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RM Sangle
Department of Agricultural Entomology, College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

SS Shetgar
Department of Agricultural Entomology, College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

VG Kharade
Department of Agricultural Entomology, College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

Correspondence
RM Sangle
Department of Agricultural Entomology, College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

Effects of temperature on development of life-stages of pigeon pea pod borer, *Helicoverpa armigera* (Hubner)

RM Sangle, SS Shetgar and VG Kharade

Abstract
Life-stages of *Helicoverpa armigera* (Hubner) were reared on pods of pigeon pea at different temperature levels *viz*., 20, 25, 30 and 35 °C to determine the effect of temperature on their development, oviposition and fecundity. The growth index and the larval duration of *H. armigera* were found to be 2.29, 3.79, 4.93 and 4.98 and 27.22, 19.05, 16.72 and 16.76 days at 20 °C, 25 °C, 30 °C and 35 °C temperature levels, respectively. The net reproductive rate (R_o) of *H. armigera* to the tune of 73.20, 124.17, 118.71 and 91.53 females per female per generation, the mean length of generation time (T) to the extent of 60.97, 45.51, 39.99 and 39.29 days, innate capacity for increase in numbers (r_m) to the tune of 0.0740, 0.0850, 0.1250 and 0.1300 female per female per day were observed at 20 °C, 25 °C, 30 °C and 35 °C temperature, respectively.

Keywords: *Helicoverpa armigera*, biology, temperature level, pigeon pea

Introduction
Helicoverpa armigera is a major insect pest of both field and horticultural crops and knowledge of the temperature-dependent population growth potential is crucial for understanding its population dynamics. The temperature requirements of development are often used for estimating developmental times because temperature has a major effect in determining the rate at which insect develops (Mohite *et al*., 2005) [17]. It is a polyphagous insect-pest which attacks about 181 species of plants belonging to 45 families in India. However, it prefers to feed more on pulses, cotton, vegetables and oilseeds. It causes huge annual losses, especially to the poorest farmers who can not afford chemical control. Damage to pods due to the borer complex was reported to be 20 to 72 per cent (Lateef and Reed, 1983) [14].
The temperature plays a very important role in the development of the pest in different seasons. Temperature influences the rate of growth and development, the duration of life-cycle, the fecundity, and the survival of insect species (Howe 1967, Andrewartha 1970)[11, 2]. A laboratory study on life-fecundity tables of pest illustrates the relationship of development and survival of the life-stages under ideal laboratory conditions (Birch, 1948 and Howe, 1953)[6, 10].
The present study aims to determine the temperature effects on egg incubation period, larval period, pupal period, oviposition period and fecundity of *H. armigera* in the laboratory tests, which would be useful in the predictability of population dynamics.

Materials and Methods
The studies on biology of *H. armigera* (Hubner) were carried out on pigeon pea at four different temperature levles *viz*., 20, 25, 30 and 35˚c (in BOD incubator) in a completely randomized design replicated five times. The pigeon pea was sown in a plot size of 10 m x 10 m at the distance of 60 × 20 cm during *kharif*. The another set of the same host plant was also sown after 15 days of first sowing in order to get continuous supply of fresh pods to the test insect under study at the farm of College of Agriculture, Latur during 2017-18.
The initial culture of *H. armigera* (Hubner) was developed by collecting large number of larvae from the field of pigeon pea and other crops. The collected larvae were reared individually in the round plastic containers by feeding them on pigeon pea pods every day till pupation. The sexes were determined on the basis of distance between genital and anal apertures. It is less in case of male and more in female. The freshly emerged adults were released in the standard oviposition cage of 50 x 30 sq.cm size covered with black muslin cloth

1. One hundred freshly laid eggs of *H. armigera* were obtained from the oviposition cage in order to study the biology on pigeon pea pods at each of four different temperature levels. The eggs were transferred to moist tissue paper kept in petri plates with a total of 20 eggs in each petri plate as one replication. The observations on incubation period and per cent egg hatch were recorded. The newly hatched larvae were reared individually in a clean plastic container on fresh pigeon pea pods.
2. The observations on larval duration, per cent larvae pupated, pre-pupal and pupal durations, per cent adult emergence and life-cycle duration of male and female moths were recorded on pigeon pea pods at four different temperature levels. The growth index was calculated by using Howes (1953) [10] formula.

$$\text{Growth index} = \frac{\text{Per cent larvae pupated}}{\text{Mean larval duration (days)}}$$

Results and Discussion

Egg

The data presented in Table 1 revealed that the incubation period of *H. armigera* was varied significantly when reared on pigeon pea pods at different temperature levels. The significantly shorter incubation period of *H. armigera* to the extent of 2.74 days was recorded when grown on pigeon pea at 35 ^{0}C temperature over at 30 ^{0}C (3.61 days), 25 ^{0}C (4.44 days) and 20 ^{0}C (4.54 days) temperatures. It seems from the present investigation that the incubation period of *H. armigera* was extended when grown on pigeon pea at 20 ^{0}C temperature.

The incubation period of *H. armigera* was observed to be 5, 4, 3 and 2 days on tomato when reared at 20 ^{0}C, 25 ^{0}C, 30 ^{0}C and 35 °C temperatures (Sharma and Chaudhary, 1988)[21], 6, 5.4, 3.4 and 2.6 days on gram when reared at 15 °C, 20 °C, 25°C and 30 °C temperatures, respectively (Tiwari and Rahalkar, 2005) [23], 4 days on pigeon pea, groundnut and cotton and 5 days on tomato, gram, cabbage and potato (Anonymous, 1990) [3]. Mohite *et al.* (2011) [16] reported that duration of egg stage was increased (10.9 ± 0.72 days) at 15 °C and decreased (2.5 ± 0.19 days) at 30 °C on chickpea in Maharashtra. The results in respect of incubation period of *H. armigera* grown on pigeon pea pods at different temperature levels are in conformity with the results reported by above referred research workers.

Table 1: The mean incubation period, per cent egg hatch, mean larval duration, and growth index of *H. armigera* on pigeon pea pods at different temperature levels

Temperature levels	Mean incubation period	Per cent egg hatch	Mean larval duration (Days)	Growth index
20 ^{0}C	4.54	71.00 (57.42)	27.22	2.29
25 ^{0}C	4.44	94.30 (76.19)	19.05	3.79
30 ^{0}C	3.61	95.85 (78.25)	16.72	4..93
35 ^{0}C	2.74	88.80 (70.45)	16.76	4.98
S.E +	0.09	1.34	0.01	0.01
C.D at 5 %	0.27	3.98	0.03	0.03
C.V. (%)	3.87	3.44	0.09	0.50

Figures in parentheses indicate arcsine transformed values.

The significantly highest egg hatching of *H. armigera* to the tune of 95.85 per cent was observed on pigeon pea pods at 30 ^{0}C temperature over 20 ^{0}C temperature (71.00 per cent), 25 ^{0}C temperature (94.30 per cent) and 35 ^{0}C temperature (88.80 per cent). This indicates that egg hatching was adversely affected when grown on pigeonpea at 20 ^{0}C temperature. More or less similar results were also observed by Sharma and Chaudhary (1988) [21]. According to them, egg hatchability of *H. armigera* was observed to be 84.2 per cent at 35 °C and 63.1 per cent at 20 °C.

Larva

Effect of different temperature levels on larval duration of *H. armigera* are presented in Table 2. The significantly longer larval duration of *H. armigera* (27.22 days) was observed on pigeon pea pods at 20 ^{0}C temperature followed by 19.05 days at 25 ^{0}C temperature, 16.76 days at 35 ^{0}C temperature and 16.72 days at 30 ^{0}C temperature. This indicates that the significantly shortest larval duration was observed at 30 ^{0}C (16.72 days). Kumari (1999) [13] reported variations in larval duration of *H. armigera* to the tune of 30.23, 25.38, 20.13 and 18.76 days at 23, 27, 31, and 35 ^{0}C, respectively. Mohite *et al.* (2011) [16] observed larval duration of *H. armigera* to the extent of 48.2 ± 3.89 days at 15 °C to 11.5 ± 0.63 days at 30 °C on chickpea. Patel *et al.* (1968) [19] reported that the larval duration of *H. armigera* to the extent of 20.7 days was recorded when reared on artificial diet at 26.7 °C. The larval period of *H. armigera* on gram was observed to be maximum (35.40 days) at 15 °C temperature followed by 30.00 days at 20 °C temperature, 19.20 days at 25 °C temperature and 14.80 days at 30 °C temperature (Tiwari and Rahalkar, 2005) [23]. The results in respect of larval duration of *H. armigera* at different temperature levels are in conformity with the results reported by above referred research workers.

Effect of different temperature levels on growth index of *H. armigera* are presented in Table 1. The significantly lowest growth index of *H. armigera* was recorded on pigeon pea pods at 20 ^{0}C temperature (2.29) over 25 ^{0}C temperature (3.79), 30 ^{0}C temperature (4.93) and 35 ^{0}C temperature (4.98). This indicates that growth index was highest when grown at 35 ^{0}C temperature. The larval growth of *H. armigera* was observed to be best on alfa-alfa with 6.66 growth index and poorest on bean with growth index of 4.08 (Bilapate and Raodeo, 1977) [5].

The data on larval instar duration of *H. armigera* on pigeon pea pods at different temperature levels are presented in Table 2.

Table 2: The mean larval instars duration of *H. armigera* on pigeon pea pods at different temperature levels

Temperature levels	Larval instars						Total	Mean
	I	II	III	IV	V	VI		
20 ^{0}C	4.25	4.43	2.83	4.02	8.63	3.05	27.21	4.53
25 ^{0}C	3.44	2.47	2.03	2.40	5.40	3.29	19.04	3.17
30 ^{0}C	2.40	2.01	2.01	3.11	4.08	3.11	16.72	2.79
35 ^{0}C	2.40	2.05	2.05	1.52	4.37	4.37	16.76	2.79
S.E. +	0.09	0.06	0.05	0.07	0.06	0.06	-	-
C.D. at 5%	0.26	0.18	0.16	0.20	0.19	0.19	-	-
C.V. (%)	4.53	4.85	5.75	5.22	2.57	4.86	-	-

It is evident from Table 2 that the *H. armigera* passed through six larval instars when reared on pigeon pea pods at different temperature levels. The duration of I, II, III, IV, V and VI larval instars ranged from 2.40 to 4.25, 2.01 to 4.43, 2.01 to 2.83, 1.52 to 4.02, 4.08 to 8.63 and 3.05 to 4.37 days, respectively at 20 ^{0}C, 25 ^{0}C, 30 ^{0}C and 35 ^{0}C different temperature levels. Each larval instar duration differed significantly when grown on pigeon pea pods at 20 ^{0}C, 25 ^{0}C, 30 ^{0}C and 35 ^{0}C temperature. In general instar duration at lower temperature was longer and at higher temperature it was shorter.

Ali *et al*. (2009) [1] revealed that larval period of *H. armigera* was completed through six instars and the average durations of first, second, third, fourth, fifth and sixth instar larvae were 2.27, 2.42, 2.67, 2.83, 3.40 and 3.37 days, respectively when reared on chickpea at 25ºC temperature and 65 per cent relative humidity. Goyal and Rathore (1988) [9] reported 6 larval instars of *H. armigera* on pigeonpea, cotton, tomato, gram, linseed and pea with larval period varying from 10.10 to 17.84 days.

Pupa

Effect of different temperature levels on per cent larvae pupated, pre-pupal and pupal duration of *H. armigera* on pigeon pea pods are presented in Table 3.

Table 3: The per cent larvae pupated, pre-pupal and pupal duration of *H. armigera* on pigeonpea pods at different temperature levels

Temperature Levels	Per cent larvae Pupated	Pre-pupal duration (days)	Pupal duration (days)
20 ^{0}C	62.38 (52.17)	2.11	20.82
25 ^{0}C	72.21 (58.19)	1.45	12.24
30 ^{0}C	82.55 (65.31)	1.53	9.24
35 ^{0}C	83.63 (70.45)	1.24	8.48
S.E. $\pm$	1.12	0.04	0.04
C.D. at 5 %	3.38	0.13	0.14
C.V. (%)	3.34	5.02	0.65

Figures in parentheses indicate arcsine transformed values.

The data (Table 3) indicated that the significantly lowest pupation of *H. armigera* was recorded on pigeon pea pods at 20 ^{0}C temperature (62.38 per cent) followed by 25 ^{0}C temperature (72.21 per cent), 30 ^{0}C temperature (82.55 per cent) and 35 ^{0}C temperature (83.63 per cent). `The significantly shortest pre-pupal and pupal durations of *H. armigera* to the extent of 1.24 and 8.48 days, respectively were recorded on pigeon pea pods at 35 ^{0}C temperature followed by 30 ^{0}C temperature (1.53 and 9.24 days) and 25 ^{0}C temperature (1.45 and 12.24 days) While, these were highest at 20 ^{0}C temperature (2.11 and 20.82 days). The pre-pupal durations recorded at 25 ^{0}C and 30 ^{0}C temperatures were at par with each other. While pupal durations observed at 4 different temperature levels were significantly superior over each other.

Sharma and Chaudhary (1988) [21] reported that the pupal duration of *H. armigera* was found to be 23.8, 16.5, 9.6 and 8.4 days at 20, 25, 30 and 35 °C, respectively. Dhandapani and Balasubramanian (1980) [8] reported that mean pupal duration of *H. armigera* varied from 13.5 days on sorghum to 12.5 days on red gram at 26±2 °C. Bartekova and Prasclika (2006) [4] concluded that pupal duration of *H. armigera* varied from 18.4 days at 20 °C to 14.07 days at 25 °C and 10.1 days at 30 °C. Mohite *et al.* (2011) [16] observed the pupal duration to the extent of 44.3±3.3 days at 15 °C to 9.6 ± 0.33 days at 30 °C. The pupal period of *H. armigera* was found to be reduced to 9.40 days at 30 °C as compared to 14.00, 19.00 and 24.60 days at 25 °C, 20 °C and 15 °C temperatures, respectively (Tiwari and Rahalkar, 2005) [23]. The pupal duration averaged 13.5, 11.1, 9.4 and 9.00 days when larvae fed on tomato fruit at 25.0 °C, 27.9°C, 30.5 °C and 32.5 °C, respectively (Jallow and Matsumura, 2001) [12]. The results in respect of pupal duration of *H. armigera* on pigeonpea at different temperature levels in the present investigation are in good line with the results reported by above referred research workers.

Adult

The data presented in Table 4 revealed that the significantly highest per cent adult emergence was observed in the case of 25 °C temperature (75.35 per cent) followed by 30 °C temperature (72.41 per cent), 35 °C temperature (71.22 per cent) and 20 °C temperature (65.39 per cent). It also revealed that statistically significant differences were observed in respect of longivity of male and female *H. armigera* when reared on pigeon pea pods at different temperature levels. The significantly highest longivity of male and female *H. armigera* was recorded on pigeon pea at 20 °C temperature (12.27 and 14.22 days). It was followed by the longivity of male and female on pigeon pea pods at 25 °C temperature

(10.33 and 11.61 days), 30 °C temperature (9.71 and 11.26 days) and 35 °C temperature (9.28 and 10.42 days). However, the longivity of male and female recorded at 30 °C and 35 °C temperature and 25 °C and 30 °C temperature, respectively where at par with each other.

Table 4: The per cent adult emergence, life-cycle duration and longevity of *H. armigera* on pigeon pea pods at different temperature levels

Temperature levels	Per cent adult emergence	Adult longevity (Days)		Life-cycle duration (Days)	
		Male	Female	Male	Female
20 ^{0}C	65.39 (53.96)	12.27	14.22	66.95	68.91
25 ^{0}C	75.35 (60.23)	10.33	11.61	47.53	48.44
30 ^{0}C	72.41 (58.31)	9.71	11.26	40.82	41.52
35 ^{0}C	71.22 (66.13)	9.28	10.42	38.49	40.83
S.E +	0.49	0.17	0.20	0.02	0.01
C.D at 5%	1.49	0.51	0.59	0.07	0.03
C.V. (%)	1.55	3.65	3.68	0.10	0.04

Figures in parentheses indicate arcsine transformed values.

According to Rosaiah and Reddy (1999) [20], the adult longevity of male and female *H. armigera* was 6.5, 8.5 and 8.7 days and 7.2, 9.3 and 12.8 days in summer, rainy and winter seasons under temperature conditions of 33.70 °C, 29.26 °C and 24.04 °C, respectively, in Andhra Pradesh. Ongoren *et al.* (1977) [18] reported that the adult life span was about 10.6 and 7.2 days in females and 7.6 and 6.9 days in males at 22 and 28 °C, respectively in Turkey. The longevity of male and female *H. armigera* was observed to be 5 to 9 and 10 to 14 days on pigeon pea, cotton, tomato, gram, linseed and pea (Goyal and Rathore, 1988) [9] and 7.7, 5.7, 6.6 and 5.8 and 11.2, 9.5, 9.9 and 9.6 days on chickpea, sweet pea, pigeonepa and lentil, respectively (Choudhary *et al.*, 1993) [7].

The life-cycle duration of male and female *H. armigera* recorded on pigeon pea pods at four different temperature levels were significantly superior over each other. Significantly the shortest life-cycle duration of male and female *H. armigera* to the extent of 38.49 and 40.83 days was observed on pigeon pea pods at 35 °C temperature followed by life-cycle duration of the male and female *H. armigera* on pigeon pea pods at 30 °C temperature (40.82 and 41.52 days) and 25 °C temperature (47.53 and 48.44 days) while, it was longest (66.95 and 68.91 days) when grown at 20 °C temperature.

It indicates from the present investigation on biology of *H. armigera* grown on pigeon pea pods at different temperature levels that the durations of different life-stages were extremely extended when grown on pigeon pea pods at 20 °C temperature as compared to their durations when grown on pigeon pea pods at 25 °C temperature and 30 °C temperature while it was shortened when grown at 35 °C temperature.

The data in respect of mean pre-oviposition and ovipositon period and fecundity of *H. armigera* on pigeon pea pods at different temperature levels are presented in Table 5.

Table 5: The pre-oviposition, oviposition and fecundity per female of *H. armigera* on pigeon pea pods at different temperature levels

Temperature Levels	Fecundity	Pre-oviposition period (days)	Oviposition period (days)
20 ^{0}C	427.40 (20.69)	3.22	12.51
25 ^{0}C	1000.31 (31.64)	1.55	14.52
30 ^{0}C	649.40 (25.49)	1.26	11.28
35 ^{0}C	417.20 (20.44)	2.24	4.54
S.E. $\pm$	9.59	0.04	0.06
C.D. at 5 %	N. S.	0.11	0.17
C.V. (%)	3.44	3.82	1.15

Figures in parentheses indicate square root transformed values.

It is evident from Table 5 that significantly highest pre-ovipositon period of *H. armigera* to the extant of 3.22 days was observed on pigeon pea pods at 20 °C temperature over at 25 °C temperature (1.55 days), 30 °C temperature (1.26 days) and 35 °C temperature (2.24 days). However, the highest oviposition period to the tune of 14.52 days was recorded on pigeon pea pods at 25 °C temperature over 20 °C temperature (12.51 days), 30 °C temperature (11.28 days) and 35 °C temperature (4.54 days). It indicates that 25 °C temperature was found to be suitable for ovipostition.

Rosaiah and Reddy (1999) [20] observed that the pre-reproductive period of *H. armigera* was 2.6, 2.9 and 3.5 days in summer, rainy and winter season at mean temperature of 33.70 °C, 29.26 °C and 24.04 °C in Andhra Pradesh. Dhandapani and Balasubramanian (1980) [8] recorded the pre-oviposition period of *H. armigera* to the extent of 2.7, 3.2, 3.4, 3.3 and 3.0 on bengal gram, pigeonpea, tomato, sorghum and sunflower, respectively.

Singh and Singh (1975) [22] reported that oviposition period of *H. armigera* was 2.28±0.38 days at minimum and maximum temperatures of 31.13±1.57 °C and 32.35±1 °C, respectively. Mironidis and Soultani (2008) [15] reported that at constant temperatures oviposition period varied from 13.5 days at 15 °C to 4.71 days at 35 °C temperature. Mohite *et al.* (2011) [16] observed that the oviposition period ranged from 8.8 ± 1.27 days at 15 °C to 3.6 ± 0.33 days at 30 °C.

Numerically the highest fecundity of *H. armigera* to the tune of 1000.31 eggs per female was recorded when grown on pigeon pea pods at 25 °C temperature followed by 30 °C temperature (649.40 eggs per female), 20 °C temperature (427.40 eggs per female) and lowest at 35 °C temperature (417.20 eggs per female).

Dhandapani and Balasubramanian (1980) [8] reported that mean number of eggs per female varied from 781 eggs on maize to 387 eggs on tomato at 26±2 °C. Kumari (1999) [13] observed that average number of eggs laid per female at various temperatures (23 °C to 35 °C) ranged between 0 and 936.8, the maximum being at 27 °C and the females failed to lay eggs at 35 °C. Mironidis and Soultani (2008) [15] reported that fecundity per female of *H. armigera* was 101.9, 309.15,

433.93, 1007.69, 794.79, 695.80, 140.09 and 92.15 at constant temperatures of 15, 17.5, 20, 25, 27.5, 30, 32.5, and 35 °C, respectively.

Conclusion

In conclusion it is to state that in the present investigation, 30 ^{0}C temperature scored the highest point of overall suitability of temperature (206) followed by 35 ^{0}C temperature (205), 25 ^{0}C temperature (194) and 20 ^{0}C temperature (177). Net reproductive rate, per cent adult emergence and oviposition period Hence, from the development point of view excepting fecundity, net reproductive rate, per cent adult emergence and oviposition period, 30 ^{0}C temperature was the most suitable temperature for *H. armigera* as compared to 20 ^{0}C, 25 ^{0}C and 35 ^{0}C temperatures.

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