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Research Paper

The host mediated effect of climate change on biotic potential of cowpea aphid, Aphis *craccivora* (Koch.)

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ABSTRACT

Climate change will alter the phytochemistry of crops, especially the C_3 plants. Cowpea (*Vigna unguiculata* L.) is an annual, photo-insensitive C_3 legume that benefits from the altered climate. Any changes in the nutritional quality of the host will certainly affect its herbivore. In this view, the study was conducted on crop-pest interaction *i.e.,* to know the impact of climate change on the growth and development of cowpea alone and in presence of associated sucking pest aphid, *Aphis craccivora* (Koch) during *Kharif* 2019-20. The crop was raised in Open Top Chambers previously set with different climatic treatments. Observations on change in plant growth and phytochemistry along with its effect on herbivore aphids were studied. The results revealed that elevated CO_2 and temperature influenced the crop positively in terms of growth and also have registered higher concentrations of leaf pigments, carbon, and 'C' based metabolites. In contrast, lower concentrations of flavonoids, 'N' based compounds were recorded which ultimately altered the C: N ratio in the plant system. The obtruded phytochemistry of cowpea under elevated treatments resulted in decreased development (12.73 ± 0.07 days) and survival fitness of aphids, wherein increased fecundity (34.56 ± 0.18 days) and population density (73.43/ top three leaves) was noticed when compared to ambient treatments.

Keywords: *Cowpea, elevated* CO_2 *and temperature, Aphis craccivora, OTCs and phytochemistry.*

The cowpea, *Vigna unguiculata* L. is an annual herbaceous photo insensitive legume and carbon responsive (C_3 group) crop can be grown mainly both in *kharif* and spring-summer season. As it is capable of fixing atmospheric nitrogen, hence, requires very few inputs, making up the crop valuable for resource poor farmers and well suited for intercropping with many other crops. However, cowpea is a remunerative crop but suffers from insect pests and diseases leading to 90 per cent loss (Jackai and Daoust, 1986). The cowpea aphid, *Aphis craccivora* (Koch.) a polyphagous, regular and persistent pest on cowpea as it is said to be an eco-fest crop. Both adults and nymphs cause significant and economic damage either directly by sucking sap or indirectly through transmission of viral diseases (over 30 plant viruses) (Wightman and Wightman, 1994) particularly devastating wide range of host plants including cowpea, chickpea, groundnut, brassicas, cucurbits, beetroot, cotton and cardamom with the yield loss more than 50 per cent (Obopile, 2006).

In recent years, it has become apparent that the temperature has increased due to global warming. The annual global average CO_2 concentration was about 412 ppm in 2019 and is likely to increase up to 540-970 ppm by the end of the 21st century and the concentration may double during the next century (Das *et al.,* 2020). The response of crops to increased temperature is always dependent on the species. However, the responses of insect herbivores to elevated CO_2 are species specific and some species respond positively whereas some species responds negatively (Gouri Shankar *et al.,* 2022). Hence, with this raising earth's temperature (global warming) and CO_2 concentration the biotic and abiotic stresses have become more severe and adversely impacting productivity and stability of crops like pulses. This can increase insect performance, which could lead a major apprehension of climate change scenarios that population that is more abundant will attack the crops in future (Awmack *et al.,* 1997).

To understand these emerging challenges of climate change on the bitrophic (cowpea plant and associated pest aphid) interaction, there is an urgent need to undertake the research on host-pest dependency, which paves way for the mitigation strategies. Hence, present investigation was planned to study the effect of

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climatic variables (elevated CO_2 and temperature) on growth and development of aphid, *Aphis craccivora* (Koch.) mediated through cowpea under OTCs.

MATERIAL AND METHODS

Varied concentrations of elevated CO_2 (eCO_2) and temperature (abiotic factors) treatments were maintained under four circular OTCs constructed at Centre for Agro-climatic Studies, Main Agricultural Research Station, University of Agricultural Sciences, Raichur, Karnataka was used for present studies. The structure of OTCs with dimensions of five-meter diameter and four-meter height was fabricated with aluminium round shaped frame installed on the ground covered with double walled six mm thick polycarbonate sheets, which traps air within, providing thermal insulation and have more than 82 per cent transmittance of light. The top of chamber was kept open to provide the near natural conditions and the chambers were equipped with a frustum at the top to deflect air and prevent dilution of the desired CO_2 concentrations within the chamber. Standard climate change study treatments in the present investigation set in OTCs and are described as,

T_1: Elevated CO_2 (550 ± 25 ppm) with ambient temperature (33°C),

T_2: Elevated CO_2 (550 ± 25 ppm) with elevated temperature (normal temperature + 2°C),

T_3: Ambient CO_2 (410 ± 25 ppm) with elevated temperature (normal temperature + 2°C),

T_4: Ambient CO_2 (410 ± 25 ppm) with ambient temperature (33°C) (reference OTC),

T_5: Reference plot (open plot). Normal temperature inside OTCs was 33°C.

Seeds of popular cowpea variety KBC-9 were dibbled in each cement pot (size 42 × 32 sq. cm) inside each OTC, containing mixture of soil, FYM and vermicompost in the ratio of 2:1:1. Such cowpea plants were used for taking observation on the growth and phytochemical parameters especially the physiological and biochemical parameters at 30 and 60 days of plant growth. When seedlings attained 10 days of age they were covered with nylon cage (size 0.15 × 0.15 sq. cm) to avoid infestation by insects.

Growth parameters observations

Observations on plant growth parameters (plant height, number of leaves, branches), yield parameters (number of pods per plant, test weight of seeds, and yield per plant), physiological parameters (chlorophyll, flavanoids and nitrogen balanced index) and biochemical constituents (organic carbon, leaf nitrogen, C:N ratio, tannins, phenols, reducing and total sugars and seed protein) were analyzed by following standard procedures.

Aphid observations

Crop mediated effect of different climate change conditions on aphids were studied under OTCs wherein, sufficient number of aphids collected from naturally infested fields of groundnut, field bean and cowpea and they were reared on the potted cowpea seedlings in the glass house. Later 10 gravid aphids from lab reared pure culture were released on to 25-30 days old cowpea plants raised in pot (size 42 × 32 sq. cm) kept in each OTCs and covered with nylon net (size 0.15 × 0.15 sq. cm) to avoid the external infestation of insects. Later, plants were visually examined daily and observation on aphid biological parameter *viz*., rate of development of aphids was recorded.

Above said experiment undertaken in OTCs was also repeated raising the cowpea seedlings in the plastic pots (size 20 × 15 sq. cm) under environmental chambers which were previously set with different standard climate change treatments as same as the OTC conditions. Each treatment with five pots (served as replications) having two cowpea plant and each containing two clip cages (size: 3 × 4 sq. cm) and each clip cage was released with single pre-matured aphid maintaining the 20 aphids per treatment. The clip cages were clipped to leaf surface to restrict the movement of aphids to that particular leaf and the biological parameters of aphids (nymphal instars and duration, adult longevity, total life cycle, fecundity) were recorded.

RESULTS AND DISCUSSIONS

Cowpea growth parameters

Climate change treatments eCO_2 @ 550 ± 25 ppm with normal temperature levels influenced positively by favoring the growth of C_3 plant cowpea as a result there was an accelerated plant height (43.10 and 77.36 cm), number of branches (6.06 and 16.43 branches/plant), leaves (16.15 and 25.51 leaves/plant) at 30 and 60 days of crop growth respectively, and also more number of flowers (20.30 flowers/plant) and pods (6.22 pods/plant) (at 60 days of crop growth) when compared to ambient treatment like aCO_2 @ 410 ± 25 ppm with 2°C rise in temperature which were recorded lowest plant height (35.57 and 66.56 cm), number of branches (3.92 and 14.39 branches/plant), leaves (14.13 and 23.13 leaves/plant) at 30 and 60 days of crop growth respectively (Fig. 1). Similarly, plants under insect stress (upon release of aphid) shown a significant reduction in the growth of *viz.,* plant height, number of branches, leaves, flowers and pods per plant when compared to the plants without insects, however, the trend remains same wherein elevated climatic treatments shown more growth than ambient (Fig. 1c). Elevated climate change treatments increased the test weight of seeds (ranging from 14.96 to 22.69 g/plant). This ultimately resulted in higher yield (61.59 g/plant) under eCO_2 @ 550 ± 25 ppm with normal temperature than those from bi-trophic (cowpea plants with aphids) interaction. The maximum yield from bi-trophic (cowpea plants with aphids) interaction was (17.46 g/plant) under eCO_2 @ 550 ± 25 ppm with normal temperature levels and minimum of (10.86 g/plant) under aCO_2 @ 410 ± 25 ppm with 2°C rise in temperature (Fig. 2).

CO_2 has a direct fertilizing effect on plant growth; therefore, elevated CO_2 has favored crop growth (Bhattacharya *et al.,* 1985). Results indicated that elevated climate change treatments maximizes the plant growth in terms of increased height, more number of branches and leaves per especially flower and pod in higher numbers. But the treatments containing aphid infested plants showed significantly reduced height, less number of branches and

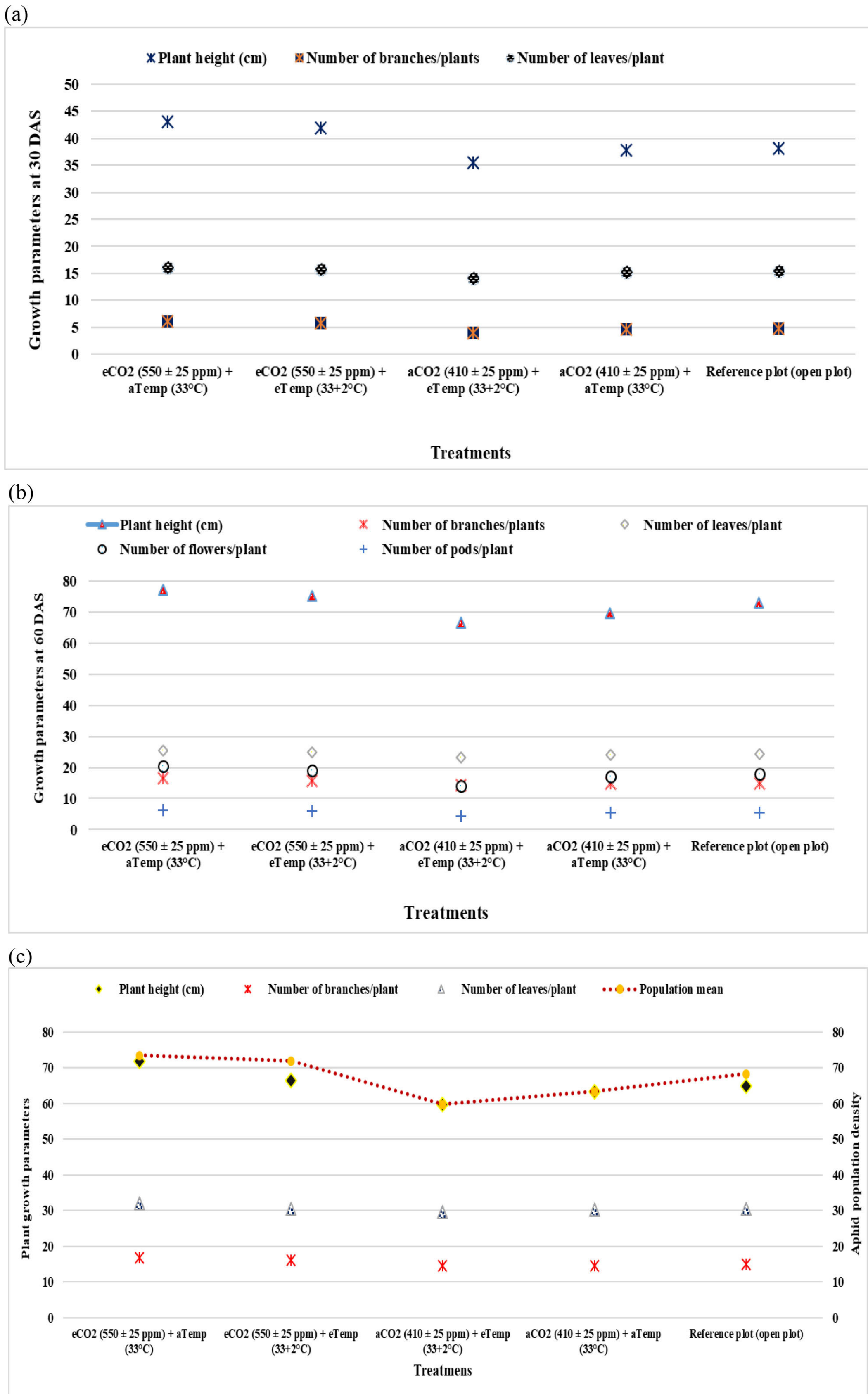

Fig. 1: Effect of different levels of CO_2 and temperature on cowpea growth parameters under OTCs (a) at 30 DAS, (b) at 60 DAS and (c) in presence of of *A. craccivora*

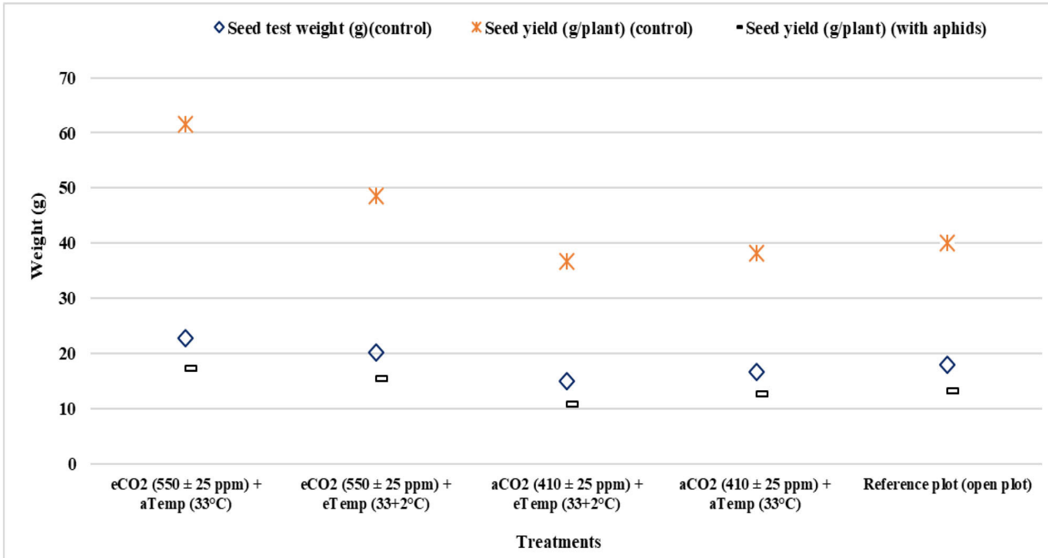

Fig. 2: Effect of eCO_2 and temperature on yield components of cowpea grown under OTCs

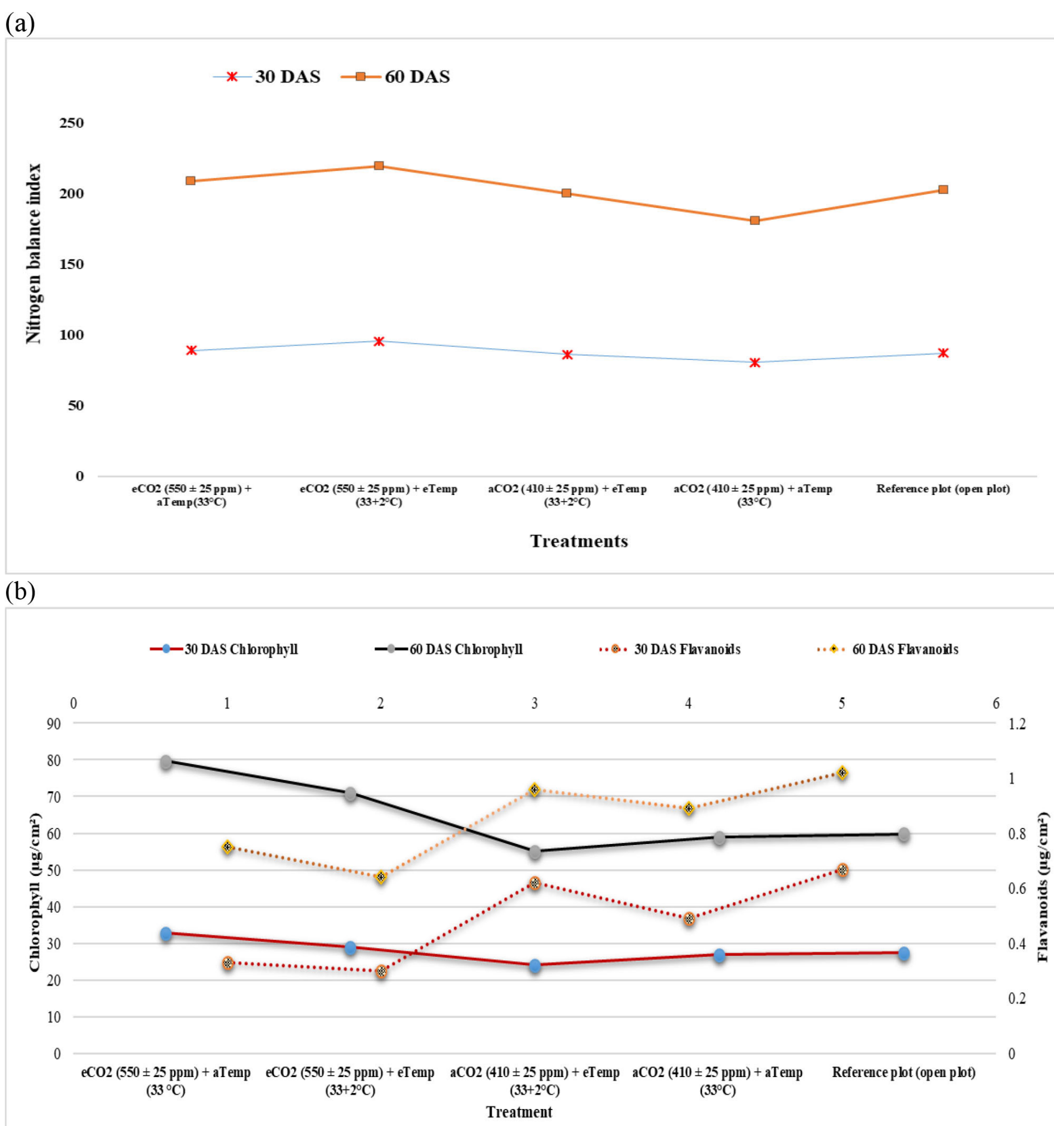

Fig. 3: Effect of different levels of CO_2 and temperature on (a) Nitrogen balance index and (b) Chlorophyll content and Flavonoids in cowpea under OTCs

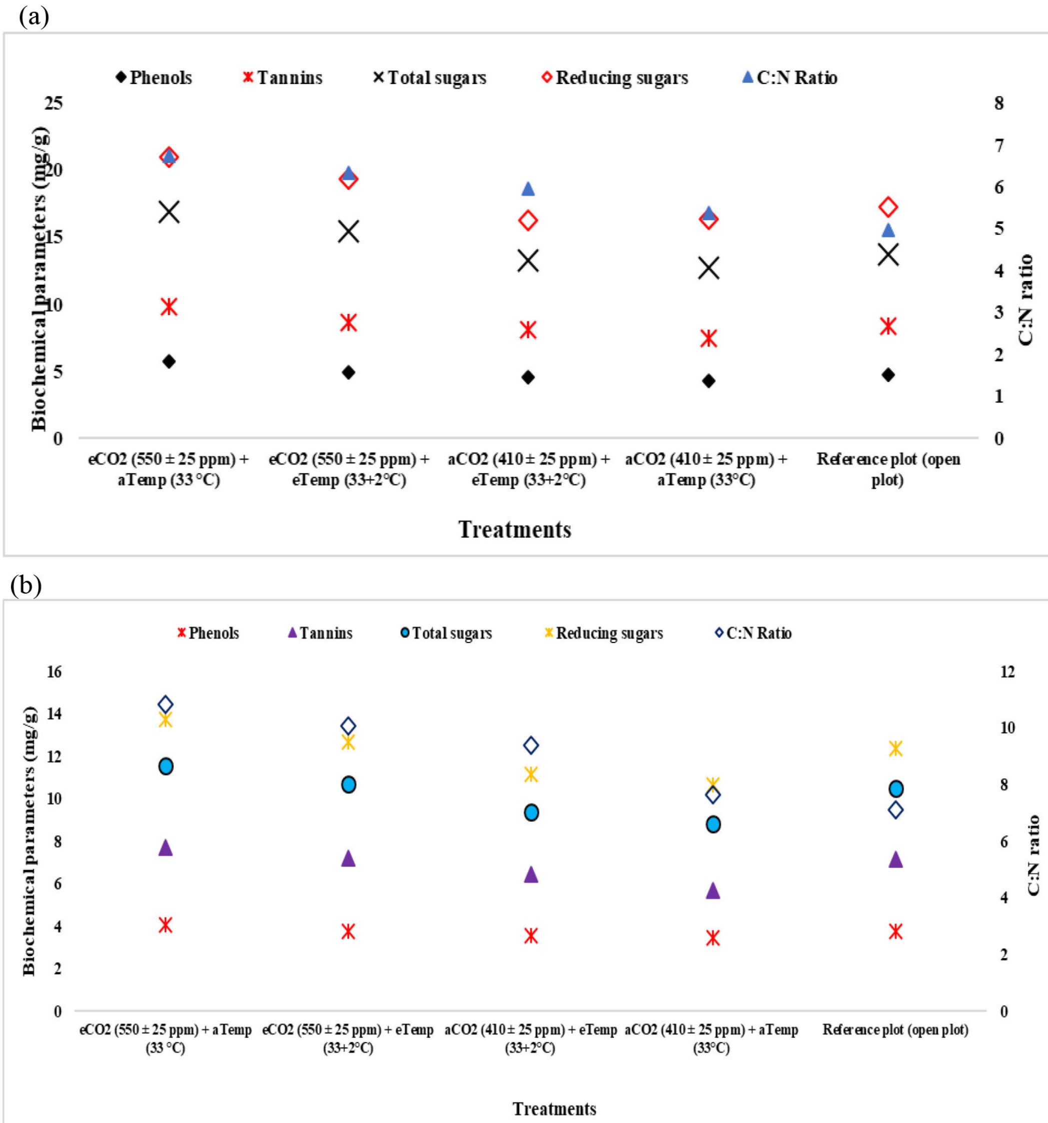

Fig. 4: Effect of different levels of CO_2 and temperature on biochemical parameters in cowpea (a) at 30 DAS and (b) at 60 DAS under OTCs

leaves per plant in comparison to those plants grown without aphids (control). From the above results, we notice that negative effects of aphids on plant growth were generally greater than the positive effects of CO_2 under changing climatic conditions. However, plants were suffering from substantial reductions in growth and yield over controlled conditions.

Phytochemistry of cowpea

Phytochemistry of cowpea such as physiological and biochemical parameters showed that plants grown under elevated CO_2 treatments have registered higher levels of Nitrogen Balance Index (95.63) as we can observe under eCO_2 @ 550 ± 25 ppm with 2°C rise in temperature. Whereas, chlorophyll content (32.82 µg/cm²), organic carbon (43.19 %) and C- based metabolites *viz.,* phenols (4.07 mg/g), tannins (3.63 mg/g), total sugars (3.84 mg/g) and reducing sugars (2.18 mg/g) were found to be highest under eCO_2 @ 550 ± 25 ppm with normal temperature than the treatments with ambient conditions. As of aCO_2 @ 410 ± 25 ppm with normal temperature recorded minimum levels of Nitrogen Balance Index (80.71) and aCO_2 @ 410 ± 25 ppm with 2°C rise in temperature recorded lowest chlorophyll content of 24.15 µg/cm². However, in contrast to this, plant grown under eCO_2 @ 550 ± 25 ppm with 2°C rise in temperature noticed decrease in per plant flavanoids content (0.30 µg/cm²), leaf nitrogen (4.06 %) as under eCO_2 @ 550 ± 25 ppm with normal temperature and N- based compounds like protein content (25.07 %) as under eCO_2 @ 550 ± 25 ppm with 2°C rise in temperature, which have resulted in significant increase in the C:N ratio (10.82) of the plant system under eCO_2 @ 550 ± 25 ppm with normal temperature condition (Fig. 3 and 4). Similar trend was noticed under both 30 and 60 days of crop growth.

The total chlorophyll content was influenced positively with increased CO_2 concentrations and temperature than in the ambient conditions. The decrease in leaf flavanoids contents was mainly associated with increased supply of CO_2 and temperature. However, decreased flavanoids and slightly increased chlorophyll content resulted in an increased NBI (chlorophyll/flavanoids ratio) in plants grown under eCO_2 and temperatures treatments.

Table 1: Direct effect of eCO_2 and temperature on growth and development of *A. craccivora* under plant growth chambers

Treatments	Nymphal duration (days)				Adult longevity (days)	Total life cycle (days)	Fecundity/ Female
	First Instar	Second instar	Third instar	Fourth Instar			
T_1: eCO_2 (550 ± 25 ppm) + aTemp (33 °C)	1.11 ±0.03^d	0.95 ±0.02^d	0.96 ±0.02^d	0.86 ±0.02^e	9.37 ±0.08^d	13.23 ±0.06^c	34.56 ±0.18^a
T_2: eCO_2 (550 ± 25 ppm) + eTemp (33+2°C)	0.92 ±0.03^e	0.86 ±0.02^e	0.84 ±0.03^e	0.96 ±0.02^d	9.17 ±0.04^d	12.73 ±0.07^c	33.15 ±0.13^a
T_3: aCO_2 (410 ± 25 ppm) + eTemp (33+2°C)	1.21 ±0.01^c	1.28 ±0.03^c	1.59 ±0.04^c	1.04 ±0.03^c	9.64 ±0.06^c	14.74 ±0.11^b	25.70 ±0.16^c
T_4: aCO_2 (410 ± 25 ppm) + aTemp (33°C) (Reference OTCs)	1.26 ±0.03^b	1.37 ±0.04^b	1.78 ±0.03^b	1.18 ±0.04^b	10.06 ±0.11^b	15.55 ±0.12^a	26.40 ±0.16^c
T_5: Reference plot (open plot)	1.33 ±0.05^a	1.43 ±0.04^a	1.85 ±0.04^a	1.41 ±0.02^a	10.34 ±0.07^a	16.06 ±0.70^a	27.88 ±0.17^b
S.Em (±)	0.01*	0.01*	0.01*	0.01*	0.01*	0.02*	0.01*
CD (p=0.01)	0.03	0.03	0.29	0.02	0.03	0.07	0.03
CV (%)	1.33	1.32	1.21	1.30	0.46	1.09	0.28

Significant @ 1% ; eCO_2: elevated carbon dioxide; aCO_2: ambient carbon dioxide; eTemp: elevated temperature; aTemp: ambient temperature
Means denoted by same letters in vertical column are not significantly different by DMRT

Altered plant physiology and biochemistry indicate that the direct supply of elevated levels of CO_2 to plants is amended by increase in foliar carbohydrates and other C based compounds in the plant tissue. Plants grown under enriched supply of CO_2 increased carbon availability for plant tissues which lead to increased concentration of carbon assimilates and decreased nitrogen and N based compound, resulting an increase in the C:N ratio in the plants. Plants also recorded increased concentration of phenols and tannins under eCO_2 treatments than ambient, CO_2 enrichment increases the C:N ratio with increased photosynthesis resulting in higher level accumulation of C- based secondary compounds and since, phenols, tannins and carbohydrate-sugars are carbon based compounds, these compounds have also increased along with increased carbon in the elevated climate change treatments. These finding were in resemblance with results obtained from the various similar studies conducted by Stiling and Cornelissen (2007); Sharma *et al.* (2016) and Swetha *et al.* (2017).

Changed crop growth and phytochemistry under different climate change treatments had a great influence over biotic potential of its associated pest like aphid. Wherein, the survival fitness of aphid is considerably altered by cowpea mediated effect of different climate change treatments. Study evidenced that eCO_2 @ 550 ± 25 ppm with normal temperature has increased the rate of development of aphids in terms of aphid population per top three leaves (73.43/ plant) (Fig. 1c) with increased fecundity (34.56 ± 0.18 aphids/ female) while, aCO_2 @ 410 ± 25 ppm with 2°C rise in temperature has recorded lowest fecundity of (25.70 ±0.16 aphids/female). However, there was decrease in nymphal duration, adult longevity (9.17 ± 0.04 days) resulting in reduced total life cycle of aphids (12.73 ± 0.07 days) under eCO_2 @ 550 ± 25 ppm with 2°C rise in temperature wherein, the total life cycle was more under reference plot (16.06 ±0.70 days) (Table 1). Moreover, morphometric studies of aphid showed that there was slight variation in the body size with reduced body length, breadth and area under elevated treatments than the ambient, but was non-significant indicating fitness of aphids affected greatly by eCO_2 environment.

Among all herbivores, the sap feeders such as aphids are only insects showing positive responses to eCO_2 as reported by Srinivasa Rao *et al.* (2016). Development rate of aphid was found maximum under elevated climate change treatments than the ambient, wherein slight increase in relative rate of development and mean population of aphid was registered under enriched CO_2 and temperature treatments compared to controlled conditions. However, aphids fed on plants grown under elevated conditions produce significantly higher number of nymph and adults than those fed on plants raised in ambient conditions. The plants resulted in increased biomass under higher levels of CO_2 conditions in turn resulting more assimilates being immediately available for aphid feeding which impacted positively on the breeding capacities and feeding behavior of the aphids, which were higher at elevated CO_2 levels than under ambient. Enriched supply of carbon dioxide increased total biomass of plants and yield among elevated treatments than the ambient by altering the plants systemic tolerance against compensatory feeding of aphids to satisfy their growth requirements under elevated CO_2 conditions.

Present results indicate that the combination of eCO_2 and high temperature significantly decreased the duration of nymphal stadia, longevity and development time of aphids on the plants raised under elevated climate change treatments than those raised under ambient conditions. Wherein, eCO_2 was reported to be major cause for decrease in the development time and longevity of *A. craccivora* which intern reduced the total life span on cowpea resembling results opined by Srinivasa Rao *et al.* (2016) and Shreevani *et al.* (2017). The reduced nutrition of the cowpea plants raised under elevated climate change treatments resulted in smaller sized aphids compared to aphids fed on the plants grown ambient conditions. Fecundity per female aphid recorded under elevated climate change treatment was comparatively more than the ambient conditions. Relatively maximum number of nymphs was produced with increased fecundity observed under eCO_2 conditions, which shows the characteristic feature of aphids able to overcome the disadvantages of the indirect effects of eCO_2 by reducing developmental time and inducing fecundity under eCO_2 conditions.

The increase or decrease in the body size primarily depends on the quality of the host plant upon which the insect were feeding (Hughes and Bazzaz, 2001; Shreevani *et al.,* 2017 and Coll and Hughes, 2008). Meanwhile, the investigations on biology of aphid revealed that it was well affected by the changed climate condition. The nutritional qualities of cowpea plant greatly influenced the growth performance of *A. craccivora*, where the exact outcome of unnerving rise in global CO_2 concentration are difficult to predict because of its interactive relationships existing with many of the environmental variables including the temperature, light and precipitation.

CONCLUSIONS

Climatic variables (elevated CO_2 and temperature) have favored the growth and development of C_3 plant like cowpea, with considerable variation among plant physiological and biochemical composition. Hence, it is proved that mono-trophic interaction has favored the crop under elevated climate change treatments. Elevated CO_2 and temperature had favored the herbivore over host plant itself, by increasing mean aphid population and fecundity, which nullified the systemic resistance offered by cowpea (C-based metabolites like phenols and tannins) resulting in decreased plant growth and development under bi-trophic (cowpea and *A. craccivora*) interaction than the mono-trophic interaction. Wherein, the response of crop was positive under elevated treatments than the ambient.

Conflict of Interest Statement: The author (s) declares (s) that there is no conflict of interest.

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