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Influence of temperature on Survival and Development of *Helicoverpa armigera* (Hubner)

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ABSTRACT

To determine the effect of temperature on survival and development of *H. armigera* five different temperatures (18, 21, 25, 29 and 31 ^{0}C) was investigated. The results showed that higher survivorship was recorded at 25 ^{0}C (35.00) followed by 29 ^{0}C (28.33) and 18 ^{0}C (13.15). The results also showed that the duration of development of *H. armigera* decreased as the temperature increased from 18 ^{0}C to 31 ^{0}C. About 100 per cent of mature larvae stopped pupating at 31 ^{0}C. The results indicated that the optimum growth temperature of *H. armigera* was about 25 ^{0}C. The percentages of larvae at first, second, third, fourth, fifth, prepupal, pupal stage different at the different temperatures. The percentage of firs t instar (41.66), 2nd instar (31.66), 3rd instar (31.66), 4th instar (31.66), 5th instar (31.66), prepupal stage (31.66) and pupa formation (31.66) was higher at 25 ^{0}C. However, the percentage of adult emergence was higher at 29 ^{0}C (25.00) followed by 25 ^{0}C (21.66).

Key words: *Helicoverpa armigera, Temperature, Survival, Development, Artificial diet*

Introduction

Helicoverpa armigera (Hubner) (Lepidoptera: Noctuidae) is a major insect pest of both field and horticultural crops in many parts of the world (Zalucki *et al.*, 1986 and Fitt, 1989). The species is becoming increasingly important as a major pest of many agricultural crops (Hamamura, 1998). Knowledge of developmental times of the life history stages of *H. armigera* is an important prerequisite to an understanding of the population dynamics of this pest in the field. The thermal requirements of development are often used for estimating developmental times because temperature has a major effect in determining the rate at which the insects develop (Zaslavski, 1988). Pest biology, distribution and abundance are largely, influenced by the relationship between the temperature and the development rate (Tobin *et al.*, 2003). Since the development of insects occurs within a specific temperature range, a change in temperature will, therefore influence the development rate, the duration of the life cycle and ultimately survival (Howe, 1967). An increase in ambient temperature to near the thermal optimum of insects cause an increase in their metabolism and therefore also their activity (Jaworski and Hilizczanski, 2013). The thermal optimum is the temperature at which a species develops, reproduces and survives optimally. Temperature lower or higher than the optimum temperature lead to a decrease in the development rate (Begon *et al.*, 2006). Temperature influences the duration of each instar, as well as the number of instars that larvae go through before reaching the adult stage (Aguilon and Velasco, 2015). A faster development rate can be advantageous to insects since it results in less time spent in vulnerable stages during which they can be attacked by predators, parasitoids and entomopathogens (Jaworski and Hilizczanski, 2013). Knowing seasonality, phenology and number of generations of a target pest is crucial to practice effective pest management; the knowledge tells, for example, the optimal timing and duration of pesticide application, improving the pest control strategy. The seasonality, phenology and number of generations are affected by a number of abiotic and biotic factors but ambient temperature is among the most important factors (Kiritani, 1997). This is because temperature is a primary determinant influencing the rate of development of insects (Honck and Kocourek, 1990). Temperature is also significant factor affecting the survival and size of insects, which can directly and indirectly impact their population dynamics (Kiritani, 2006). Examing the effects of temperature on the survival, development is thus the primary step in pest research. The status of pest species is, therefore affected by changes in climate and weather. It is therefore important that the effect of temperature on the development of target insect species under the current changing climatic conditions is known since this will contribute risk analysis, forecasting and management strategies in order to minimize pest infestation levels (Porter *et al*.1991).

Many studies in fact have investigated the relationship between temperature and development of *H. armigera* (Mironidis, 2014). The purpose of this study was to investigate the effects of constant temperature on the development and survival of the immature stages of *H. armigera* in laboratory conditions, the number of degree days required for each stage to complete development as well as the degree days required for larva to adult development.

Materials and Methods

The experiment was conducted in the IPM laboratory of Department of Entomology, Punjab Agricultural University, Ludhiana. The larvae of *H. armigera* were reared on artificial diet. The various ingredients of diet viz. 165g gram flour, 2.48g methyl1-4hydroxybenzoate, 1.28g sorbic acid, 0.15g cysteine, 4.125g ascorbic acid, 0.37g streptocyclin, a pinch of vitamin mixture, 2.55 ml formaldehyde solution, 5.25 ml linceed oil, a drop of vitamin E were added to 400 ml water in a large bowl and mixed thoroughly. Active dried yeast (39.75g) was added after that 12.75g agar agar was added slowly and heated until complete uniform melting without the formation of clots. The larvae of *H. armigera* were collected from the fields and reared on artificial synthetic diet. Male and female adults were kept in adult rearing cage. Honey solution provided as a feed. Eggs were collected from the cage after 3rd day onwards and allowed to hatch freshly hatched neonate larvae were transferred to containers (25 ml capacity) having freshly prepared above mentioned experimental diet. Each container having one larva. Growth and development studies were conducted in a BOD incubator at 18,21,25,29 and 31 ^{0}C. Six replications were maintained for each treatment. Observations on the biological parameters of the larvae viz. larval period, pupal period and adult emergence were recorded. The observations were recorded at 24hours interval. The observations on the per cent mortality of neonates, 1st instar and 2nd instar larval development, per cent pupation and adult emergence of larvae of *H. armigera* were recorded. In this study, survival rate and development duration of each growth stage were recorded. The survival rate was calculated as:

$$S = \frac{N1}{N2}$$

S is survival rate, N1 is the number of insects that progressed into the next developmental stage and N2 is the number of is the number of insects in the previous developmental stage.

Results and Discussion

The effect of temperature on *Helicoverpa armigera* survival

The data presented in Table 1 revealed that after three day of release of neonates of *H. armigera* on artificial diet at different temperatures, significantly higher survivorship was recorded at 18^{o}C (100.00) followed by 25 ^{o}C (95.00) and 21 ^{o}C (94.73) as compared to other temperatures. After 5 day of release of *H. armigera* the per cent survivorship was significantly higher at 21 ^{o}C (84.21) followed by 18 ^{o}C (78.94) and 25 ^{o}C (51.66). After 10 day of release the per cent survivorship was significantly higher at 18 ^{o}C (73.68) followed by 21 ^{o}C (71.05). After 15 day of release of *H. armigera* higher survivorship was recorded at 18 ^{o}C (44.73) followed by 25 ^{o}C, 29 ^{o}C, 31^{o}C (40.00 each) being at par with each other. Similarly, after 24 days of release of *H. armigera* higher survivorship was recorded at 25^{o}C (35.00) followed by 31^{o}C (33.33) however, the data were statistically non significant. After 30 day of release of *H. armigera* on different temperatures the per cent survivorship was significantly higher at 25 °C (35.00) followed by 29 °C (28.33) and 18 °C (18.42) as compared to other temperatures. Similarly, after 35 day of release of *H. armigera* significantly higher survivorship was observed at 25 °C (35.00) followed by 29 °C (28.33) and18 °C (13.15). After 45 day of release of *H. armigera* significantly higher survivorship was observed at 25 °C (31.66) followed by 29 °C (26.66) and 18 °C (10.52). Similarly, according to Virachack *et al*. (2018) survivals of *H. armigera* from larval hatching to adult emergence from the pupa were lower under lower temperature. The duration of the developmental stages decreased as temperature increased from 20°C to 30°C. According to Mironidis and Savopaulau (2008) the survival rates of the total immature stage (egg to adult emergence) differed slightly between constant and corresponding alternating temperature regimes at the low and moderate temperatures (20-27.5 °C). However, at higher mean temperature (30 and 32.5 °C), alternating conditions were more favourable than constant ones for survival. Survival of the immature stages was significantly different among the temperature regimes. High alternating temperature regimes increased total survival rate in relation to mean constant of 30 and 32.5 °C**.** Over a wide constant thermal range, 15-27.5 °C, total survival is stable and apparently not affected by temperature. Below 15°C, survival decreased rapidly reaching zero at 12.5 °C**.** At warmer temperature, survival also decreased very quickly above 28 °C and fell to zero at 40 °C. Similarly, according to Dhileepan *et al*. (2005) the survival rate of *Aconophora compressa* (Walker) at alternating temperatures was higher than that at constant temperatures, but the general trend of lower survival at higher temperatures was similar.

Development of *Helicoverpa armigera* under different temperature conditions

At constant temperature, the developmental times of *H. armigera* decreased as temperature increased up to 31 °C. The total developmental time of first instar was longer at 18 °C (7.67±1.97) and shorter at constant 29 °C and 31°C (3.00 ±0.62) (Table 2). The developmental times of second instar was longer at 18°C (3.67±1.35) followed by 25°C (1.50±0.31) days. However, the developmental times of 3rd instar was longer at 18°C (7.75±5.56) followed by 31 °C (3.50±0.51) and 29 °C (3.17±0.43) days. The results were in accordance with Plessis *et al*. (2020) the developmental times of *Spodoptera frugiperda* (first instar, second instar, third instar, fourth instar, fifth instar, sixth instar were significantly longer at a constant temperature of 18°C compared to 22,26,30,3 2 °C . Mortality of larvae at 18 °C was also very high 70 per cent indicating that a constant temperature of 18 °C was not suitable for the development of S. frugiperda larvae. The developmental times of 4th instar was longer at 18 °C (7.00±1.22) followed by 21 °C (6.70±0.27) and 25 °C (5.33±0.73) days. Similarly, the developmental times of 5th instar was longer at 18 °C (6.25±0.89) followed by 25 °C (5.67±0.90) days. Prepupal stage duration was longer at 21 °C (7.75±0.21) followed by 18 °C (4.25±0.54) days. No prepupal stage was observed at 31 °C. Pupa formation duration was longer at 21 °C (5.50±0.25) followed by 25 °C (3.00±0.31) days. Similarly, accord-

Table 1. Survival of *Helicoverpa armigera* at different temperatures

Temperature	Per cent (Survival)										
	Days after treatment										
	3	5	10	15	17	21	24	30	35	40	45
18°C	100.00 (89.96)	78.94 (62.72)	73.68 (59.13)	44.73	36.84	28.94	26.31	18.42 (24.82)	13.15 (21.16)	10.52 (18.56)	10.52 (18.56)
21°C	94.73 (77.47)	84.21 (66.66)	71.05 (57.46)	31.57	26.31	21.05	21.04	7.89 (16.11)	5.26 (13.09)	2.63 (8.76)	2.63 (8.76)
25°C	95.00 (79.51)	51.66 (45.93)	41.66 (40.17)	40.00	38.33	35.00	35.00	35.00 (36.22)	35.00 (36.22)	35.00 (36.22)	31.66 (34.04)
29°C	85.00 (67.37)	50.00 (44.98)	40.00 (39.13)	40.00	33.33	28.33	28.33	28.33 (31.90)	28.33 (31.90)	26.66 (30.80)	26.66 (30.80)
31°C	80.00 (63.52)	50.00 (44.98)	40.00 (39.13)	40.00	40.00	40.00	33.33	18.33 (24.75)	16.66 (23.36)	10.00 (18.04)	6.66 (14.46)
CD (P=0.05)	(6.51)	(7.70)	(7.50)	NS	NS	NS	NS	(4.39)	(9.64)	(8.75)	(9.78)

ing to Bartekova and Praslicka (2006) on average, the pupal stage took 10-15 days, i.e. 18.4 days at 20 ^{0}C, 14.07 days at 25 ^{0}C and 10.1 days at 30 ^{0}C. But according to Matlak (1995) the cotton bollworm pupal stage lasts 14 days in natural conditions. Adult emergence duration was longer at 25 ^{0}C (14.67±0.18) followed by 18 ^{0}C (13.25±0.41) days. But according to Bartekova and Praslicka (2006) the duration of larval development of cotton bollworm *H. armigera* was 39.3 days at 20 ^{0}C, 24.57 days at 25 ^{0}C and 18.27 days at 30 ^{0}C. However, according to Vlckova (2000) the larval development stage last 3 days at 25 ^{0}C and 10-11 days in colder weather. Similarly, Wang *et al*. (2013) studied the effect of temperature on the development of *Laodelphax striatellus* (Homoptera : Delphacidae). The estimate of lower developmental thresholds of eggs (10.0 ^{0}C**)** was different from that of nymphs (7.5 ^{0}C) and the estimate of upper developmental thresholds of eggs (35.5 ^{0}C) was also different from that of nymphs (30.2 ^{0}C). However, for male and female nymphs, the difference in the lower development threshold is non-significant and the difference in the upper developmental thresholds is very small. According to Jallow and Matsumura (2001) *H. armigera* larval development itself takes two months at 13.3 ^{0}C (4th instar at about 45 to 48 days) and 11 days a 32.5 ^{0}C (4th instar a about 8 to 8.5 days). Negative association between developmental period of the *Campoletis chlorideae* and temperature has also been reported by Teggelli *et al*. (2004). A decrease in development period of immature stages of *Pnigalio pectinicarnis* L. has been observed on citus leaf miner, *Phyllocnistis citrella* Stainton with an increase in temperature from 15 to 30^{0}C (Kalaitzaki *et al*., 2007).

The effect of temperature on survival rates of different stages of *Helicoverpa armigera* at different temperatures

The effects of temperature on the survival rates of different instars of *H. armigera* varied at different developmental stages. Larvae at the 1st and last instar stages were more susceptible to the influence of temperature. The survival rate of 1st instar larvae was 23.68, 21.05, 41.66, 38.33 and 40.00 per cent at 18, 21, 25, 29,31^{0}C, respectively (Figure 1). Similarly, the survival rate of 2nd instar larvae was 21.05, 13.15, 31.66, 25.00 and 30.00 per cent. The survival rate of 3rd instar larvae was 13.15, 7.89, 31.66, 25.00 and 30.00 per cent. Similarly, the survival rate of 4th instar was 10.52, 2.63, 31.66, 25.00 and 20.00 per cent. The survival rate of 5th instar was 10.52, 2.63, 31.66, 25.00 and 16.66 per cent. Similarly, the survival rate of prepupal stage was 10.52, 2.63, 31.66, 25 and 10.00 per cent. At 31 ^{0}C, mature larvae stopped pupating. Similarly, no adult emergence was recorded at 31 ^{0}C. The results are in line with Li *et al*. (2013) who studied the effects of temperature at different developmental stages of *Athetis lepigone*. According to them larvae at the 1st and last instar stages were more susceptible to the influence of temperature. The survival rate of 1st instar larvae was 20.56, 50.48 and 62.49 per cent at 18, 21 and 30 ^{0}C respectively. Survival rates increased to over 95 per cent when the

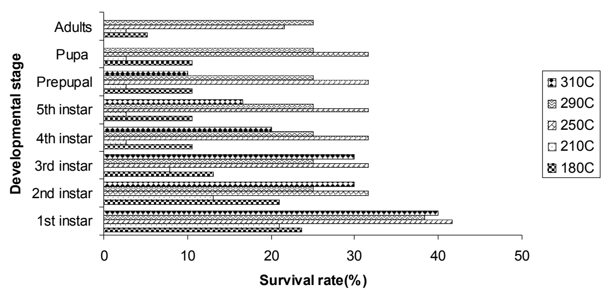

Fig. 1. Survival rates of *Helicoverpa armigera* at different temperatures

Table 2. Development duration of *Helicoverpa armigera* at different temperatures

Development stage	Developmental duration (days)				
	18 ^{0}C	21 ^{0}C	25 ^{0}C	29 ^{0}C	31 ^{0}C
1st instar	7.67±1.97	3.33±0.45	3.33±0.45	3.00±0.62	3.00±0.62
2nd instar	3.67±1.35	1.25±0.21	1.50±0.31	1.17±0.15	1.17±0.15
3rd instar	7.75±5.56	1.50±0.35	1.40±0.21	3.17±0.43	3.50±0.51
4th instar	7.00±1.22	6.70±0.27	5.33±0.73	3.33±0.30	4.17±0.27
5th instar	6.25±0.89	2.66±0.27	5.67±0.90	3.50±0.56	4.00±0.5
Prepupal stage	4.25±0.54	7.75±0.21	3.42±0.34	2.16±0.27	0.00±0.0
Pupa formation	2.00±0.35	5.50±0.25	3.00±0.31	1.50±0.25	0.00±0.0
Adult emergence	13.25±0.41	10.50±0.25	14.67±0.18	11.20±0.64	0.00±0.0

temperatures were 24 and 27 ^{0}C.At 18 ^{0}C mature larvae stopped pupating.

Conclusion

Thus, the present studies suggest that the change in temperature is likely to affect the growth and development of *H. armigera* resulting in considerable influence on the survival and development of *H. armigera*. Temperature thresholds determined in this study, can be used as parameters to model areas that are suitable for predicting the potential distribution and permanent establishment of *H. armigera.* The optimum range for larval to adult development of *H. armigera* was between 25 ^{0}C and 29 ^{0}C. This indicates that *H. armigera* populations will not develop and persist in geographical region where temperatures decrease to below these levels and increase to above these levels during winter and summer months.

References

Aguilon, D.J.D. and Velasco, L.R.I. 2015. Effects of larval rearing temperature and host plant condition on the development, survival and coloration of African armyworm *Spodoptera exempta* walker (Lepidoptera: Noctuidae). *J. Environ. Sci. Manag.* 18: 54-60.

Bartelova, A. and Praslicka, J. 2006 The effect of ambient temperature on the development of cotton bollworm *Helicoverpa armigera* (Hubner, 1808). *Plant Protection Science*. 42: 135-138.

Begon, M., Townsend, C.R. and Harper, J.L. 2006 *Ecology From Individuals To Ecosystems;* Blackwell Publishing Ltd: Oxford UK, 3: 30-57.

Dhileepan, K. Trevino, M. and Raghu, S. 2005 Effects of temperature on the survival on the survival of *Aconophora compressa* Walker (Hemiptera: Membracidae): implications for weed biocontrol. *Australian Journal of Entomology*. 44: 457-462.

Fitt, G.P. 1989. The ecology of heliothis in relation to agroecosystems. *Annual Review of Entomology.* 34: 17-52.

Hamamura, T. 1998 Recent occurrence and injury of *Heliothis armigera* from a questionnaire investigation. *Plant Protection*. 52: 407-413.

Honek, A. and Kocourek, F. 1990 Temperature and development time in insects. A general relationship between thermal constants. *Zool. Jb. Syst*. 117: 401-439.

Howe, R.N. 1967 Temperature effects on embryonic development in insects. *Annu. Rev. Entomol.* 12: 15-42.

Jallow, M.F.A. and Matsumura, M. 2001 Influence of temperature on the rate of development of *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae). *Applied Entomology and Zoology.* 36: 427-430.

Jaworski, T. and Hilszczanski, J. 2013. The effect of temperature and humidity changes on insect development and their impact on forest ecosystems in the context of expected climate change. *For. Res.Pap*. 74: 345-355.

Kalaitzaki, A.P., Lykouressis, D.P.,Perdikis, D. Ch and Alexandrakis, V.Z. 2007 Effect of temperature on development and survival of the parasitoid *Pnigalio pectinicornis* (Hymenoptera: Eulophidae) reared on *Phyllocnistis citrella* (Lepidoptera: Gracillariidae). *Environmental Entomology.* 36: 497-505.

Kiritani, T. 1997. The low development threshold temperature and the thermal constant in insects, mites and nematodes in Japan. Misc. Publi. *Natl.. Inst. Agro-Enviro*n. Sciences Tsukuba isboraki (Japan). cir. nii.ac.jp.

Kiritani, K. 2006. Predicting impacts of global warming on population dynamics and distribution of arthropods in Japan. *Population Ecol.* 48: 5-12.

Li, Li Tao, Wang, Yu-Qiang, Ma, Ji- Fang, Lei Liu, Hao, Yan Tang, Chao, Dong, Gan, Yao Jin, Dong, Zhi- Ping and Wang, Qin Ying, 2013. The effects of temperature on the development of the moth *Athetis lepigone* and prediction of field occurrence. *Journal of Insect Science.* 13: 1-13.

Matlak, J. 1995. Mora bavlnikova-novy polyfagny skodca. Polnohospodarska vyroba a skusobnictvo, 3 (3-4): 24-25.

Mironidis, G.K. and Savopaulou- Soutani, M. 2008. Development, Survivorship and Reproduction of *Helicoverpa armigera* (Lepidoptera : Noctuidae) under constant and Alternating temperatures. *Environ. Entomol.* 37: 16-28.

Mironidis, G.K. 2014. Development survivorship and reproduction of *Helicoverpa armigera* (Lepidoptera: Noctuidae) under fluctuating temperature. *Bulletin Entomol. Research.* 104: 751-764.

Pleessis, H.D., Schlemmer, M.L. and Berg, V.D. 2020. The effect of temperature on the development of *Spodoptera frugiperda* (Lepidoptera: Noctuidae). Insects 11:228; doi:10.3390/insects 11040228.

Porter, J.H., Parry, M.L. and Carter, T.R. 1991. The potential effects of climatic chage on agricultural insect pests. *Agric. For. Meteorol.* 57: 221-240.

Teggelli, R.G., Rao, K.J. and Kulkarni, K.A. 2004. Effect of temperature and relative humidity and their interactions on the development of *Campoletis chlorideae* Uchida. *Karnataka Journal of Agricultural Sciences.* 17: 476-478.

Tobin, P.C., Nagarkatti, S. and Saunders, M.C. 2003. Phenology of Grape berry moth(Lepidoptera: Tortricidae) in cultivated grape at selected geographic locations. *Environ. Entomol.* 32: 340-346.

Virachack, H., Giang, T.H., Giang, H.T.T. and Ueno, T. 2018. Temperature effects on the development of

Vietnamese cotton Bollworm *Helicoverpa armigera* (Hubner). *J. Fac. Agri Kyushu University.* 63(2): 303-309.

Vlckova, H. 2000. Mora bavlnikova Slovensku Informace pro zahradnictvi. 10: 17.

Wang, L., Shi, P. Chen, Chao and Fangsen Xua, 2013 Effect of temperature on the development of *Laodelpix striatellus* (Homoptera: Delphacidae). *Journal of Economic Entomology.* 106: 107-114.

Zalucki, M.P., Daglish, G., Firempong, S. and Twine, P.H. 1986. The biology and ecology of *Heliothis armigera* (Hubner) and *H. Punctigera* (Wallengren) (Lepidoptera: Noctuidae) in Australia: What do we know? *Aus. J. Zool.* 34 : 779-814.

Zaslavski, V.A . 1988. *Insects Development (Photoperiodic and Temperature Control*). Spinger Verlag, Berlin. Pp187.