Lepidoptera: Noctuidae). Gainesville, FL: University of Florida Cooperative Extension Service, *Institute of Food and Agricultural Sciences*, EDIS. 1-5. [Direct Link](#).
- Cardona, E. V., Ligat, C. S., & Subang, M. P. (2007). Life History of Common Cutworm, *Spodoptera Litura* Fabricius (Noctuidae: Lepidoptera). *Research Benguet State University Research Journal*, 56, 69-80. [Direct Link](#).
- Cruz, I., Bruce, A., Sevgan, S., Akutse, K. S., Mohamed, F. S., Niassy, S., Rangaswamy, M., Sidhu, J., Goergen, G., Rwomushana, I., Kasina, M., Ba, M., Aboagye, E., Stephan, D., Wennmann, J., Neering, E., & Mushobazi, W. (2018). Biological control and biorational

- pesticides for fall armyworm management. *Embrapa Milho e Sorgo-Capítulo em livro técnico (INFOTECA-E)*. 4-6. [Direct Link](#).
- District Agriculture Development Office (2016). *Vegetable Farming Techniques Manual*. Gorkha: JICA. [Direct Link](#).
- Desmukhe, P., Hooli, A., & Holihosur, S. (2011). Effect of *Lantana camara* (L.) on growth, development and survival of tobacco caterpillar (*Spodoptera litura* Fabricius). *Karataka Journal of Agricultural Sciences*, 24(2), 137-139. [Direct Link](#).
- European and Mediterranean Plant Protection Organization (2012). Plant Quarantine Information Retrieval System (PQR). version 5.0.5540.
- Fand, B., Sul, N., Bal, S., & Minhas, P. (2015). Temperature impacts the development and survival of common cutworm (*Spodoptera litura*): simulation and visualization of potential population growth in India under warmer temperatures through life cycle modelling and spatial mapping. *journal pone*. 10(4).
- Food and Agriculture Organization. (2018). Integrated management of the fall armyworm on maize - A guide for Farmer Field Schools in Africa. [Direct Link](#).
- Garad, G., Shaivpuje, P., & Bilapate, G. (1984). Life fecundity tables of *Spodoptera litura* (Fabricius) on different hosts. *Proceedings: Animal Science* 93, 29-33. [CrossRef](#)
- Ghosh, E., Varshney, R., & Venkatesan, R. (2020). Performance of *Bracon brevicornis* (Wesmael) on two *Spodoptera* species and application as potential biocontrol agent against fall armyworm. *bioRxiv*. [CrossRef](#)
- Goergen, G., Kumar, P., Sankung, S., & Togola, A. (2016). First report of outbreaks of the fall armyworm *Spodoptera frugiperda* (J E Smith) (Lepidoptera, Noctuidae), a new alien invasive pest in West and Central Africa. *PLoS one*, 11(10), e0165632. [Cross-Ref](#)
- Gupta, M., Tara, J., Sharma, S., & Bala, A. (2015). Biology and morphometry of *Spodoptera litura* Fabricius, a serious defoliator of mango (*Mangifera indica*) in Jammu Region (J&K). *Munis Entomology & Zoology*, 10, 215-221. [Direct Link](#).
- Hamzah, A., & Norsyazwina, M. (2019). Crops damaged by armyworm (*Spodoptera litura* f.) in Malaysia and control tactics. *Melaka International Conference on Social Science, Science and Technology*. 1-9.
- Hardke, J., Lorenz, G., & Leonard, R. (2015). Fall armyworm (Lepidoptera: Noctuidae) ecology in Southeastern cotton. *Journal of Integrated Pest Management*, 6(1), 1-8. [CrossRef](#)
- Hopper, G., & Ahmed, A. (1980). Developmental and reproductive biology of *Spodoptera litura* (f.) (Lepidoptera: Noctuidae). *Australian Journal of Entomology*, 18(4), 363-372. [CrossRef](#)
- Ishikura, S., Hirama, J., Nomura, M., Yamashita, S., Higashiura, M., Iwai, T. & Yamanaka, M. (2010). Development of a physical control device using a yellow pulsed LED for controlling insect pests in the production of autumn-flowering chrysanthemums - a lighting technique to avoid delay in flowering. *Journal of Science and High Technology in Agriculture*. 22(4): 167-174. doi: [CrossRef](#)
- Insect and Plant Disease Control Manual (IPDCM). (2018). Real life solutions. Department of Entomology and Plant Pathology, University of Tennessee Extension.
- Kafle, L., G.C, Y. D., Bhattarai, S., & Zeng Tze, Y. (2014). Integrated Pest Management in Nepal. The 5th International Conference of Clinical Plant Science. Pingtung, Taiwan. 113-124.-DOI: [CrossRef](#)
- Kaur, M., Chadha, P., Kaur, S., Kaur, A., & Kaur, R. (2020). Schizophyllum commune induced oxidative stress and immunosuppressive activity in *Spodoptera litura*. *BMC microbiology*, 20(1), 1-10. [Direct Link](#).
- Kim, H. H., Cho, S. R., & Choo, H. Y. (2008). Biological control of Tobacco Cutworm, *Spodoptera litura* (Lepidoptera: Noctuidae) by Steinernematid and Heterorhabditid Entomopathogenic Nematodes. *Korean Journal of Applied Entomology* 47(4), 447-456. doi: [CrossRef](#)
- Kumar, S., & Ray, P. (2007). Biology of *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae) on some of its major weed hosts. *Association for Advancement of Entomology* 32(4), 287-290.
- Kumar, S., Baskar, K., Johnson, A., & Vincent, S. (2014). Geographic variation in cypermethrin insecticide resistance and morphometry in *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae). *Journal of Coastal Life Medicine*, 2(3), 225-229. doi: [CrossRef](#)
- Latha, M., Shivanna, B. K., Manjunatha, M., & Kumaraswamy, M. C. (2014). Biology of *Spodoptera litura* on chewing tobacco in vitro. *Journal of Eco-friendly Agriculture*, 9(1), 43-47. [Direct Link](#).
- Loh shew, F., Muhamad, R., Dzolkhifl, O., & Mawardi, R. (2011). Insecticidal properties of Piper nigrum fruit extracts and essential oils against *Spodoptera litura*. *International Journal of Agricultural Biology*, 13(4), 517-522.

- Mainali, R., Dangi, N., Aryal, S., Bhandari, G., & Bajracharya, A. (2014). Management of armyworm outbreak in rice field of Chitwan district. *Asian Journal of science and technology*, 774-776.
- Mamun, M., & Ahmed, M. (2011). Integrated pest management in tea: prospects and future strategies in Bangladesh. *Journal of Plant Protection science* 3 (2), 1-13.
- Mamun, M., & Ahmed, M. (2011). Prospects of indigenous plant extracts in tea pest management. *International Journal of Agricultural Research and Technology* 1, 16-23. DOI: [CrossRef](#)
- Mani, M., & Krishnamoorthy, A. (1986). Susceptibility of *Telenomus remus* Nixon, an exotic parasitoid of *Spodoptera litura* (F.), to some pesticides. *International Journal of Pest Management*, 32(1), 49-51. [CrossRef](#)
- Maree, J., Kallar, S., & Khuhro, R. (1999). Relative abundance of *Spodoptera litura* F. and *Agrotis epsilon* Rott. on cabbage. *Pakistan Journal of Zoology*, 31(1), 31-34.
- Mau, R.F.L. & Martin Kessing, J.L. (1991). *Spodoptera exigua*. Department of Entomology, Honolulu, Hawaii. [Direct Link](#).
- Maung, N. (2016). Study of *Spodoptera litura* larvae parasitoid in cabbage fields, the crucifer pest rearing on natural various foods and explain the knowledge to farmers to apply in fields of Myanmar. In *Proceedings of the Ninth Agricultural Research Conference, Yezin Agricultural University, Nay Pyi Taw, Myanmar* (102-110). Yezin Agricultural University.
- Meagher, R., Brambila, J., & Hung, E. (2008). Monitoring for exotic *Spodoptera* species (Lepidoptera: Noctuidae) in Florida. *Florida Entomologist*, 91(4), 517-522. DOI: [CrossRef](#)
- Moekasan, T. K., Prabaningrum, L., & Samudra, I. M. (2020). Determination of control threshold of *Spodoptera litura* on hot pepper. *Advances in Agriculture & Botany*, 12(1), 34-43. [Direct Link](#).
- Msr, M., & Vankateshalu. (2017). Taxonomic description of the genus *Spodoptera* (Lepidoptera: Noctuidae) from Karnataka. *Journal of Entomology and Zoology Studies*, 5(5), 1854-1858.
- Mudassar, V. (2017). Taxonomic description of the genus *Spodoptera* (Lepidoptera: Noctuidae) from Karnataka. *Journal of Entomology and Zoology Studies*, 5(5), 1854-1858.
- Mukherjee, S. (2003). Influence of plant allelochemicals on growth rate, nutrition physiology and midgut esterase activity in fifth instar larvae of *spodoptera litura*. production and development, *Indian Journal of Plant Protection* 41, 125-132 doi: [CrossRef](#)
- Narayanamma, V., Reddy, D., & Reddy, A. (2013). Management of Lepidopteran pests through newer insecticides in Castor. *Indian Journal of Plant Protection*. 41, 25-29.
- Natikar, P., & Balikai, R. (2017). Present status on bio-ecology and management of tobacco caterpillar, *Spodoptera litura* (Fabricius) – An update. *International Journal of Plant Protection*, 10(1), 193-202 doi: [CrossRef](#)
- Natikar, P. K., & Balikai, R. A. (2015). Tobacco caterpillar, *Spodoptera litura* (Fabricius): Toxicity, ovicidal action, oviposition deterrent activity, ovipositional preference and its management. *Biochem. Cell. Arch*, 15(2), 383-389.
- Negal, G., Verma, G., & Rathore, L. (2016). Management of *Spodoptera litura* (Fabricius) through some novel insecticides and biopesticides on bell pepper under polyhouse environment. *Advances in life sciences* 5 (3), 1082-1084. [Direct Link](#).
- Nishida, G. M. (2002). Hawaiian terrestrial arthropod checklist 4th ed. *Honolulu, Hawaii: Hawaii Biological Survey (Bishop Museum) Technical Report*, (22).
- European and Mediterranean Plant Protection Organization. (2015). PM 7/124 (1) *Spodoptera littoralis*, *Spodoptera litura*, *Spodoptera frugiperda*, *Spodoptera eridania*.
- Patil, R., Meheta, D., Jat, B., & Gheytia, L. (2014). Biology of leaf eating caterpillar *Spodoptera litura* on different bidi tobacco. *Journal of Insect Science* 27 (2), 254-256.
- Perveen, F. (2005). Reduction in egg hatch after a sublethal dose of chlorfluazuron to larvae of the common cutworm, *Spodoptera litura*. *Physiological Entomology*, 31(1), 39-45. DOI: [CrossRef](#)
- Pham, T., & Shaw, Y. (2020). High temperatures reduce nutrients and defense compounds against generalist *Spodoptera litura* F.. *Arthropod Plant Interactions*, 14, 333-344. DOI: [CrossRef](#)
- Pinhey, E. C. (1975). *Moths of Southern Africa. Descriptions and colour illustrations of 1183 species*. AA Balkema, Netherlands.
- Pogue, G. M. (2002). A world revision of the genus *Spodoptera guenee* (Lepidoptera: Noctuidae). *American Entomological Society*. 43, 1-20. [Direct Link](#).
- Punithivali, M., Sharma, A., & Rajkumar, B. M. (2014). Seasonality of the common cutworm, *Spodoptera litura* in a soybean ecosystem. *Phytoparasitica*, 42, 213-222. DOI: [CrossRef](#)

- Ramaiah, M., & Maheshwori, T. (2018). Biology studies of tobacco caterpillar, *Spodoptera litura* Fabricius. *Journal of Entomology and Zoology Science*, 31(1), 31-34. [Direct Link](#).
- Reddy, A., Srihari, G., & Kumar, A. K. (2014). Newer insecticides against pod borer *Spodoptera litura* and thrips *Scirtothrips dorsalis* in chilli (*Capsicum annum* Linn.) *Pesticide Research Journal*, 6(4): 1458-1462, [Direct Link](#).
- Revathi, K., Chandrasekaran, R., Thanigaivel, A., Arunachalam Kirubakaran, S., & Senthil-Nathan, S. (2014). Biocontrol efficacy of protoplast fusants between *Bacillus thuringiensis* and *Bacillus subtilis* against *Spodoptera litura* Fabr. *Archives of Phytopathology and Plant Protection*, 47(11), 1365-1375. [CrossRef](#)
- Sarwar, M. (2017). Characteristics of armyworm *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae) occurrence and control on cotton. *Scholars Journal of Research in Agriculture and Biology*, 2(1), 33-38. [Direct Link](#).
- Selvaraj, S., Adirobane, D., Ranesh, V., & Narayanan, A. (2010). Impact of ecological factors on incidence and development of tobacco cutworm *Spodoptera litura* on cotton. *Journal of Biopesticide*, 3, 043-046. [Direct Link](#).
- Shekhawat, S., Shafiq, M., & Basri, R. (2018). Effect of host plants on life table parameters of *Spodoptera litura*. *International Journal of Pure and Applied Bioscience* 6 (2), 324-332.
- Shivankar, S. B., Magar, S. B., Shinde, V. D., Yadav, R. G., & Patil, A. S. (2008). Field bio-efficacy of chemical, botanical and bio-pesticides against *Spodoptera litura* Fab. in sugarbeet. *Annals of Plant Protection Sciences*, 16(2), 312-315.
- Singh, A., Shah, L., G C, Y., Devkota, M., Colavito, L., Rajbhandari, B., & Munippan, R. (2018). Evaluation of pest exclusion net to major insect pest of tomato in Kavre and Lalitpur. *Nepalese Journal of Agricultural Science*, 16,135-144.
- Sintim, H., Tashiro, T., & Motoyama, N. (2009). Response of the cutworm *Spodoptera litura* to sesame leaves or crude extracts in diet *Journal of Insect Science* 9, 1-13. DOI: [CrossRef](#)
- Sireesha, K., Latha, M. P., Reddy, M. T., & Vijaya, M. (2014). Management of pest cabbage through trap cropping with Chinese cabbage. 2nd International Conference on Agricultural & Horticultural Sciences. Hyderabad. [CrossRef](#)
- Taludker, S., Khan, M., Ferdous, J., & Faruq, M. (2018). Integrated management of tobacco caterpillar and cabbage butterfly with host plant resistance and organic amendments. *Bangladesh Journal of Agricultural Research* 43 (4), 619-630. Doi: [CrossRef](#)
- Tiwari, S., Sharma, S., & Wratten, S. D. (2020). Flowering alyssum (*Lobularia maritima*) promote arthropod diversity and biological control of *Myzus persicae*. *Journal of Asia-Pacific Entomology*, 23(3), 634-640 DOI: [CrossRef](#)
- Tuan, S. J., Yeh, C. C., & Atlihan, R. (2016). Demography and consumption of *Spodoptera litura* (Lepidoptera: Noctuidae) reared on Cabbage and Taro. *Journal of Economic Entomology Advance Access* 109(2), 1-8. DOI: [CrossRef](#)
- Ulrich, Sven, & Ziebert C. (2008). Nanocrystalline metastable hard coatings provided for non-commercial research and education use not for reproduction, distribution or commercial use. *Egyptian Academic Journal of Biological Sciences*, 13, 97-120, DOI: [CrossRef](#)
- Xue, Y. Y. (2000). Effect of temperature and food on *Spodoptera litura* population. *Journal of Applied Ecology*. 11(1): 111-4. [Direct Link](#).
- Yadav, A., Kumar, M., & Chauhan, A. (2014). Biology of tobacco caterpillar (*Spodoptera litura* Fab.) on different host plants. *Asian Journal of Animal Science* (9), 111-112.
- Zong, S., Ze Peng, C., & Zai Fu, Z. (2012). Effect of three *Spodoptera litura* control strategies on Arthropod diversity and abundance in tobacco agroecosystem in south china. *Pakistan Journal of Zoology* 44(1), 151-157. [Direct Link](#).