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Effect of climatic factors on survival and development of legume pod borer, *Helicoverpa armigera*

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ABSTRACT

The survival and development of legume pod borer, *Helicoverpa armigera* were studied at different temperatures, relative humidities and CO_2 regimes under laboratory conditions. Larval weight increased significantly with an increase in temperature from 15 (8 mg/larvae) to 35°C (398.8 mg/larvae) at 10 DAI (days after initiation of the experiment) while the larval survival showed a reverse trend and maximum larval survival was recorded at 15ºC (76%). The larval period varied between 40.2 days at 15ºC to 10 days at 35°C. Pupal weight decreased with an increase in temperature from 15 (373.8 mg/pupa) to 35°C (331.2 mg/pupa). The pupal period also decreased as the temperature increased (61.6 days at 15°C and 8.4 days at 35°C). The growth of *H armigera* was faster at 35°C than at 15 and 25°C (larval period 10 days, pupal period 8.4 days). Larval and pupal periods were prolonged to 40.2 and 61.6 days respectively at 15ºC. Highest larval survival (67.6%) was recorded at 75 and minimum (44.09%) at 25 per cent RH but the larval period was longer at 25 (11 days) than at 50-90 per cent RH (10 to 10.2 days). There were no significant differences in pupal period and adult emergence across humidity regimes. The larval survival (67.6%), pupation (61.06%) and adult emergence (55.2%) were maximum at 75 per cent RH and the larval and pupal periods were shortest. There were no significant differences in larval weight, larval survival, larval and pupal periods, pupal weight, pupation, adult emergence and fecundity across CO_2 concentrations. Elevated CO_2 shortened the life cycle of *H armigera* but the fecundity increased with an increase in CO_2 concentration suggesting that elevated CO_2 will lead to rapid generation turnover and increased rates of population increase of *H armigera*.

Keywords: *Helicoverpa armigera*; survival; development; temperature; relative humidity; CO_2

INTRODUCTION

Chickpea (*Cicer arietinum* L) also known as Bengal gram or gram is the second most important food legume in Asia, North Africa and Mexico. It is grown on 13.5 Mha worldwide with an average production of 8.8 MT. India is the largest producer of chickpea in the world sharing 71.0 and 67.2 per cent of the total area (9.6 Mha) and production (8.8 MT) respectively (Anon 2013). Several abiotic and biotic constraints limit the production and productivity of chickpea of which pod borer, *Helicoverpa armigera* is the major constraint in production in Asia and Africa (Sharma 2005, Yadav et al 2006). Losses due to insect damage are likely to increase as a result of changes in crop diversity and increased incidence of insect pests due to global warming and climate change (Sharma 2014). Current estimates of changes in climate indicate an increase in global mean annual temperatures of 1°C by 2025 and 3°C by the end of the next century. The date at which an equivalent doubling of CO_2 will be attained is estimated to be between 2025 and 2070 depending on the level of emission of greenhouse gases (Houghton et al 1990). Geographical distribution of insect pests confined to tropical and subtropical regions will extend to temperate regions along with a shift in the areas of production of their host plants while distribution and relative abundance of some insect species vulnerable to high temperatures in the temperate regions may decrease as a result of global warming. Thus the aim of the present investigations was to determine the survival and development of *H armigera* at different temperature, relative humidity (RH) and CO_2 levels.

MATERIAL and METHODS

Different temperatures viz T1 (15°C), T2 (25°C), T3 (35°C) and T4 (45°C) at a constant RH (70%), different levels of relative humidity (25, 50, 75 and 95%) at a constant temperature (30ºC) and different CO_2 regimes (350, 550 and 750 ppm) at a constant temperature (30ºC) and RH (70%) were maintained in incubators in the laboratory. Neonate larvae of *H armigera* obtained from the insect rearing laboratory were released on artificial diet in four treatments and replicated five times with 50 larvae in each replication. Data were recorded on larval weight, larval survival, larval and pupal periods, pupation, adult emergence, adult longevity and fecundity. Data on larval weight were recorded on 10th day after initiating the experiment. The larvae were removed from the cell wells, cleaned, weighed and then placed back on the respective diets. The pupal weights were recorded one day after pupation. Pupae from each replication were placed in a 1-litre plastic jar containing moist vermiculite. Larval survival on 10th day and pupation and adult emergence were computed in relation to number of neonate larvae released in each replication. Data were also recorded on larval and pupal periods. The adults were collected from the jars and three pairs of adults that emerged on the same day were placed inside a plastic cage and the number of eggs laid was counted.

RESULTS

Effect of temperature on growth and development of *H armigera*

Temperature below the species threshold limited the development and rapid increase of pest population. There were significant differences in larval weight, larval survival, larval and pupal periods, pupal weight, pupation, adult emergence and fecundity across different temperature regimes (Table 1). Mean larval weight increased significantly with an increase in temperature from 15 (8 mg/larvae) to 35°C (398.8 mg/larvae) at 10 DAI (days after initiation) of the experiment. However the larval survival showed a reverse trend and maximum larval survival was recorded at 15ºC (76%) and minimum at 35°C (47.2%). The larvae did not survive at 45°C. The larval period varied between 40.2 days at 15ºC to 10 days at 35°C indicating that the larval period decreased as the temperature increased. Pupal weight decreased from 15 (373.8 mg/pupa) to 35°C (331.2 mg/pupa). Highest pupation was recorded in insects reared at 25°C (53.2%) followed by those reared at 35 (24.8%) and 15°C (22.4%). The pupal period also decreased as the temperature increased ie 61.6 days at 15°C and 8.4 days at 35°C. Maximum adult emergence was recorded in insects reared at 25 (48.8%) and minimum at 15°C (11.2%). Maximum fecundity was recorded in insects reared at 25°C (866.4 eggs/female). There was no egg laying at 35°C. At 15°C the fecundity was 175 eggs/female. The growth of *H armigera* was faster at 35 than at 15 and 25°C (larval period 10 and pupal period 8.4 days). Larval and pupal periods were prolonged to 40.2 and 61.6 days respectively at 15°C.

Effect of relative humidity on survival and development of *H armigera*

There were significant differences in larval weight and the larval period across different RH regimes. After 10 days of exposure the maximum larval weight was recorded at 25 per cent RH (444.3 mg/larva) followed by 50 per cent (441.0 mg/larva) (Table 2). The larval weights were 400.0 and 398.4 mg/larva at 75 and 95 per cent RH respectively. Highest larval survival was recorded at 75 (67.6%) and minimum at 25 per cent RH (44.09%). There were significant differences in larval period at different RH regimes. The larval period was longer at 25 (11 days) than at 50-90 per cent RH (10 to 10.2 days). Pupation was maximum in the insects reared at 75 (61.6%) followed by 50 (54.4%), 95 (51.6%) and 25 per cent RH (41.6%). There were no significant differences in pupal period across RH regimes. RH regimes did not influence adult emergence. Maximum (55.2%) and minimum (35.2%) adult emergence was recorded at 75 and 25 per cent RH respectively. The average fecundity per female ranged from 897.6 eggs/female at 75 per cent RH to 683.2 eggs/female at 50 per cent. The larval survival (67.6%), pupation (61.06%) and adult emergence (55.2%) were maximum at 75 per cent RH and the larval and pupal periods were shortest.

Effect of CO_2 on growth and development of *H armigera*

As global atmospheric CO_2 concentration is increasing at an alarming rate its influence on survival and development of *H armigera* was studied under

Table 1. Survival and development of *Helicoverpa armigera* on artificial diet at different temperatures using diet incorporation assay

Temperature (°C)	Mean larval weight (mg)	Larval survival (%)	Larval period (days)	Pupal weight (mg)	Pupation (%)	Pupal period (days)	Adult emergence (%)	Fecundity (eggs/female)
15	8.0[a]	76.0 (60.7)[d]	40.2[d]	373.8[d]	22.4 (28.2)[b]	61.6[c]	11.2 (19.5)[b]	175[b]
25	317.6[b]	62.4 (52.2)[c]	12.0[c]	354.1[c]	53.2 (46.8)[c]	10.4[b]	48.8 (44.3)[c]	866.4[c]
35	398.8[c]	47.2 (43.4)[b]	10.0[b]	331.2[b]	24.8 (29.7)[b]	8.4[b]	12.4 (20.6)[b]	0.0[a]
45	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]
GM	181	46.4 (39.1)	15.55	264.8	25.0 (26.2)	20.1	18.1 (21.1)	260.4
Fp	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
SE±	24.8	1.4 (0.8)	0.1	3.2	1.8 (1.2)	0.7	1.4 (0.9)	12.7
LSD (0.05)	76.4	4.4 (2.6)	0.3	9.9	5.6 (3.6)	2.2	4.5 (2.7)	39.3
CV (%)	30.6	6.8 (4.9)	1.4	2.7	16.1 (9.9)	8.0	17.9 (9.3)	10.9

Figures in parentheses are angular transformed values, Figures followed by the same letter within a column are not significantly different at $P \leq 0.05$

Table 2. Survival and development of *Helicoverpa armigera* on artificial diet at different levels of relative humidity

RH (%)	Mean larval weight (mg)	Larval survival (%)	Larval period (days)	Mean pupal weight (mg)	Pupation (%)	Pupal period (days)	Adult emergence (%)	Fecundity
25	444.3[b]	48.4 (44.1)[a]	11.0[b]	336.0[a]	41.6 (40.2)[a]	8.4[b]	35.2 (36.4)[a]	750.0[ab]
50	441.0[b]	63.6 (53.0)[b]	10.2[a]	326.4[a]	54.4 (47.5)[b]	8.4[b]	50.4 (45.2)[b]	683.2[a]
75	400.3[a]	67.6 (55.4)[b]	10.0[a]	334.8[a]	61.6 (51.8)[b]	7.6[a]	55.2 (48.0)[b]	897.6[c]
95	398.4[a]	59.6 (50.6)[b]	10.2[a]	321.6[a]	51.6 (45.9)[ab]	8.4[ab]	46.0 (42.7)[ab]	789.2[b]
GM	421	59.8 (50.8)	10.35	329.7	52.3 (46.4)	8.2	46.7 (43.1)	780
Fp	<.001	0.006 (0.006)	<.001	0.6	0.01 (0.01)	0.1	0.01 (0.03)	0.004
SE±	4.22	3.1 (1.8)	0.1	8.5	3.4 (2.0)	0.3	3.5 (2.0)	32.4
LSD (0.05)	12.99	9.6 (5.7)	0.4	NS	10.5 (6.1)	NS	10.8 (6.3)	99.8
CV (%)	2.2	11.7 (8.2)	2.5	5.8	14.5 (9.5)	6.7	16.8 (10.6)	9.3

Figures in parentheses are angular transformed values, Figures followed by the same letter within a column are not significantly different at $P \leq 0.05$

different CO_2 regimes. There were no significant differences in larval weight, larval survival, larval and pupal periods, pupal weight, pupation, adult emergence and fecundity across CO_2 concentrations. After 10 days of releasing the neonate larvae on artificial diet maximum larval weight was recorded in insects reared at 550 ppm of CO_2 (439.9 mg/larva) followed by 350 (409.8 mg/larva) and 750 ppm (348.8 mg/larva) (Table 3). Highest larval survival (51.2%) was recorded in insects reared at 350 ppm and minimum at 550 ppm (45.6%). Larval period decreased from 13.2 days to 10.6 days in insects reared at 350 to 750 ppm CO_2. Mean pupal weight increased marginally with an increase in CO_2 (307.7 to 344.3 mg/larva) at 350 to 750 ppm CO_2. Highest fecundity was recorded in insects reared at 750 ppm CO_2 (1186 eggs/female) followed by 350 (827.2 eggs/female) and 550 ppm (817.2 eggs/female). Elevated CO_2 levels shortened the life cycle of *H armigera* and the fecundity increased with an increase in CO_2 suggesting that elevated CO_2 lead to rapid generation turnover and increased rates of population increase of *H armigera.*

DISCUSSION

Temperatures below the species threshold limited the development and rapid increase of pest populations. Bartekova and Praslicka (2006) reported that the developmental time of the larvae of *H armigera* decreased from 24.57 days at 25°C to 18.27 days at 30°C. Wu et al (1992) reported that the time required from egg to adult varied between 122.6 days at 15°C and 22.5 days at 35 and 25°C was the optimum time for insect development. Though the growth rate was faster at 35°C the adult emergence was quite low in addition to malformed adults and decreased egg laying.

Table 3. Survival and development of *Helicoverpa armigera* on artificial diet at different concentrations of CO_2

CO_2 (ppm)	Mean larval weight (mg)	Larval survival (%)	Larval period (days)	Mean pupal weight (mg)	Pupation (%)	Pupal period (days)	Adult emergence (%)	Fecundity
350	409.8[b]	51.2 (45.7)[a]	13.2[b]	307.7[a]	44.4 (41.8)[a]	10.6[a]	34 (35.6)[a]	827.2[a]
550	439.9[b]	45.6 (42.5)[a]	12.8[b]	342.3[a]	43.2 (41.1)[a]	10.6[a]	36.8 (37.3)[a]	817.2[a]
750	348.8[a]	49.6 (44.8)[a]	10.6[a]	344.3[a]	44.4 (41.8)[a]	11.2[a]	33.6 (35.4)[a]	1186[a]
GM	399.5	48.8 (44.3)	12.2	331.4	44.0 (41.5)	10.8	34.8 (36.1)	943
Fp	0.0	0.2 (0.2)	0.0	0.3	0.8 (0.8)	0.2	0.4 (0.4)	0.0
SE±	14.7	2.1 (1.2)	0.4	17.2	1.4 (0.8)	0.2	1.6 (1.0)	67.3
LSD (P 0.05)	48.0	NS	1.2	NS	NS	NS	NS	219.5
CV (%)	8.2	9.4 (6.0)	6.9	11.6	7.1 (4.3)	4.8	10.4 (6.0)	15.9

Figures in parentheses are angular transformed values, Figures followed by the same letter within a column are not significantly different at $P \leq 0.05$

Similar effects of temperature on survival and development of *H armigera* were observed in the present studies. There was no larval survival at 45°C and no eggs were laid by the insects reared at 35°C.

Though differences in RH did not have significant influence on the survival and development of *H armigera* unlike temperature, 75 per cent RH was found to be the most favourable for the growth and development of the insect. The present results are in conformity with the findings of Wu et al (1992) who reported that 70-90 per cent RH was favourable for the development of *H armigera.*

Yin et al (2009) recorded non-significant differences in population generation time (*T*) or intrinsic rate of increase (r_m) between CO_2 treatments on *H armigera*. Significantly lower potential female fecundity, larval number and population were recorded in second and third generations of *H armigera* fed on cotton bolls grown under elevated CO_2 (Wu et al 2007). Qayyum and Zalucki (1987) reported that exposure to 35 and 38°C had little effect on hatching but prolonged exposure to temperature above 38°C decreased the hatchability of *H armigera.* Long exposure to high temperatures retarded development of *H armigera.* High humidity prolonged development at high temperature (>35°C). The maximum development rate of all stages of *Heliothis* spp was found to occur around 35°C (Room 1983). Constant temperatures of 41 and 44°C are above the lethal maximum for hatching in both species but would be below the lethal maximum if exposure time was short (Kay 1981).

Polyvoltine species eg some economically important bark beetles like *Ips typographus* will profit from accelerated development rates allowing for an earlier completion of life cycles and the establishment of additional generations within a season (Lange et al 2006, Jonsson et al 2009). Temperature above the specific optimum range led to decreased growth rates, reduced fecundity and increased rates of mortality for a multitude of species (Rouault et al 2006). The phenology-based model for grape berry moth, *Paralobesia viteana* (Clemens) predicted that the increase in mean surface temperature >2°C can have dramatic effect on insect voltinism by causing a shift in the ovipositional period that currently is subjected to diapause-inducing photoperiods (Tobin et al 2008). Warm temperature halved the time required to reproduce in case of spruce beetle, *Dentroctonus rufipennis* (Berg et al 2006).

The results indicated that temperature, relative humidity and CO_2 had considerable influence on survival and development of *H armigera* but their effects were quite diverse. Among the three environmental factors temperature exercised a major effect on growth and development of the insect.

Global warming and climate change influence survival, development and population dynamics of *H armigera* and it has a major bearing on extent of crop losses and timing and of diferent components of pest management to minimize the losses due to this pest. Larval weight and larval and pupal developmental periods increased significantly with an increase in temperature while the larval survival got decreased. There was no larval survival at 45°C and no eggs were laid by the insects reared at 35°C indicating adverse effects of global warming on *H armigera* in the tropics but the temperate regions seem to become more hospitable to this insect. The growth of the insect was faster at 35°C than at 15 and 25°C suggesting faster generation turnover with warmer climates. The investigations depited that decrease in relative humidity decreased the survival of *H armigera* but elevated CO_2 led to rapid generation turnover and increased rates of population of this insect. There is a need to develop population prediction models for this insect under global warming and climate change to develop strategies for controlling this pest for sustainable crop production.

REFERENCES

Anonymous 2013. The state of food insecurity in the world: the multiple dimensions of food security. Food and Agriculture Organization of the United Nations, Rome.

Bartekova A and Praslicka J 2006. The effect of ambient temperature on the development of cotton bollworm (*Helicoverpa armigera* Hubner 1808). Plant Protection Science **42(4):** 135-138.

Berg EE, Henry JD, Fastie CL, De Volder AD and Matsuoka SM 2006. Spruce beetle outbreaks on the Kenai peninsula, Alaska and Kluane National Park and Reserve, Yukon territory: relationship to summer temperatures and regional differences in disturbance regimes. Forest Ecology and Management **227(3):** 219-232.

Houghton JT, Jenkins GJ and Ephraums JJ 1990. Climate change: the IPCC scientific assessment. Inter-governmental Panel on Climate Change, Cambridge University Press, Cambrige, 365p.

Jonsson AM, Appelberg G, Harding S and Barring L 2009. Spatio-temporal impact of climate change on the activity and voltinism of the spruce bark beetle, *Ips typographus.* Global Chang Biology **15:** 486- 499.

Kay IR 1981. The effect of constant temperatures on the development time of eggs of *Heliothis armigera* (Hubner) (Lepidoptera: Noctuidae). Journal of Australian Entomological Society **20:** 155-156.

Lange H, Okland B and Krokene P 2006. Thresholds in the life cycle of the spruce bark beetle under climate change. International Journal for Complex Systems **1648:** 1-10.

Qayyum A and Zalucki MP 1987. Effects of high temperature on survival of eggs of *Heliothis armigera* (Hubner) and *H punctigera* Wallengren (Lepidoptera: Noctuidae). Journal of Australian Entomological Society **26:** 295-296.

Room PM 1983. Calculations of temperature-driven development by *Heliothis* spp (Lepidoptera:Noctuidae) in the Namoi Valley, New South Wales. Journal of Australian Entomological Society **22:** 211-215.

Rouault G, Candau JN, Lieutier F, Nageleisen LM, Martin JC and Warzee N 2006. Effects of drought and heat on forest insect populations in relation to the 2003 drought in Western Europe. Annals of Forest Science **63(6):** 613-624.

Sharma HC 2005. *Heliothis*/*Helicoverpa* management: emerging trends and strategies for future research. Oxford and IBH and Science Publishers, USA and India, 469p.

Sharma HC 2014. Climate change effects on insects: implications for crop protection and food security. Journal of Crop Improvement **28:** 229-259

Tobin PC, Nagarkatti S, Loeb G and Saunders MC 2008. Historical and projected interactions between climate change and insect voltinism in a multivoltine species. Global Change Biology **14:** 951-957.

Wu G, Chen FJ, Sun Y and Ge F 2007. Response of successive three generations of cotton bollworm, *Helicoverpa armigera* (Hubner) fed on cotton bolls under elevated CO_2. Journal of Environmental Sciences **19:** 1318-1325.

Wu K, Chen Y and Minghui Li M 1992. Performances of cotton bollworm, *Heliothis armigera* (Hubner) at different temperatures and relative humidities. Journal of Environmental Sciences (China) **52:** 158-168.

Yadav SS, Kumar J, Yadav SK, Singh S, Yadav VS, Turner NC and Redden R 2006. Evaluation of *Helicoverpa* and drought resistance in Desi and Kabuli chickpea. Plant Genetics Resources **4:** 198-203.

Yin J, Sun Y, Wu G, Parajulee MN and Ge F 2009. No effects of elevated CO_2 on the population relationship between cotton bollworm, *Helicoverpa armigera* Hubner (Lepidoptera: Noctuidae) and its parasitoid, *Microplitis mediator* Haliday (Hymenoptera: Braconidae). Agriculture, Ecosystems and Environment **132:** 267-275.