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Purohit H
Division of Entomology, Department of Zoology, Faculty of Science, The Maharaja Sayajirao University of Baroda, Gujarat, India

Kumar D
Division of Entomology, Department of Zoology, Faculty of Science, The Maharaja Sayajirao University of Baroda, Gujarat, India

Corresponding Author:
Purohit H
Division of Entomology, Department of Zoology, Faculty of Science, The Maharaja Sayajirao University of Baroda, Gujarat, India

Influence of biotic factor on the life cycle of *Spodoptera litura* fabricius, 1775 (Lepidoptera: Noctuidae)

Purohit H and Kumar D

Abstract
Influence of biotic factor was studied on *Spodoptera litura* Fabricius, 1775 by comparing life cycle on different hosts like tomato (*Solanum lycopersicum*), chilli (*Capsicum annum*), cabbage (*Brassica oleracea*) and cotton (*Gossypium sp*.). As we change the host, insect also changes its life cycle. From the study it was observed that *Spodoptera litura* completes its life cycle in 31.8, 32.5, 34, 39.2 days on tomato, chilli, cabbage and cotton leaves respectively. Also consumption of leaf and larval weight were studied on different hosts. It was observed that after 72 hours, consumption of leaf is more in tomato (0.47g) followed by chilli (0.42g), cabbage (0.37g) and cotton (0.26g) leaves. Larval weight gain was recorded which indicates 0.1575g increased in weight when fed with tomato leaf followed by chilli (0.1388g), cabbage (0.0913g) and cotton (0.0613g) leaves.

Keywords: *Spodoptera litura*, pest, host

Introduction
Agro ecosystem is largely governed by interactions between abiotic (temperature, humidity, light, wind, soil etc.) and biotic (host, vegetative biodiversity etc.) components. Insects are powerful and rapid adaptive organisms with high fecundity rate and short life cycle. These factors significantly influence the insects and their population dynamics. In response to these factors insect may prolong their metamorphic stages, survival and rate of multiplication [1]. Global changes are responsible for wide range of anthropogenic and natural environmental variation & these climatic and weather changes not only affect the status of insect pests but also affect their population dynamics, distribution, abundance, intensity and feeding behavior [2]. Intensity of change in climatic ecosystem noted by meteorological science has showed a direct and indirect effect on the prey and host relationship, their immune responses and rate of development, their fecundity and various physiological functions [2].
Spodoptera litura Fabricius, 1775. (Lepidoptera: Noctuidae) is a moth also known as cluster caterpillar, cotton leaf worm, tobacco cutworm and tropical armyworm in different parts of the world. It is a polyphagous pest in India, China and Japan of about 290 host plant species belonging to 99 families [3]. Economically important crops like cotton, chilli, castor, groundnut, tobacco, pulses etc are attacked by the Pest. In India, *Spodoptera litura* is widespread in almost all the states and inflict significant losses to crops of economic importance like soybean [4], cotton and groundnut. A single larva is reported to cause average pod yield loss of 27.3% in groundnut in per square meter through damage to various parts like leaves, flowers and pods [6]. Since 2002, it has frequently been reported that the larvae of *Spodoptera litura* (Fabricius) are causing widespread damage to soybean crops at several localities in India [5]. Recent outbreaks of *Spodoptera litura* (Fabricius) on soybean in Kota (Rajasthan state), Marathwada and Vidarbha (Maharashtra state) regions of India have been reported to cause monetary losses to the tune of USD 4.5 crores and USD 22.5 crores respectively [7]. Due to prominent climatic changes and the non-judicious use of agrochemicals has increased the problem of pest. It is realized that the inherent resistant power of plant is diminishing day by day. Further noted that there is an urgent need for enhancement of agricultural system productivity due to imminent climate change as agricultural system productivity is going down due to complex problem; insect pests are posing serious threat to agricultural productivity [8]. Due to the nocturnal nature, moth of *S. litura* becomes active at night and move overnight for oviposition on a wide range of host plants, which promotes or

even ensures survival of *S. litura* individual over a broad range of environmental conditions [8]. It also becomes resistant to many commonly used insecticides, particularly pyrethroids and carbamates, resulting in failure of effective controls [9]. Out breaks of the pest occurs due to its resistance to insecticides, favorable weather conditions, cyclonic weather and heavy rainfall after a long dry spell. In Punjab, *S. litura* seems to have developed resistance to insecticides, as the pest is not being managed effectively with the commonly recommended insecticides [10]. The reproductive capacity and migration ability over long distances have made it economically important pest of many agricultural crops, with a wider geographical range throughout Asia, from North Africa to Japan, Australia and New Zealand [11]. The population of *S. litura* in cabbage crop to be negatively correlated with average and maximum temperature. It is a sporadic pest with a high mobility and reproductive capacity [12]. The caterpillar is widely distributed throughout tropical and temperate regions of Asia, Australia and Pacific islands [13]. Its wide spread and pest status has been attributed to its polyphagy and its ability to undergo both facultative diapause and seasonal migration and also observed three distinct peaks of tobacco caterpillar brood emergence on bean [14]. The first peak occurred in the 4th week of January when averages of 823.5 moths per trap was collected. The moth coughed in the trap increased progressively during February with 1143.5 moths per trap indicating a second peak. *S. litura* is generally synchronous with the growing period of tobacco, especially during summer, providing plenty of food sources for oviposition and larval feeding [15]. The species is migratory on all continents and is a key pest in all of them [16].

Insect host plant interaction & relationship is of prime importance, which helps us to know the possible effect of host plants on insect development. It is also observed that food plants and their physical and chemical constituents play a vital role in survival and reproductive potential of insects [17].

Materials and Methods

Collection and multiplication

A colony of *Spodoptera litura* (Fabricius) was collected from agricultural field & reared on artificial diet [10] and maintained at constant condition of 27±2°C Temperature & 70±5 % RH. In the laboratory, the larvae were fed with artificial diet placed in plastic containers. Fresh diet was provided every 2-4 days. All the instars of larvae were maintained on artificial diet. Pupae were collected in plastic container & kept 5 pupae in single container. Adults were collected as soon as they emerge; this is to avoid starvation of adults. The adult moths were kept inside containers, covered with black cloth. Male and Female chosen for oviposition cage are such that they are healthy i.e. there is no deformity in them with respect to their development and are freshly emerged. The cloth & surface of container serve as substrate for oviposition. The adult moths were fed with a 10% honey-water solution through cotton swab. Cotton swabs are prepared by using medicated absorbent cotton. The hatched neonates were allowed to complete their development on artificial diet.

Fig 1: Damage symptoms on the underside of castor leaves

Fig 2: Sting bug infesting the same host plant.

Fig 3: Castor field at Padra

Fig 4: Maize field at Padra

Procedure for preparing artificial diet

Distilled water was taken into mixing jar and add propionic acid, formaldehyde and becosule into distilled water and mix well. Thereafter add ascorbic acid, sorbic acid, methyl p-hydroxybenzoate & mix well. Add wheat germ and chickpea floor, mixed properly by using hand blender. Remaining half quantity of distilled water was taken in pan and placed for heating. When bubbles start coming, yeast is added in pan and dissolved by continuous stirring with the help of spatula. Agar agar was added slowly. After 10 minutes of cooking, this mixture starts boiling. Mixing was done properly by using hand blender. Pour diet in different plastic trays. For storing it was kept in refrigerator at 5 °C.

Table 1: List of ingredient used for preparing artificial diet for *S. litura*

Sr. No.	Ingredients	500ml
1	Wheat germ	25 gm.
2	Chickpea flour	75 gm.
3	Sorbic acid	0.75 gm.
4	Ascorbic acid	2.50 gm.
5	Methyl-p-hydroxy benzoate	2.30 gm.
6	Formaldehyde 5%	12 ml
7	Becosule	8 ml
8	Propionic acid	1.8 ml
9	Yeast	28 gm.
10	Agar agar	10 gm.

Experiment design

Newly hatched larvae were selected having age of 0-12 hours old. Plants were grown and leaves collected as and when required from green house. Plastic trays having small cells were used for the experiments. Total of 10 larvae were tested per host. Newly emerged larva was kept singly with fresh leaf in individual cell. Excreta and left behind of leaves were cleaned daily to maintain hygienic condition. Fresh leaves were provided after every 24 hours. All the set up was kept at constant condition i.e. 27±2°C Temperature & 70±5 % RH.

Along with life cycle study another experiment was conducted to see host preference and after feeding, weight gain of 3rd instar larvae. For that four 3rd instar larvae were taken into plastic container individually and provided with pre weighed tomato leaf. Same thing was done with other hosts too. After 48 hours post weight of leaves were recorded. And for larval weight gain study, total of 8 larvae were taken. Before releasing larvae into container having fresh leaf, pre weighing was done for individual larvae and after 48 hours post weight was recorded.

Data Analysis

For data analyses following formula were used. From these observations, the growth and developmental index were calculated as follows:

$$\text{Larval growth index} = \frac{\%\text{Pupation}}{\text{Larval period (Days)}}$$

$$\text{Pupal growth index} = \frac{\%\text{Adult emergence}}{\text{Pupal period (Days)}}$$

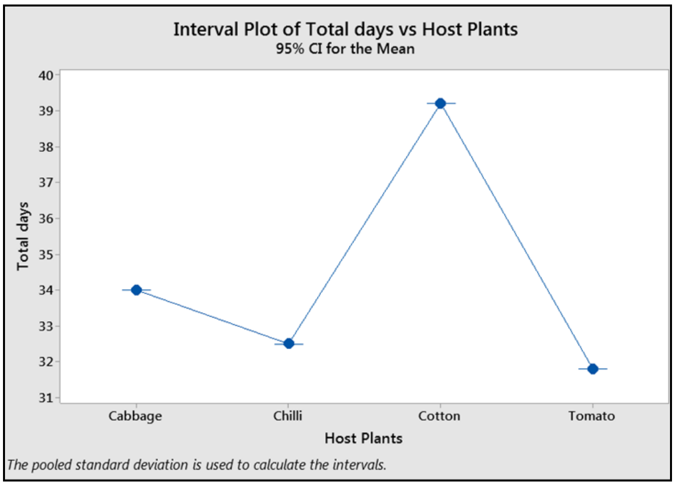
$$\text{Total developmental index} = \frac{\%\text{Survival}}{\text{Total developmental period (Days)}}$$

Results

Larval development from one instar to another instar was observed in number of days which indicated in table 2 along with pupal and adult period. The developmental period of S. *litura* was significantly affected by host plant tested (Table 2). *Spodoptera litura* takes as much as of 31.80 days when fed with tomato leaves, 32.50 days when fed with chilli leaves, 34.00 days if we fed with cabbage leaves and 39.20 days when fed with cotton leaves as seen from the graph 1. Total developmental time from larva to adult of *S. litura* was short when larva fed on tomato leaves, but did not differ significantly with larva fed on chili & cabbage leaves.

Table 2: Lifecycle of *Spodoptera litura* on different host plants.

Host Plants	Larval period (Days)	Pupal period (Days)	Adult period (Days)	Total days
Tomato	19.40	6.20	6.20	31.80
Chilli	19.80	6.30	6.40	32.50
Cabbage	21.40	6.40	6.20	34.00
Cotton	26.00	6.80	6.40	39.20

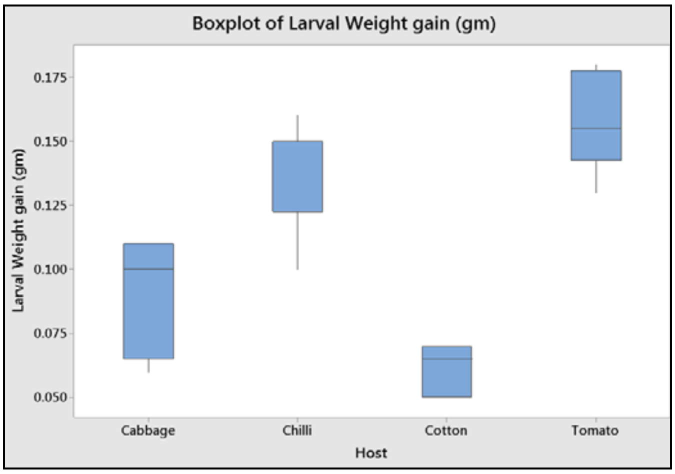


Graph 1: Days to complete different stages of *Spodoptera litura*

In case of feeding preference clear response was observed by seeing on consumption of leaf. Leaf was pre weighed and given to larvae and after 48 hours post weight difference recorded. Highest consumption was observed on tomato leaf i.e. 0.475g followed by chili leaf 0.423g, cabbage leaf 0.375g and cotton leaf 0.260g.

Larval growth in terms of weight gain on different host was observed after 48 hours of feeding. Maximum gain in weight was recorded when larvae fed with tomato leaf followed by chili, cabbage and cotton leaves. As we can see from the graph 2, weight gain was 0.157g, 0.138g, 0.091 and 0.061g when fed with tomato, chili, cabbage and cotton leaves respectively.

Larval growth index in case of tomato, chili, cabbage & cotton is 5.15, 5.05, 4.67, 3. 84 respectively. Pupal growth index in case of tomato, chili, cabbage & cotton is 16.12, 15.87, 15.62 & 14.70 respectively. Total developmental index for tomato, chili, cabbage & cotton is 3.14, 3.07, 2.94 & 2.55 respectively.



Graph 2: Larval weight gain when fed with different hosts

Discussion

The results from this present study revealed the effect of different host plant on the growth and development of S. *litura*. Generally, shorter developmental times, higher reproduction rates, and low mortality of insects on a host indicate greater suitability of a host plant [19]. This result on pupal duration was little similar with previous study reported by Shahout *et al*. (2011) [20] where pupal duration was about 8.43 days when larva fed on soybean. Favetti *et al*. (2015) [21] also revealed that pupal duration of *S. litura* when larva fed on soybean cultivar ranged from 10.5-11.2 days for female and 11.2-11.8 days for male, indicated longer than pupal duration in this present study. The biological parameters of *S. litura* including life cycle duration, larval weight, and the number of larval instars were studied towards assessing the suitability of hosts for the larvae of *S. litura*. The results were compared with similar parameters reported from other host plants especially castor, a plant that has been considered as the most suitable host for *S. litura*. Favourable results were obtained for all biological parameters of *S. litura* when the larvae were fed on tomato leaves. Moreover, the insect pest went through a normal life cycle without impaired morphological or during the process testing. From the results we can see the influence of biotic factors like host has influence on lifecycle of *Spodoptera litura*. When we change the host the days to complete life cycle will also changes [6].

4. Conclusion

Every organism particularly insects in arthropods respond to every deviation from normal abiotic and biotic factors. Host can affect their development, survival, multiplication and various immune and genetic responses. Host plant plays an important role in regulating *S. litura* population and mass rearing. This study can be helpful in predicting seasonal distribution of insect pests depending on the host and also predict pest pressure if similar crops are sown in adjoin fields. It can also be helpful for farmers to see when insect pest can invade the crop.

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Effect of Abiotic Factors on the Life Cycle of *Spodoptera litura* Fabricius, 1775 (Lepidoptera: Noctuidae)

Purohit Hardik*, Kumar Dolly

Department of Zoology, Faculty of Science, The Maharaja Sayajirao University of Baroda, Vadodara, India
*Corresponding author: hardikpurohit007@gmail.com

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Abstract Influence of abiotic factors was studied on *Spodoptera litura* Fabricius, 1775 by decreasing temperature & humidity from the optimum conditions (27±2°C Temp & 70±5 % RH). As a result of fluctuation, insect can shorten or elongate their life cycle. Two ranges which were taken for these studies were 40% humidity & 20°C temperature. At normal condition generation time was 35-36 days but at 40% humidity it was prolonged to 48-50 days & at 20°C temperature it was prolonged to 47-49 days. It was observed that when we decrease temperature & humidity from optimum conditions the life cycle elongates. At optimum condition, 40% humidity & 20°C temperature larval growth index was 5.09, 3.15 & 3.32, pupal growth index was 19.96, 16.56 & 16.39 & total developmental index was 2.82, 2.00 & 2.00 respectively. From the results we can see the influence of abiotic factors like temperature and humidity on the lifecycle of *Spodoptera litura* which can help in the prediction of population dynamics of insect pests.

Keywords: *abiotic factors, humidity, temperature, Spodoptera litura*

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1. Introduction

Our ecosystem is largely governed by interactions between abiotic (temperature, humidity, light, wind, soil etc.) and biotic (host, vegetative biodiversity etc.) components. Insects are powerful and rapid adaptive organisms with high fecundity rates and short life cycles. These factors significantly influence insects and their population dynamics. In response to these factors, the insect may prolong its metamorphic stages, survival and rate of multiplication [5]. Global changes are responsible for a wide range of anthropogenic and natural environmental variation. These climatic and weather changes not only affect the status of insect pests but also affect their population dynamics, distribution, abundance, intensity and feeding behavior [1]. The intensity of change in climatic the ecosystem noted by meteorological science has shown a direct and indirect effect on the prey and host relationship, their immune responses and rate of development, their fecundity and various physiological functions [4].

Spodoptera litura Fabricius. (Lepidoptera: Noctuidae) is a moth also known as cluster caterpillar, cotton leaf worm, tobacco cutworm and tropical armyworm in different parts of the world. *S. litura* is an important polyphagous pest in India, China and Japan (Kandagal and Khetagoudar, 2013) of about 290 plants species belonging to 99 families (Dhaliwal *et al.*, 2019) of the agricultural and forestry importance crop such as cotton, chili, castor, groundnut, tobacco, pulses etc. (Ahmed *et al*., 1979). It is believed that the increasing area of some economically important crops (mainly vegetable) and protected cultivation provide suitable sites for feeding and over wintering of *S. litura* [11]. In India, *Spodoptera litura* is widespread in almost all the states and inflict significant losses to crops of economic importance like soybean, cotton and groundnut [2]. A single larva per square meter is reported to cause an average pod yield loss of 27.3% in groundnut through damage to various plant parts like leaves, flowers and pods [2]. Since 2002, it has frequently been reported that the larvae of *Spodoptera litura* (Fabricius) are causing widespread damage to soybean crops at several localities in India [12]. Recent outbreaks of *Spodoptera litura* (Fabricius) on soybean in Kota (Rajasthan state), and Marathwada and Vidarbha (Maharashtra state) regions of India have been reported to cause monetary losses to the tune of USD4.5 crores and USD 22.5 crores respectively [3]. Due to prominent climatic changes and the non-judicious use of agrochemicals also forced the problem of pest. It is realized that the inherent resistant power of the plant is diminishing day by day [7]. Further [7] noted that there is an urgent need for enhancement of agricultural system productivity due to imminent climate change as agricultural system productivity is going down due to complex problems; insect pests are posing a serious threat to realizing agricultural productivity. Due to the nocturnal nature, the moth of *S. litura* becomes active at night and move overnight for oviposition on a wide range of host plants, which promotes or even ensures the survival of *S. litura* individual over a broad range of environmental conditions [4]. It also becomes resistant to many commonly used insecticides, particularly pyrethroids and carbamates, failing effective controls [3,4,5,6].

Temperature: Being poikilothermic organisms, the developmental rate in insects is highly contingent on external temperature conditions. Hence, the temperature is generally considered the single most significant environmental factor influencing behavior, distribution, development, survival and reproduction in insects [10]. Knowledge of the temperature-dependent population growth potential of insect pests is highly imperative for understanding their population dynamics and implementing agro-eco region specific pest control strategies, especially in the context of predicted global climate warming [12]. The vast majority of studies that infer the effects of temperature on the developmental biology of *Spodoptera litura* have been undertaken only under one constant temperature in the laboratory [13]. Few studies that addressed the development of *Spodoptera litura* at a range of constant temperature was concerned with predicting only developmental rates [13], but no emphasis was given to the simulation of variability in development times, mortality and fecundity with temperature changes. Due to non-linearity in developmental response at temperature extremes, linear models are generally considered poor predictors of insect developmental rates [9]. Yet, the specific effects of associated daily and seasonal temperature extremes on *Spodoptera litura* development are less understood which warrants estimation of the temperature-dependent population growth potential for understanding the impact of climate change on its future incidence and damage activity [4].

Humidity: Moisture also plays a critical role in insect development, especially in the desert. Many insect pests encountered in our crops do not require free moisture to survive. They obtain water through their food supply. For instance, *Liriomyza* leaf miners spend their entire egg and larval stages inside melon or lettuce leaves, extracting water and nutrients from plant tissue. However, relative humidity or lack thereof can influence insect growth and behavior by affecting the insect's ability to regulate water loss. Low humidity is often detrimental to insect development, but most insects found in desert crops have adapted physiological and behavioral mechanisms to prevent dehydration. As a general rule of thumb, cool, wet extremes in weather are the most detrimental to insects because they can promote disease, slow growth rates, and interrupt feeding activities. There is no doubt that weather plays a major role in determining the survival and growth rates of insect populations because of its direct impact on them and their food supply. These interactions have been studied for many years and are fairly well understood. Unfortunately, predicting insect abundance in a particular area is like predicting the weather or vice-versa [13].

2. Materials and Method

2.1. Collection & Multiplication

A colony of *Spodoptera litura* (Fabricius) was collected from the agricultural field (Figure 1 & Figure 2) & reared on an artificial diet [6] and maintained at a constant condition of 27±2°C Temperature & 70±5 % RH. In the laboratory, the larvae were fed with artificial diet placed in plastic trays (Figure 4). The fresh diet was provided every 2-4 days. All the instars of larvae were maintained on artificial diet (Figure 5). Pupae were collected in the plastic container & kept 5 pupae in a single container. Adults were collected as soon as they emerge; this is to avoid starvation of adults. The adult moths were kept inside containers, covered with black cloth. Males and Females chosen for oviposition cage are such that they are healthy i.e. there is no deformity in them concerning their development and have freshly emerged. The cloth & surface of the container serves as a substrate for oviposition. The adult moths were fed with a 10% honey-water solution through a cotton swab. Cotton swabs are prepared by using medicated absorbent cotton. The hatched neonates were allowed to complete their development on an artificial diet.

Figure 1. *S. litura* damage on the castor leaves

Figure 2. Sting bug infesting the castor leaf

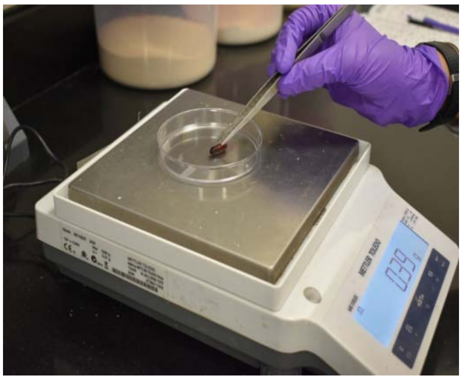

Figure 3. Growth parameters recorded using a weighing balance

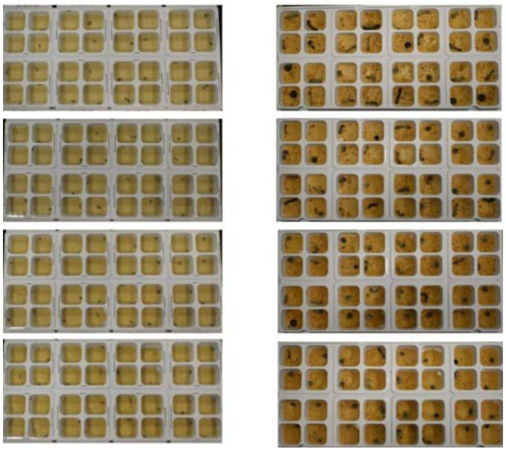

Figure 4. Setup showing larval rearing

2.1.1. Diet Preparation for *Spodoptera litura*

Table 1. List of ingredients used for preparing artificial diet

Sr. No.	**Ingredients**	**500ml**
1	Wheat germ	25 gm
2	Chickpea flour	75 gm
3	Sorbic acid	0.75 gm
4	Ascorbic acid	2.50 gm
5	Methyl-p-hydroxy benzoate	2.30 gm
6	Formaldehyde 5%	12 ml
7	Becosule	8 ml
8	Propionic acid	1.8 ml
9	Yeast	28 gm
10	Agar agar	10 gm

Procedure for preparing artificial diet: Distilled water was taken into mixing jar and added propionic acid, formaldehyde and becosule into distilled water and mixed well. Thereafter add ascorbic acid, sorbic acid, methyl p-hydroxybenzoate & mix well. Add wheat germ and chickpea floor, mixed properly by using a hand blender. The remaining half quantity of distilled water was taken in the pan and placed for heating. When bubbles start coming, yeast is added in a pan and dissolved by continuous stirring with the help of the spatula. Agar agar was added slowly. After 10 minutes of cooking, this mixture starts boiling. Mixing was done properly by using hand blender. Pour diet in different plastic trays. For storing it was kept in the refrigerator at 5°C. Careful weighing is done as per Table 1.

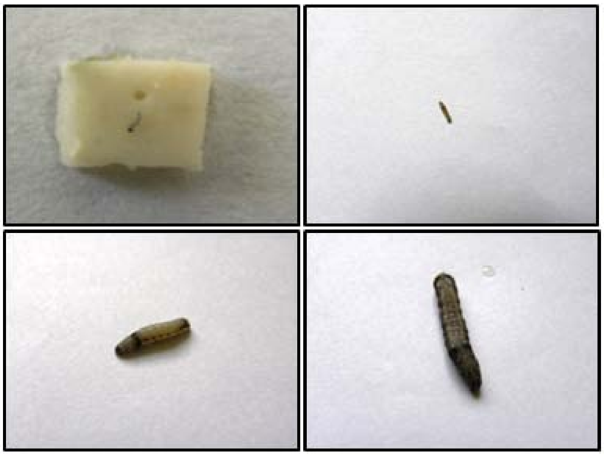

Figure 5. Different stages of *S. litura*

2.1.2. Experimental Design

Abiotic factors like temperature and relative humidity were studied by keeping two different range (20°C Temp & 40% RH) considering optimum range (27±2°C Temp & 70±5 % RH). When testing temperature all the other factors were kept as normal, this will be done to see the only impact of that factor which we were looking for. BOD will be utilized to regulate different abiotic factors. In the current study decrease in these two parameters were studied i.e. 7°C decrease in temperature & 30% decrease in humidity. The duration of the lifecycle was studied by observing whether it prolongs or become shorter due to the fluctuation of these factors. Other growth parameters were observed by weighing different stages (Figure 3).

3. Results & Discussion

The influence of these abiotic factors were studied by observing the life cycle of *Spodoptera litura* i.e. the total number of days were recorded to complete one generation. A total of 100 larvae were taken for this study and data shown in the Table 2 indicates, days taken to complete one generation. When optimum condition provided than it takes 31-35 days to complete one generation but when we provide decreased temperature it will take 47-49 days to complete one generation. Same with the case when we decrease humidity, it will take 48-50 days to complete one generation. Day wise data given in Table 2, Table 3 & Table 4.

Table 2. Completion of life cycle in days

Conditions	**Eggs**	**1st instar**	**2nd instar**
Normal condition	4.5	4.21	4.14
Low humidity 40%	6	6.86	6.69
Low temperature 20°C	7.5	6.3	6.34

Table 3. Completion of life cycle in days

Conditions	**3rd instar**	**4th instar**	**5th instar**
Normal condition	4.11	3.56	3.64
Low humidity 40%	6.61	5.86	5.74
Low temperature 20°C	6.28	5.66	5.56

Table 4. Completion of life cycle in days

Conditions	Pupa	Adult	Total days
Normal condition (27±2°C Temp & 70±5 % RH)	5.01	6.29	35.46
Low humidity 40%	6.04	6.14	49.94
Low temperature 20°C	6.1	6.17	49.91

As Seen from Figure 6 & Figure 7, days will be prolonged when we decrease temperature & humidity. Data on larval and pupal development were recorded. From these observations, the growth and developmental index were calculated as follows:

$$Larval\ growth\ index = \frac{\%\ Pupation}{Larval\ period\ (Days)}$$

$$Pupal\ growth\ index = \frac{\%\ Adult\ emergence}{Pupal\ period\ (Days)}$$

$$\%\ Survival = \frac{\%\ Survival}{Total\ developmental\ period\ (Days)}$$

Table 5. The biological attributes recorded on normal conditions compared with other conditions

Condition	Larval growth index	Pupal growth index	Total developmental index
Normal condition	5.08	19.96	2.82
Low humidity	3.14	16.56	2.00
Low temperature	3.32	16.39	2.00

At optimum condition, 40% humidity & 20ºC temperature larval growth index was 5.08, 3.14 & 3.32, pupal growth index was 19.96, 16.56 & 16.39 & total developmental index was 2.82, 2.00 & 2.00 respectively (Table 5).

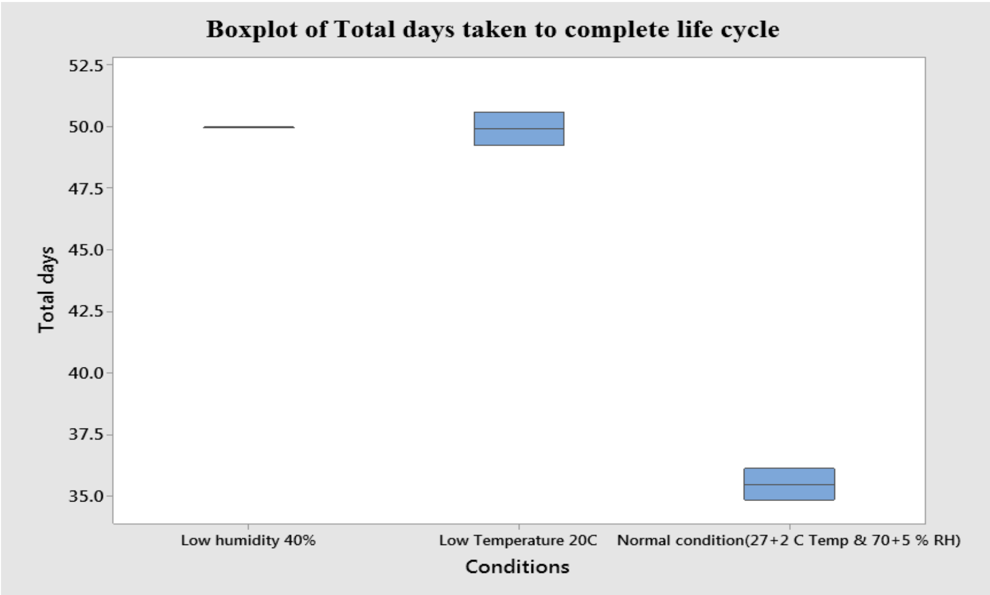

Figure 6. Total days to complete the life cycle at different abiotic conditions

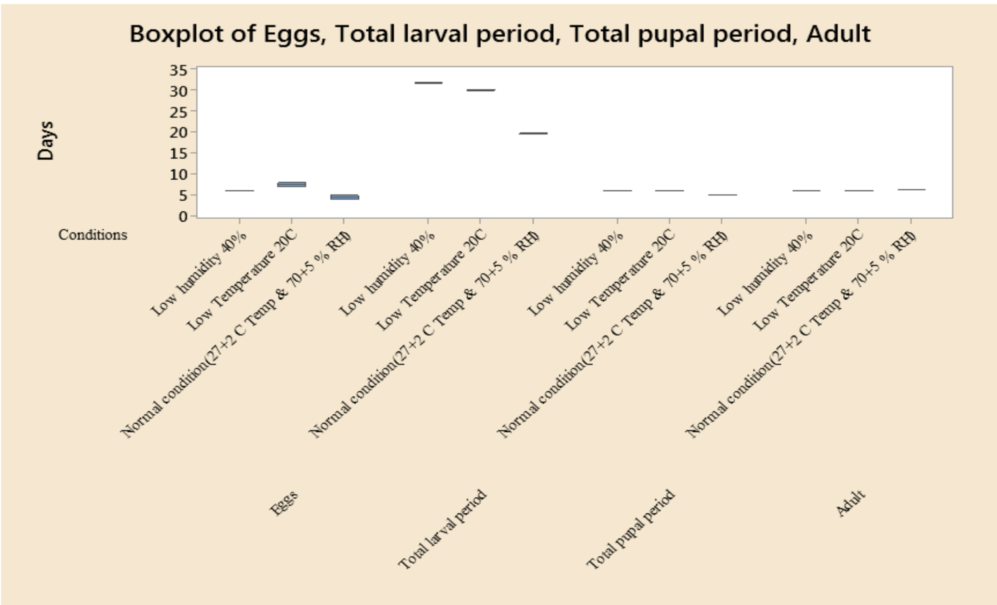

Figure 7. Completion of the life cycle under different conditions

4. Conclusion

Our results are in larger agreement with those reported by [13], who also did not get *S. litura* oviposition at constant high temperatures of 35°C and 37°C, however, the only deviation that existed for the low temperature of 15°C, where they reported egg laying. The studies by [13] on the developmental effects of constant and alternating temperatures on *S. litura* addressed only the development rates and estimation of thermal constants. However, they did not consider the temperature-dependent immature mortality, adult senescence and female fecundity which are considered highly important in understanding pest population dynamics [14]. Rest of the studies that deal with estimating *S. litura* life table parameters were conducted using only a single constant temperature [11]. From the results we can see the influence of abiotic factors like temperature and humidity on the lifecycle of *Spodoptera litura*. When we reduce temperature and humidity the lifecycle was prolonged. This study can be helpful in predicting seasonal distribution of insect pests depending on the weather conditions. Also can be helpful for farmers to see when insect pest can invade the crop. So by this we can reduce the use of pesticides by correlating abiotic factors with the pest of different crops.

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