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Short communication

Effect of ambient temperature on food consumption and utilization by eggplant shoot and fruit borer, *Leucinodes orbonalis* Guenee (Lepidoptera: Crambidae)

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Food intake and utilization is a critical factor for growth, development and reproduction of an insect. Nutritionists developed the concept of food consumption and utilization in order to relate the quality of food with growth and development of animals. These indices lead to understanding of the effect of biotic and abiotic factors on insect life (Parra *et al.*, 2012).Temperature is a critical abiotic factor, which has significant influence on the activity of insect pests as well as natural enemies (Thakur and Rawat, 2014; Sahoo *et al*. 2016).Temperature also affects the nutritional aspects *viz.* consumption and utilization of food. Metabolic demands of insect increase with increases in temperature levels, which is usually met with by increasing the food consumption. Eggplant shoot and fruit borer (ESFB), *Leucinodes orbonalis* Guenee is the most damaging pest of eggplant (*Solanum melongena* Linnaeus), and incur huge losses ranging from 60-100% (Singh and Nath, 2010; Mainali *et al.*, 2015). In the era of changing climate, it is imperative to study effect of temperature on food consumption of this noxious pest so that stakeholders could outline the strategies to tackle the pest.

The present study was conducted in a Controlled Environment Chamber at Entomological Research Farm, Punjab Agricultural University, Ludhiana. Food consumption and utilization by *L. orbonalis* was studied at six fluctuating temperature levels (max:min), *viz.* 25:15, 30:15, 35:15, 25:20, 30:20 and 35:20^{o}C, at a constant relative humidity (RH) of 65±5% and photoperiod of 14:10 (L:D). Treatments were replicated four times. Newly hatched larvae of uniform age were reared on pesticide free eggplant fruits in battery jars (20x15 cm) at the rate of 10 neonates at each of the temperature combinations. The larvae, upon entering the third instar were starved for 5 hours, and then weighed and kept in plastic tubes (3x4.5 cm). At every 24 hours, measured quantity of food was given to the larvae and observations were recorded regarding the changes in weight of larvae, food eaten and faecal matter. An additional set of larvae was maintained under same set of conditions so that upon the death of test larva it could be replaced with larva of same age. To estimate natural moisture loss and to determine the corrected weight of food consumed by larvae, a parallel set of eggplant fruit pieces was maintained under similar conditions without larvae. Growth and development indices were calculated as per the methods suggested by Waldbauer (1968). The data were analyzed with SPSS Statistic 20 software and treatment means were compared by Tukey's HSD (p= 0.05).

Influence on food consumption and utilization indices

Consumption index (CI) represents the amount of food consumed by an insect. CI of different larval instars of *L. orbonalis* increased with rise in temperature levels (Table 1). Total CI for the three larval instars was highest at highest temperature of 35:20^{o}C (2.72±0.07) which was statistically at par with CI at 30:20^{o}C (2.61±0.08) and 25:20^{o}C (2.49±0.06). On the other hand, lowest CI was recorded at lowest temperature combination of 25:15^{o}C (2.01±0.06) and 30:15^{o}C (2.17±0.06). CI of *Spodoptera littoralis (Boisduval)* and *Spodoptera litura* Fabricius has also been reported to increase with the rise in temperature levels (Khafagi *et al.*, 2016; Karmakar and Pal, 2017). Fifth instar has the lowest CI, which could be due to the fact that weight gain in this instar is higher as compared to the food consumed by the larva. Lower CI in the last larval instar and higher CI in the penultimate instar has been reported in *Helicoverpa armigera* Hubner and *S. littoralis* (Baghery *et al.*, 2013; Khafagi *et al*., 2016). However, Dalal and Arora (2016) reported highest CI in fifth larval instar followed by third and fourth instar in *H. armigera.*

Approximate digestibility (AD) measures the percentage of food assimilated effectively by the insect. Highest AD was recorded at the temperature of 30:20^{o}C (43.42±0.92%), 35:15^{o}C (41.97±0.85%) and 25:20^{o}C (40.57±0.85%) (Table 2).AD of *L. orbonalis* increased with

Table 1: Effect of alternating temperatures on consumption index (CI) of *L. orbonalis* larvae reared on brinjal fruits

Temperature (°C) (Max:Min)*	Third instar	Fourth instar	Fifth instar	Total (3rd to 5th instars)
25:15	2.25±0.09c	2.03±0.07c	2.05±0.08c	2.01±0.06d
30:15	2.40±0.08bc	2.30±0.08c	2.19±0.09c	2.17±0.06cd
35:15	2.46±0.09bc	2.81±0.09b	2.36±0.08abc	2.31±0.06bc
25:20	2.55±0.10abc	2.88±0.11ab	2.31±0.09bc	2.49±0.06ab
30:20	2.76±0.10ab	3.02±0.10ab	2.60±0.09ab	2.61±0.08a
35:20	2.90±0.08a	3.24±0.11a	2.65±0.08a	2.72±0.07a

*Temperatures were maintained for 14:10 hours along with L:D photoperiod
Mean values marked with same alphabet within a column are non-significantly different ($p<0.05$, Tukey'sHSD)

Table 2: Effect of alternating temperatures on approximate digestibility (AD) of *L. orbonalis* larvae reared on brinjal

Temperature (°C) (Max:Min)*	Third instar	Fourth instar	Fifth instar	Total (3rd to 5th instars)
25:15	53.40±0.63c	31.58±0.55e	31.04±0.54d	37.81±0.73c
30:15	54.93±0.56bc	34.05±0.55d	34.59±0.67c	38.22±0.66c
35:15	57.13±0.71ab	37.14±0.55bc	36.92±0.58ab	41.97±0.85ab
25:20	56.02±0.54ab	35.11±0.58cd	35.63±0.54bc	40.57±0.85abc
30:20	58.26±0.53a	39.94±0.59a	38.07±0.58a	43.42±0.92a
35:20	55.86±0.65ab	37.92±0.75ab	31.19±0.44d	40.02±0.82bc

*Temperatures were maintained for 14:10 hours along with L:D photoperiod
Mean values marked with same alphabet within a column are non-significantly different ($p<0.05$, Tukey's HSD)

Table 3: Effect of temperatures on growth rate of *L. orbonalis* larvae reared on brinjal fruits

Temperature (°C) (Max:Min)*	Third instar	Fourth instar	Fifth instar	Total (3rd to 5th instars)
25:15	0.269±0.008c	0.242±0.010d	0.223±0.009d	0.233±0.006c
30:15	0.298±0.009c	0.269±0.010cd	0.241±0.011cd	0.242±0.007c
35:15	0.345±0.009b	0.308±0.010bc	0.271±0.011bc	0.288±0.006b
25:20	0.298±0.009c	0.269±0.010cd	0.232±0.010cd	0.239±0.006c
30:20	0.364±0.009ab	0.330±0.011ab	0.301±0.012ab	0.307±0.007b
35:20	0.396±0.010a	0.367±0.011a	0.316±0.010a	0.333±0.006a

*Temperatures were maintained for 14:10 hours along with L:D photoperiod
Mean values marked with same alphabet within a column are non-significantly different ($p<0.05$, Tukey's HSD)

temperature up to 30:20°C and declined at higher temperature. Similar to this, AD of *S. littoralis* and *S. litura* escalated as the temperature rose from 15°C to 25°C, but dropped at 30°C (Khafagi *et al*., 2016; Karmakar and Pal, 2017). Fluctuating values of AD at different temperature regimes could be the result of changes in food consumption as well as activity of digestive enzymes (Akbar *et al*., 2016). AD was highest in the third instar of *L. orbonalis* followed by fourth and fifth instar. Initial larval instars have higher AD values due to selective consumption of food with high nutritive value as compared to the older instars (Parra *et al*., 2012). Declining AD in subsequent instars has been recorded in *H. armigera* by several workers by Dalal and Arora (2018).

Growth rate (GR) indicates the gain in biomass of insect and it was significantly higher at 35:20°C (0.333±0.006), followed by 30:20°C (0.307±0.007) and lowest at 25:15°C (0.233±0.006) (Table 3). Similar to this, accelerated GR at elevated temperature levels has been reported in case of *S. littoralis* and *S. litura* (Khafagi *et al*., 2016; Karmakar and Pal, 2017). In present study, growth rate of *L. orbonalis*

Table 4 : Effect of alternating temperatures on efficiency of conversion of ingested food (ECI) of *L. orbonalis* larvae reared on brinjal fruits

Temperature (ºC) (Max:Min)*	Third instar	Fourth instar	Fifth instar	Total (3rd to 5th instars)
25:15	19.51±0.57[c]	13.63±0.48[e]	9.77±0.33[c]	13.91±0.37[e]
30:15	24.92±0.79[b]	17.24±0.61[d]	11.57±0.55[bc]	16.91±0.49[d]
35:15	31.62±0.74[a]	28.75±0.63[ab]	13.32±0.37[b]	22.04±0.51[ab]
25:20	27.27±0.51[b]	26.55±0.95[b]	13.09±0.52[b]	21.08±0.47[bc]
30:20	33.49±0.61[a]	30.83±0.67[a]	16.33±0.50[a]	23.51±0.37[a]
35:20	26.65±0.53[b]	23.71±0.49[c]	11.90±0.42[b]	19.97±0.33[c]

*Temperatures were maintained for 14:10 hours along with L:D photoperiod

Mean values marked with same alphabet within a column are non-significantly different ($p<0.05$, Tukey's HSD)

Table 5: Effect of alternating temperatures on efficiency of conversion of digested food (ECD) of *L. orbonalis* larvae reared on brinjal fruits

Temperature (ºC) (Max:Min)*	Third instar	Fourth instar	Fifth instar	Total (3rd to 5th instars)
25:15	46.44±0.72[c]	40.46±0.82[d]	40.11±0.98[d]	41.89±1.13[c]
30:15	62.49±0.61[b]	44.22±1.13[c]	44.24±1.22[c]	49.09±1.39[b]
35:15	64.46±0.61[ab]	54.19±0.70[a]	51.35±0.83[a]	55.48±1.48[a]
25:20	62.97±0.71[b]	52.12±0.64[ab]	49.10±0.61[ab]	52.59±1.39[ab]
30:20	65.64±0.56[a]	55.24±0.72[a]	52.45±1.00[a]	55.99±1.37[a]
35:20	62.74±0.68[b]	48.62±1.20[b]	46.19±0.80[bc]	51.40±1.50[ab]

*Temperatures were maintained for 14:10 hours along with L:D photoperiod

Mean values marked with same alphabet within a column are non-significantly different ($p<0.05$, Tukey's HSD)

receded with advancing instars. As immature instars are not prolific feeders but consume highly nutritive food, it results in higher rate of growth in earlier instars as compared to the later instars (Parra *et al*., 2012). Similar to present results, GR was higher in early instars of *H. armigera* and declined in older instars (Khafagi *et al*., 2016; Jooyandeh *et al*., 2018). Baghery *et al*. (2013) and Fite *et al*., 2018 recorded highest GR in the penultimate larval instar of *H. armigera*, while third instar had the lowest GR.

Efficiency of conversion of ingested food (ECI) and efficiency of conversion of digested food (ECD) denote the percentage of ingested food and digested food, respectively, transformed in to biomass. ECI was highest at 30:20ºC (23.51±0.37%) followed by 35:15ºC (22.04±0.51%), and lowest at 25:15ºC (13.91±0.37%) (Table 4).Rise in temperature improved the utilization of ingested food by *S. litura* larvae (Karmakar and Pal, 2017).ECI declined with advancing larval instars of *L. orbonalis* which could be due to the fact that weight gained by larvae is less possibly due to the physiological changes as well as high energy spent for the event of pupation (Parra *et al*., 2012). Some workers have recorded declining ECI in advancing larval instars of *H. armigera* and *S. littoralis* (Khafagi *et al*., 2016; Jooyandeh *et al*., 2018). On the other hand higher ECI has been reported in older instars of *H. armigera* Fite *et al.* (2018).

Similar to ECI, ECD was also highest at 30:20ºC (55.99±1.37%) followed by 35:15ºC (55.48±1.48 %), and lowest at 25:15ºC (41.89±1.13%)(Table 4).ECD of *S. littoralis* has been reported to improve with rising temperatures (Khafagi *et al*., 2016). At the third instar ECD of *L. orbonalis* was highest, followed by fourth and fifth instar. Declining ECD values with progression in larval stage has been reported in *H. armigera* (Baghery *et al*., 2013; Jooyandeh *et al*., 2018).

In aggregate, nutritional indices at fluctuating temperature regimes reveal the expected feeding damage by *L. orbonalis* in the event of increase in global temperature levels. Higher food consumption accompanied with accelerated growth rate at high temperature will result in escalation of feeding damage. Higher AD, ECI and ECD values at 30:20 and 35:15°C, indicate efficient utilization of food by the larvae. There are no reports on the food utilization by *L. orbonalis* at varying temperature levels. Besides having applications in nutrition, ecology and behavior, nutritional aspect studies also hold significance in the pest management strategies.

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