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Research Paper

Food consumption and relative growth rate of *Cnaphalocrocis medinalis* (Guenee) on rice under elevated temperature and carbon dioxide conditions

SIMRANPREET KAUR, RUBALJOT KOONER* and KAMALJEET SINGH SURI

Department of Entomology, Punjab Agricultural University, Ludhiana, Punjab, India

**Corresponding author email: rubalsidhu05@pau.edu*

ABSTRACT

The present studies were conducted at Punjab Agricultural University, Ludhiana during 2019-22. The impact of variable minimum:maximum temperature for 10:14 h, CO_2 and RH on food consumption and relative growth rate (RGR) of *Cnaphalocrocis medinalis* was analysed. The food consumption and RGR of *C. medinalis* larvae were significantly influenced with change in temperature, CO_2 and RH conditions. Food consumption and RGR increased with increase in temperature, CO_2 and RH. The increase in temperature (22:32°C to 26:35°C), CO_2 concentration (400 to 450 ppm) and RH (75 to 85 %) was found to increase the food consumption (0.0210 to 0.0450 g $larva^{-1}$) and RGR (0.0200 to 0.0770 mg $mg^{-1} day^{-1}$).

Keywords: Carbon dioxide; Food Consumption; Leaffolder; Plant growth chamber; Temperature, Relative growth rate

In India, insect pests pose major menace to the rice production causing 31.1-86.0 per cent yield losses with 25-30 per cent average losses to its production (Dhaliwal and Arora 2010). Climate change is the foremost environmental concern that affects most ecosystems globally (Gray *et al.,* 2014). Insects, being poikilothermic are greatly affected by various environmental factors, including a change in temperature and carbon dioxide concentrations in the atmosphere (Bale *et al.,* 2002). Climate change is already causing adverse impact on the agriculture sector and is also affecting the livelihood of people depending on agriculture (IPCC, 2023). Climatic factors such as temperature, rainfall and relative humidity greatly influence the outbreak of the insect population (Siswanto *et al.,* 2008). The global distribution, abundance and ecology of plants and animals will all be significantly impacted by the climate change (Mutamiswa *et al.,* 2018).

The climate change influences physiology and behaviour of herbivores directly (Merill *et al.,* 2008) or indirectly through its effects on insect's host plants, natural enemies and competitors. It also affects their population dynamics, abundance, intensity and feeding behaviour (Ayres and Schneider 2009; Stiling and Cornelissen 2007). Temperature influences insect behaviour, distribution, development, survival, and reproduction. Rise of CO_2 and temperature directly affects the food grain production and indirectly affects through its effect on crop pests (Sunil *et al.,* 2024).

Rice leaf folder, *Cnaphalocrocis medinalis* (Guenee) (Lepidoptera: Pyralidae) which earlier was considered as a pest of minor importance has attained the status of major pest in many parts of India causing yield losses to the tune of 30 to 80 per cent (Rani *et al.,* 2007, Park *et al.,* 2014, Zhou *et al.,* 2021). Studies by Lv *et al.,* (2021) revealed that rice leaffolder larvae reared at high temperature showed weaker reproductive capacity but stronger flight potential, which might be more likely to trigger the migration and Fang *et al.,* (2013) reported increased egg hatchability of this insect under elevated relative humidity. Hence present study aimed to evaluate the possible impact of variable temperature, carbon dioxide and relative humidity on nutritional indices of *C. medinalis* on rice.

MATERIALS AND METHODS

Rearing and maintenance of the test insect

To start the culture of rice leaf folder, male and female adults of *C. medinalis* were collected from the rice fields. These adults were released on about a month old plants of rice variety TN1 sown in pots. The pots were placed in a water tray (70×50×12cm)

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Table 1: Test combinations of temperature, carbon dioxide and RH

CO_2 (400 ppm)						
RH (%)	(Min:Max) temp. (^{0}C)					
75 85	(22:32)	(22:35)	(24:32)	(24:35)	(26:32)	(26:35)
CO_2 (450 ppm)						
RH (%)	(Min:Max) temp. (^{0}C)					
75 85	(22:32)	(22:35)	(24:32)	(24:35)	(26:32)	(26:35)

and covered with steel bar frame cage (68×48×50cm) with nylon netting (40 mesh) all around the four sides and the top. Three to four such cages of insect culture were maintained throughout the study period to procure sufficient number of the test insects for experimentation.

Raising and maintenance of test plants

The soil mixture for filling pots was prepared by mixing soil with farmyard manure thoroughly. Seeds of the test variety (Non-basmati PAU recommended rice variety, PR 121) were sown at different time intervals in pots containing puddled soil. Ten day old seedlings of test variety were transplanted at the rate of two seedlings per pot for conducting the studies. Seeds of rice variety, TN1 were also sown periodically in the pots to ensure regular supply of rice plants for mass rearing of the test insect.

Plant growth chambers

The various abiotic factors during study period were maintained in the plant growth chambers viz., Walk-In type Plant Growth Chamber: PGW-40 (M/s Percival Scientific, Inc., USA) and Reach-In type Plant Growth Chambers: E-36L2 and E-41L (M/s Percival Scientific, Inc., USA). The various experiments were conducted under the following set of minimum:maximum temperature maintained for 10:14 hours (Dark:Light), carbon dioxide and relative humidity (Table 1).

The experiment was conducted on two 30-day old plant of the test rice variety (Non-basmati PAU recommended rice variety, PR 121) sown in pots enclosed in cylindrical Mylar film, for each of the specified test combination. There were four replications for each of the test combination.

Food consumption calculation

The data on food consumption were calculated from 3rd instar larvae of *C. medinalis* using rice leaves as a food. Larvae were placed singly in plastic sample containers to avoid overcrowding and congestion. Holes were made in lid of containers for aeration of larvae. Initial weight of each larva and rice leaf used as food was recorded before the start of experiment. After 24 hours, the weight of remaining leaf, larval weight and faecal matter was recorded. Each replication was consisted of 5 larvae at each test combination. The data on weight of larva, food and faeces were recorded on an electronic weighing balance with sensitivity of 0.1 mg (Make-A&D Company, USA). Under each condition, a set of control leaves (without larva) were also kept and weighed every day to ascertain the moisture loss of leaves from the food offered to the larvae and were used to calculate the actual weight of food eaten by larvae. The corrected weight of food consumed was also calculated. A set of additional larvae were maintained at test combinations in similar way. Whenever any of the test larvae died, larva from the additional set was used to replace it so that the number of larvae in each replication remained same.

Corrected weight of consumed food= (1- a/2) [W- (L+bL)]

Where, W= Weight of food introduced; L= Weight of uneaten food; a= Ratio of weight loss to the initial weight of the food; b= Ratio of weight loss to the final weight of the food

The observations on weight of fresh leaf, weight of eaten leaf, weight of faeces, initial and final weight of surviving larvae, and duration of feeding period were recorded on different test combinations. The data were analyzed using ANOVA to test significance of difference among the treatments using SPSS software.

RESULTS AND DISCUSSION

Influence of temperature, CO_2 concentration and RH on food consumption of C. medinalis larvae

The maximum mean food consumption of 0.0450 g larva^{-1} was recorded in the test combination exhibiting min. and max. temperature of 26:35°C for 10:14 h (Dark:Light), CO_2 (450 ppm) and RH (85%), while minimum mean food consumption of 0.0210 g larva^{-1} was recorded in 22:32°C for 10:14 h, CO_2 (400 ppm) and RH (75%). Significant increase of 0.0235, 0.0240, 0.0332, 0.0350, 0.0388 and 0.0426 g larva^{-1} in mean food consumption was observed at varying temperatures combinations viz. 22:32, 22:35, 24:32, 24:35, 26:32, 26:35°C, respectively. The overall mean effect of CO_2 concentration on food consumption at 400 ppm was 0.0288 g larva^{-1} which got increased to 0.0327 g larva^{-1}at 450 ppm. Likewise, overall effect of RH; food consumption of 0.0305 g larva^{-1} at 75 per cent increased to 0.0329 g larva^{-1}at 85 per cent (Table 2). Effect of temperature, CO_2 concentration and interaction among temperature and CO_2 was recorded as statistically significant for food consumption whereas effect of RH and other interactions were recorded non-significant (Table 2).

The present results on food consumption are in agreement with Pandey *et al.,* (2015) who reported that food consumption of

Table 2: Influence of temperature, CO_2 concentration and RH on food consumption (g larva^{-1}) of *C. medinalis* larvae

*Temp. (ºC)→ RH (%) ↓	CO_2 concentration (400 ppm)							CO_2 concentration (450 ppm)							Overall mean (RH)
	T_1 (22:32)	T_2 (22:35)	T_3 (24:32)	T_4 (24:35)	T_5 (26:32)	T_6 (26:35)	Mean (RH× CO_2)	T_1 (22:32)	T_2 (22:35)	T_3 (24:32)	T_4 (24:35)	T_5 (26:32)	T_6 (26:35)	Mean (RH× CO_2)	
75	0.0210 **±0.01** (0.14)	0.0235 ±0.03 (0.15)	0.0311 ±0.02 (0.18)	0.0339 ±0.01 (0.18)	0.0357 ±0.01 (0.19)	0.0420 ±0.02 (0.20)	0.0312 (0.18)	0.0221 ±0.02 (0.15)	0.0238 ±0.01 (0.15)	0.0332 ±0.02 (0.18)	0.0342 ±0.01 (0.18)	0.0360 ±0.01 (0.19)	0.0433 ±0.01 (0.21)	0.0321 (0.18)	0.0305 (0.17)
85	0.0234 ±0.01 (0.15)	0.0237 ±0.01 (0.15)	0.0328 ±0.03 (0.18)	0.0350 ±0.01 (0.19)	0.0387 ±0.03 (0.20)	0.0437 ±0.01 (0.21)	0.0328 (0.18)	0.0249 ±0.01 (0.16)	0.0246 ±0.01 (0.16)	0.0350 ±0.02 (0.19)	0.0353 ±0.01 (0.19)	0.0407 ±0.02 (0.20)	0.0450 **±0.02** (0.21)	0.0342 (0.18)	0.0329 (0.18)
Mean (Temp.× CO_2)	0.0222 (0.15)	0.0236 (0.15)	0.0319 (0.18)	0.0344 (0.19)	0.0372 (0.19)	0.0428 (0.21)		0.0235 (0.15)	0.0242 (0.16)	0.0341 (0.18)	0.0347 (0.19)	0.0383 (0.20)	0.0441 (0.21)		
Mean (Temp.×RH-75)	0.0216 (0.15)	0.0237 (0.15)	0.0322 (0.18)	0.0341 (0.18)	0.0359 (0.19)	0.0427 (0.21)									
Mean (Temp.×RH-85)	0.0242 (0.16)	0.0242 (0.16)	0.0339 (0.18)	0.0352 (0.19)	0.0397 (0.20)	0.0443 (0.21)									
Overall mean (CO_2)				0.0288 (0.16)							0.0327 (0.18)				
Overall mean (Temp.)	0.0235 (0.15)	0.0240 (0.15)	0.0332 (0.18)	0.0350 (0.19)	0.0388 (0.20)	0.0426 (0.21)									
LSD (p=0.05)	Temperature=0.02; CO_2=0.01; RH=NS Temperature×CO_2=0.01; CO_2× **RH=NS**; Temperature × RH=NS; Temperature×CO_2×**RH=NS**														

Figures in parentheses are the means of √n+1 transformations; Data values are Mean ±SE of food consumption (g larva^{-1}) of four replications
*Temperature ($T_{1....}T_6$) values in parentheses are Minimum: Maximum temperature in ºC

H. armigera increased by 12.78 and 32.84 per cent with increase in temperature by 3°C and 6°C. Khadar *et al.,* (2014) also reported increase in food consumption upto 81.67 per cent by *H. armigera* under elevated CO_2 conditions (700 ppm). Sharma and Brar (2018) reported that food consumption in *S. litura* increased from 0.18 g larva^{-1} at temperature of 25:11°C and CO_2 (350 ppm) to 0.31g larva^{-1} at temperature of 25:14°C and CO_2 (450 ppm). Similarly, Dalal and Arora (2016) also observed that food consumption by *H. armigera* increased by 14.69, 14.19, 22.3 and 5.19 per cent with increase in temperature from 25:10°C to 25:13°C, 25:13°C to 25:16°C, 30:10°C to 30:13°C and 30:13°C to 30:16°C, respectively. Hunter (2001) opined that food consumption by *S. litura* larvae increased under elevated CO_2 and temperature might be due to the reduction in protein content and increase of C/N ratio in leaves under elevated CO_2. Under elevated CO_2 conditions, the nutritional quality of leaves gets reduced considerably due to dilution of nitrogen level by 10-30 per cent (Coley and Markham 1998). The reduced N content in foliage due to elevated CO_2 level, caused nearly 40 per cent increase in consumption of food by herbivores (Hunter 2001).

Rao *et al.,* (2009) conducted feeding trials with lepidopterans using castor leaves from plants grown under different concentration of CO_2 (700, 550, 350 and ambient) and reported that larvae fed on 700 and 550 ppm CO_2 exhibited increased consumption. Srivastava *et al.,* (2002) also reported more food consumption by *S. litura* on host leaves grown under enriched CO_2 (700 ppm) and fecal matter production was also higher under the enriched CO_2 conditions. They observed that relatively small increases in leaf temperature caused by elevated CO_2 and increase in temperature could strongly affect consumption rates. Sharma *et al.,* (2018) also reported an increase of 20 per cent food consumption at elevated CO_2 concentration (500 ppm) whereas increase in minimum temperature by 5°C increased the food consumption by 43.23, 50.83 per cent in *S. litura*. Gang *et al.,* (2007) also reported increased food consumption and more frass per larva of bollworm fed on cotton bolls showed significant increase for the first, second and third generations under elevated CO_2. The carbon:nitrogen (C:N) ratio of the plant foliage generally increases when plants are grown under elevated CO_2 than in the ambient CO_2. As a result, insect larvae increase leaf consumption and their infestation rates under elevated CO_2 to compensate for lower nitrogen in plant foliage (Kumar *et al.,* 2012, Daravath *et al.,* 2018).

Influence of temperature, CO_2 concentration and RH on relative growth rate (RGR) of C. medinalis larvae

The mean RGR of *C. medinalis* larvae varied from 0.0200 mg mg^{-1}day^{-1} to 0.0770 mg mg^{-1}day with maximum mean RGR of 0.0770 mg mg^{-1}day^{-1} in test combination of 26:35°C for 10:14 h (Dark: Light), CO_2 (450 ppm) and RH (85%) (Table 3). Significant change of 0.0220, 0.0240, 0.0290, 0.0380, 0.0430 and 0.0660 mg mg^{-1}day^{-1} in mean RGR was observed at varying temperatures viz. 22:32, 22:35, 24:32, 24:35, 26:32, 26:35°C, respectively. The RGR value was 0.0270 mg mg^{-1}day^{-1} at CO_2 concentration of 400 ppm which got increased to 0.0420 mg mg^{-1}day^{-1}at 450 ppm. Same trend was recorded for overall mean effect of RH on RGR of 0.0280 mg mg^{-1}day^{-1} at 75 per cent and increased to 0.0380 mg mg^{-1}day^{-1} at 85 per cent. Temperature and CO_2 showed statistically significant impact whereas RH and interactions among factors showed non-significant effect.

Present results of increased RGR with increase in temperature, CO_2 concentration and RH are in line with the findings of Dalal and Arora (2016) who reported lowest RGR of 0.139±0.002 mg mg^{-1}day^{-1} in case of *H. armigera* at the lowest alternating temperature (25:10°C) which then increased to 0.174±0.003 mg mg^{-1}day^{-1} at the alternating temperature of 30:10°C. Sharma and Brar

Table 3: Influence of temperature, CO_2 concentration and RH on relative growth rate (mg mg^{-1}day^{-1}) of *C. medinalis* larvae

*Temp. (ºC)→ RH (%) ↓	CO_2 concentration (400 ppm)							CO_2 concentration (450 ppm)							Overall mean (RH)
	T_1 (22:32)	T_2 (22:35)	T_3 (24:32)	T_4 (24:35)	T_5 (26:32)	T_6 (26:35)	Mean (RH× CO_2)	T_1 (22:32)	T_2 (22:35)	T_3 (24:32)	T_4 (24:35)	T_5 (26:32)	T_6 (26:35)	Mean (RH× CO_2)	
75	0.0200± 0.02 (0.14)	0.0290± 0.06 (0.17)	0.0250± 0.05 (0.16)	0.0400± 0.08 (0.20)	0.0370± 0.02 (0.19)	0.0570± 0.08 (0.24)	0.0346 (0.19)	0.0220± 0.03 (0.15)	0.0220± 0.06 (0.15)	0.0410± 0.04 (0.20)	0.0350± 0.03 (0.19)	0.0490± 0.04 (0.22)	0.0580± 0.05 (0.24)	0.0378 (0.19)	0.0280 (0.17)
85	0.0270± 0.09 (0.16)	0.0220± 0.07 (0.15)	0.0400± 0.05 (0.20)	0.0380± 0.11 (0.19)	0.0530± 0.05 (1.23)	0.0720± 0.01 (0.27)	0.0420 (0.20)	0.0210± 0.01 (0.14)	0.0240± 0.05 (0.15)	0.0370± 0.06 (0.19)	0.0410± 0.03 (0.20)	0.0550± 0.11 (0.23)	0.0770± 0.08 (0.28)	0.0425 (0.21)	0.0380 (0.19)
Mean (Temp.×CO_2)	0.0235 (0.15)	0.0255 (0.16)	0.0325 (0.18)	0.0390 (0.20)	0.0450 (0.21)	0.0645 (0.25)		0.0215 (0.14)	0.0230 (0.15)	0.0390 (0.20)	0.0380 (0.19)	0.0520 (0.23)	0.0675 (0.26)		
Mean (Temp.×RH-75)	0.0210 (0.14)	0.0260 (0.16)	0.0330 (0.18)	0.0380 (0.19)	0.0430 (0.21)	0.0575 (0.24)									
Mean (Temp.×RH-85)	0.0240 (0.15)	0.0230 (0.15)	0.0390 (0.20)	0.0390 (0.20)	0.0540 (0.23)	0.0750 (0.27)									
Overall mean (CO_2)				0.0270 (0.16)							0.0420 (0.20)				
Overall mean (Temp.)	0.0220 (0.15)	0.0240 (0.15)	0.0290 (0.17)	0.0380 (0.19)	0.0430 (0.21)	0.0660 (0.26)									
LSD (p=0.05)	Temperature=0.01; CO_2=0.01; RH=NS Temperature×CO_2=NS; CO_2× **RH=NS**; Temperature × RH=NS; Temperature × CO_2 × RH=NS;														

Figures in parentheses are the means of √n+1 transformations; Data values are Mean ±SE of RGR (mg mg^{-1} day^{-1}) of four replications
*Temperature ($T_{1----}T_6$) values in parentheses are Minimum: Maximum temperature in ºC

(2018) also reported increase in relative growth rate from 0.15 to 0.27 mg mg^{-1} day^{-1} at elevated temperature and CO_2. It was opined that most leaf-chewing insects exhibit compensatory increase in food consumption. Insects, when fed on elevated CO_2 grown plants, increase their individual consumption due to the poor food quality of these plants led to increased growth rate.

CONCLUSION

The study revealed that food consumption and relative growth rate of rice leaffolder increased with increase in minimum temperature by 4 ^{0}C. These parameters also increased with increase in carbon dioxide concentration from 400 to 450 ppm. It can be concluded that minimum temperature, carbon dioxide and their interactive effect influences the nutritional indices of *C. medinalis*.

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REFERENCES

Ayres, J.S. and Schneider, D. (2009). The role of anorexia in resistance and tolerance to infections in *Drosophila*. *PLoS Biol.,* 7:1000-1005.

Bale, J., Mas ters, G.J., Hodkins, I.D., Awmack, C., Bezemer, T.M., Brown, V.K., Buterfield, J., Buse, A., Coulson, J.C., Farrar, J., Good, J.E.G., Harrigton, R., Hartley, S., Jones, T.H., Lindroth, R. L., Press, M.C., Symrnioudis, I., Watt, A.D. and Whittaker, J.B. (2002). Herbivory in global climate change research: Direct effects of rising temperature on insect herbivores. *Global Change Biol.,* 8:1-16.

Coley, P.D. and Markham, A. (1998). Possible effects of climate change on plant/ herbivore interactions in moist tropical forests. *Climate Change,* 39:455-472.

Dalal, P.K. and Arora, R. (2016). Impact of temperature on food consumption and nutritional indices of tomato fruit borer, *Helicoverpa armigera* (Hübner) (Noctuidae: Lepidoptera). *J. Agrometeorol.,* 18:62-67. https://doi.org/10.54386/jam.v18i1.901

Daravath, V., Chander, S. and Sagar, D. (2018). Impact of elevated carbon dioxide on the protective enzymes in brown planthopper (*Nilaparvata lugens*) and infested rice (*Oryza sativa*) plants. *Indian J. Agric. Sci.,* 88(9):1366-1370.

Dhaliwal G.S. and Arora R. (2010). *Integrated Pest Management*. 369pp. Kalyani Publishers, New Delhi, India.

Fang, Y., Liao, H., Qiu, Q. and Xiangdong, L. (2013). Combined effects of temperature and relative humidity on eggs of the rice leaf folder, *Cnaphalocrocis medinalis* (Lepidopetra: Pyralidae). *Acta Entomologica Sinica.,* 56 (7):769-791.

Gang, W.U., Chen, F.J., Sun, Y.C. and Feng, G.E. (2007). Response of successive three generations of cotton bollworm, *Helicoverpa armigera* (Hubner), fed on cotton bolls under elevated CO_2. *J. Envir. Sci.,*19 (11):1318-1325.

Gray, J., Frolking, S., Kort, E., Deepak, R., Christopher, J., Navin, R. and Mark, A. (2014). Direct human influence on atmospheric CO_2 seasonality from increased cropland productivity. *Nature,* 515: 398-401.

Hunter, M.D. (2001). Effects of elevated atmospheric carbon dioxide on insect-plant interactions. *Agric. Forest Ent.,* 3:153-159.

IPCC. (2023). Climate Change 2022 - Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (1st ed.). Cambridge University Press. https://doi.org/10.1017/9781009325844

Khadar, A.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* (Hübner). *Appl. Ecol. Envir. Res.,* 12:345-353.

Kumar, S., Gupta, D. and Nayyar, H. (2012). Comparitive response of maize and rice genotypes to heat stress: Status of oxidative stress and antioxidants. *Acta Physiol. Pl.,* 34:75-86.

Lv, W., Jiang, X., Chen, X., Cheng, Y., Xia, J. and Zhang, L. (2021). Flight and reproduction variations of rice leaf roller, *Cnaphalocrocis medinalis* in response to different rearing temperatures. *Insects,* 12: 1083. https://doi.org/10.3390/insects12121083

Merill, R., Gutierrez, D., Lewis, O., Gutierrez, J., Diez, S. and Wilson, R. (2008). Combined effects of climate and biotic interactions on the elevational range of a phytophagous insect. *J. Anim. Ecol.,* **77**:145-155.

Mutamiswa, R., Machekano, H., Chidawanyika, F. and Nyamukondiwa, C. (2018). Thermal resilience may shape population abundance of two sympatric congeneric *Cotesia* species (Hymenoptera: Braconidae). *PLoS One*., 13(2):1019-1840.

Pandey, S., Sharma, S., Sandhu, S.S. and Arora, R. (2015). Development and food consumption of some lepidopteran pests under increased temperature conditions. *J. Agrometeorol.,* 17:36-42. https://doi.org/10.54386/jam.v17i1.973

Park, H.H., Ahn, J.J. and Park, C.G. (2014). Temperature-dependent development of *Cnaphalocrocis medinalis* Guenée (Lepidoptera: Pyralidae) and their validation in semi field condition. *J. Asia Pacific Ent.,*17(1):83-91.

Rani W., Amutha R., Muthulakshmi S., Indira K. and Mareeswari P. (2007) Diversity of rice leaf folders and their natural enemies. *Res. J. Agric. Biol. Sci.,* 3(5):394-97.

Rao, M.S., Srinivas, K., Vanaja, M., Rao, G.N., Venkateswarlu, B. and Ramakrishna, Y.S. (2009). Host plant mediated effects of elevated CO_2 on growth performance of two insect folivores. *Curr. Sci.,* 97: 1047-1054.

Sharma, S. and Brar, T. S. (2018). Effects of elevated temperature and carbon dioxide on food consumption and growth of *Spodoptera litura* Fabricius on cauliflower. *J. Agrometeorol.,* 20 (4):305-310. https://doi.org/10.54386/jam.v20i4.571

Sharma, S., Kooner, R., Sandhu, S.S. and Arora, R. (2018). Impact of elevated temperature and carbon dioxide on insect performance indices of *Spodoptera litura* Fabricius. *J. Ent. Res.,* 42 (3):315-324.

Siswanto, R. M., Dzolkhifli, O. and Elna, K. (2008). Population fluctuation of *Helopeltis antonii* Signoret on cashew Anacarcium occidentalle L. in Java Indonesia. *Pertanika J. Tropical Agric. Sci.,* 31:191-196.

Srivastava, A.C., Tiwari, L.D., Madan, P. and Sengupta, U.K. (2002). CO_2 mediated changes in mung bean chemistry: Impact on plant-herbivore interactions. *Curr. Sci.,* 82**:**1148-1151.

Stiling, P. and Cornelissen, T. (2007). How does elevated carbon dioxide (CO_2) affect plant-herbivore interactions? A field experiment and meta-analysis of CO_2-mediated changes on plant chemistry and herbivore performance. *Glob. Chang. Biol.,* 13(9): 1823-1842.

Sunil V., Lakshmi V. J., Chiranjeev K., Rao D. S. and Kumar M. S. (2024) Rice brown planthopper, *Nilaparvata lugens* (Stål) feeding behavior in relation to elevated CO_2 and temperature. *J. Agrometeorol.,* 26(1): 92-98. https://doi.org/10.54386/jam.v26i1.2519

Zhou, Y.J., Du, J., Li, S.W., Shakeel, M., Li, J.J. and Meng, X.G. (2021). Cloning, characterization, and RNA interference effect of the *UDP-N-Acetylglucosamine Pyrophosphorylase* gene in *Cnaphalocrocis medinalis*. *Genes,* 12(4):464