

Short communication

Elevated CO₂ and temperature effect on canopy development and seed yield of sunflower (*Helianthus annuus* L)

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Climate is one of the main determinants of agricultural production. Throughout the world there is significant concern about the effects of climate change and its variability on agricultural production. The Intergovernmental Panel on Climate Change (IPCC) has predicted that the present atmospheric CO₂ (aCO₂) concentration (>400 ppm) may increase up to 660 ppm and 790 ppm in 2060 and 2090, respectively (IPCC, 2007 and 2014). This is expected to raise global temperatures due to the CO₂ capacity to absorb infrared light and possibly change the precipitation patterns. Studies have shown a significant effect of change in climatic factors on the average crop yield (Seo and Mendelsohn, 2008). Sunflower being C₃ crop responded significantly and positively with increased CO₂ and temperature than C₄ plants. The present study was conducted with an objective to identify the potential sunflower hybrid under elevated/enhanced carbon dioxide and temperature concentration over aCO₂.

Experimental Setup

Controlled set of experiment was carried out to study the response of sunflower genotypes to elevated CO₂ (eCO₂) and temperature regimes under Open Top Chambers (OTC) at Center for Agro-climatic studies belongs to University of Agricultural Sciences, Raichur Karnataka during *Kharif* 2016. Four sunflower genotypes RSFH-1, KBSH-44, DRSH-1 and PAC-37904 were selected for the study. In each OTC and open field condition all hybrids were planted at 5.55 plants/m². Different set of treatments comprised of eCO₂ @ 550 ± 25ppm, eCO₂ @ 550 ± 25ppm with 2°C rise in temperature, aCO₂ @390 ± 25ppm with 2°C rise in temperature, Reference open top chamber and reference plot in open field condition. Prevailed temperature, rainfall, relative humidity and sunshine hours were collected throughout the season. Collected data were analyzed by using Fisher's method of covariance at significance level of 5% as

completely randomized design.

Crop period and weather condition

Daily maximum and minimum temperature, relative humidity, evaporation, rainfall was found optimum for crop growth. However distribution of rainfall during the experimental period was erratic for plants outside OTC. Even though experiment was conducted in controlled condition but open field plot was significantly influenced by prevailed weather. Experiment was irrigated both in inside and outside OTC's. The region is characterized by tropical high temperature during cropping period.

Plant height

Elevated CO₂ and temperature levels brought about significant difference in the height of sunflower across different hybrids. The RFSH-1 and KBSH-44 hybrids recorded taller plants (16.88 and 16.63 cm) in 550 ppm CO₂ treatment. Rate of increased plant height was observed between 45 to 60 days after sowing. Greater difference in plant height at 75 DAS was observed in DRSH-1 (8.5%) and PAC 37904 (7.0%). Irrespective of the CO₂ and temperature treatments dwarf plants were observed in PAC-37904 (Table 1). At CO₂ 550 ppm, plant height much higher than CO₂ @550 ppm + 2°C temperature rise. Whereas, plants grown in CO₂ @ 390 ppm with increased temperature was taller than rest of the treatments. This might be due to effect of eCO₂ and temperature levels which favoured cell elongation resulted in taller plants. Similar results on increased plant height under eCO₂ were reported by Das *et al.* (2020). Similar response of sunflower plant height among hybrids and eCO₂ and temperature rise was observed throughout the growing period.

Leaves per plant

Sunflower plant growth has primarily indicated by development of individual leaves. Elevated CO₂ generally

Table 1: Effect of elevated CO₂ and temperature in open top chambers under controlled condition on plant height (cm) of sunflower hybrids at different stages (DAS)

| | 30 DAS | | | | 45 DAS | | | | 60 DAS | | | | 75 DAS | | | |
|-------------------------------------|--------|------|------|------|--------|-------|-------|------|--------|-------|-------|-------|--------|-------|-------|-------|
| | H1 | H2 | H3 | H4 | H1 | H2 | H3 | H4 | H1 | H2 | H3 | H4 | H1 | H2 | H3 | H4 |
| CO ₂ @ 550ppm | 31.3 | 44.5 | 52.8 | 31.5 | 73.2 | 116.2 | 112.0 | 79.0 | 144.5 | 170.2 | 179.5 | 121.5 | 140.0 | 173.0 | 182.5 | 115.0 |
| CO ₂ @ 550ppm + 2°C rise | 41.3 | 37.3 | 42.0 | 27.5 | 80.2 | 73.5 | 82.8 | 58.5 | 138.7 | 165.0 | 166.0 | 113.5 | 138.7 | 167.2 | 168.2 | 107.5 |
| CO ₂ @390 ppm | 36.3 | 38.0 | 44.5 | 33.3 | 62.7 | 75.5 | 84.3 | 70.2 | 139.2 | 139.0 | 155.0 | 119.0 | 142.7 | 139.2 | 153.2 | 117.5 |
| CO ₂ @390 ppm+ 2°C rise | 29.0 | 33.3 | 34.0 | 23.3 | 61.2 | 69.5 | 76.0 | 60.2 | 116.2 | 148.2 | 178.7 | 98.0 | 118.7 | 149.7 | 188.0 | 100.3 |
| Control | 21.5 | 28.3 | 26.5 | 18.0 | 34.2 | 46.5 | 43.3 | 32.2 | 77.0 | 96.3 | 111.2 | 63.0 | 82.0 | 89.5 | 123.0 | 54.5 |
| CD@1 % | 1.7 | 1.9 | 2.1 | 1.4 | 3.3 | 4.1 | 4.2 | 3.2 | 6.5 | 7.5 | 6.5 | 5.4 | 6.5 | 7.5 | 9.1 | 5.2 |

H1- RSFH-1, H2- KBSH-44, H3- DRSH-1, H4- PAC-37904

Table 2: Effect of elevated CO₂ and temperature in open top chambers under controlled condition on number of leaves per plant at various growth stages of sunflower

| Treatments | 30 DAS | | | | 45 DAS | | | | 60 DAS | | | | 75 DAS | | | |
|-------------------------------------|--------|------|------|------|--------|------|------|------|--------|------|------|------|--------|------|------|------|
| | H1 | H2 | H3 | H4 | H1 | H2 | H3 | H4 | H1 | H2 | H3 | H4 | H1 | H2 | H3 | H4 |
| CO ₂ @ 550ppm | 12.5 | 16.0 | 17.0 | 14.5 | 18.5 | 21.3 | 20.3 | 18.0 | 18.8 | 22.8 | 22.5 | 17.3 | 13.8 | 12.8 | 17.3 | 14.3 |
| CO ₂ @ 550ppm + 2°C rise | 15.5 | 13.5 | 14.8 | 13.3 | 18.5 | 18.5 | 19.0 | 17.8 | 17.0 | 19.0 | 21.3 | 18.5 | 14.8 | 14.3 | 18.5 | 15.8 |
| CO ₂ @390 ppm | 12.8 | 13.3 | 13.5 | 12.0 | 16.8 | 17.8 | 16.3 | 17.0 | 19.5 | 17.8 | 19.3 | 15.0 | 17.8 | 13.3 | 18.5 | 16.3 |
| CO ₂ @390 ppm+ 2°C rise | 12.8 | 12.5 | 14.8 | 11.5 | 16.0 | 16.3 | 17.3 | 15.0 | 15.3 | 15.8 | 20.8 | 13.0 | 15.0 | 15.3 | 21.3 | 16.5 |
| Control | 8.5 | 9.0 | 7.8 | 6.8 | 10.5 | 13.0 | 12.3 | 11.3 | 15.5 | 15.3 | 16.8 | 13.5 | 8.0 | 9.8 | 14.5 | 7.3 |
| CD @1 % | 0.7 | 0.7 | 0.7 | 0.6 | 0.8 | 0.9 | 2.9 | 2.9 | 0.9 | 0.9 | 1.0 | 0.8 | 0.7 | 0.7 | 0.9 | 0.7 |

H1- RSFH-1, H2- KBSH-44, H3- DRSH-1, H4- PAC-37904

resulted in increased biomass accumulation in leaves, stem and total. All the sunflower hybrids exhibited greater number of leaves per plant in the eCO₂ and temperature treatments. Hybrid DRSH-1 (22.3) and KBSH-44 (22.8) recorded more number of leaves in 550 ppm CO₂ treatment followed by 550 ppm CO₂ with 2°C treatment. However, less number of leaves was recorded in the reference plot irrespective of the genotype (Table 1). Though the number of leaves decreased at 75 DAS, the trend remained same with respect to the eCO₂ and temperature rise treatments. The results of the present study are in line with earlier findings of Lavanya *et al.* (2017) reported that leaves per plant (24.7 and 35.0) plant height (70.33 and 93.74 cm) showed significant increase under eCO₂ (550 ± 25 ppm and 550 ± 25 with 2° C) over the cropping period compare to ambient condition (Table 1). Jyothi Lakshmi *et al.* (2017) also reported eCO₂ has enhanced number and dry weight of leaves per plant as compared to aCO₂.

Days to 50% flowering

The days to 50 per cent flowering in sunflower

was recorded in all the genotypes under climate change treatments. Less number of days was taken for 50 per cent flowering by all genotypes under eCO₂ and temperature treatments. However, the genotypes RSFH-1 and PAC-37904 took least days (52.0 and 53.0 days respectively) for 50 per cent flowering under elevated climate change treatments. On contrary, these two genotypes took more days for 50 per cent flowering in the reference plot.

Days to maturity

The physiological maturity of a plant is an important factor in determining the yield of the plant. Early maturity was showed by all the genotypes grown under eCO₂ and temperature conditions, while, they showed late maturity in the aCO₂ and temperature conditions. The genotypes PAC-37904 and DRSH-1 matured very early at 82 and 84 days respectively, followed by RSFH-1 (88.0 days) and KBSH-44 (92.0 days) at eCO₂ and temperature conditions. However, more number of days for maturity were taken by the genotypes KBSH-44 (97.0 days) and followed by other three genotypes (92.0 days) in the aCO₂ and temperature treatments.

Table 3: Effect of elevated CO₂ and temperature on head diameter, seed yield per plant, days to 50% flowering and days to maturity of sunflower hybrids

| Treatments | Sunflower hybrids (H) | | | | | | | |
|------------------------------|-----------------------|---------|--------|-----------|--------------------------------|---------|--------|-----------|
| | RSFH-1 | KBSH-44 | DRSH-1 | PAC-37904 | RSFH-1 | KBSH-44 | DRSH-1 | PAC-37904 |
| | Head diameter (cm) | | | | Seed yield per plant (g) | | | |
| CO ₂ @ 550 ppm | 19.22 | 16.66 | 19.75 | 18.45 | 25.98 | 24.28 | 26.55 | 24.98 |
| CO ₂ @550 ppm+2°C | 18.65 | 16.01 | 19.53 | 18.40 | 25.50 | 24.00 | 26.28 | 24.40 |
| CO ₂ @390 ppm | 18.58 | 15.55 | 19.11 | 17.94 | 24.23 | 23.53 | 25.90 | 23.98 |
| CO ₂ @390 ppm+2°C | 17.98 | 15.03 | 18.38 | 17.43 | 23.08 | 22.98 | 25.05 | 23.53 |
| Control | 18.27 | 15.50 | 18.90 | 17.60 | 23.95 | 23.20 | 25.60 | 23.65 |
| | H | T | H x T | | | H | T | H x T |
| CD@1% | 0.24 | 0.27 | 0.54 | | | 0.27 | 0.3 | 0.6 |
| | Days to 50% flowering | | | | Days to physiological maturity | | | |
| CO ₂ @ 550 ppm | 52 | 56 | 57 | 52 | 88 | 92 | 88 | 82 |
| CO ₂ @550 ppm+2°C | 54 | 57 | 59 | 55 | 91 | 94 | 90 | 84 |
| CO ₂ @390 ppm | 53 | 59 | 60 | 56 | 93 | 95 | 92 | 85 |
| CO ₂ @390 ppm+2°C | 58 | 62 | 62 | 57 | 96 | 97 | 95 | 88 |
| Control | 53 | 60 | 61 | 55 | 95 | 96 | 93 | 86 |
| | H | T | H x T | | | H | T | H x T |
| CD@1% | 0.77 | 0.34 | 1.02 | | | 1.25 | 0.54 | 1.64 |

Table 3a: Effect of elevated CO₂ and temperature in controlled open top chambers compared with ambient temperature and CO₂ on grain yield (kg ha⁻¹) of *Kharif* sunflower hybrids

| | Sunflower hybrids (H) | | | |
|----------------|-----------------------|---------|--------|-----------|
| | RSFH-1 | KBSH-44 | DRSH-1 | PAC-37904 |
| 550 ppm | 1443 | 1349 | 1475 | 1388 |
| 550 ppm+2°C | 1419 | 1333 | 1460 | 1358 |
| 390 ppm+2°C | 1282 | 1277 | 1392 | 1307 |
| Reference OTC | 1346 | 1307 | 1439 | 1332 |
| Reference plot | 1330 | 1289 | 1422 | 1314 |
| | H | T | H×T | |
| CD@1% | 27.0 | 8.9 | 20.9 | |

Yield attributes

The Head diameter of sunflower was taken at maturity under different climatic conditions. The genotypes showed more head diameter in the eCO₂ and temperature treatments when compared to ambient treatments. More head diameter was recorded by the genotypes DRSH-1 (19.75) and RSFH-1 (19.22) followed by PAC-37904 (18.45) and KBSH-44 (16.66) genotypes in the 550 ppm CO₂ with normal temperature treatment. Meanwhile, smaller heads with diameters 15.03 and 17.43 were recorded by KBSH-44 and PAC-37904 genotypes in the reference plot respectively (Table 3). Similar results in biomass and yield differences due to CO₂ concentration was reported by Jyothi Lakshmi *et al.* (2017).

Seed yield per plant of different genotypes were

taken under different climatic conditions. More yield was recorded by DRSH-1 (26.55 g/plant) and RSFH-1 (25.98 g/plant) under 550 ppm CO₂ with normal temperature treatment followed by 550 ppm with 2°C rise in temperature treatment in which the genotypes PAC-37904 and KBSH-44 recorded yield of 24.98 and 24.28 g/plant respectively. However, fewer yields were recorded under ambient treatments irrespective of the genotypes. The genotypes KBSH-44 and RSFH-1 recorded least seed yield of 22.98 and 23.08 g/plant in the ambient treatments (Table 3). Elevated CO₂ caused increase in crop growth and yield due to increased photosynthesis, decreased photorespiration (C₃ crops) and decreased stomatal conductance. Increase in CO₂ negates negative effect of rise in temperature up to certain degree. Under rain fed conditions, in spite of higher CGR, harvestable yield of sunflower will be reduced due to reduction in harvest index (Koocheki *et al.*,

2006). Similarly, Ainsworth *et al.* (2002) reported that yield improvement in soybean was upto 24 per cent was due to the effects of doubled CO₂ over aCO₂.

Seed yield

Elevated CO₂ concentration generally results in increased biomass production in sunflower plants. Biomass accumulation in plant part ultimately reflected in seed yield (Table 3). Across hybrids sunflower seed yield were significantly greater in eCO₂@550 ppm (1414 kg ha⁻¹) and lowest in increased temperature (2°C) at aCO₂@390 ppm (1314 kg ha⁻¹). Improvement in seed yield with increased CO₂ upto has increased seed yield 7.61%. At similar CO₂ concentration increased temperature has not significantly (p=0.01) influenced seed yield. Among hybrids seed yield were higher in DRSH-1 (1437 kg ha⁻¹) and lowest in KBSH-44 (1311 kg ha⁻¹). Jyothi Lakshmi *et al.* (2017) also reported 21.0 to 45.9 per cent yield difference due to increased CO₂ concentration from 550 to 700 ppm as compared to aCO₂@380 ppm. Similar results were reported in mungbean (Vanaja *et al.*, 2007) and pigeonpea (Vanaja *et al.*, 2010).

Hence it was concluded that sunflower responds positively to increase CO₂ in terms of growth and yield attributes. Various morphological parameters studied indicated that, the hybrids DRSH-1 performed better under eCO₂ and high temperature. The maximum reduction with respect to these parameters was observed in PAC-37904 hybrid. Leaf emergence rate, days to attain 50% flowering and also physiological maturity was earlier in hybrid DRSH-1 under eCO₂ treatment. Whereas, increase in both CO₂ and temperature affects these morphological parameters (Table 3a).

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