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Development and food consumption of some lepidopteran pests under increased temperature conditions

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ABSTRACT

Climate change has direct influence on the development and survival of herbivores in addition to indirect effects through trophic interactions. The present studies were carried out to observe the effect of increase in minimum temperature on development and food consumption of *Helicoverpa armigera* Hubner*, Pieris brassicae* Linnaeus and *Spodoptera litura* Fabricius. The mean food consumption increased by 12.78 and 32.64 per cent with increase in minimum temperature of 3^0C and 6^0C, respectively accompanied by decrease in larval duration by 10.37 and 27.97 per cent. Similarly, observations on *P. brassicae* larvae at four temperature ranges indicated that the mean food consumption increased by 4.87 with rise in minimum temperature by 3^0C accompanied by faster development. Likewise, effect of temperature ranges viz. 21°C: 7°C and 21°C: 10°C for 16: 8 hrs on biology of *S. litura* was estimated. The observations revealed faster growth when the mean minimum temperature was raised from 7 to 10°C. The rise in minimum temperature by 3°C resulted in decrease in larval and pupal duration by 5.36 and 10.43 per cent, respectively. The survival per cent was also increased by 1.44 per cent when rise in minimum temperature by 3°C.

Key words: Food consumption, Larval duration, Minimum temperature, H. armigera, P. brassicae, S. litura.

Climate change is one of the most significant events that has attracted the attention of scientific communities all over the globe**.** Climate change will have serious consequences on diversity, abundance of arthopods and extent of crop losses due to insect pests, which will impact food security. As a result of their close relationship with host plants, insect herbivores are likely to suffer direct or indirect effects of global climate change (Cornelissen, 2011) directly through changes in physiology, behavior and life history parameters; indirectly through changes experienced by host plants. These probable impacts of climate change on the agricultural sector have prompted concern for future global food production. Under changing environmental conditions, it is essential to determine the effect of elevated temperature on pest population buildup to devise successful management tactics. In Punjab, significant increase in annual minimum temperature was noticed at Ludhiana, Patiala, Jalandhar and Bathinda with high rate of increase at Ludhiana ($0.06\ ^0$C/ year) and Jalandhar ($0.05\ ^0$C/ year) during the last three decades (Kaur *et al*., 2013). For many insect species, increase in temperature (below their upper threshold limit) will result in faster development leading to rapid population increase. As metabolic demands increase exponentially with rising temperatures, herbivore invertebrates generally either increase food intake or switch to higher quality diets to offset the rising costs of metabolism (O'Connor, 2009 & Lemoine *et al*., 2013). As a result, predation and herbivory rates tend to increase exponentially with increased temperature (Hillebrand *et al*., 2009 and Vucic-Pestic, 2011).

Helicoverpa armigera (Hubner) is a cosmopolitan, highly polyphagous pest damaging many economically important crops in Africa, Asia, Australia and parts of Europe (King 1994). In India it is a major pest of cotton, chickpea, pigeon pea, Egyptian clover, tomato, okra and black gram etc. *Pieris brassicae* Linnaeus is a destructive cos-mopolitan lepidopteran pest of crucifers (Ansari *et al*. 2012) infesting leaves, branches and pods of 83 species of plants of the family (Lal and Ram 2004). During its development, single larva of *P. brassicae* can consume 74–80 cm^2 leaf area (Younas *et al*. 2004). Tobacco caterpillar, *Spodoptera litura* (Fabricius) is a polyphagous pest causing economic damage to more than 50 crops *viz.,* tobacco, cole crops, castor, cotton, sunflower, chilli, etc. (Murthy *et al*., 2007). Hence, the present studies were undertaken to study the effect of rise in minimum temperature on food consumption and larval duration of H. armigera, P. brassicae, S. litura.

MATERIAL AND METHODS

Maintenance of culture and experimentation of H. armigera

H. armigera was reared singly in specimen tube on natural (Egyptian clover foliage) and semi-synthetic artificial diet (modified from Armes *et al*., 1992) at temperature of 25±2^{0}C with relative humidity of 75 per cent**.** The pupae were surface sterilized by dipping in 0.025 per cent sodium hypochlorite solution, air died and transferred to jars (height 150cm, diameter 15cm) with a moistened foam disc (14 mm thick) at the bottom to prevent desiccation. The adults were paired in cage for one day and then two pairs were transferred to oviposition chamber made from a simple earthen pot with a hole at the bottom. A cotton swab dipped in a solution of the adult diet (10 g sucrose + 2 ml ABCDE multivitamin mixture + 200 mg methy1-4-hydoxy benzoate in 1 ml ethanol and 10 ml distilled water) was placed on top of the foam disc. The top of the pot was covered with a muslin cloth, which was changed daily to obtain fresh batch of eggs. Extreme sanitary conditions were maintained and 0.025 per cent sodium hypochlorite solution was used for surface sterilization of eggs of *H. armigera* laid on muslin cloth (Rabindra *et al*., 1997). These eggs were used for further multiplication and experimentation.

The present studies were carried out in controlled environment chamber (PGW-40, M/s Percival Scientific, Inc., USA), Punjab Agricultural University, Ludhiana to observe the effect of rise in minimum temperature on development and food consumption**.** To study the duration of larval stage at each selected alternating temperature of 25^{0}C: 10^{0}C (T_1), 25^{0}C: 13^{0}C (T_2), 25^{0}C: 16^{0}C (T_3) along with 14:10 L:D photoperiod, 70±5 per cent relative humidity. Twenty five first instar larvae per replication were transferred using a camel hairbrush in glass vial in four replications and reared on berseem leaves till the pupal stage. To study the food consumption larvae were kept in specimen tubes at above mentioned conditions in 4 replications @ 5 larvae per tube and pre-weighed fresh foliage of berseem was provided as food daily. The excreta and uneaten food was removed and weighed daily. After 4 days the larvae were kept singly in the specimen tubes and reared similarly till pupation. A set of additional larvae were maintained under similar set of conditions to replace dead larvae. A control was maintained by keeping pre-weighted leaf in a Petri dish and weighing it after 24h to assess loss of moisture from them.

Maintenance of culture and experimentation of P. brassicae

Eggs of cabbage butterfly in clusters on the lower sides of the leaves were collected from the fields and maintained in laboratory at 25±2ºC and 70±5 per cent relative humidity. Newly hatched larvae were transferred to jars (15x10cm) provided with fresh cabbage leaves with blotting paper at the bottom. Fresh food and blotting paper changed daily to maintain hygiene until pupation. The pupae were surface sterilized by dipping in 0.025 per cent sodium hypochlorite solution, air dried and transferred to jars with a moistened foam disc (14 mm thick) at the bottom to prevent desiccation (Hasan and Ansari 2011)**.** Newly emerged two pairs of male and female were kept together in net cage with cabbage plants for mating and oviposition. To study the duration of larval stage on four different temperature ranges, 25°C: 10°C, 25°C: 13°C, 30°C: 10°C and 30°C : 13°C for 14:10 hrs under a constant relative humidity of 75%, newly hatched first instar larva @ 25 larvae per replication were reared on cabbage leaves in four replications and kept till the pupal stage. To study the food consumption by larvae, 25 larvae were kept in glass jars (15x10 cm) at each temperature and fresh cabbage leaves are provided as food. The excreta and uneaten food will be removed daily and fresh leaves were provided daily. A set of additional larvae will be maintained as earlier explained. A control was maintained by keeping weighed leaf in a Petri dish and reweighing it after 24h to assess loss of moisture from the food offered to the larvae.

Maintenance of culture and experimentation of S. litura

Field collected batch of eggs of *S. litura* were used to establish the laboratory culture after surface sterilization with 0.02% sodium hypochlorite solution. After hatching, the neonate larvae were reared on leaves of castor *Ricinus communis* till prepupal stage at room temperature of 27±2°C with 14:10 photoperiod and 70±5% relative humidity. Sterilized soil was provided for pupation and then pupae were placed inside the oviposition chamber for adult emergence. Cotton swab soaked with 10% (w/v) sugar solution with few drops of multivitamins was provided for adult feeding to increase the fecundity and muslin cloth was kept inside the glass jar for egg laying. The newly hatched larvae were provided with tender castor leaves and were used for the further studies. To study the duration of larval stage at two different selected alternating temperatures, 21°C: 7°C and 21°C: 10°C for 16: 8 hrs under a constant relative humidity of 70±5%, newly hatched first instar larva @ 20 larvae per replication was transferred using a camel hairbrush in glass vial and reared on cabbage leaves till the pupal stage with 4 replications. To study the duration of pupal stage at two different selected alternating

Table 1: Mean daily consumption by larvae of *H. armigera* reared on Egyptian clover foliage at different temperatures

Treatment	Food consumed in mg/ larva (Mean±SE)					
	III instar	IV instar	V instar	VI instar	Total	Increase (%)
T_1(25⁰: 10⁰C)	134.90±6.33	278.84±9.21	386.15±8.14	265.05±22.27	1061.94±11.09	-
T_2(25⁰:13⁰C)	160.45±9.55	321.08±10.03	489.19±5.13	306.83±14.91	1197.56±17.17	12.78
T_3(25⁰:16⁰C)	188.32±10.01	368.02±16.59	489.44±12.84	362.66±9.70	1408.44±18.66	32.64
C.D (5%)	(4.73)	(7.66)	(8.42)	(5.69)	(10.77)	

Table 2: Duration of different larval instar of *H. armigera* on Egyptian clover foliage at different temperatures

Treatment	Larval duration in days (Mean±SE)							
	I instar	II instar	III instar	IV instar	V instar	VI instar	Total	Decrease (%)
T_1(25⁰: 10⁰C)	3.0±0.45	3.0±1.0	3.33±0.58	4.67±0.56	4.33±0.54	4.33±0.58	22.67±1.58	-
T_2(25⁰:13⁰C)	3.33±0.56	3.0±0.58	3.33±0.56	4.0±1.0	3.33±0.56	3.33±0.58	20.32±1.53	10.37
T_3(25⁰:16⁰C)	2.67±1.0	2.33±0.52	3.0±0.50	3.0±1.0	3.0±0.58	2.33±0.54	16.33±1.79	27.97
C.D (5%)	(NS)	(NS)	(NS)	(0.38)	(0.32)	(0.14)	(0.89)	

Table3: Amount of fresh food consumed by different larval instars of *P. brassicae* at different temperatures

Treatment*	Food consumed in mg/larva/day (Mean±SE)					
	II instar	III instar	IV instar	V instar	Total	Increase (%)
T_1(25⁰: 10⁰C)	12.02±0.79	49.74±2.31	147.76±6.49	1127.81±61.33	1337.33±20.23	-
T_2(25⁰:13⁰C)	13.97±0.82	53.92±2.80	155.30±6.85	1182.66±82.01	1405.85±23.12	4.87
T_3(30⁰:10⁰C)	14.95±0.89	57.30±3.21	166.47±7.43	1278.95±98.98	1517.67±27.63	12.83
T_4(30⁰:13⁰C)	15.54±0.87	63.13±3.60	176.87±7.88	1319.64±93.74	1575.18±26.52	16.92
C.D.(5%)	(0.76)	(1.21)	(0.56)	(6.07)	(2.95)	

Table4 : Duration of different larval instars of *P. brassicae* on cabbage at different temperatures

Treatment*	Larval duration in days (Mean±SE)						
	I instar	II instar	III instar	IV instar	V instar	Total	Decrease (%)
T_1(25⁰:10⁰C)	3.70±0.57	3.34±0.43	3.74±0.52	3.79±0.49	4.09±0.60	18.66±0.52	-
T_2(25⁰:13⁰C)	3.11±0.46	3.04±0.29	3.55±0.47	3.54±0.46	3.85±0.50	17.09±0.44	9.19
T_3(30⁰:10⁰C)	2.91±0.38	2.69±0.31	3.39±0.44	3.16±0.47	3.64±0.47	15.79±0.41	16.79
T_4(30⁰:13⁰C)	2.72±0.29	2.59±0.28	3.08±0.48	2.98±0.45	3.25±0.47	14.62±0.39	23.64
C.D(5%)	(0.31)	(0.15)	(0.11)	(0.36)	(0.28)	(0.18)	

Table 5: Effect of the mean minimum temperature on biology of *S. litura* on Cole crops

Parameter	Temperature*		Increase /decrease (%)	C.D(p= 0.05)
	T_1	T_2		
Larval duration (days)	16.61	15.72	-5.36	(0.21)
Larval survival (%)	86.25	87.50	+1.44	(0.39)
	(68.2)	(69.27)		
Pupal duration (days)	10.74	9.62	-10.43	(0.23)

*Temperature: T_1 - 21⁰C: 7⁰C (14:8 hrs), T_2 – 21⁰C:10⁰C (16:8 hrs)

Figures in parentheses are n+1 arc sine transformed values under the column per cent larval survival

temperatures 21°C: 7°C and 21°C: 10°C for 16: 8 hrs under a constant relative humidity of 75%, first day formed pupae was kept in glass vial till the adult emergence and were observed daily for emergence. Each treatment was replicated 4 times. To calculate per cent survival, number of pupa formed out of number of larva hatched from the eggs and percent survival was calculated.

Statistical analysis

Calculation of food consumption by larvae was calculated using formula given by Waldbauer (1968). The data were analyzed statistically as per Completely Randomized Design (CRD) using computer programme CPCS1.

RESULTS AND DISCUSSION

Food consumption of H. armigera reared on Egyptian clover foliage at alternating temperatures

Results of mean daily food consumption revealed that there were significant differences in the amount of food consumed by different instars with rise in minimum temperature by 3^0C and 6^0C (Table 1). In third instar larvae, increased daily food consumption of 160.45 mg and 188.32 mg was recorded with rise in minimum temperature by 3^0C and 6^0C, respectively as compared to T_1 (25^0C: 10^0C). In fourth instar also, mean daily food consumption was 278.84, 321.08 and 368.02 mg/larva at T_1, T_2 and T_3, respectively, which was significantly different from each other. Similarly in fifth instar, mean daily food consumption was observed on par with each other (489.19& 489.44 mg) with rise in minimum temperature by 3^0C and 6^0C, respectively as compared to T_1 (386.15 mg). In sixth instar, all selected alternating temperatures (T_1, T_2 & T_3) were found to be significantly different. Mean daily food consumption was recorded to be 265.05, 306.83 and 362.66 mg/ larva at T_1, T_2 and T_3, respectively. Consequently total food consumed from third instar to prepupal stage, was also found to be significantly different at these temperatures. Similar findings were also reported by Levesque *et al*., (2002) that fourth instar larvae of the forest tent caterpillar *Malacosoma disstria* Hübner reared at 18°C had lower consumption rates than larvae reared at the warmer temperatures (24 and 30°C). Moreover, the duration of the instar decreased considerably with increasing temperatures. Gündüz and Gülel (2002) also reported that the food consumption by *Schistocerca gregaria* was higher at 30°C temperature than 25 °C until the end of the first week of adult life and decreased thereafter. From the first nymphal stages to the end of the first week of adult life, each insect consumed 23.82 g fresh wheat sprout and 4.27 g bran at 25ºC, and 25.41 g fresh wheat sprout and 4.27 g bran at 30ºC. Similar finding was reported by Kingsolver and Woods (1997) that consumption rates increased between 14 and 26ºC, reached a maximum value near 34ºC, and declined rapidly above 38 ºC in fifth instar caterpillar of *Manduca sexta*.

Duration of different larval instars of H. armigera at different alternating temperatures

The data on duration of different larval instars of *H. armigera* on Egyptian clover foliage at different alternating temperatures is presented in Table 2. The minimum larval duration of first instar was recorded at 25^0:16^0C (T_3) followed by 3.0±0.45 at 25^0:10^0C (T_1) and 3.33±0.56 at 25^0:13^0C (T_2), respectively, however these varied non-significantly with respect to one another. Similarly the duration of second and third instar larvae varied non-significantly with respect to change in minimum temperature from 10^0C in T_1 to 16^0C in T_3. The longest larval duration (4.67±0.56 days) was observed at minimum temperature of 10^0C, which further decreased significantly from 4.0±1.0 days at minimum temperature of 13^0C to 3.0±1.0 days at 16^0C, the maximum temperature being kept constant at 25^0C. Similarly fifth and sixth instars recorded significantly lower larval durations at minimum temperature of 16^0C, as compared to 13^0 and 10^0C with maximum temperature kept constant at 25^0C. The total larval duration was highest at 25^0:10^0C (22.67±1.58 days) followed by 20.32±1.53 and 16.33±1.79 days at 25^0:13^0C and 25^0:16^0C, respectively. All these differ significantly with respect to one another. The larval period reduced by 10.37 and 27.97 per cent at minimum temperature of 13^0 and 16^0C, respectively, as compared to minimum temperature of 10^0C. Similar findings were reported by Wu *et al*., (1993) that duration of larval stage of *H. armigera* decreased exponentially as the temperature increased and they observed that the lowest threshold temperature required to initiate development in larval stage was 8.36ºC. Mironidis and Soultani (2008) also reported that total larval duration was completed in 22.70, 18.74, 15.98, 14.91 and 13.53 days at different alternating temperatures *viz.,* 25ºC: 10ºC, 30ºC: 15 ºC, 32.5ºC: 17.5ºC, 35ºC: 20ºC and 35ºC: 27.5ºC, respectively. Likewise, Papova (1969) also reported that larval duration was 24 and 18 days at 27.06 and 35.2ºC, respectively while, Sharma and Chaudhary (1988) stated that 31.4, 19.3, 15.3 and 10.3 days were required to complete the larval stage at 20, 25, 30 and 35 ºC, respectively.

Amount of fresh food consumed by different larval instars of P. brassicae at alternating temperatures

Significant difference was observed in food consumption by different larval instars with rise in minimum and maximum temperature by 3ºC and 5ºC, respectively (Table 3). In second instar, mean daily food consumption increased to 13.97, 14.95 and 15.54 mg day^{-1} at 25^0:13^{0}C (T_2), 30^0:10^{0}C (T_3) and 30^0:13^{0}C (T_4) respectively as compared to 25^0:10^{0}C (T_1). These differences were observed with rise in minimum and maximum temperature by 3ºC and 5ºC, were found to be significant, while the treatments with maximum temperature (T_3 and T_4) were found to be at par with each other. In third instar, effect of rise in minimum and maximum temperature by 3ºC and 5ºC revealed that mean daily food consumption increased to 53.92, 57.30 and 63.13 at T_2, T_3 and T_4, respectively over T_1 (49.74 mg day^{-1}) and all treaments were found to be significantly different from each other. In fourth instar, mean daily food consumption by larvae was 147.76, 155.30, 166.47 and 176.87 mg day^{-1} at T_1, T_2, T_3 and T_4, respectively and all treatments were found to be significantly different from each other. Similarly in fifth instar, mean daily food consumption by larvae increased to 1182.66, 1278.95 and 1319.64 mg day^{-1} at T_2, T_3 and T_4, respectively while in T_1 it was 1127.81 mg day^{-1}. There were significant differences found among the different treatments with rise in minimum and maximum temperature.

Total daily food consumption from second instar to prepupal stage was also found to be significantly different from each other. Increase of minimum and maximum temperature by 3ºC and 5ºC led to respective increase in mean daily food consumption by larvae i.e. 1337.33, 1405.85, 1517.67 and 1575.18 mg day^{-1} at warmer temperatures of 25:10^{0}C, 25:13^{0}C, 30:10^{0}C and 30:13^{0}C, respectively. Similar finding was also reported by Levesque *et al*., (2002) that fourth instar larvae of the forest tent caterpillar *Malacosoma disstria* Hübner reared at 18°C had lower consumption rates than larvae reared at the warmer temperatures (24 and 30°C).

Duration of different larval instars of P. brassicae on cabbage at different alternating temperatures

Observations on duration of different larval instars of *P. brassicae* indicated that the duration at warmer temperature was significantly different from the lower temperatures and has been presented in Table 4. The highest mean minimum temperature (13^{0}C) recorded the lowest larval duration (2.72±0.29 days) of first instar which was significantly lower compared to duration at 25:10^{0}C (3.70±0.57 days) and 25^0:13^{0}C (3.11±0.46 days) while it was statistically at par with larval duration of 2.91±0.38 days at 30:10^{0}C. Similarly rearing at temperature of 30^0:13^{0}C recorded the lowest larval duration (2.59±0.28 days) of second instar which was at par with larval duration (2.69±0.31 days) recorded at 30^0:10^{0}C. Both these treatments recorded appreciably lower larval duration as compared to 3.34±0.43 days and 3.04±0.29 days recorded at 25^0:10^{0}C and 25^0:13^{0}C, respectively. The latter two temperature conditions differed significantly with respect to one another. The minimum larval duration of fourth instar was recorded at 30:13^{0}C followed by 3.39±0.44 days at 30:10^{0}C, 3.55± 0.47 days at 25:13^{0}C and 3.74 ± 0.52 days at 25:10^{0}C. All these four treatments differ significantly with respect to one another. The temperature condition of 30^0:13^{0}C (T_4) recorded the lowest larval duration (2.98±0.45 days) of fourth instar which was at par with larval duration (3.16±0.47 days) recorded at 30^0:10^{0}C (T_3). Both these treatments recorded significantly lower larval duration as compared to 3.79±0.49 days at 25^0:10^{0}C and 3.54±0.46 days at 25^0:13^{0}C which were statistically at par with each other. The lower larval duration (3.25±0.47 days) of fifth instar was recorded in 30^0:13^{0}C (T_4) followed by 3.64±0.47 days, 3.85±0.50 days and 4.09±0.60 days at 30^0:10^{0}C (T_3), 25^0:13^{0}C (T_2) and 25^0:10^{0}C (T_1), respectively. The latter three treatments were at par with each other while the larval duration at T_1 was higher as compared to T_3.

The lowest total larval duration (14.62±0.39 days) was recorded in 30^0:13^{0}C (T_4) which followed by 15.79±0.41, 17.09±0.44 and 18.66±0.52 days at 30^0:10^{0}C, 25^0:13^{0}C and 25^0:10^{0}C respectively. All these treatments differ significantly with respect to one another. With rise in maximum and minimum temperature the larval duration decreased, consequently faster growth and shorter life cycle of insect was observed. The larval duration decreased by 9.19, 16.79 and 23.64 per cent as the temperature varied from 25^0:13^{0}C, 30^0:10^{0}C and 30^0:13^{0}C, respectively. Comparable findings were reported by Mironidis and Soultani (2008) that total larval duration of *H. armigera* was decreased with increase in temperature. Similarly, Jallow and Matsumura (2001) also reported that the duration of different life history stages of *H. armigera* (eggs, larvae and pupal) decreased as temperature increased from 13.3 ºC to 32.5 ºC.

Effect of the mean minimum temperature on biology of S. litura on Cole crops

The data on effect of the mean minimum temperature

on biology of *S. litura* on cole crops is presented in Table 5. It showed that with increase in mean minimum temperature of 3^0C, the larval duration (15.72 days) and pupal duration (9.62 days) decreased significantly from interval at lower temperature of 7^0C in T_1 with the constant maximum temperature. The per cent larval survival 87.50 at mean minimum temperature of 10^0C was significantly higher than per cent larval survival of 86.25 at mean minimum temperature of 7^0C. Therefore it can be concluded that with increase in mean minimum temperature the larvae of *S. litura* developed faster with increased survival percentage. Similarly Wu *et al* (1993) reported that duration of larval stage of *H. armigera* decreased exponentially as the temperature increased. Shah and Shahzad (2005) reported that there was positive correlation between duration of larval stage and average maximum and minimum temperatures.

CONCLUSION

It can be concluded that temperature change has direct influence on the development and food consumption of *H. armigera, P. brassicae* and *S. litura*. The mean food consumption of *H. armigera* larvae increased by 12.78 and 32.64 per cent with respective increase in minimum temperature of 3^0C and 6^0C. This was accompanied by faster development with decrease in larval duration by 10.37 and 27.97 per cent at minimum temperature of 13^0C and 16^0C respectively. Similarly, the mean daily food consumption of *P. brassicae* increased by 4.87 with rise in minimum temperature by 3^0C accompanied with faster development with larval duration declining by 9.19 per cent. Likewise, faster growth of *S. litura* was recorded when the mean minimum temperature was raised from 7 to 10°C. The survival per cent was also increased by 1.44 per cent when rise in minimum temperature by 3°C.

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REFERENCES

Ansari, M. S., Hasan, F. and Ahmad, N. (2012). Influence of various host plants on the consumption and utilization of food by *Pier-is brassicae* (Linn.). *Bull. Ent. Res.,* 102: 231–237.

Armes, N. J., Bond, G. S. and Cooter, R. J. (1992). "The Laboratory Culture and Development of *Helicoverpa armigera*". (Natural Resource Institute Bulletin 57, NRI, Chatham, UK) pp 22.

Cornellisen, T. (2011). Climate change and its effects on terrestrial insects and herbivory patterns. *Neotrop. Entomol.,* 40: 155-163.

Gunduz, N. E. A. and Gulel, A. (2002). Effect of Temperature on Development, Sexual Maturation Time, *Food Consumption* and Body Weight of *Schistocerca gregaria* Forsk. (Orthoptera: Acrididae). *Turk. J. Zool.,* 26: 223-27.

Hasan, F. and Ansari, M. S. (2011), Population growth of *Pieris brassicae* (L.) (Lepidoptera: Pieridae) on different cole crops under laboratory conditions. *J. Pest Sci*., 84:179–186.

Hillebrand, H., Borer, E. T., Bracken, M. E. S., Cardinale, B. J., Cebrian, J., Cleland, E. E., Elser, J. J., Gruner, D. S., Harpole, W. S., Ngai, J. T., Sandin, S., Seabloom, E. W., Shurin, J. B., Smith, J. E. and Smith, M. D. (2009). Herbivore metabolism and stoichiometry each constrain herbivory at different organizational scales across ecosystems. *Ecology Lett.,* 12: 516–527.

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

Kaur, P., Sandhu, S. S., Singh, S. and Gill, K. K. (2013). Climate change- Punjab Scenario. AICRPAM, School of Climate Change and Agricultural Meterology, Punjab Agricultural University, Ludhiana. Page 16.

King, A. B. S. (1994). *Heliothis/Helicoverpa* (Lepidoptera: Noctuidae). In: "Insect Pests of Cotton". (Eds. G. A. Matthews and J.P. Tunstall). pp. 39-106. (CAB International, Wallingford).

Kingsolver, J. G. and Woods, H. A. (1997). Thermal sensitivity of growth and feeding in *Manduca sexta* Caterpillars. *Physiol. Zool.,* 70: 631-638.

Lal, M. N. and Ram, B. (2004). Cabbage butterfly, *Pieris brassicae* L. an upcoming menance for Brassicae oilseed crop in Northern India. *Cruciferae Newsl*., 25: 83.

Lemoine, N. P., Drews, W. A., Burkepile, D. E. and Parker, J. D. (2013). Increased temperature alters feeding behaviour of a generalist herbivore. *Oikos,* 122: 1669-1678.

Levesque, K. R., Fortin, M. and Mauffette, Y. (2002). Temperature and Food Quality Effects on Growth, Consumption and Post-Ingestive Utilization Efficiencies of the Forest Tent Caterpillar *Malacosoma disstria* (Lepidoptera: Lasiocampidae). *Bull. Ent. Res.,* 92: 127-136.

Mironidis, G. K. and Soultani, M. S. (2008). Development, survivorship and reproduction of *Helicoverpa armigera* (Lepidoptera:Noctuidae) under constant and alternating temperatures. *Environ. Ent.* **37**: 16-28.

Murthy, K. S. R. K., Reddy, A. R. and Kavuri, Y. (2007). Testing of *Jatropha curcas* seed oil on *Spodoptera litura* (Fab) for insecticidal properties. *Pestology,* 31: 13-15.

O'Conoor, M. I. (2009). Warming strengthens an herbivore – plant interaction. *Ecology,* 90: 388-398.

Rabindra, R. J., Philip, S. R., Sundarababu, P. C. and Gopalan, M. (1997) *Technology for Mass Production of Biopesticides*. (Center for plant protection studies, Tamil Nadu Agricultural University, Coimbatore). pp 30-40.

Shah, Z. A. and Shahzad, M. K. (2005). Population fluctuations with reference to different developmental stages of *Helicoverpa armigera* (Lepidoptera:Noctuidae) on chickpea and their relationship with the environment. *Int. J. Agri. Biol.,* **7:** 90-93.

Sharma, S. K. and Chaudhary, O. P. (1988). Effect of different levels of constant temperature and humidity on the development and survival of Heliothis armigera. *Indian J. Ent.,* 50: 76-81.

Vucic-Pestic, O., Ehnes, R. B., Rall, B.C. and Brose, U. (2011). Warming up the system: higher predator feeding rates but lower energetic efficiencies. *Glob. Change Biol.,* 17: 1301–1310.

Waldbauer, G. P. (1968). The consumption and utilization of food by insects. *Adv. Insect Physio.,* 5: 229-282.

Wu, K. C., Chen, Y. P. and Li, M. H. (1978). Life-tables for experimental population of the cotton bollworm, *Heliothis armigera* (Hubner) at different temperature. *Acta Ent. Sin.,* 21: 385-392.

Younas, M., Naeem, M., Raquib, A. and Masud, S. (2004). Population dynamics of *Pieris brassicae* on five cultivar of cauliflower at Peshawar. *Asian J. Pl. Sci.,* 3: 391–393.

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