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Developmental Biology of *Spodoptera exigua* (Hubner) (*Lepidoptera*: *Noctuidae*) on Tomato under Mid hills (sub-humid) Conditions of India

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ABSTRACT: The beet armyworm, *Spodoptera exigua* (Hubner) is a polyphagous insect pest that damage and causes economic losses to several field and vegetable crops including maize, cotton, soybean, alfalfa, cotton, tomato etc. in many parts of the world. It is a major pest of tomato under protected and field conditions in Himachal Pradesh and thus, the present investigation was carried out to investigate certain biological parameters of *S. exigua* on tomato leaves and fruits under laboratory conditions (25±4.2°C and 65-80% RH) by following proper and simple methodology. The eggs were laid in clusters with an incubation period of 3.50±0.82 days. There were six larval instars and the total larval period was 20.50±3.84 days. Prior to pupation, the mature larvae curled into C-shape and the prepupal period lasted for 1.50±0.13 days, while the pupa was object with a pupal period of 10.50±0.42 days. The female moths were larger and survived for a longer time (11.00±0.87) than male moths (8.50±0.71). The total life cycle (egg to emergence of adult) was completed in 35.50±5.12 days. *S. exigua* can lead to severe economic losses and therefore, this developmental study would give farmers and researchers of the state, an idea of the time period and importance of different stages of *S. exigua*.

Keywords: *Spodoptera exigua*, tomato, biology, life history, laboratory condition, Himachal Pradesh.

INTRODUCTION

The beet armyworm, *Spodoptera exigua* Hubner (*Lepidoptera*: *Noctuidae*), is a widespread and polyphagous pest, which attacks more than 90 plant species in at least 18 major families including Liliaceae, Fabaceae, Solanaceae, Malvaceae, Chenopodiaceae, Apiaceae, Asteraceae and Amaranthaceae, causing severe economic damage to crops such as sugar beet, soybean, cabbage, cauliflower, Brussels, sprouts, tomato, maize, cotton etc. (McAuslane and Alborn, 2000; Shankar *et al.*, 2014). It is widely distributed in the tropical and subtropical regions. In India, *S. exigua* has been reported as a serious pest of jute, indigo and a minor pest of chillies, onion, brinjal, sweet potato, lentil, cabbage, safflower and sunflower (David and Ramamurthy, 2012; Ueno, 2015). The young larvae feed gregariously and skeletonise host foliage. As they grow up, they became solitary, feed extensively on leaves causing large irregular holes in the foliage. They burrow into the crown or centre of the head on lettuce, or on the buds of brassica crops (East *et al*., 1989), and can also complete development on a number of common weeds. In its larval stage, *S. exigua* is gregarious, particularly in its feeding habits as a first and second instar; large numbers of individuals have been observed feeding together. As armyworm larvae mature, they exhibit less gregarious behaviour (Ueno, 2006; Bradshaw, 2012). Their feeding and behaviour are directly or indirectly affected by temperature variations (Li, 2002; Rathore *et al.*, 2013). Most moths glide at 200 m above the ground, but some have been known to fly above 500 m. If it is early in the season, adults may stay within the same region and reproduce in the spring or early summer. When the moths do not migrate before reproducing, armyworm population densities can reach infestation levels. Extensive crop damage commonly accompanies infestations by this insect. Alternatively, if it is late in the season, the moths migrate to warmer regions or other countries, where their offspring have a higher probability of survival due to increased food availability and increased temperatures. Adults and larvae often are found together in forests and fields; however, adults are not limited to their immediate surroundings, due to their ability to fly (Zheng *et al.*, 2011).

In recent years, the beet armyworm has become a serious pest of many vegetable crops under protected and open field conditions in Himachal Pradesh (Kumar *et al.*, 2020). It has been found feeding voraciously on tomato plants and fruits under polyhouse condition in the state. We collected the larva and the leaves and fruits from such polyhouses for studying their complete biology. Study of the effect of food on the biology of insects is important in understanding host suitability of plant-infesting insect species. Such information will be essential in developing an efficient strategy for controlling beet armyworm, particularly on its biological relationship with tomato plants. Thus, our objectives were to determine the developmental behaviour, number of instars and other biological parameters of *S. exigua* on tomato plants.

MATERIALS AND METHODS

The present investigation was carried out in Department of Entomology, CSK Himachal Pradesh Agricultural

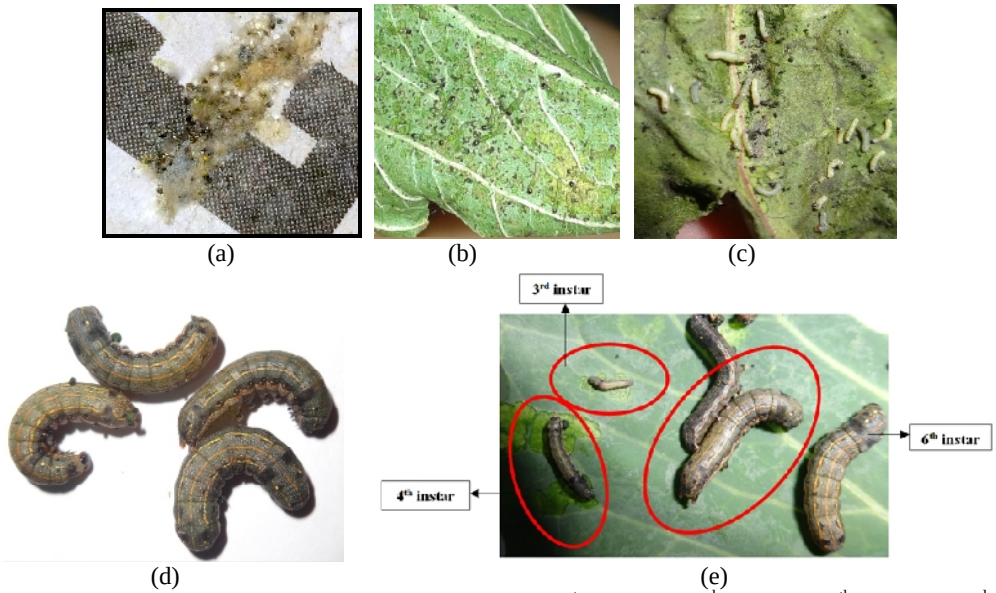
University, Palampur situated at an elevation of 1290.8 m amsl, between 32.11°North latitude and 76.23°East longitude. The initial culture (4^{th}/5^{th} instar larvae) of *S. exigua* was collected from a tomato polyhouse of CSK Himachal Pradesh Agricultural University, Palampur and brought to laboratory (25±4.2°C and 65-80% RH). These larvae were reared on tomato leaves in plastic jars (18 × 15 cm) till the adult emergence. The emerged adults were sexed on the basis of wing pattern and transferred to glass chimneys for mating. In each chimney, one pair of moths was released and their tops were covered with muslin cloth. A cotton swab soaked in honey solution (15%) was also provided in each chimney as food for the moths in a 60mm × 15mm Petri plate. The eggs laid by the moths on muslin cloth/ crumpled paper (placed in the chimney) were collected. The eggs laid occasionally on the walls of the chimney were moistened before separating these with the help of camel hair brush carefully. The papers and muslin cloth pieces having egg masses were then transferred to plastic jars and were monitored daily for egg hatching.

Tomato leaves were provided in jars as food when the eggs were about to hatch. The neonate larvae of each clutch were kept separately in the individual jars (7.0 × 4.5 cm) and provided with fresh food. To keep the leaves fresh for longer duration, the leaf petioles were wrapped with wet cotton plugs. The larvae were observed daily for ecdysis and the presence of exuviae and larval head capsules was used to discriminate the larval instars. Larvae were reared in masses during the early instars and later on (third instar onward), 15 larvae were transferred in each jar (18 × 15 cm). These larvae were provided tomato leaves and fruits, time to time as per their requirement. The full fed larvae were transferred to plastic jars (18 × 15 cm) containing a layer of about 10 cm moist soil-sand mixture. 2-3 days old pupae were removed and kept separately in another jar (15 × 13 cm) for adult emergence. Data on incubation period, larval period (different instars), pre-pupal and pupal period, pre-oviposition and oviposition period, male and female longevity and total life cycle were recorded.

RESULTS AND DISCUSSION

Eggs: The eggs were spherical and the newly laid eggs were light green in colour which turned creamish after sometime. The eggs were shaped like a cone with a round bottom and were laid in clusters and piled in two or three layers. They were covered in golden brown scales detached from the abdomen of the female moth during oviposition (Fig. 1). Capinera, (1999) has reported that female lays 300-600 eggs in clusters, with 50-150 eggs/mass. The incubation period ranged between 3-4 days. Sivapragasam and Syed (2001) also found the incubation period to be 3 days, while, Khalid Ahmed *et al*., (1997); Kumar *et al*., (2020) stated that the incubation period was 2.8-3.1 days and 2-3 days, respectively. The present findings were similar to earlier observations, where the incubation period of *Spodoptera litura* (Fabricius) on tomato was 3-4 days and 3-5 days as reported by Schreiner (2000); Shakya *et al*., (2015), respectively.

Larva: Newly hatched larva was light green with a distinct black head capsule. This larval stage remains together radiating out from the egg mass. Before moulting, the body colour turned to light yellow. The second instar was paler in colour than the first instar and the size of body and head capsule increased with a clear light band on the thoracic region. The third instar was greenish brown with brown head capsule and turned pale before moulting with dark patches on the mesothorax. Larva grew bigger and attained fourth instar stage, it became greyish brown in color with three thin yellow lines down the back one in the middle and two on each side. A row of black dots in pleural region and conspicuous row of dark triangles just above yellow lines on each segment run along with each decorated in dorso-lateral side of the larva during the fifth and sixth intars and it stopped feeding prior to pre-pupal stage (Fig. 1).



(a) (b) (c) (d) (e)

Fig. 1. Different larval instars of *S. exigua*; (a) egg mass; (b) 1^{st} instar; (c) 2^{nd} instar; (d) 5^{th} instar; (e) 3^{rd},4^{th}, 6^{th} instars.

Table 1: Biological parameters of *S. exigua* on tomato.

Life stages	Range (days)	Mean ± S.D.
Incubation period	3-4	3.50±0.82
1st instar	2-3	2.50±0.73
2nd instar	2-3	2.50±0.76
3rd instar	2-3	2.50±0.79
4th instar	3-4	3.50±0.79
5th instar	2-3	2.50±0.67
6th instar	2-3	2.50±0.89
Total Larval period	17-23	20.50±3.84
Pre-Pupal	1-2	1.50±0.13
Pupal period	7-14	10.50±0.42
Male	8-9	8.50±0.71
Female	10-12	11.00±0.87
Pre oviposition period	2-3	2.50±0.92
Oviposition period	2-3	2.50±0.92
Total life span	28-43	35.50±6.12

The larval stages of *S. exigua* were completed in six instars on tomato, which was compatible with the previous investigation conducted by Anwar *et al*., (1996). However, Azidah and Sofian-Azirun (2006) have reported five to eight larval instars. This variation in the number of larval instars may be attributed to the quality of the host plant, differences in geographic population, presence of hairs on leaves, variability or reduction of nutritional quality of the host plant species and age differences within a plant (Naseri *et al*., 2009). The average larval period was 2.50, 2.50, 2.50, 3.50, 2.50 and 2.50 days for the six larval instars respectively with the total larval period ranging from 17-23 days (Table 1). Contrasting results to our findings for larval development, *S. exigua* had a larval period of 12 days on long bean Azidah and Sofian-Azirun, (2006), 13 days on chilli (Idris and Emelia, 2001), 12.4 days on pigweed (Greenberg *et al*., 2001) and 11.98 and 15.58 days on *Gossypium hirsutum* and *Brassica napus*, respectively (Farahani *et al*., 2011). The present findings were in close conformity with Gill *et al*., (2015); Ashwini *et al*., (2016), who stated 16-20 days and 18.93-23.23 days of larval period of *S. exigua* and *S. litura* respectively.

Prepupa and Pupa: Prior to pupation, the mature larvae curled into C-shape and the prepupal period lasted for about 1-2 days with an average of 1.50±0.13 days (Table 1). Pupation took place in soil and the pupa was obtect with two small spines on tip of abdomen. Newly formed pupa was yellowish but later turn reddish brown and finally blackish, prior to adult emergence (Fig. 2). Gill *et al*., (2015) reported pupation of *S. exigua* in a thin and loose cocoon, which turned from light brown to reddish brown. The sex of the adults can be determined at the pupal stage by using a magnifying lens to identify the structure of the sternal or ventral plates and the position of the gonopore (Capinera, 2006). Pupal duration was of 7-14 days. These observations are closely related to observations made by earlier workers. The total pupal period of *S. litura* was 7.54 days (Shahout *et al.*, 2011) and 6.95-11.92 days (Ashwini *et al.*, 2016) while, Shakya *et al*. (2015) noticed a pupal period for 7-9 days on tomato host. However, contrary to our results, Kumar *et al*. (2020) reported a pupal period of *S. exigua* between 4-5 days. The difference in the pupal period may be accounted to the favourable environmental conditions around the pupa and the surface used for its pupation in the laboratory.

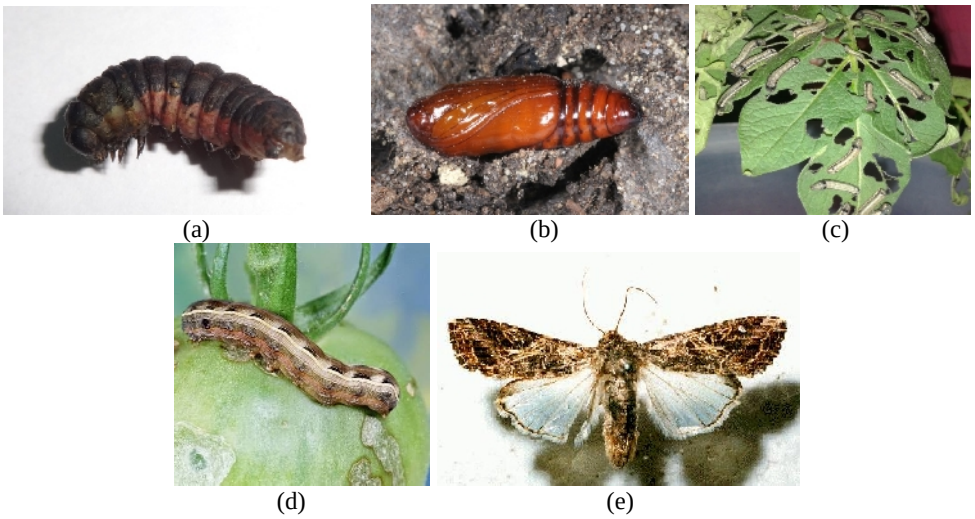


Fig. 2. (a) Pre pupa; (b) Pupa; (c) Leaves damaged by *S. exigua*; (d) Larva feeding on fruit; (e) Adult of *S. exigua.*

Adults: Moths had a mottled grey and brown, irregular banding patterns (criss-cross) with a pale bean shape spot on forewings, while, hindwings were more uniform, greyish white and had a dark line along the margin (Fig. 2). Thorax was covered with bright coloured scales. The female moths were slightly larger than the male. Wing expanse was 38 mm in case of females, while in case of males, it was 35 mm. Males survived for 8-9 days while females for 10-12 days. However, it is not similar to the findings of Farahani *et al*., (2011) who reported 13.69 and 11.72 days, respectively for female longevity of *S. exigua* on *Zea mays* and *G. hirsutum*. Adult males can detect female sex pheromones from long distances and can also migrate to breeding areas, sometimes traveling thousands of kilometres. Adult males and females have 4 to 10 days to find mates before they die. The average male mates with 5 females, but the number ranges from 1 to 11 (Luo *et al*., 2003). The quality and quantity of food consumed, can influence the growth, development and reproduction of insects (Scriber and Slansky, 1981). Contrary to our findings, the adult longevity of *S. litura* (Fabricius) on cabbage host lasted for 7.7 ± 0.48 days (Ravi *et al*., 2015) and 7.23-8.74 days (Ashwini *et al*., 2016), while it was 9 days on tomato (Shakya *et al*., 2015).

Pre oviposition, oviposition and total life cycle: The pre-oviposition and oviposition period lasted for 2-3 days each. The total developmental period from hatching of larvae to emergence of adults was 28-43 days. Farahani *et al*., (2011) reported that the development time of *S. exigua* was 21.63 days on *B. napus* and 27.22 days on *G. hirsutum*. Patel *et al.*, (1987) has reported pre-oviposition and oviposition period of 2.06-2.08 and 3.56-3.59 days on vegetable soybean respectively. Earlier workers have reported that the total developmental period of *S. litura* was 32.47-39.46 days on cabbage (Ashwini *et al*., 2016) and 42-46 days on tomato (Shakya *et al*., 2015). The reasons for such differences between our findings and above-mentioned researchers might be due to the factors such as leaf morphology, chemical composition or other non-tested interactions.

All the insect-pests show a phenomenon of either antixenosis or antibiosis with respect to different crops and different cultivars of same crop (Mehta and Kumar, 2021). Antibiosis in host plant resistance to insect herbivores can be manifested in several ways such as fecundity reduction, decreasing size, increasing development time and increasing mortality. This reduces the quality of host plant as a food source for insect growth (Painter, 1951). Longer life cycle can also be attributed to low temperature condition at our experimental location as compared to other location. Sanjrani *et al*., (1989) has reported that the shortest duration of the life cycle (26.6 days) was at higher temperature i.e. 34.9ºC and duration increased as the temperature decreased.

CONCLUSION AND FUTURE SCOPE

Our study aimed to reveal the biological aspects of *S. exigua* on tomato, which would give an idea to the researchers and personnel involved in tomato production about the basic biology of this pest on tomato. Experiments conducted by us clearly showed the ease of development of this pest even in laboratory conditions (less mortality). Furthermore, future studies should be focused on evaluating different hosts simultaneously or varieties of same crop against *S. exigua* under natural and controlled conditions, evaluating chemical components responsible for their susceptibility/resistance and more attention should be dedicated to study demographic parameters of this pest under field conditions for developing effective management strategies.

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Conflict of Interest. None.

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