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# Biochemical response of maize (*Zea mays* L.) genotypes to elevated carbon dioxide and temperature regimes

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**Abstract**

Temperature and $CO_2$ are two of the main environmental factors associated with climate change. It is generally expected that elevated $CO_2$ will increase crop production. However, other environmental factors such as temperature along with management practices could further modify a crop's response to $CO_2$. The goal of this study was to determine the interactive effects of elevated $CO_2$ and above optimum temperature on growth, development and yield of five maize(*Zea mays L.*) genotypes, e.g., HTMR-1, HTMR-2, ARJUN, 900M Gold, and NK 6240.Global climate change can affect yields of agricultural crops are likely to be affected due to rise in $CO_2$ and temperature, apart from other factors. In this context, the present study aimed at to assess the maize (*Zea mays L.*) genotypes to elevated carbon dioxide and temperature regimes. Series of climates were synthesized by increasing $CO_2$ levels from 390 to 550ppm with an increasing the temperature at $2^0$ C. A significant increase in chlorophyll content, reducing and non-reducing sugars was seen in elevated $CO_2$ treatment but soluble protein was decreased. Whereas, under elevated temperature regimes chlorophyll content, reducing and non-reducing sugars are decreased due to altered C: N ratio. The results indicated that on doubling the $CO_2$ level of the existing (350ppm) at existing temperature, a yield of grain in maize was increased. Unlike effect of $CO_2$, crop yields were decreased with increase in temperature.

**Keywords:** Elevated $CO_2$and temperature, biochemical parameters, maize genotypes

## 1. Introduction

The Inter-government Panel for Climate Change (IPCC) has compiled the magnitude of change in $CO_2$ and temperature under climate change scenario for different parts of the world. According to this, $CO_2$ level may increase to 397-416 ppm by 2010 and 605- 755 by 2070. These gases can cause a giant green house effect and thereby make the earth warmer. The reports state that average surface temperature across the globe has shot up 0.74 ºC in the past century. The mean global surface temperature exhibited an increase over the past decade with particularly sharp increase since the 1970's (Gadgil, 1996) [6]. In the past 150 years, the hottest years witnessed were since 1995. The all India mean annual temperature derived from 73 stations showed a significant warming of 0.4ºCover the last 100 years, which is comparable to global mean trend of 0.3ºC increase per hundred years (Hingane *et al*, 1985) [8]. Hundaland Prabhjot Kaur (2001) have reported gradual increasing minimum temperature of about 0.4 - 1.6ºC over the past 30 years.

Increase in $CO_2$ and temperature affect the crop productivity directly (physiological processes of the plants–photosynthesis, respiration, evapotranspiration and phenology) and indirectly (weather induced incidences of diseases and thermal and water stresses). The global atmospheric concentration of carbon dioxide, which is 379 ppm in 2005, is increasing at an average (1995–2005) rate of 1.9 ppm per year. Inview of this futuristic change in climate, it is imperative to assess their quantitative impact on crop productivity in a given region. Itis reported that productivity of food grain could drop by 30 per cent in the next 30 years (Chingappa, 2007) [4]. The crop growth and yield generally have positive relation with atmospheric $CO_2$ and antagonistic with temperature. The crop productivity is increased with increased carbon dioxide (Kimball, 1983; Cure and Acock, 1986; Allen *et al*, 1997) [10, 5, 1] and decreased with increased air temperature (Seddigh *et al*, 1984 a & b) [20-21]; Rosenzweig and Hillel, 1998) [17]. But little is known how much increase intemperature at given level of increased $CO_2$ concentration, will level off the beneficial effect of $CO_2$.The present study was undertaken with the objective of response of maize genotypes to elevated carbon dioxide ($CO_2$) and temperature regimes on biochemical parameters under open top chamber and also response of maize genotypes to elevated $CO_2$ and temperature regimes on yield and yield parameters under open top chamber.

## Material and Methods

An investigation was carried out to study the response of maize genotypes to elevated carbon dioxide and temperature regimes under Open Top Chamber (OTC's) at Main Agricultural Research Station (MARS), University of Agricultural Sciences, Raichur, and Karnataka during *summer* and *kharif* season 2014-15. Five maize genotypes (HTMR-1, HTMR-2, ARJUN, 900M Gold, NK 6240) were sown in each OTC and in reference plot with controlled conditions with a spacing of 60 cm x20 cm. Five plants were raised for each genotypes, therefore total 25 plants were raised in each open top chambers. For each genotype all the agronomic practices for raising the crop were practiced as per the package of practices of the University of Agricultural Sciences, Raichur. The following traits were recorded under elevated $CO_2$ and temperature regimes. Chlorophylla, chlorophyll b, total chlorophyll, reducing and non-reducing sugars, soluble protein, cob length, number of rows per cob, number of seeds per cob and grain yield per plant. The temperature and $CO_2$ treatments were randomly allocated in each of the five growth chambers as follows

$T_1$: Reference open top chamber (390 ppm $CO_2$)

$T_2$: Ambient $CO_2$ @390 ± 25ppm with 2$^{O}$C rise in temperature

$T_3$: Elevated $CO_2$ @ 550 ± 25ppm with normal temperature

$T_4$: Elevated $CO_2$ @ 550 ± 25ppm with 2$^{O}$C rise in temperature

$T_5$: Reference plot (Open field)

## Results and Discussion

Significant difference was observed among the treatments, genotypes and also interaction effect. In general irrespective of the treatments, elevated $CO_2$ treatment had recorded maximum chlorophyll a, chlorophyll b and total chlorophyll followed by e-$CO_{2+}$ e –temp, a-$CO_2$ and reference plot and the least Chlorophyll a, chlorophyll b and total chlorophyll was noticed in a-$CO_{2+}$ e –temp treatment. Among five maize genotypes the genotype HTMR-1, ARJUN and HTMR-2 influenced the chlorophyll a, chlorophyll b and total chlorophyll whereas, non-responsive genotypes 900M-GOLD and NK 6240 genotype did not influence the chlorophyll a, chlorophyll b and total chlorophyll under elevated $CO_2$ and temperature regimes. A significant increase in chlorophyll content was seen in elevated $CO_2$ and elevated temperature treatment this was supported by several numbers of authors (Hamid *et al*., 2009; Srivastav *et al*., 2012; and Urbonaviciute *et al.,* 2006) [7] who reported significant increase in chlorophyll content at 1,500 ppm $CO_2$ treatment. There was no effect on carbohydrate and chlorophyll contents in radish leaves up to seven days after returning plants to ambient $CO_2$.Whereas, under elevated temperature condition chlorophyll content was significantly reduced this was supported by Warrington *et al*. (1983) [24], Bonhomme *et al*. (1994) and Rupinder Kaur and Saxena (2011) [18].

The chlorophyll content showed an increased trend in the elevated altered condition, wherein they showed more values. This increase in the chlorophyll content may be reasoned to the much utilization of carbon in the tissues which in turn has increased the chlorophyll content. More the chlorophyll, more the photosynthesis and growth rate in the elevated altered condition which was evident by the increase in the growth and yield parameters. The rise in chlorophyll content in the elevated altered condition treatments was reported by many studies in various crops. Studies of numerous authors are in line with the present findings wherein, they reported thatplant chlorophyll content increased with increased $CO_2$ concentration especially in $C_3$ plants. Hamid *et al.* (2009) [7] and Ramachandra *et al.* (1998) recorded less chlorophyll content in elevated treatments as compared to ambient in cotton crop which is contradictory to the present studies. However, this may be reasoned to the variation in the genotype used in our studies.

Elevated $CO_2$ treatment had recorded maximum reducing sugars in leaves and grains followed by a-$CO_2$, e-$CO_{2+}$ e –temp, reference plot and least reducing sugars was noticed in a-$CO_{2+}$ e –temp treatment. Among the genotypes HTMR-1, HTMR-2 and ARJUN genotypes recorded highest reducing and non-reducing sugar in leaves compared to NK 6240 and 900M-GOLD genotypes. However, the a-$CO_2$ treatments showed low sugars as compared to e-$CO_2$ treatments. Similar trend was noticed in 30, 60 and 90 days. The studies by Ramachandra *et al.* (1998) are in line with the present findings, which showed that Starch and sucrose concentrations were always high in leaves grown under e-$CO_2$ when compared to ambient treatments. Sari *et al.* (2008) [19] recorded more sugars in *Bt* oilseed rape plant under e-$CO_2$ conditions than ambient conditions. Studies by Xin*et al.* (2013) reported that e-$CO_2$ increased carbohydrates accumulation in tomato plants. The leaf carbohydrate determinations showed that the starch, total soluble sugar, and sucrose concentrations increased significantly in plants exposed to e-$CO_2$.

Irrespective of the treatments, a-$CO_{2+}$ e –temp treatment had recorded maximum soluble protein in leaves, followed by reference plot, a-$CO_{2,}$ and e-$CO_{2+}$ e –temp and the least soluble protein in leaves was recorded in e-$CO_2$ treatment. Irrespective of the treatments the HTMR-2 recorded maximum soluble protein in leaves, followed by HTMR-1, NK 6240 and 900M-GOLD and the least soluble protein in leaves was recorded in ARJUN genotype. The present investigations showed that soluble proteins had a significant negative effect of e-$CO_2$ and temperature treatments. Elevated $CO_2$ treatments recorded low soluble proteins and while the a-$CO_2$ treatments recorded highest values are decreased due to altered C: N ratio. Under elevated CO2 condition plant uses more of carbon for photosynthesis resulted in nitrogen (protein) content was decreased. Similar trend was recorded at 30, 60 and 90 days. Yin *et al*., 2010 reported that atmospheric $CO_2$ enrichment induced changes in phytochemistry of cotton plant which decreased protein and total amino acids. Under $CO_2$ treatment, soluble protein and reducing sugars decreased while total soluble sugars and starch showed an opposite trend (Mishra and Agrawal 2014) [13].

There is significant difference was observed among the treatments. In general, irrespective of the genotypes mean of all the genotypes showed that e-$CO_2$ treatment had recorded maximum grain yield per plant followed by, e-$CO_{2+}$ e –temp, a-$CO_2$ and reference plot and the least was noticed in a-$CO_{2+}$ e –temp. Irrespective of the treatments, the genotype HTMR-1recorded maximum grain yield per plant compared to HTMR-, 900M-GOLD, ARJUN and the least was observed in NK 6240 genotype. Results of present investigation showed significant increase in the yield parameters and yield in the e-$CO_2$ conditions as compared to a-$CO_2$ conditions. The increase in the growth rates and increase in photosynthetic rates resulted in increase in the yield. Maximum cob length, the highest no of rows per cob, highest number of seeds per cob and also grain yield per plant was highest in e-$CO_2$ treatment due to substantial increase in yield in elevated climate change treatments. Likewise, the combination of increasing $CO_2$ concentration and air temperature resulted in reduced grain yield and declining harvest index compared to increased $CO_2$ alone. (Moya *et al*. (1998) [14]. Similarly Mishra and Agrawal (2014) [13] reported that in Mung bean crop under elevated $CO_2$ 700 ppm increased total chlorophyll, photosynthetic rate, growth and yield parameters. Higher temperature decrease the plant biomass and yield by decreasing photosynthesis and increasing transpiration and stomatal conductance (Nobel 2005) [15] Also, plants mitigate overheating by leaf rolling and drooping and vertical leaf orientation (Larcher 2003; Nobel 2005) [11, 15] or by transient wilting (Chiariello *et al*. 1987 and Nobel 2005) [15]. Such adaptive mechanisms likely reduce leaf exposure to incident light and in turn, may lead to decreased photosynthesis.

**Table 1**: Effect of elevated $CO_2$ and temperature regimes on chlorophyll a (mg/g of fresh weight)

| Treatment | **Chlorophyll a (mg/g of fresh weight)** | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **30 DAS** | | | | | | **60 DAS** | | | | | | **90 DAS** | | | | | |
| | **HTMR-1** | **HTMR-2** | **ARJUN** | **900 M GOLD** | **NK 6240** | **Mean** | **HTMR-1** | **HTMR-2** | **ARJUN** | **900 M GOLD** | **NK 6240** | **Mean** | **HTMR-1** | **HTMR-2** | **ARJUN** | **900 M GOLD** | **NK 6240** | **Mean** |
| $T_1$ | 1.53 | 1.52 | 1.48 | 1.51 | 1.44 | 1.50 | 2.23 | 1.79 | 2.20 | 2.11 | 1.91 | 2.05 | 1.13 | 1.15 | 1.09 | 1.18 | 1.17 | 1.14 |
| $T_2$ | 1.12 | 0.88 | 1.16 | 0.90 | 0.94 | 1.00 | 1.76 | 1.83 | 1.48 | 1.45 | 1.53 | 1.61 | 0.84 | 0.71 | 0.77 | 0.74 | 0.81 | 0.77 |
| $T_3$ | 2.05 | 1.96 | 1.87 | 1.87 | 1.79 | 1.91 | 2.41 | 2.44 | 2.27 | 2.26 | 2.39 | 2.35 | 1.55 | 1.48 | 1.51 | 1.43 | 1.46 | 1.49 |
| $T_4$ | 1.75 | 1.68 | 1.67 | 1.69 | 1.63 | 1.69 | 2.30 | 2.30 | 2.36 | 2.28 | 2.31 | 2.31 | 1.30 | 1.34 | 1.23 | 1.15 | 1.17 | 1.24 |
| $T_5$ | 1.47 | 1.24 | 1.47 | 1.27 | 1.36 | 1.36 | 1.97 | 1.62 | 2.05 | 1.68 | 1.66 | 1.79 | 1.01 | 1.02 | 0.97 | 1.00 | 0.97 | 1.00 |
| Mean | 1.59 | 1.46 | 1.53 | 1.45 | 1.43 | | 2.13 | 2.00 | 2.07 | 1.95 | 1.96 | | 1.17 | 1.14 | 1.11 | 1.10 | 1.11 | |
| | S.Em± | | | CD @ 1% | | | S.Em± | | CD @ 1% | | | | S.Em± | | CD @ 1% | | | |
| A | 0.014 | | | 0.052 | | | 0.013 | | 0.049 | | | | 0.032 | | 0.120 | | | |
| B | 0.014 | | | 0.052 | | | 0.013 | | 0.049 | | | | 0.032 | | 0.120 | | | |
| A X B | 0.031 | | | 0.117 | | | 0.029 | | 0.109 | | | | 0.072 | | 0.269 | | | |

$T_1$ = Ambient $CO_2$ (390 ppm) $T_2$ = 390 ppm $CO_2$+ $2^0$ C in temperature A= Treatments
$T_3$ = Elevated $CO_2$ (550 ppm) with normal temperature $T_4$ = 550 ppm $CO_2$+ $2^0$ C in temperature B=Genotypes
$T_5$ = Reference plot (open field)

**Table 2:** Effect of elevated $CO_2$ and temperature regimes on chlorophyll b (mg/g of fresh weight)

| Treatment | **Chlorophyll b (mg/g of fresh weight)** | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **30 DAS** | | | | | | **60 DAS** | | | | | | **90 DAS** | | | | | |
| | **HTMR-1** | **HTMR-2** | **ARJUN** | **900 M GOLD** | **NK 6240** | **Mean** | **HTMR-1** | **HTMR-2** | **ARJUN** | **900 M GOLD** | **NK 6240** | **Mean** | **HTMR-1** | **HTMR-2** | **ARJUN** | **900 M GOLD** | **NK 6240** | **Mean** |
| $T_1$ | 0.29 | 0.31 | 0.32 | 0.28 | 0.38 | 0.32 | 0.62 | 0.66 | 0.46 | 0.88 | 0.57 | 0.64 | 0.30 | 0.33 | 0.29 | 0.30 | 0.28 | 0.30 |
| $T_2$ | 0.26 | 0.27 | 0.28 | 0.28 | 0.22 | 0.26 | 0.52 | 0.49 | 0.57 | 0.37 | 0.38 | 0.47 | 0.22 | 0.19 | 0.29 | 0.20 | 0.22 | 0.22 |
| $T_3$ | 0.57 | 0.56 | 0.47 | 0.47 | 0.39 | 0.49 | 1.74 | 1.41 | 1.43 | 1.69 | 1.09 | 1.47 | 0.44 | 0.42 | 0.31 | 0.31 | 0.32 | 0.36 |
| $T_4$ | 0.42 | 0.41 | 0.35 | 0.30 | 0.29 | 0.36 | 1.00 | 0.98 | 0.85 | 0.92 | 0.78 | 0.91 | 0.39 | 0.29 | 0.30 | 0.35 | 0.32 | 0.33 |
| $T_5$ | 0.26 | 0.24 | 0.28 | 0.30 | 0.28 | 0.27 | 0.54 | 0.60 | 0.37 | 0.57 | 0.39 | 0.50 | 0.32 | 0.29 | 0.26 | 0.28 | 0.28 | 0.29 |
| Mean | 0.36 | 0.36 | 0.34 | 0.33 | 0.31 | | 0.88 | 0.83 | 0.74 | 0.89 | 0.64 | | 0.33 | 0.30 | 0.29 | 0.29 | 0.29 | |
| | S.Em± | | | CD @ 1% | | | S.Em± | | CD @ 1% | | | | S.Em± | | CD @ 1% | | | |
| A | 0.003 | | | 0.012 | | | 0.005 | | 0.018 | | | | 0.004 | | 0.016 | | | |
| B | 0.003 | | | 0.012 | | | 0.005 | | 0.018 | | | | 0.004 | | 0.016 | | | |
| A X B | 0.007 | | | 0.026 | | | 0.011 | | 0.039 | | | | 0.010 | | 0.036 | | | |

$T_1$ = Ambient $CO_2$ (390 ppm) $T_2$ = 390 ppm $CO_2$+ $2^0$ C in temperature A= Treatments
$T_3$ = Elevated $CO_2$ (550 ppm) with normal temperature $T_4$ = 550 ppm $CO_2$+ $2^0$ C in temperature B=Genotypes
$T_5$ = Reference plot (open field)

**Table 3:** Effect of elevated $CO_2$ and temperature regimes on total chlorophyll (mg/g of fresh weight)

| Treatment | Total chlorophyll (mg/g of fresh weight) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | | | | | | 60 DAS | | | | | | 90 DAS | | | | | |
| | HTMR-1 | HTMR-2 | ARJUN | 900 M GOLD | NK 6240 | Mean | HTMR-1 | HTMR-2 | ARJUN | 900 M GOLD | NK 6240 | Mean | HTMR-1 | HTMR-2 | ARJUN | 900 M GOLD | NK 6240 | Mean |
| $T_1$ | 1.82 | 1.83 | 1.80 | 1.80 | 1.81 | 1.81 | 2.85 | 2.46 | 2.67 | 2.99 | 2.47 | 2.69 | 1.43 | 1.47 | 1.37 | 1.48 | 1.45 | 1.44 |
| $T_2$ | 1.38 | 1.16 | 1.45 | 1.17 | 1.17 | 1.27 | 2.28 | 2.32 | 2.06 | 1.82 | 1.92 | 2.08 | 1.06 | 0.91 | 1.06 | 0.94 | 1.03 | 1.00 |
| $T_3$ | 2.62 | 2.52 | 2.34 | 2.33 | 2.18 | 2.40 | 4.15 | 3.85 | 3.69 | 3.96 | 3.49 | 3.83 | 2.00 | 1.90 | 1.82 | 1.74 | 1.79 | 1.85 |
| $T_4$ | 2.17 | 2.09 | 2.03 | 1.99 | 1.93 | 2.04 | 3.31 | 3.28 | 3.21 | 3.20 | 3.09 | 3.22 | 1.69 | 1.63 | 1.53 | 1.49 | 1.49 | 1.56 |
| $T_5$ | 1.74 | 1.48 | 1.75 | 1.57 | 1.64 | 1.63 | 2.51 | 2.22 | 2.41 | 2.25 | 2.05 | 2.29 | 1.33 | 1.31 | 1.23 | 1.28 | 1.25 | 1.28 |
| Mean | 1.95 | 1.82 | 1.87 | 1.77 | 1.75 | | 3.02 | 2.83 | 2.81 | 2.84 | 2.60 | | 1.50 | 1.44 | 1.40 | 1.39 | 1.40 | |
| | S.Em± | | CD @ 1% | | | | S.Em± | | CD @ 1% | | | | S.Em± | | CD @ 1% | | | |
| A | 0.015 | | 0.055 | | | | 0.017 | | 0.063 | | | | 0.034 | | 0.126 | | | |
| B | 0.015 | | 0.055 | | | | 0.017 | | 0.063 | | | | 0.034 | | NS | | | |
| A X B | 0.033 | | 0.123 | | | | 0.038 | | 0.141 | | | | 0.075 | | NS | | | |

$T_1$ = Ambient $CO_2$ (390 ppm) $T_2$ = 390 ppm $CO_2$+ $2^0$ C in temperature A= Treatments
$T_3$ = Elevated $CO_2$ (550 ppm) with normal temperature $T_4$ = 550 ppm $CO_2$+ $2^0$ C in temperature B=Genotypes
$T_5$ = Reference plot (open field)

**Table 4:** Effect of elevated $CO_2$ and temperature regimes on reducing sugar (mg $g^{-1}$) in leaves

| Treatment | Reducing sugar in leaves (mg $g^{-1}$) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | | | | | | 60 DAS | | | | | | 90 DAS | | | | | |
| | HTMR-1 | HTMR-2 | ARJUN | 900 M GOLD | NK 6240 | Mean | HTMR-1 | HTMR-2 | ARJUN | 900 M GOLD | NK 6240 | Mean | HTMR-1 | HTMR-2 | ARJUN | 900 M GOLD | NK 6240 | Mean |
| $T_1$ | 22.64 | 19.30 | 18.70 | 11.43 | 14.81 | 17.38 | 25.14 | 21.80 | 21.20 | 13.93 | 17.31 | 19.88 | 21.10 | 18.03 | 17.43 | 10.40 | 14.13 | 16.22 |
| $T_2$ | 14.60 | 18.25 | 11.95 | 9.73 | 8.93 | 12.69 | 17.10 | 20.75 | 14.45 | 12.21 | 11.43 | 15.19 | 13.53 | 17.15 | 10.70 | 8.75 | 7.71 | 11.57 |
| $T_3$ | 23.43 | 20.25 | 19.43 | 13.25 | 17.38 | 18.75 | 25.93 | 22.71 | 21.97 | 15.75 | 19.88 | 21.25 | 22.18 | 19.03 | 17.73 | 12.30 | 16.22 | 17.49 |
| $T_4$ | 21.25 | 19.00 | 16.98 | 10.49 | 15.83 | 16.71 | 23.75 | 21.50 | 19.48 | 12.99 | 18.37 | 19.21 | 19.51 | 18.01 | 16.08 | 9.60 | 14.68 | 15.58 |
| $T_5$ | 21.03 | 19.13 | 17.03 | 11.06 | 14.95 | 16.64 | 23.53 | 21.64 | 19.53 | 13.56 | 17.45 | 19.14 | 20.10 | 18.15 | 16.20 | 10.45 | 13.95 | 15.77 |
| Mean | 20.59 | 19.19 | 16.82 | 11.19 | 14.38 | | 23.09 | 21.69 | 19.32 | 13.69 | 16.88 | | 19.29 | 18.08 | 15.63 | 10.30 | 13.34 | |
| | S.Em± | | CD @ 1% | | | | S.Em± | | CD @ 1% | | | | S.Em± | | CD @ 1% | | | |
| A | 0.121 | | 0.452 | | | | 0.294 | | 1.101 | | | | 0.146 | | 0.547 | | | |
| B | 0.121 | | 0.452 | | | | 0.294 | | 1.101 | | | | 0.146 | | 0.547 | | | |
| A X B | 0.271 | | 1.012 | | | | 0.658 | | 2.461 | | | | 0.327 | | 1.223 | | | |

$T_1$ = Ambient $CO_2$ (390 ppm) $T_2$ = 390 ppm $CO_2$+ $2^0$ C in temperature A= Treatments
$T_3$ = Elevated $CO_2$ (550 ppm) with normal temperature $T_4$ = 550 ppm $CO_2$+ $2^0$ C in temperature B=Genotypes
$T_5$ = Reference plot (open field)

**Table 5:** Effect of elevated $CO_2$ and temperature regimes on non- reducing sugar (mg $g^{-1}$) in leaves

| Treatment | Non- reducing sugars in leaves (mg $g^{-1}$) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | | | | | | 60 DAS | | | | | | 90 DAS | | | | | |
| | HTMR-1 | HTMR-2 | ARJUN | 900 M GOLD | NK 6240 | Mean | HTMR-1 | HTMR-2 | ARJUN | 900 M GOLD | NK 6240 | Mean | HTMR-1 | HTMR-2 | ARJUN | 900 M GOLD | NK 6240 | Mean |
| $T_1$ | 8.83 | 6.53 | 5.30 | 5.57 | 6.18 | 6.47 | 11.33 | 9.03 | 7.80 | 8.08 | 8.68 | 8.97 | 7.73 | 5.58 | 4.20 | 4.38 | 5.13 | 5.40 |
| $T_2$ | 4.61 | 5.60 | 5.23 | 2.88 | 5.55 | 4.78 | 7.13 | 8.10 | 7.73 | 5.38 | 8.05 | 7.28 | 3.85 | 4.68 | 4.24 | 2.14 | 4.95 | 3.97 |
| $T_3$ | 9.98 | 8.68 | 6.45 | 7.31 | 9.65 | 8.43 | 12.48 | 11.18 | 8.95 | 9.88 | 12.15 | 10.93 | 8.78 | 7.58 | 5.38 | 6.25 | 8.60 | 7.32 |
| $T_4$ | 6.23 | 6.35 | 5.30 | 3.65 | 8.83 | 6.07 | 8.73 | 8.85 | 7.80 | 6.13 | 11.33 | 8.57 | 5.15 | 5.23 | 4.45 | 2.90 | 7.70 | 5.09 |
| $T_5$ | 8.13 | 6.45 | 5.05 | 5.53 | 5.75 | 6.19 | 10.63 | 8.95 | 7.55 | 8.05 | 8.25 | 8.69 | 7.50 | 5.50 | 4.16 | 4.33 | 4.73 | 5.24 |
| Mean | 7.56 | 6.72 | 5.47 | 5.01 | 7.19 | | 10.06 | 9.22 | 7.97 | 7.50 | 9.69 | | 6.60 | 5.71 | 4.48 | 4.00 | 6.22 | |
| | S.Em± | | CD @ 1% | | | | S.Em± | | CD @ 1% | | | | S.Em± | | CD @ 1% | | | |
| A | 0.092 | | 0.344 | | | | 0.307 | | 1.148 | | | | 0.087 | | 0.327 | | | |
| B | 0.092 | | 0.344 | | | | 0.307 | | 1.148 | | | | 0.087 | | 0.327 | | | |
| A X B | 0.206 | | 0.770 | | | | 0.687 | | 2.566 | | | | 0.195 | | 0.731 | | | |

$T_1$ = Ambient $CO_2$ (390 ppm) $T_2$ = 390 ppm $CO_2$+ $2^0$ C in temperature A= Treatments
$T_3$ = Elevated $CO_2$ (550 ppm) with normal temperature $T_4$ = 550 ppm $CO_2$+ $2^0$ C in temperature B=Genotypes
$T_5$ = Reference plot (open field)

**Table 6:** Effect of elevated $CO_2$ and temperature regimes on soluble protein (mg/g) in leaves

| Treatment | Soluble protein in leaves ( mg/g) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | | | | | | 60 DAS | | | | | | 90 DAS | | | | | |
| | HTMR-1 | HTMR-2 | ARJUN | 900 M GOLD | NK 6240 | Mean | HTMR-1 | HTMR-2 | ARJUN | 900 M GOLD | NK 6240 | Mean | HTMR-1 | HTMR-2 | ARJUN | 900 M GOLD | NK 6240 | Mean |
| $T_1$ | 0.75 | 0.77 | 0.68 | 0.67 | 0.72 | 0.72 | 0.79 | 0.80 | 0.72 | 0.71 | 0.76 | 0.75 | 0.78 | 0.78 | 0.71 | 0.70 | 0.74 | 0.74 |
| $T_2$ | 0.76 | 0.79 | 0.67 | 0.69 | 0.71 | 0.72 | 0.82 | 0.84 | 0.71 | 0.74 | 0.76 | 0.77 | 0.80 | 0.82 | 0.70 | 0.73 | 0.75 | 0.76 |
| $T_3$ | 0.65 | 0.68 | 0.60 | 0.62 | 0.66 | 0.64 | 0.68 | 0.70 | 0.63 | 0.63 | 0.68 | 0.66 | 0.61 | 0.64 | 0.59 | 0.60 | 0.64 | 0.62 |
| $T_4$ | 0.66 | 0.69 | 0.61 | 0.63 | 0.65 | 0.65 | 0.70 | 0.70 | 0.63 | 0.65 | 0.67 | 0.67 | 0.60 | 0.62 | 0.57 | 0.59 | 0.62 | 0.60 |
| $T_5$ | 0.76 | 0.78 | 0.65 | 0.68 | 0.70 | 0.71 | 0.79 | 0.81 | 0.69 | 0.73 | 0.74 | 0.75 | 0.78 | 0.80 | 0.68 | 0.72 | 0.72 | 0.74 |
| Mean | 0.72 | 0.74 | 0.64 | 0.66 | 0.69 | | 0.75 | 0.77 | 0.67 | 0.69 | 0.72 | | 0.71 | 0.73 | 0.65 | 0.67 | 0.69 | |
| | S.Em± | | CD @ 1% | | | | S.Em± | | CD @ 1% | | | | S.Em± | | CD @ 1% | | | |
| A | 0.008 | | 0.028 | | | | 0.010 | | 0.038 | | | | 0.010 | | 0.037 | | | |
| B | 0.008 | | 0.028 | | | | 0.010 | | 0.038 | | | | 0.010 | | 0.037 | | | |
| A X B | 0.017 | | NS | | | | 0.023 | | NS | | | | 0.022 | | NS | | | |

$T_1$ = Ambient $CO_2$ (390 ppm) $T_2$ = 390 ppm $CO_2$+ $2^0$ C in temperature A= Treatments
$T_3$ = Elevated $CO_2$ (550 ppm) with normal temperature $T_4$ = 550 ppm $CO_2$+ $2^0$ C in temperature B=Genotypes
$T_5$ = Reference plot (open field)

**Table 7a:** Effect of elevated $CO_2$ and temperature regimes on yield components

| Treatment | Yield components | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Cob length (cm)** | | | | | | **No of rows per cob** | | | | | |
| | **HTMR-1** | **HTMR-2** | **ARJUN** | **900 M GOLD** | **NK 6240** | **Mean** | **HTMR-1** | **HTMR-2** | **ARJUN** | **900 M GOLD** | **NK 6240** | **Mean** |
| $T_1$ | 13.31 | 10.75 | 11.56 | 13.38 | 14.44 | 12.69 | 11.88 | 12.50 | 12.50 | 12.25 | 14.00 | 12.63 |
| $T_2$ | 12.25 | 10.88 | 9.69 | 9.69 | 12.00 | 10.90 | 11.25 | 11.75 | 11.63 | 11.50 | 11.13 | 11.45 |
| $T_3$ | 16.00 | 14.69 | 14.13 | 13.00 | 15.13 | 14.59 | 14.88 | 15.13 | 13.00 | 14.25 | 12.75 | 14.00 |
| $T_4$ | 15.63 | 12.94 | 12.63 | 14.81 | 13.75 | 13.95 | 13.38 | 13.00 | 12.88 | 12.50 | 12.50 | 12.85 |
| $T_5$ | 15.38 | 13.31 | 10.69 | 12.25 | 12.50 | 12.83 | 12.50 | 12.25 | 11.38 | 11.88 | 10.25 | 11.65 |
| Mean | 14.51 | 12.51 | 11.74 | 12.63 | 13.56 | | 12.78 | 12.93 | 12.28 | 12.48 | 12.13 | |
| | S.Em± | | | CD @ 1% | | | S.Em± | | | CD @ 1% | | |
| A | 0.349 | | | 1.303 | | | 0.378 | | | 1.412 | | |
| B | 0.349 | | | 1.303 | | | 0.378 | | | NS | | |
| A X B | 0.780 | | | NS | | | 0.844 | | | NS | | |

$T_1$ = Ambient $CO_2$ (390 ppm) $T_2$ = 390 ppm $CO_2$+ $2^0$ C in temperature A= Treatments
$T_3$ = Elevated $CO_2$ (550 ppm) with normal temperature $T_4$ = 550 ppm $CO_2$+ $2^0$ C in temperature B=Genotypes
$T_5$ = Reference plot (open field)

**Table 7b**: Effect of elevated $CO_2$ and temperature regimes on yield components

| Treatment | yield components | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **No of seeds per cob (number)** | | | | | | **Grain yield per plant (g)** | | | | | |
| | **HTMR-1** | **HTMR-2** | **ARJUN** | **900 M GOLD** | **NK 6240** | **Mean** | **HTMR-1** | **HTMR-2** | **ARJUN** | **900 M GOLD** | **NK 6240** | **Mean** |
| $T_1$ | 296 | 312 | 304 | 312 | 283 | 301 | 97.26 | 92.99 | 91.56 | 92.69 | 85.35 | 91.97 |
| $T_2$ | 172 | 154 | 167 | 147 | 190 | 166 | 64.56 | 59.63 | 63.13 | 56.40 | 64.71 | 61.68 |
| $T_3$ | 484 | 463 | 409 | 412 | 417 | 437 | 163.00 | 154.00 | 139.50 | 139.63 | 139.88 | 147.20 |
| $T_4$ | 388 | 391 | 343 | 347 | 341 | 362 | 127.75 | 127.75 | 116.20 | 118.65 | 117.33 | 121.54 |
| $T_5$ | 260 | 242 | 230 | 267 | 242 | 248 | 86.38 | 80.88 | 76.95 | 82.44 | 72.96 | 79.92 |
| Mean | 320 | 312 | 290 | 297 | 294 | | 107.79 | 103.05 | 97.47 | 97.96 | 96.05 | |
| | S.Em± | | | CD @ 1% | | | S.Em± | | | CD @ 1% | | |
| A | 12.379 | | | 46.268 | | | 3.183 | | | 11.896 | | |
| B | 12.379 | | | NS | | | 3.183 | | | NS | | |
| A X B | 27.679 | | | NS | | | 7.117 | | | NS | | |

$T_1$ = Ambient $CO_2$ (390 ppm) $T_2$ = 390 ppm $CO_2$+ $2^0$ C in temperature A= Treatments
$T_3$ = Elevated $CO_2$ (550 ppm) with normal temperature $T_4$ = 550 ppm $CO_2$+ $2^0$ C in temperature B=Genotypes
$T_5$ = Reference plot (open field)

## Conclusion

Among five maize genotypes the genotype HTMR-1, ARJUN and HTMR-2 have better response to chlorophyll a and b whereas 900M-GOLD and NK 6240 genotype have non-responsive genotypes with respect to chlorophyll a and b under elevated $CO_2$and temperature regimes. A significant increase in chlorophyll content was seen in elevated $CO_2$ treatment and e-$CO_{2+}$ e –temp treatment. Whereas, under a-$CO_{2+}$ e –temp treatment chlorophyll a and b are decreased due to higher growth temperature.e-$CO_2$ treatment recorded maximum reducing sugars in leaves followed by a-$CO_2$, e-$CO_{2+}$ e –temp, reference plot and least reducing sugars was noticed in a-$CO_{2+}$ e –temp treatment. Among the genotypes HTMR-1, HTMR-2 and ARJUN genotypes have better or higher reducing and non-reducing sugar in leaves whereas, NK 6240 and 900M-GOLD genotype had non-responsiveness genotypes with respect to reducing and non-reducing sugar in leaves.

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