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Impact of temperature on food consumption and nutritional indices of tomato fruit borer, *Helicoverpa armigera* (Hübner) (Noctuidae: Lepidoptera)

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ABSTRACT

Rising temperatures under changing climatic conditions results in the increase in food intake by the insect pests. The present studies on effect of different alternating temperatures on food consumption and nutritional indices of *Helicoverpa armigera* (Hübner) on tomato crop were conducted during 2013-14. The total food consumption by *H. armigera* larvae during total (third to fifth instar) larval duration increased from 2.457±0.048 g/larvae at 25:10°C to 3.545±0.021 g/larva at 30:16°C. This suggests that with increase in temperature there is increase in food consumption by *H. armigera* larvae. The share of food consumption by fifth instar larvae was e" 80 per cent of total food consumption by *H. armigera* larvae in all the treatments.Nutritional indices for total larval duration of *H. armigera* such as consumption Index (CI) rose from 0.929±0.020 at 25:10°C to 1.495±0.014 at 30:16°C, The relative growth rate (RGR) of total larval period varied from 0.139±0.002 at 25:10°C to 0.174±0.003 at 30:10°C. The rise in alternating temperature from 25:10°C to 30:10°C resulted in increased RGR of *H. armigera* larvae.

Key words: Helicoverpaarmigera, tomato, food consumption and nutritional indices

Insects being poikilothermic, temperature is the most important factor affecting their distribution range, development, food consumption, multiplication and number of generations per year (Speight *et al.* 2008; Arora andDhawan,2011).In Punjab, a slow but steady rise in minimum temperature by 0.06°C per year over the past four decades and unchanged while the maximum temperature has been reported by Kaur *et al.*(2012). As the temperatures rise the metabolic demands of the insects increase exponentially, as a result the insects likely to fulfill these demands by means of increased food consumption (O'Connor, 2009).

Helicoverpa armigera is highly polyphagous and widely distributed insect pest occurring throughout Africa, Europe, Asia and Australia (Fitt, 1989). *H. armigera* attacks a total of 156 host plants from 41 families of angiosperms and tomato is listed among its major hosts (Manjunath *et al.* 1989).It is estimated that annual crop losses globally due to *H. armigera* alone are about five billion US dollars (Sharma 2001). The tomato fruit borer, *H. armigera* Hübner (Lepidoptera: Noctuidae) is one of the major biotic constraints in the quality tomato *Solanumlycopersicum* (L.) production. The pest is active throughout the year and prefers to feed on the floral bodies of its numerous host plants (Parsons, 1940; Goyal and Rathore, 1988; Arora *et al.* 2011). The yield losses caused by *H. armigera* in tomato have been reported to range from 20 to 88 per cent (Tewari and Krishnamoorthy, 1984; Lal and Lal, 1996). It has been reported that due to increased temperature under changing climatic condition *H. armigera* will cause more damage to the crops in northern India as the pest will have additional generations due to reduced incidence of diapause and faster development (Sharma *et al.* 2010). In order to manage this pest efficiently, it is essential to determine the role of abiotic factors especially temperature under changing climatic condition on its build up. Keeping these facts in view, present study on the effect of rise in temperature on food consumption and nutritional indices of *H. armigera* on tomato crop was planned during July 2013 to May 2014.

MATERIALS AND METHODS

The present studies were carried out in a digitally controlled walk- in- type plant growth chamber (PGW 40, Percival Scientific Company, USA) and at the Entomological Research Farm, Department of Entomology, Punjab Agricultural University, Ludhiana during July 2013 to May 2014. For raising of tomato crop, the seeds of tomato genotype US-8502 (Ujjawal Seeds Pvt. Ltd, Delhi) were obtained from the local market and raised in the medium size earthen pots and there after transplanted in the field as per recommended package of practices (Anonymous, 2013). But no insecticides were applied to the crop for management of any insect pest. Larvae of *H. armigera* were collected from tomato field and were used to establish the laboratory culture of the insect. All the larvae were reared in specimen tubes singly and the culture was maintained at controlled temperature of 25±1°C in the plant growth chamber. A semi-synthetic diet after Armes *et al.* (1992) was used for larval rearing.

The adults were paired in cage for one day and then were transferred to oviposition chamber made from a simple earthen pot with a hole at the bottom (Arora &Battu, 1996). Two pairs of one day old moths were released inside the pot. The top of the pot was covered with a muslin cloth, which was changed daily to obtain fresh eggs. A small quantity of water was added everyday to the plastic tub to maintain water level in the pot. 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). The muslin cloth containing the eggs was kept in a glass jar (20 cm x 15 cm) at the base of which a moistened disc of foam was placed. These eggs were used for further multiplication and experimentation. A total of six alternating temperature regimes (max: min) were selected as treatments (T_1-25:10°C, T_2-30:10°C, T_3-25:13°C, T_4-30:13°C, T_5-25:16°C, T_6-30:16°C) at a constant relative humidity (65±5%) along with 14:10 L:D photoperiod. Each treatment was replicated four times. Fifty larvae were kept in plastic tubes at the rate of five neonates per tube at each temperature and were provided tomato leaf discs of 2 cm diameter as fresh food. The excreta and uneaten food were removed daily and fresh food was provided daily. A set of additional larvae was maintained similarly. Whenever any of the test larvae died, a larva from the additional set was added to replace it so that number of larvae in each replication remains the same. After 4 days of larval development these larvae were provided green fruits of tomato and kept similarly till the pupal stage. Changing of instars of *H. armigera* was observed from the removed head capsule and exuvia of previous instar. Observations on weight of fresh food, weight of uneaten food, weight of excreta and fresh weight of surviving larvae were recorded daily with the help of a digital weighing balance (sensitivity 0.1mg) from third instar of *H. armigera* larvae to pre-pupal stage. A parallel set was maintained to estimate the natural loss of moisture from tomato leaf discs when kept in specimen tubes under similar conditions without larvae to calculate the corrected weight of consumed leaves. The food consumption and nutritional indices are calculated on fresh weight basis. The corrected weight of food consumed and various nutritional indices were calculated as per Waldbauer (1968). The significant difference between treatment means with respect to food consumption, CI and RGR of *H. armigera* in different larval instars were analyzed with SPSS 16.0 software and means were compared by using Tukey's HSD.

RESULTS AND DISCUSSION

Food consumption

The results of food consumption of *H. armigera* larvae reared on green tomato fruits at different alternating temperatures are presented in Table 1. The total amount of food consumed by a larva of *H. armigera* during the third instar varied from 0.113±0.009 g/larva at 25:10°C to 0.234±0.007 g/larva at 25:16°C. The former value was at par with the food consumption of 0.117±0.026 g/larva and 0.128±0.012 g/larva recorded at 25:13°C and 30:10°C, respectively. The amount of food consumed at 30:13°C was significantly higher at 0.172±0.008 g/larva than the food consumed both at 25:13°C and 30:10°C. But the amount of food consumed at 30:16°C was significantly lower at 0.192±0.005 g/larva, than that consumed at 25:16°C, which was the highest. The total amount of food consumed by a fourth instar varied from 0.136±0.010 at 25:10°C to 0.428±0.003 g/larva at 25:16°C. However, the latter value was at par with the amount of food consumed at 25:13°C (0.408±0.015 g/larva) and at 30:10°C (0.383±0.015 g/larva). The mean temperature at these three alternating temperatures varied within a narrow range of 20.0 to 21.67°C which appeared to be most suitable for food consumption by the fourth instar larvae of *H. armigera*. But in contrast to the third and fourth instars, the maximum amount of food consumed (2.990±0.009 g/larva) during the fifth instar was at the highest alternating temperature (30:16°C). The minimum amount of food consumed (2.209±0.046 g/larva) was expectedly at the lowest alternating temperature of 25:10°C. It was, however, at par with the amount of food consumed at 25:13°C (2.292±0.037 g/larva) and 30:10°C (2.244±0.008 g/larva). Taking the total amount of food consumed during third to fifth instars of *H. armigera*, the maximum food consumption of 3.545±0.021 g/larva was recorded at the highest alternating temperature of 30:16°C while the minimum (2.457±0.048 g/larva) was recorded at the lowest alternating temperature of 25:10°C. The amount of larval food consumption increased significantly from the alternating temperature of 25:10°C to 25:13°C (2.818±0.052 g/larva) and further to 25:16°C (3.218±0.071 g/larva). The latter value was at par with the food consumption of 3.370±0.104 g/larva recorded at 30:13°C which in turn was at par with the highest food

Table 1 : Effect of various alternating temperatures on food consumption of *H. armigera* larvae reared on green tomato fruits in a growth chamber at constant relative humidity (65±5%)

Temperature°C (Max:Min)*	Food consumption in g / larva (mean±SE)			
	Third instar	Fourth instar	Fifth instar	Total(third to fifth instars)
25:10 (18.75)**	0.113±0.009a	0.136±0.010a	2.209±0.046a	2.457±0.048a
25:13 (20.00)	0.117±0.026a	0.408±0.015bc	2.292±0.037a	2.818±0.052b
25:16 (21.25)	0.234±0.007c	0.428±0.003c	2.556±0.073b	3.218±0.071c
30:10 (21.67)	0.128±0.012a	0.383±0.015bc	2.244±0.008a	2.755±0.022b
30:13 (22.91)	0.172±0.008b	0.372±0.018bc	2.825±0.086c	3.370±0.104cd
30:16 (24.17)	0.192±0.005b	0.363±0.007b	2.990±0.008c	3.545±0.021d

Means sharing similar letters are not significantly different by Tukey's HSD Test at P = 0.05

* These temperatures were maintained for 14:10 h along with L: D photoperiod

**Figures in parentheses represent mean value of temperature

Table 2 : Effect of various alternating temperatures on consumption index (CI) of *H. armigera* larvae reared on green tomato fruits in a growth chamber at constant relative humidity (65±5%)

Temperature°C (Max:Min)*	Consumption index (mean±SE)			
	Third instar	Fourth instar	Fifth instar	Total (third to fifth instars)
25:10(18.75)**	1.247±0.058c	0.428±0.050a	1.181±0.031a	0.929±0.020a
25:13(20.00)	0.750±0.028a	0.720±0.049b	1.135±0.042a	1.125±0.060b
25:16(21.25)	1.090±0.020bc	0.841±0.015bc	1.368±0.005b	1.257±0.049bc
30:10(21.67)	1.198±0.121bc	0.992±0.071c	1.543±0.043c	1.356±0.013cd
30:13(22.91)	0.979±0.026ab	0.730±0.032b	1.369±0.016b	1.261±0.046bc
30:16(24.17)	1.206±0.010bc	0.699±0.004b	1.993±0.001d	1.495±0.014d

Means sharing similar letters are not significantly different by Tukey's HSD Test at P = 0.05

* These temperatures were maintained for 14:10 h along with L: D photoperiod

**Figures in parentheses represent mean value of temperature

consumption (3.545±0.021 g/larva) recorded at 30:16°C. Dhandapani and Balasubramanian (1980) recorded the total food consumption from third to last larval instar (1.9663 g/ larva) on tomato crop was less than any of the total food consumption values from third to fifth larval instar at any alternating temperature in the present study. Xiuzhen *et al.* (1990) reported that the food ingestion of last instar of another noctuid, *Mythimnaseparata* was highest at a moderate constant temperature of 24°C (40.9±4.4 mg) than highest (32°C) and lowest temperature (16°C) but in the present study there were only low (25:10°C) to moderate (30:16°C) temperature regimes hence food consumption of fifth instar of *H. armigera* increased with increase in temperature.

Out of the total food consumed by *H. armigera* larvae during third to fifth instar it was observed that fifth instar consumed the highest amount of food, which was 90, 81, 80, 81, 84 and 84 per cent at alternating temperatures of 25:10°C, 25:13°C, 25:16°C, 30:10°C, 30:13°C and 30:16°C, respectively. Earlier studies by Jayaraj (1981) also concluded that food consumption by the last larval instar of *H. armigera* accounted for approximately 80 per cent of total food consumption. Similarly Xiuzhen *et al.*(1990) also confirmed that last two larval instar of lepidopterous insects account for more than 90 per cent of total food consumption. Hence the present study with respect to share of food consumption by last larval instar of *H. armigera* was found to be in agreement with Jayaraj (1981) and Xiuzhen *et al.* (1990).

Consumption index (CI)

The consumption index (CI) measures the amount of food consumed by an insect relative to mean weight of insect during a feeding period (Waldbauer, 1968). In the third instar larvae of *H. armigera*, the highest value of CI (1.247±0.058) was recorded at the lowest alternating

Table 3 : Effect of various alternating temperatures on relative growth rate (RGR) of *H. armigera* larvae on green tomato fruits in a growth chamber at constant relative humidity (65±5%)

Temperature°C	RGR (mean±SE)			
(Max:Min)*	Third instar	Fourth instar	Fifth instar	Total (third to fifth instars)
25:10(18.75)**	0.388±0.014ab	0.161±0.006b	0.092±0.002a	0.139±0.002a
25:13(20.00)	0.329±0.010a	0.224±0.009c	0.120±0.006ab	0.168±0.009bc
25:16(21.25)	0.422±0.0058ab	0.113±0.004a	0.090±0.009a	0.156±0.004abc
30:10(21.67)	0.573±0.110b	0.248±0.004d	0.123±0.018ab	0.174±0.003c
30:13(22.91)	0.227±0.066a	0.183±0.003b	0.144±0.007b	0.145±0.004ab
30:16(24.17)	0.237±0.005a	0.132±0.001a	0.093±0.0002a	0.142±0.005a

Means sharing similar letters are not significantly different by Tukey's HSD Test at P = 0.05
* These temperatures were maintained for 14:10 h along with L: D photoperiod
**Figures in parentheses represent mean value of temperature

temperature (25:10°C). It was however at par with the CI values of 1.206±0.010 and 1.198±0.121 recorded at 30:16°C and 30:10°C, respectively (Table 2). The lowest value of CI (0.750±0.028) was recorded at 25:13°C which was at par with the CI of 0.979±0.026 recorded at 30:13°C. Thus no trend could be observed in the impact of temperature on the CI values in the third instar larvae. In the fourth instar larvae the value of CI varied from 0.428±0.050 at 25:10°C to 0.992±0.071 at 30:10°C. It was observed that at all the six alternating temperatures the CI values at the fourth instar were lower than the corresponding values at the third instar stage. In the fifth instar larvae the CI values varied from 1.135±0.042 at 25:13°C to 1.993±0.001 at 30:16°C. The CI values at all the six alternating temperatures were higher than the corresponding values at the fourth instar stage. Taking the total larval duration from third to fifth instars, the CI value was maximum (1.495±0.014) at the highest alternating temperature (30:16°C) and minimum (0.929±0.020) at the lowest alternating temperature (25:10°C). The latter increased significantly to 1.125±0.0608 with rise in alternating temperature to 25:13°C and further to 1.257±0.049 at 25:16°C. The latter value was at par with the CI value of 1.356± 0.013 recorded at 30:10°C, which in turn was at par with the CI value (1.261±0.046) recorded at 30:13°C.

In the present study, CI values of *H. armigera* decreased significantly from third to fourth instar at all the alternating temperatures which were found to be to be in agreement with earlier studies by Sidhu and Arora (2011) and Jayaraj (1981). The high value of CI during third instar might be due to the higher nutritional requirement of third instar larvae of *H. armigera* as pointed by Jayaraj (1981). The CI values of *H. armigera* fifth instar larvae were highest compared to other two instars at all the alternating temperature except 25:10°C. Earlier study of CI values of last larval instar of *H. armigera* varied from 0.45±0.26 to 3.13±0.30 on *rabi* forage legumes at 25±0.5°C. The range of CI values in the present findings which was 1.135±0.042 at 25:10°C to 1.993±0.001 at 30:16°C differed from the range of CI values reported by Sidhu and Arora (2011) on different *rabi* forage legumes.

Relative growth rate (RGR)

The data on relative growth rate (RGR) of *H. armigera* larvae feeding on green tomato fruits from third to fifth instars at different alternating temperatures are presented in Table 3. The RGR was highest in the third instar, and lowest in the fifth instar with intermediate values in the fourth instar at each of the six alternating temperatures. The highest values of mean RGR were observed to be 0.573±0.110, 0.248±0.004 and 0.144±0.007 during the third, fourth and fifth instar, respectively. Taking the total mean RGR from the third to the fifth instar into consideration, the mean lowest RGR (0.139±0.002) was observed at the lowest alternating temperature (25:10°C). It increased to a peak of 0.174±0.003 at the alternating temperature of 30:10°C and declined thereafter to 0.142±0.005 at the higher alternating temperatures of 30:13°C and 30:16°C. Thus 30:10°C was observed to be the optimum temperature for growth of *H. armigera* larvae.

The RGR values of fifth instar and total larval duration from third to fifth instar in the present study do not include the duration and mean fresh weight of *H. armigera* at the pre-pupal stage. This may account for the difference in RGR value of 0.013 reported by Dhandapani and Subramanian (1980) on tomato crop under laboratory conditions. But the values of RGR in the present findings during total larval duration were close to the values of RGR reported by Sidhu and Arora (2011) on *rabi* forage legumes which varied from 0.12±0.004 to 0.26±0.009 at 25±0.5°C.

CONCLUSION

It can be concluded that the temperature change has a direct impact on food consumption of insect as there is increase in food consumption with increase in both minimum and maximum temperature. The consumption index (CI) value declined from third instar to fourth instar but increased again during fifth instar. The CI value for total larval duration was maximum (1.495±0.014) at the highest alternating temperature (30:16°C) and minimum (0.929±0.020) at the lowest alternating temperature (25:10°C). The food consumption by final instar of *H. armigera* was found to be more than 80 per cent in all the treatments. The rise in mean minimum and maximum temperatures from 25:10°C to 30:10°C (mean 21.67°C) also resulted in increased relative growth rate (RGR) of *H. armigera* larvae.

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