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Influence of Elevated CO_2 on Growth and Development of Beet Armyworm, *Spodoptera exigua* Hub. (Noctuidae: Lepidoptera) on Chickpea

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ABSTRACT

Changes in quality of host plants under elevated CO_2 conditions likely in future can affect the survival, growth and its development and population dynamics of insect herbivores. The present study is aimed to examine the growth and development of *Spodoptera exigua* (Hubner) (Noctuidae: Lepidoptera) chickpea grown under elevated CO_2 condition in open top chambers at CRIDA, Hyderabad. Significantly lower leaf nitrogen, higher carbon, higher relative proportion of carbon to nitrogen and higher tannins, lower proteins and amino acids and higher carbohydrates were observed in the chickpea foliage grown under elevated CO_2 conditions. This alteration in food quality significantly affected the growth parameters of *S. exigua* in the form of increased food consumption, more fed leaf area, gain in larval weight and more faecal matter production due to extended larval duration and pupal duration. This resulted in reduced fecundity, particularly in *S. exigua* raised under elevated CO_2 conditions compared to ambient conditions. Further feeding indices were recorded and revealed increased approximate digestibility and relative consumption rate of *S. exigua* under elevated CO_2 condition coupled with reduced efficiency of conversion of ingested food and digested food. As a result, the relative growth rate was decreased under elevated CO_2 conditions. In nutshell, it can be concluded that elevated CO_2 concentrations altered the quality of chickpea foliage and has the negative effect on the growth and development of *S. exigua*.

Key words: *Chickpea, CO_2 concentration, Climate change, Feeding indices, Spodoptera exigua.*

According to Intergovernmental Panel on Climate Change (IPCC), Climate Change is defined as "change in climate over time, either due to natural variability (or) as a result of human activity" of late Climate change has become the most important, complex and global environmental phenomenon to date. Atmospheric CO_2 had reached to a concentration of 380 ppm during 2005 and has been predicted to reach up to550 ppm by 2050 and to be doubled by the end of the 21st century due to continuous high levels of fossil fuel consumption. The increase in the amount of atmospheric CO_2 would be about 40 per cent compared with pre-industrial levels of 280 ppm (IPCC, 2007 and 2013).

Elevated CO_2 can directly stimulate plant growth, affect plant resource allocation and change plant tissue quality and it is consequently predicted to indirectly affect insect- herbivory. Increased CO_2 lead to decline in nutritional quality of host plant and affect the performance of herbivore insects (Whittaker, 1999). Leaf nitrogen is considered to be imperative factor for growth and reproduction of insects, reduction in leaf nitrogen content in the plants grown under enriched CO_2 condition result in a nutritionally depleted food source for leaf eating insects (Lindroth *et al.,* 1993). As a result of which insect herbivores which feed on those plants will have increased consumption rate, developmental times, decreased fitness and fecundity (Feng *et al.,* 2010).

Among the biotic stresses that influence chickpea production, the beet armyworm (*Spodoptera exigua* Hubner.) (Noctuiidae: Lepidoptera) was reported as an important folivorous insect pest in India (Singh and Bichoo, 1976).

MATERIAL AND METHODS

Growth and development of *S. exigua* for four generations were conducted under both ambient CO_2 (aCO_2; 380 ± 25 ppm) and elevated CO_2 (eCO_2; 550 ± 25 ppm) conditions. The egg masses collected were incubated at controlled conditions. Upon hatching, neonate larvae were allowed to feed on tender leaves of chickpea grown at different levels of CO_2 concentrations in OTCs. From third day onwards, the larvae were reared individually for feeding trial in petridishes (75 x 10 mm). Twenty replications were maintained under each set CO_2 conditions and in total, 40 larvae were observed for eCO_2 and aCO_2 conditions. Moist filter paper was kept at the bottom of the petriplate to maintain leaf turgidity and humidity. Fresh chickpea leaves obtained from the corresponding ambient and elevated CO_2 chambers were collected and measured for the leaf area using leaf area meter (LI-3000, LI-COR Biosciences) and were also weighed. Enough caution was taken to give leaf material of uniform area

and weight to the larvae on alternate day. The left over leaves were measured for their weight and area to calculate the fed leaf weight and fed leaf area. The weight of the faecal matter was also recorded regularly. The mean larval weight and pupal weight was recorded on alternate days by weighing twenty larvae. Durations of different growth stages of *S. exigua viz.*, larval, pre-pupal, pupal and adult periods were recorded. The adults emerged from the sexed pupae were paired in separate plastic containers (15 x 15 x 15 cm) and were fed with 10 % honey solution through cotton swabs. The egg masses laid on the filter paper and inner wall of plastic containers were daily collected and counted.

Various insect feeding indices were determined by using the data relating to amount of food ingested, faecal matter excreted, larval weight and larval duration (Waldbauer, 1968). Approximate digestibility (AD%), Efficiency of conversion of ingested food (ECI%), Efficiency of conversion of digested food (ECD%), Relative consumption rate (RCR, mg $mg^{-1}day^{-1}$) and Relative growth rate (mg $mg^{-1}day^{-1}$) were computed.

STATISTICAL ANALYSIS

The effects of CO_2 concentrations on larval parameters were analyzed using one-way ANOVA. Treatment means were compared and separated using the least significant difference (LSD) at p<0.01. The data on weight of food ingested, larval weight, faecal matter weight, larval duration, pupal weight, fecundity and feeding indices were analyzed using ANOVA with the help of STAR (Statistical tool for agriculture research), version 1.00.

RESULTS AND DISCUSSION

Growth parameters of *S. exigua*

The results on variation of primary parameters of *S. exigua* on chickpea due to effect of eCO_2 were furnished in Table 1. The results pertaining to growth parameters of *S. exigua* on chickpea was differed significantly under aCO_2 and eCO_2 conditions were presented in Table 1. The total consumption of chickpea foliage was significantly ($F_{1, 19}$ = 3669.94, P < 0.01) higher under eCO_2 (908.85 mg) compared to aCO_2 conditions (688.10 mg). Similar trend was reflected in the total leaf area consumed was significantly ($F_{1, 19}$ =14554.24, P < 0.01) more under eCO_2 (23.24 sq.cm) than aCO_2 (17.67 sq.cm). The faecal matter released by larvae was significantly ($F_{1, 19}$=285.58; P<0.01) varied and was more in *e*CO2 (215.30 mg) than aCO_2 (189.25 mg). The average weight gain by the larva ($F_{1, 19}$ = 120.66, P < 0.0) was more under eCO_2 (183.25 mg) as compared to aCO_2conditions (169.10 mg). The effect of eCO_2 on pre-pupal weight of *S. exigua* on chickpea foliage showed a non-significant difference across two CO_2 conditions, despite it recording lower weight (70.05 mg) at eCO_2 than in aCO_2conditions (70.50 mg). Whereas the pupal weights of *S. exigua* were significantly ($F_{1, 19}$=12.04; P<0.01) lower under eCO_2 (61.70 mg) than aCO_2 conditions (63.30 mg).

The present results are in conformity with the findings of Srinivasa Rao *et al*., (2012) who reported that the total consumption of *S. litura* on peanut foliage was more under eCO_2 (2.15 - 2.50 g) than aCO_2 conditions (1.04 g) and also reported that faecal matter weight was more under eCO_2 (0.85 - 0.91 g) than aCO_2 conditions (0.68 g); with higher pupal weights at aCO_2 (0.30 g). Studies on the effects of CO_2 enrichment on the performance of *Spodoptera litura* on mungbean indicated that the feeding, growth rate of larvae and faecal matter release were highest at eCO_2 conditions as compared to aCO_2 (Srivastava *et al.,* 2002). Goverde and Erhardt (2003) found that the pupal weight of *Coenonympha pamphilus* differed slightly between eCO_2 (64.1mg) and aCO_2 (71.5 mg) conditions.

Significantly ($F_{1, 19}$=133.83; P<0.01) extended larval duration was noticed under eCO_2 (14.60 days) conditions than aCO_2 conditions (12.80 days). Similarly, the pupal duration was significantly ($F_{1, 19}$ = 1.90; P>0 .01) longer under eCO_2 (8.10 days) conditions than eCO_2 conditions (7.85 days). Significant differences were observed in fecundity of *S. exigua* ($F_{1, 19}$ = 797.25, P <0.01) was more (433.60 eggs/female) under eCO_2 compared to aCO_2 conditions (459.70 eggs) (Table 1).

The present results are in conformity with Coviella *et al*. (2000) observed longer developmental time of *S. exigua* under eCO_2 as compared with aCO_2 conditions. Similar results observed by Akey and Kimball (1989) and Mevischutz *et al.* (2003). The mean pupal duration among the treatments ranged from 8.4 days in 550 ppm, 8.8 days in 700 ppm and 8 days in ambient condition. Under eCO_2 condition pupal duration were more as compare to aCO_2 (Tejusing *et al.*, 2014). Srinivasa Rao *et al*. (2012) reported that the less fecund adults were noticed under eCO_2, and resulted in a total of 424- 427 eggs per female per day, as compared with 467 eggs per female per day under aCO_2 conditions. The fecundity of *S. litura* was found reduced under eCO_2 conditions, and might be due to lower pupal weights. Similar observations reported by Wu *et al*., (2006) and Abdul Khadar *et al*., (2014). Karowe (2007) observed that pupal weight in insects has a significant and positive correlation with fecundity in lepidopterans.

Feeding indices of *S. exigua*

The data on growth parameters of *S. exigua* were used for estimating the insect feeding indices and data were presented in Table 2. A perusal of data

Table 1: Effect of elevated CO_2 on growth parameters of *S. exigua* larvae on chickpea

CO_2 concentration (ppm)	Fed leaf weight (mg)	Fed leaf area (sq.cm)	Faecal matter weight (mg)	Larval weight (mg)	Pre-pupal weight (mg)	Pupal weight (mg)	Larval duration (days)	Pupal duration (days)	Fecundity
Ambient CO_2 (380 ppm)	688.10±3.19	17.67±0.18	189.25±6.53	159.15±3.57	70.50±3.49	63.30±1.59	12.80±0.41	7.85±0.88	459.70±1.89
Elevated CO_2 (550 ppm)	908.85±15.95	23.24±0.25	215.30±3.29	167.80±1.36	70.05±2.28	61.70±1.63	14.60±0.50	8.10±0.81	433.60±1.71
F test	3669.94**	4554.24**	285.58**	94.60 **	0.22^{NS}	12.04**	133.83**	6.33*	797.25**
S.Em ±	3.64	0.05	1.54	0.889	0.95	0.46	0.16	0.1	0.92
CD (p = 0.05)	7.63	0.10	3.23	1.861	NS	0.97	0.33	0.21	2.09
CD (p = 0.01)	10.42	0.13	4.41	2.544	NS	1.32	0.45	NS	3.00
CV (%)	1.44	0.71	2.41	1.72	4.29	2.33	3.59	3.94	0.46

All values are mean ± standard deviation
** Significant @ 1% level of significance
*Significant @ 5 % level of significance;
NS = Non-significant

Table 2: Effect of elevated CO_2 on feeding indices of *S. exigua* larvae on chickpea in first generation

CO_2 concentration (ppm)	AD (%)	ECI (%)	ECD (%)	RCR (mg mg^{-1} day^{-1})
Ambient CO_2 (380 ppm)	72.50 ± 0.98	22.99 ± 0.56	31.71 ± 0.93	672.32 ± 26.85
Elevated CO_2 (550 ppm)	76.31 ± 0.63	18.36 ± 0.35	24.06 ± 0.61	738.14 ± 16.08
F test	218.62**	1001.19**	913.29**	80.47**
S.Em±	0.26	0.15	0.26	7.39
CD (p= 0.05)	0.54	0.31	0.53	15.47
CD (p= 0.01)	0.74	0.42	0.72	21.15
CV (%)	1.1	2.24	2.87	3.31

AD = Approximate Digestibility; ECI = Efficiency of Conversion of Ingested food; ECD = Efficiency of Conversion of Digested food; RCR = Relative Consumption Rate; RGR = Relative Growth Rate
All values are mean ± standard deviation
** Significant @ 1% level of significance

Table 3: Effect of elevated CO_2 on biochemical constituents of chickpea foliage at 27 ^{o}C

CO_2 Concentration (ppm)	Biochemical constituents of Chickpea								
	Carbon (%)	Nitrogen (%)	C : N	Proteins (mg g^{-1})	Amino acids (mg g^{-1})	Tannins (mg g^{-1})	TSS (mg g^{-1})	Starch (mg g^{-1})	Carbohydrates (mg g^{-1})
Ambient CO_2 (380 ppm)	32.17±1.19	3.49 ±0.07	9.22±0.20	72.38±0.83	3.48±0.04	2.23±0.03	20.91±0.23	4.92±0.07	25.83±0.18
Elevated CO_2 (550 ppm)	36.10±1.02	2.71±0.07	13.33±0.21	62.81±0.65	2.99±0.02	2.76±0.05	27.13±0.28	6.49±0.04	33.62±0.30
F. test	44.43**	840.67**	732.77**	484.56**	600.25 **	731.17**	792.82**	1381.25**	8424.02**
S.Em±	0.59	0.03	0.15	0.43	0.02	0.02	0.07	0.04	0.09
CD(p = 0.05)	1.64	0.08	0.42	1.21	0.06	0.06	0.18	0.12	0.24
CD (p = 0.01)	2.72	0.12	0.7	2.00	0.09	0.09	0.31	0.19	0.39
CV (%)	2.74	1.37	2.13	1.02	0.98	1.25	0.44	1.17	0.45

TSS- Total soluble sugars
All values are mean ± standard deviation
** Significant @ 1% level of significance

showed that indices were differed significantly across two CO_2 conditions. The proportion of consumed food that was digested is denoted by approximate digestibility (AD) and a significant variation ($F_{1, 19}$=218.62; P<0.01)) in the AD of chickpea foliage was noticed between CO_2 conditions and the higher AD of 76.31 per cent was recorded in *e*CO_2 than the *a*CO_2 (72.50 %). The effect of *e*CO_2 on both efficiency of conversion of ingested food (ECI- the larval weight gain per unit weight of leaf consumed) ($F_{1, 19}$=1001.19; P<0.01) and efficiency of conversion of digested food (ECD - the larval weight gain per unit weight of leaf digested) ($F_{1, 19}$=913.29; P<0.01) of *S. exigua* were significantly differed. The lower percent of ECI and ECD by larvae were noticed under *e*CO_2 (18.36 and 21.10 %) than ambient CO_2 (22.99 and 30.22 %), respectively. Relative consumption rate (RCR) indicates the per capita consumption of food by larva per day. Significantly ($F_{1, 19}$=80.47; P<0.01) *S. exigua* consumed more foliage under *e*CO_2- (738.14 mg $mg^{-1}day^{-1}$) as compared with *a*CO_2 conditions (692.32 mg $mg^{-1}day^{-1}$). The relative growth rate (RGR) of insect indicates that the growth gained by larva per day. RGR of *S. exigua* varied significantly ($F_{1, 19}$=569.16; P<0.01) and was lower under *e*CO_2 (135.52 mg $mg^{-1}day^{-1}$) than *a*CO_2 conditions (153.82 mg $mg^{-1}day^{-1}$)

The present results are in conformity with the findings of Lindroth *et al*., (1993), who reported that RCR of gypsy moth was increased by 75% under high CO_2 level and RGR of was decreased by 35 per cent whereas, efficiency parameters *viz.*, ECI and ECD for the larvae fed on high CO_2 foliage decreased significantly. Similar trend of results were reported by Srinivasa Rao *et al.,* (2012) on the growth and development of *S. litura* on peanut under two CO2 conditions indicating that the increased AD and RCR of peanut foliage under *e*CO_2 (59.95 % in 550 ppm and 61.78 % in 700 ppm) compared with *a*CO_2 (51.69 %). RCR was significantly higher under 550 (333.50 mg $mg^{-1}day^{-1}$) and 700 ppm (348.86 mg $mg^{-1}day^{-1}$) than *a*CO_2 (281.42 mg $mg^{-1}day^{-1}$). Decreased ECI (30.39 % in 550 ppm and 30.27 % in 700 ppm), ECD (51.43% in 550 ppm and 53.20 % in 700 ppm) and RGR (99.55 in 550 ppm and 98.38 mg $mg^{-1}day^{-1}$ in 700 ppm) of larvae were observed under *e*CO_2 conditions than ambient CO_2 conditions (109.12 mg $mg^{-1}day^{-1}$).

Biochemical constituents of chickpea foliage

The results on variation of biochemical constituents of *S. exigua* on chickpea due to effect of *e*CO_2 were furnished in Table 3. Leaf nitrogen content was distinctly lower (2.71 %) under *e*CO_2 conditions compared to *a*CO_2 conditions (3.49%) ($F_{1, 9}$ = 840.67; P < 0.01). However, the carbon content of leaf tissue increased significantly ($F_{1, 9}$ = 44.43; P =< 0.01) under *e*CO_2 conditions (36.10 %) over *a*CO_2 (32.17 %) and resulted in a significant increase of C: N ratio under eCO_2 (13.33) compared to *a*CO_2 conditions (9.22). In contrast, the tannin content was varied significantly across CO_2 conditions ($F_{1, 9}$ = 731.17; P < 0.01). The amino acid ($F_{1, 9}$ = 600.25; P < 0.01) and protein content ($F_{1, 9}$ = 484.56; P < 0.01) were significantly lower under *e*CO_2 conditions (2.99 and 62.81 mg g^{-1}) compared to *a*CO_2 conditions (3.48 and 72.38 mg g^{-1}), respectively. Significantly higher TSS ($F_{1, 9}$ = 792.82; P < 0.01), starch ($F_{1, 9}$ = 1381.25; P < 0.01) and carbohydrates ($F_{1, 14}$ = 8424.02; P < 0.01) were recorded under *e*CO_2 conditions (27.13, 6.49 and 33.62 mg g^{-1}) compared to *a*CO_2 conditions (20.91, 4.92 and 41.45 mg g^{-1}), respectively.

The present results are in conformity with the findings shown in sugar beet, *Beta Vulgaris* (Caulfield and Bunce, 1994); mungbean, *Vigna radiata* (Srivastava *et al*., 2002); maize, *Zea mays* (Yin *et al*., 2010) and chickpea, *Cicer arietinum* (Abdul khadar *et al*., 2014) where in plants grown under *e*CO_2 had significantly lower nitrogen content with increase in carbon and C: N ratio of plants and confirm the result of the present investigations. Under elevated CO_2 conditions, chickpea plants exhibited lower nitrogen levels due to increased photosynthesis resulting in poorer food quality for *S. exigua* larvae leading to extended larval duration, lower pupal weight and fecundity, increasing food consumption (higher RCR) and assimilation (higher AD) reducing food conversion efficiency by larvae (lower ECI and ECD) and resulted in slow growth (lower RGR).

CONCLUSION

It is understood that the dilution of biochemical constituents of chickpea foliage caused the poor growth, development and fecundity of *S. exigua* under elevated CO_2 conditions. Based on the present study, it can be speculated that, the growth performance of beet armyworm under elevated CO_2 conditions, affects badly resulting in poor perpetuation of the population which might reduce its fitness in subsequent generations.

LITERATURE CITED

Abdul Khadar B, Prabhuraj A, Srinivasa Rao M, Sreenivas A G and Naganagoud A 2014 Influence of elevated CO_2 associated with chickpea on growth performance of gram caterpillar, *Helicoverpa armigera* (HUB.). *Applied Ecology and Environmental Research.* 12(2): 345-353.

Akey D H and Kimball B A 1989 Growth and development of the beet armyworm on cotton grown in an enriched carbon dioxide atmosphere. *Southwestern Entomologist.* 14(3): 255-260.

Caulfield F and Bunce J A 1994 Elevated atmospheric carbon dioxide concentrations affects interactions between *Spodoptera exigua* (Lepidoptera: Noctuidae) larvae and two host plants species outdoors. *Physiological and Chemical Ecology.* 23(4): 999-1005.

Feng, G, Gang W and Chen F 2010 Elevated CO_2 lessens predation of *Chrysopa sinica* on *Aphis gossypii*. *Entomologia Experimentalis et Applicata*. 135: 140.

Goverde M and Erhardt A 2003 Effect of elevated CO_2 on development and larval food plant preference in the butterfly *Coenonympha pamphilus* (Lepidoptera: Satyridae). *Global Change Biology*. 9: 74-83.

IPCC 2007 Climate change 2007 Synthesis Approach. Intergovernmental Panel on Climate Change. *Cambridge University Press*, Cambridge, UK.

IPCC 2013 Climate Change: The Physical Science Basis, Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. *Cambridge University Press*, Cambridge, UK.

Karowe D N 2007 Are legume-feeding herbivores suffered against direct effects of elevated carbon dioxide on host plants? A test with the sulfur butterfly, *Colias philodice*. *Global Change Biology*. 13: 2045-2051.

Lindroth R L, Kiney K K and Platz C L 1993 Responses of deciduous trees to elevated atmospheric CO_2, productivity, phytochemistry and insect performance. *Ecology.* 74: 763-777.

Mevischutz J, Goverde M and Erhardt A 2003 Effect of fertilization and elevated CO2 on larval food and butterfly nectar amino acid preference in *Coenonympha pamphilus* L. *Behavioural Ecology Sociobioology*. 54: 36-43

Singh Y and Bichioo S L 1976 Bionomics of *Spodoptera exigua* (Hubner) on gram. *Indian Journal of Entomology.* 38 (2): 138 - 141.

Srinivasa Rao M, Manimanjari D, Vanaja M, Ramarao C A, Srinivas K, Rao V U M and Venkateswarlu B 2012 Impact of elevated CO_2 on tobacco caterpillar, *Spodoptera litura* on peanut, *Arachis* hypogea. *Journal of Insect Science.* 12(103): 1-10.

Srivastava A C, Tiwari L D, Pal M and Sengupta U K 2002 CO_2-mediated changes in mungbean chemistry: Impact on plant-herbivore interactions. *Current Science*. 82(9): 1148-1151.

Tejusing, Shrikant and Bandeppa 2014 Influence of elevated CO_2 on biology of Bihar hairy caterpillar, *Spilosoma obliqua* (Wlk.) on castor. *Journal of Entomological Research*. 38(3): 169-172.

Waldbauer G P 1968 The consumption and utilization of food by insects. *Advance in Insect Physiology.* 5: 229-288.

Whittaker J B 1999 Impacts and responses at population level of herbivorous insects to elevated CO_2. *Environmental Entomology.* 96: 149:156.

Wu G, Chen F J and Ge F 2006 Response of multiple generations of cotton bollworm *Helicoverpa armigera* Hubner, feeding on spring wheat, to elevated CO_2. *Journal of Applied Entomology*. 130(1): 2-9.

Yin J, Sun Y C and Wu G 2010 Effects of elevated CO_2 associated with maize on multiple generations of cotton bollworm, *Helicoverpa armigera. Entomologia Experimentalis et Applicata*. 136: 12–20.

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