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Determination of minimum threshold temperature and degree day requirements for the development of *Spodoptera litura* on different host plants

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Abstract
The tobacco caterpillar, *Spodoptera litura*, is a highly destructive pest known for its polyphagous nature, affecting various wild and cultivated plants worldwide. Climatic factors, particularly temperature, greatly influence the development and behavior of *S. litura*, making it crucial to understand their thermal requirements for effective pest management strategies. Given the considerable economic impact of *S. litura* infestations on crops such as capsicum, tomato, and castor, there is a pressing need to study the insect's developmental biology and its response to temperature variations. The primary objective of this study is to determine the minimum threshold temperature for the development of *S. litura* and to calculate the degree day requirements for its development on various host plants, including capsicum, tomato, and castor. The study utilized a linear regression model to calculate the lower developmental threshold and thermal constants for different developmental stages of *S. litura* on castor, capsicum, and tomato. Results indicated significant variations in the minimum temperature thresholds and thermal constants across host plants, highlighting the influence of host plant species on the developmental biology of *S. litura*. Additionally, the study observed differences in the thermal requirements of *S. litura* stages, with higher values observed on capsicum and tomato compared to castor. The findings of this study provide valuable insights into the thermal requirements of *S. litura*, shedding light on its developmental biology and host plant preferences.

Keywords: Minimum threshold temperature, degree day requirements, developmental biology, capsicum, tomato, castor

Introduction

The tobacco caterpillar, *Spodoptera litura* (Fabricius), is a polyphagous and highly destructive pest that affects a wide variety of wild and cultivated plants (Ahmad *et al*., 2013) [2]. Initially described by Fabricius in 1775, *S. litura* is known by several common names, including the common cutworm and armyworm (Ahmad *et al.*, 2007) [1]. This pest is prevalent throughout tropical and temperate regions of Asia, Australia and the Pacific islands (Monobrulla and Shankar 2008; Noma *et al.*, 2010) [10, 14], causing significant economic damage due to its high reproductive rate and ability to thrive on numerous host plants (Divya 2016; Ahmad *et al*., 2013; Thodsare and Srivastava 2012; Sharma and Bisht 2008) [8, 2, 23, 18]. Notable host plants include capsicum, tomato and castor, making *S. litura* a major concern for agricultural production (Sushilkumar and Ray 2018) [21].

The larvae of *S. litura* cause extensive damage by feeding on the leaves of host plants, which reduces photosynthetic activity and ultimately impacts crop yields (Selvaraj *et al*., 2010) [15]. In the early stages, the larvae feed gregariously and scrape the chlorophyll content of leaf lamina, giving it a papery white appearance. As they grow, the larvae become voracious feeders, creating irregular holes in the leaves and eventually skeletonizing them, leave only veins and petioles. This feeding behavior can lead to significant defoliation and, in severe infestations, complete crop loss.

Climatic factors exert great influence on the development, survival and reproductive capacity of insect pests. Sudden or periodic changes in temperature adversely affect the insect development. Different levels of humidity and rainfall also reduce the population of certain insect species (Prasad and Logiswaran, 1997) [12]. These factors affect the life cycle, propagation and outbreaks of insects to such an extent that they are forced either to adapt themselves to the changing climatic conditions or perish (Pedigo, 2004) [11]. Since insects are ectothermal, the temperature of their body is approximately the same as that of their environment, therefore, temperature play important role in distribution, survival, development, multiplication, overwintering, number of generations per year, abundance, dispersal, migration and behaviour of insects (Bale *et al*., 2002; Sharma, 2010; Arora and Dhawan, 2011 and Arora, 2013) [5, 17, 3, 4]. Moreover, insect development occurs within a specific temperature range thus high temperatures can also affect photosynthesis, respiration, aqueous relations and membrane stability as well as levels of plant hormones, primary and secondary metabolites. Knowledge on biology and ecology of insects is a pre-requisite for pest management methods compatible with Integrated Pest Management and organic pest management which rather than eliminating insect pests aim to manage them. A successful management plan, therefore, requires information about a species biology which includes life cycle, its interaction with the environment, responses to varying temperatures, humidity etc. For developing different methods of protection, it is imperative to know the complete record of the life history parameters such as development, longevity, survivorship and fecundity and a complete life table of the insect on particular host or variety. The developmental biology and life table of species are important components in understanding the population dynamics of a species (Southwood, 1978) [20]. These biological observations are powerful tools for analyzing and understanding the impact of external factors such as temperature on the growth, survival, reproduction and rate of increase of the insect populations (Chi and Su, 2006) [7]. Therefore, the objective of this study was to determine the minimum threshold temperature and degree day requirements for the development of *S. litura* on different host plants under controlled laboratory conditions. By investigating how temperature influences the developmental biology of this pest across various host plants, the study aimed to provide valuable insights that could aid in the development of targeted and sustainable pest control methods.

Material and Methods

Determination of minimum threshold temperature for development

The study to determine the minimum threshold temperature and degree day requirements for the development of *S. litura* on different host plants was conducted in the Vegetable Entomology Laboratory, Department of Entomology, Dr. Y S Parmar University of Horticulture and Forestry, Nauni, Solan, HP, India. The host plants used were capsicum, tomato and castor. Plastic jars (15 cm × 21 cm) covered with muslin cloth were used for studying the biology of *S. litura* and for rearing the insects. Seeds of tomato (*var*. Solan Lalima) and capsicum (*var*. Solan Bharpur) were sourced from the Department of Seed Science and Technology, prepared with soil and farmyard manure in a 1:1 ratio and transplanted into the field at eight weeks old. Standard cultural practices were followed, except for insecticide application and fresh leaves were used in the study. Larvae of *S. litura* were collected from polyhouses and fields and reared in jars under laboratory conditions with fresh castor leaves, changed daily. To prevent microbial infections, leaves were washed with a dilute potassium permanganate solution and air-dried, while jars were cleaned with detergent and air-dried. Larvae were reared for at least two generations on the same host plant species. Larvae ready to pupate were transferred to jars with moist soil for pupation, and pupae were moved to new jars for adult emergence. Newly emerged adults were paired for mating and egg laying in jars with a cotton wick soaked in 10% sucrose solution, and the inner surfaces were lined with filter paper for oviposition. Eggs were collected after 12 hours for use in experiments. The data on biological studies of *S. litura* at different temperatures and different hosts were used to calculate the developmental thresholds and degree day requirements of the pest. The developmental threshold was determined by regressing the rate of development (Y) of *S. litura* on temperature (X) as.

$$Y = a + bX$$

Where:
Y = rate of development which is calculated as, Y = 1/D where D is the duration of development in days.
a = intercept of the equation.
b = slope of the equation.
X = temperature.

The value of temperature corresponding to Y = 0 represents the developmental threshold.
The degree day (DD) requirement was calculated as under.
$DD = 1/b$
Where b is the slope of the equation (as above)

Results and Discussion

Determination the minimum threshold temperature for development of *S. litura*

The lower developmental threshold for a species is the temperature below which the development stops. Lower temperature threshold and thermal constant for *S. litura* were calculated by using linear regression model (Figure 1). Table 1 presents the effect of different host plants on the minimum temperature thresholds and thermal constants of each developmental stage of *S. litura*, along with regression equations and R^2 values.
For the egg stage, the regression equations indicate the relationship between temperature and development rate. The R^2 values, which measure the goodness of fit of the regression model, range from 0.7341 to 0.8744, indicating a relatively strong correlation between temperature and egg development rate. The minimum temperature thresholds for egg development vary across host plants, with values ranging from 12.71 °C to 15.61 °C. Similarly, the thermal constants range from 12.71 to 52.36-degree days, indicating

the amount of heat required for egg development on different host plants. In the larval stage, the regression equations also show significant correlations between temperature and development rate, with R^2 values ranging from 0.9199 to 0.9441. The minimum temperature thresholds for larval development are lower compared to the egg stage, ranging from 7.53 °C to 13.07 °C. The thermal constants for larval development are considerably higher, ranging from 175.44 to 312.5-degree days.

For the pupal stage, the regression equations exhibit strong correlations between temperature and development rate, with R^2 values ranging from 0.9024 to 0.9496. The minimum temperature thresholds for pupal development range from 9.53 °C to 13.54 °C, while the thermal constants range from 93.46 to 181.82-degree days. In the adult stage, the regression equations also show significant correlations between temperature and development rate, with R^2 values ranging from 0.8449 to 0.9522. The minimum temperature thresholds for adult development are the lowest among all stages, ranging from 6.15 °C to 9.42 °C. The thermal constants for adult development are comparatively higher, ranging from 188.67 to 256.41-degree days.

The findings regarding the minimum development thresholds and thermal requirements of *S. litura* across different host plants present interesting insights, corroborated by previous studies and supported by various references. Firstly, in the egg stage, the study concurs with Thakur *et al*. (2017) [22] in identifying a minimum developmental threshold of 11.93 °C on castor, but diverges from earlier reports by Rao *et al*. (1989) [13], Shih & Shih (1995) [19], and Kim *et al*. (1997) [9], who proposed lower thresholds. Notably, the thermal requirement estimated in the present study contrasts with previous findings, suggesting variations in methodologies or environmental conditions. Similarly, discrepancies are noted in larval and pupal stages, with minimum thresholds aligning with some previous studies while conflicting with others. For instance, the larval stage's minimum threshold on castor agrees with Thakur *et al*. (2017) [22] but contradicts their thermal requirement, indicating potential variations in developmental responses. Furthermore, for the adult stage on castor, differences are observed in the minimum development threshold compared to Thakur *et al*. (2017) [22] and Rao *et al*. (1989) [13], indicating varying environmental influences or experimental setups. Such disparities underscore the importance of considering multiple studies for comprehensive insights into insect development dynamics. Additionally, similar trends are observed across host plants, albeit with slightly higher values on tomato and capsicum, possibly attributed to differences in nutritional content. Moreover, the observations align with Bergant *et al*. (2006) [6] regarding the influence of temperature on insect development, emphasizing the significance of degree days in predicting developmental patterns. This underscores the utility of thermal constant requirements in elucidating insect life cycle completion, as highlighted by Selvaraj *et al*. (2020) [16]. The higher thermal requirements on capsicum and tomato compared to castor further underscore the influence of host plant nutrition on insect development, echoing previous findings.

Table 1: Effect of different hosts on minimum temperature thresholds and thermal constants of each development stage of *Spodoptera litura*

Development Stage	Regression equation			R^2 value			Minimum Temperature Threshold ($T_0 = -a/b$) (°C)			Thermal constant K=1/b (Degree days - DD)		
	Castor	Capsicum	Tomato	Castor	Capsicum	Tomato	Castor	Capsicum	Tomato	Castor	Capsicum	Tomato
Egg	y = 0.0393x - 0.6133	y = 0.0191x - 0.2427	y = 0.0195x - 0.255	0.7341	0.8643	0.8744	15.61	12.71	13.08	25.45	52.36	51.28
Larva	y = 0.0057x - 0.0745	y = 0.0032x - 0.0241	y = 0.0036x - 0.0293	0.9274	0.9441	0.9199	13.07	7.53	8.14	175.44	312.5	277.78
Pupa	y = 0.0107x - 0.1449	y = 0.0055x - 0.0524	y = 0.0067x - 0.0734	0.9024	0.9496	0.9261	13.54	9.53	10.96	93.46	181.82	149.25
Adult	y = 0.0039x - 0.024	y = 0.0052x - 0.0414	y = 0.0053x - 0.0499	0.9522	0.8449	0.8816	6.15	7.96	9.42	256.41	192.31	188.67

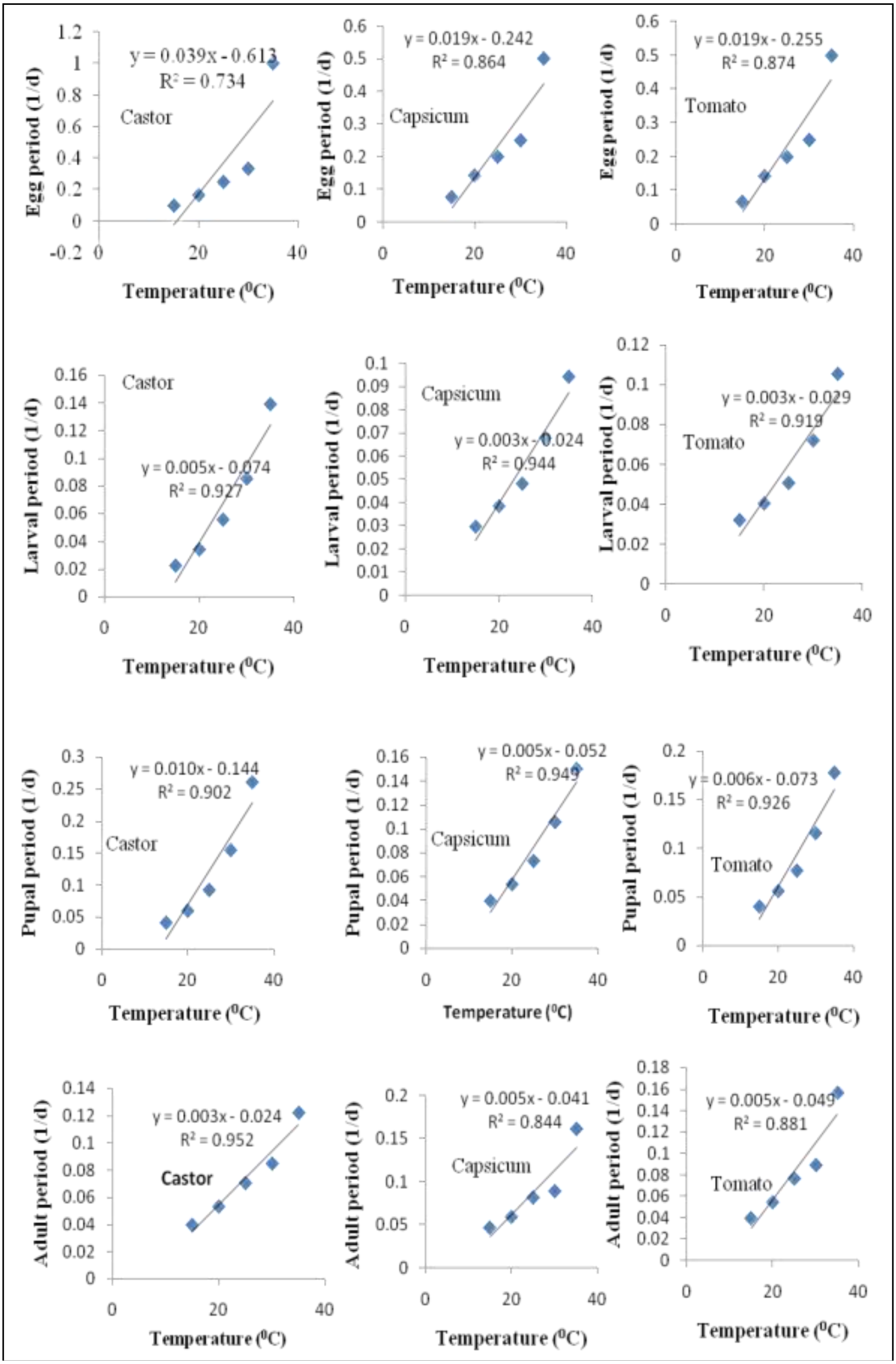

Fig 1: Regression analysis between temperatures and development rate to determine lower development threshold and thermal constant for egg, larval, pupal and adult stages of *S. litura* on castor, capsicum and tomato

Conclusion
The findings, supported by references, offer valuable insights into the temperature-dependent developmental dynamics of *S. litura* across various host plants. The discrepancies observed underscore the need for comprehensive understanding, considering diverse environmental factors and methodological nuances. Such insights are crucial for refining pest management strategies and predicting insect population dynamics accurately.

Declaration
The authors should declare that they do not have any conflict of interest.

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