International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2017; 5(5): 2448-2456

Received: 05-07-2017
Accepted: 06-08-2017

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

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Abstract
As per recent IPCC (2013) assessment report global scale climate change has occurred and it will be continued in near future at different rates. Due to climate change globle atmospheric carbon dioxide concentration (CO_2) are rising and projected to reach between 540 and 970 ppm by the end of 21st century and globle surface temperature may increase 1.4- 5.8° C in association with this doubling of CO_2. Crop species (both C_3 as well as C4) are directly affected by elevated levels of temperature and CO_2 due to changes in plant physical structures, leaf chemistry and carbon: nitrogen balance etc. which in turn affect yield, tolerance to drought stress and susceptibility to pests and herbivores. 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 University of Agricultural Sciences, Raichur, Karnataka during summer and *kharif* season 2014-15. Various morphological parameters studied indicated that, the genotypes HTMR-1, 900M-GOLD and HTMR-2 performed better under elevated CO2 and temperature regime. The maximum reduction with respect to these parameters was observed in ARJUN and NK 6240 genotypes. The exposure of the crop elevated CO2 and temperature regime resulted in the significant decrease in the photosynthetic rates. The minimum reduction was observed in HTMR-1, HTMR-2 and NK 6240 and the maximum in ARJUN and 900M-GOLD. The results indicated that on doubling the CO2 level of the existing (350 ppm) at existing temperature, a yield of grain in maize was increased. Unlike effect of CO2, crop yields were decreased with increase in temperature.

Keywords: physiology of maize, elevated CO_2 and temperature, maize genotypes

Introduction
Crop species (both C_3 as well as C4) are directly affected by elevated levels of temperature and CO_2 due to changes in plant physical structures, leaf chemistry and carbon: nitrogen balance etc. which in turn affect yield, tolerance to drought stress and susceptibility to pests and herbivores. These results are only preliminary and need more intensive and systematic understanding is required for enhancing the knowledge on behavioural responses of more genotypes, which will help in not only enhancing the crop productivity in adverse weather and climate, but also towards the climate sustenance and resilience of the farmers in future. Yet, more intensive and systematic studies needed to understand the implications of climate change on soil and its dependents as well as crops and its dependents to mitigate climate change effects to help farming community. This research therefore envisages, identifying the responses of biological traits in crop microclimate to the elevated CO_2 and temperature situation. Despite abundance evidence about the direct effect of elevated temperature and carbon dioxide on crop plants, we still need a more thorough understanding of the impact of elevated temperature and CO_2 levels on identifying genotypic traits that possess characters like heat tolerance, high harvest index, high photosynthetic capacity per unit leaf area etc that will be suitable at both high and intermediate temperatures. Testing them under controlled and field environments is also required.

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, 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., photosynthetic rate, stomatal conductance, transpiration rate, cob length, and 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

Mean of all the genotypes showed that e-CO_2 treatment had higher plant height except at 25 DAS and 75 DAS followed by a-CO_{2+} e –temp except 25 DAS and at harvest. Result indicated that significant difference was observed among the treatments, interaction effect and also among the genotypes at all the growth stages. Least plant height was noticed in reference plot. Irrespective of the treatments the HTMR-1 recorded higher plant height except 25 and 50 DAS followed by 900M-GOLD except 25 and 50 DAS, NK 6240 except 25 and 50 DAS, and ARJUN except 25 and 50 DAS and the least plant height was noticed in HTMR-2 genotype except 25 and 50 DAS. Leaf area per plant at different growth stages of maize was significantly influenced by elevated CO_2 and temperature regimes. Significant difference exists among the treatment except 25 and harvest stages. Irrespective of genotypes mean of all the genotypes showed that e-CO_2 treatment had higher leaf area per plant was noticed followed by e-CO_{2+} e –temp, a-CO_{2+} e –temp except 100 DAS and at harvesting stages and a-CO_2 except 100 DAS and at harvesting stages, and least leaf area per plant was noticed in reference plot. Irrespective of the treatments HTMR-1 recorded higher leaf area per plant followed by HTMR-2 except 25 and 75 DAS, ARJUN except 25 and 75 DAS and NK 6240 except 25 DAS and the least leaf area per plant was noticed in 900M-GOLD genotype. In total dry matter accumulation there was significant difference was observed among the treatments, genotypes and also interaction effect. Maximum total dry matter accumulation was observed in HTMR-1(122.3 g plant^{-1}) genotype under e-CO_2 treatment. The lowest total dry matter accumulation was observed in HTMR-2 (69.1 g plant$^{-1)}$ in a-CO_{2+} e –temp treatment.

Various morphological characters such as plant height, leaf area per plant, dry matter accumulation and its distribution in different plant parts were significantly influenced under elevated CO_2 and temperature regimes as compared to reference plot treatment. The reason for better performance of all the morphological characters under elevated CO_2 regime may be due to increased photosynthetic rate and reduced photorespiration. In contrast, under elevated temperature regimes all five maize genotypes responded variably as the elevated temperature regime affected photosynthetic apparatus particularly chloroplast and also morphological character of plants such as plant height, leaf area per plant and dry matter accumulation in different plant parts compared to reference plot. Under elevated temperature regime it is mainly because of the documentation of heat stress, which resulted in detrimental effect on plant growth and events involved in the growth and development of reproductive organs, such as tassel initiation, time of flowering, pollination, fertilization, and pollen sterility in maize (Warrington and Kanemasu 1983) [20]. There are many reports in the literature supporting our findings (Thompson, 1986., and Filippove *et al.*, 1994) [19, 5]. Under elevated temperature regime leaf area per plant was severely affected in all five maize genotypes. Similarly, Leipner *et al*. 1999 [9] reported that high temperature reduced the total leaf area in maize. Plant growth was enhanced in e-CO_2 conditions as compared to a-CO_2. The leaves and plant height showed significant increase in elevated CO_2 conditions over the cropping period.

Among the treatments, e-CO_2 treatment recorded maximum photosynthetic rate followed by, e-CO_{2+} e –temp, a-CO_2 and a-CO_{2+} e –temp and the least photosynthetic rate was observed in reference plot. Among the genotypes HTMR-1, NK 6240 and HTMR-2 genotypes recorded the highest photosynthetic rate, whereas and ARJUN and 900M-GOLD had less photosynthetic rate under altered conditions. This was mainly due to the e-CO_2 increase net photosynthesis in C_3 plants and C_4 plants because higher CO_2 can suppress RuBP oxygenase activity; decrease photorespiration (C_3 plants); and increase carbon assimilates for plant growth and development. Elevated CO_2 accelerates the photosynthetic rate, stimulates plant growth, and increases the carbon: nitrogen ratio of most plant species (Poorter *et al.*, 1997; Curtis and Wang, 1998) [14, 4]. Likewise, results of the study on spring wheat (*Triticum aestivum* L.) revealed that the host plants grown at e-CO_2 (550 and 700 ppm) generally had greater starch, sucrose, glucose, total non-structural carbohydrates (TNCs), free amino acids, soluble protein and less fructose and nitrogen as reported by Chen *et al*. (2010) [2]. Whereas, under elevated temperature conditions photosynthetic rate was low mainly because plant could not maintain appropriate metabolism to keep normal development like photosynthesis, nutrient uptake, photorespiration, cell development, and so on and also higher temperature disrupts the movement of water, ion and organic solute across plant membranes, which interferes with photosynthesis and respiration (Christiansen (1978) [3]. This was supported by number of authors (Berry and Bjorkman 1980) [1].

Assimilation rate significantly increased in all the genotypes when CO_2 was increased such increase in assimilation rates was due to increase in intercellular CO_2 concentration, which clearly suggests that the chloroplast is substrate limited. Considerable amount of information is available to suggest that the assimilation rate increases substantially when the plants were exposed to increasing CO_2 concentration. Among the treatments a-CO_{2+} e –temp treatment had recorded maximum transpiration rate and stomatal conductance followed by e-CO_{2+} e –temp, a- CO_2, reference plot, and least transpiration rate and stomatal conductance was noticed e-CO_2 treatment. Among the genotypes NK 6240, HTMR-1 and 900M-GOLD genotype recorded maximum transpiration rate and stomatal conductance whereas the genotypes HTMR-2 and ARJUN had the least transpiration rate and stomatal conductance. Under elevated CO_2 condition transpiration rate and stomatal conductance was lowered mainly due to decrease in the water vapour pressure of the air inside the plant stand (Kocsis., 2007) [8] and due to stomatal closure, and abundant carbon-dioxide concentration raised the intensity of photosynthesis.

A significant increase in chlorophyll content was seen in elevated CO_2 treatment and elevated CO_2 and elevated temp treatment this was supported by several numbers of authors (Hamid *et al*., 2009; Srivastav *et al*., 2012;) [6, 18] 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 and kanemasu (1983) [20]. 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. Studies of numerous authors are in line with the present findings wherein, they reported that plant chlorophyll content increased with increased CO_2 concentration especially in C_3 plants. Hamid *et al.* (2009) [6] recorded less chlorophyll content in elevated treatments as compared to ambient in cotton crop which is contradictory to the present studies.

e-CO_2 treatment had 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 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) [15] 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) [17] recorded more sugars in *Bt* oilseed rape plant under e-CO_2 conditions than ambient conditions. The leaf carbohydrate determinations showed that the starch, total soluble sugar, and sucrose concentrations increased significantly in plants exposed to e-CO_2.

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 (147.20 g) followed by, e-CO_{2+} e –temp (121.54 g), a-CO_2 (91.97 g) and reference plot (79.92 g) and the least was noticed in a-CO_{2+} e –temp(61.68 g). Irrespective of the treatments, the genotype HTMR-1(107.79 g) recorded maximum grain yield per plant compared to HTMR-2 (103.05 g), 900M-GOLD (109.97 g) ARJUN (97.47 g) and least was observed in NK 6240 (96.05 g) 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. Various studies are in line with the present findings with respect to yields who reported that yields of C_4 agricultural crops are estimated to increase by about 6.5 per cent if CO_2 is doubled. 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) [12]. Similarly Mishra and Agrawal (2014) [11] reported that in Mung bean crop under elevated CO_2 700 ppm increased total chlorophyll, photosynthetic rate, growth and yield parameters.

Grain yield per plant and yield attributing characters like cob length, no of rows per cob and no of grains per cob was least in a-CO_{2+} e –temp (61.68 gm) treatment was mainly due to every degree increase in day temperature above 30°C would decrease yield by 1 % in optimum conditions and 1.7% in drought conditions (Lobell *et al.* (2011) [10] and also Rowhani *et al.* (2011) [16] reported that for every 2°C increase in temperature reduced the maize yields by 13%. So under elevated temperature grain yield was decreased. Higher temperature decrease the plant biomass and yield by decreasing photosynthesis and increasing transpiration and stomatal conductance (Nobel 2005) [13] Also, plants mitigate overheating by leaf rolling and drooping and vertical leaf orientation (Nobel 2005) [13]. Such adaptive mechanisms likely reduce leaf exposure to incident light and in turn, may lead to decreased photosynthesis.

Table 1a: Effect of elevated CO2 and temperature regimes on plant height (cm) at 25, 50 and 75 DAS (pooled data).

Treatments	Plant height (cm)																	
	25 DAS						50 DAS						75 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	23.63	19.75	20.91	20.06	24.06	21.68	86.62	86.21	61.63	92.83	92.85	84.03	155.96	109.88	99.21	155.31	139.00	131.87
T_2	18.31	26.51	21.38	22.30	19.11	21.52	83.65	113.77	134.63	100.08	73.35	101.10	164.19	122.68	152.67	158.48	149.29	149.46
T_3	25.96	24.91	25.15	21.00	22.83	23.97	126.04	139.19	126.56	130.11	105.50	125.48	176.78	160.38	154.17	180.56	145.90	163.56
T_4	25.08	26.79	26.54	20.60	23.10	24.42	127.17	132.19	137.83	132.65	95.75	125.12	177.38	158.71	175.42	160.00	152.85	164.87
T_5	12.13	16.40	14.25	13.23	10.69	13.34	57.92	69.88	63.77	65.48	54.33	62.28	111.25	83.75	91.71	114.68	115.31	103.34
Mean	21.02	22.87	21.65	19.44	19.96		96.28	108.25	104.88	104.23	84.36		157.11	127.08	134.63	153.81	140.47	
	S.Em±			CD @ 1%			S.Em±			CD @ 1%			S.Em±			CD @ 1%		
A	0.390			1.457			1.826			6.824			1.933			7.224		
B	0.390			1.457			1.826			6.824			1.933			7.224		
A X B	0.872			3.259			4.083			15.260			4.322			16.153		

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 1b: Effect of elevated CO_2 and temperature regimes on plant height (cm) at 100 DAS and at harvest (pooled data)

Treatments	Plant height (cm)											
	100 DAS						At harvest					
	HTMR-1	HTMR-2	ARJUN	900 M GOLD	NK 6240	Mean	HTMR-1	HTMR-2	ARJUN	900 M GOLD	NK 6240	Mean
T_1	169.51	124.60	114.19	170.49	154.29	146.61	180.94	154.56	149.69	201.31	155.94	168.49
T_2	169.28	128.86	158.58	164.64	152.98	154.87	170.74	159.18	168.61	177.08	156.30	166.38
T_3	187.29	171.42	164.74	187.17	157.00	173.52	202.75	178.43	171.13	186.90	181.79	184.20
T_4	189.26	167.30	182.06	165.33	161.41	173.07	190.78	169.88	185.30	167.18	168.50	176.33
T_5	137.08	94.27	103.12	124.05	126.06	116.92	138.25	96.19	104.55	126.56	127.39	118.59
Mean	170.48	137.29	144.54	162.33	150.35		176.69	151.65	155.86	171.81	157.98	
	S.Em±			CD @ 1%			S.Em±			CD @ 1%		
A	1.906			7.125			1.926			7.198		
B	1.906			7.125			1.926			7.198		
A X B	4.262			15.932			4.306			16.095		

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 2a: Effect of elevated CO_2 and temperature regimes on leaf area per plant (dm^2 $plant^{-1}$) at 25, 50 and 75 DAS (pooled data)

Treatments	Leaf area per plant (dm^2 $plant^{-1}$)																	
	25 DAS						50 DAS						75 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	7.1	6.8	6.5	7.3	7.5	7.1	25.3	24.4	23.3	26.3	25.0	24.9	34.2	31.4	34.9	36.4	35.2	34.4
T_2	9.3	9.3	6.6	7.3	8.7	8.2	31.0	27.1	24.2	19.4	25.9	25.5	38.3	38.4	33.0	29.0	35.2	34.8
T_3	10.3	11.3	9.0	9.8	8.2	9.7	41.4	41.8	35.5	38.9	40.3	39.6	59.7	58.4	50.6	52.2	52.5	54.7
T_4	8.5	10.5	10.6	7.7	9.3	9.3	35.5	36.2	40.1	30.0	29.5	34.3	43.1	41.2	51.4	39.1	39.4	42.8
T_5	2.9	4.7	2.8	3.1	3.7	3.5	17.7	19.8	17.6	19.9	18.3	18.7	26.6	30.2	30.3	29.7	29.3	29.2

Mean	7.6	8.5	7.1	7.0	7.5		30.2	29.9	28.1	26.9	27.8		40.4	39.9	40.1	37.3	38.3	
	S.Em±			CD @ 1%			S.Em±			CD @ 1%			S.Em±			CD @ 1%		
A	0.309			1.154			0.627			2.345			0.606			2.264		
B	0.309			1.154			0.627			2.345			0.606			2.264		
A X B	0.690			NS			1.403			5.243			1.355			5.063		

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 2b: Effect of elevated CO_2 and temperature regimes on leaf area per plant (dm^2 $plant^{-1}$) 100 DAS and at harvest (pooled data)

Treatments	**Leaf area per plant (dm^2 $plant^{-1}$)**											
	100 DAS						**At harvest**					
	HTMR-1	**HTMR-2**	**ARJUN**	**900 M GOLD**	**NK 6240**	**Mean**	**HTMR-1**	**HTMR-2**	**ARJUN**	**900 M GOLD**	**NK 6240**	**Mean**
T_1	17.2	15.3	15.9	17.8	18.5	16.9	6.2	5.7	5.4	6.3	6.9	6.1
T_2	15.9	15.2	13.8	11.5	13.0	13.9	5.3	5.2	5.0	4.6	4.6	4.9
T_3	33.1	35.3	32.4	30.9	32.1	32.8	13.3	11.7	11.2	10.8	10.3	11.5
T_4	28.9	27.3	26.6	22.6	21.4	25.4	9.6	8.5	8.5	8.8	8.5	8.8
T_5	11.2	10.7	11.3	10.6	9.7	10.7	4.6	4.0	4.1	3.4	3.5	3.9
Mean	21.3	20.8	20.0	18.7	18.9		7.8	7.0	6.8	6.8	6.8	
	S.Em±			CD @ 1%			S.Em±			CD @ 1%		
A	0.452			1.689			0.343			1.283		
B	0.452			1.689			0.343			1.283		
A X B	1.010			3.776			0.767			2.868		

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)

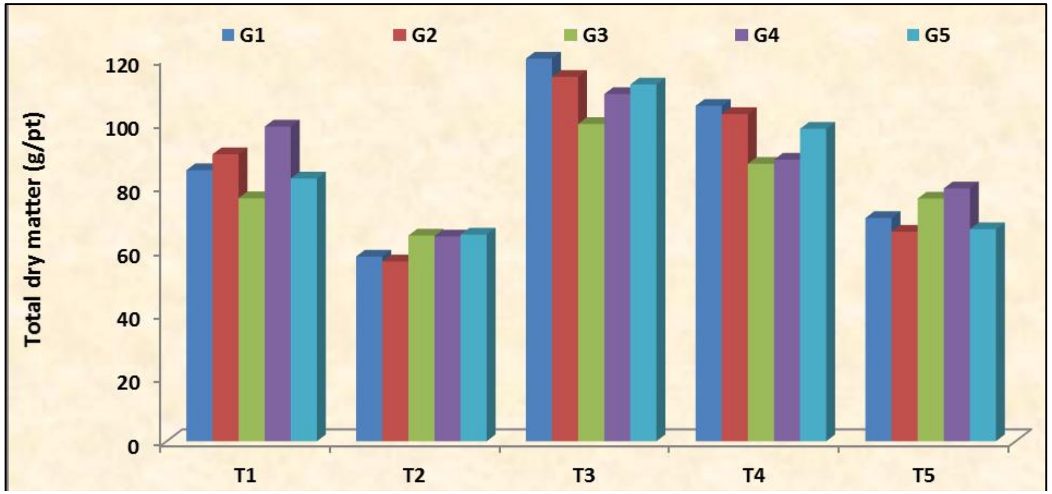

Fig 1: Effect of elevated CO_2 and temperature regimes on total dry matter.

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

Treatments	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 photosynthetic rate ($\mu molCO_2m^{-2}s^{-1}$) (pooled data)

Treatments	Photosynthetic rate ($\mu molCO_2m^{-2}s^{-1}$)																	
	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	29.79	29.25	28.38	28.25	29.90	29.11	43.39	41.93	38.44	39.79	41.64	41.04	22.21	23.10	21.46	23.44	23.39	22.72
T_2	30.13	29.30	24.41	23.60	27.93	27.07	41.08	40.61	39.14	38.15	41.34	40.06	20.38	20.21	18.10	19.35	21.14	19.83
T_3	35.13	34.06	33.54	31.91	33.73	33.67	50.78	52.36	48.88	47.95	50.51	50.10	27.70	27.23	25.23	24.33	26.50	26.20
T_4	33.66	33.81	32.43	32.69	34.71	33.46	49.15	47.00	46.08	46.03	50.46	47.74	25.96	25.31	24.48	24.18	24.88	24.96
T_5	30.06	29.04	25.98	26.38	28.33	27.96	42.43	41.26	39.64	42.86	42.93	41.82	22.89	22.55	21.01	20.13	22.49	21.81
Mean	31.75	31.09	29.75	29.57	31.32		45.36	44.83	42.83	43.34	45.38		23.83	23.68	22.66	22.28	23.68	
	S.Em±			CD @ 1%			S.Em±			CD @ 1%			S.Em±			CD @ 1%		
A	0.234			0.875			0.370			1.382			0.203			0.759		
B	0.234			0.875			0.370			1.382			0.203			0.759		
A X B	0.523			NS			0.827			NS			0.454			1.698		

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 stomatal conductance (mmol $CO_2m^{-2}s^{-1}$) (pooled data).

Treatments	Stomatal conductance ($\mu mol\ CO_2m^{-2}s^{-1}$)																	
	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	0.299	0.276	0.287	0.279	0.295	0.287	0.393	0.364	0.383	0.368	0.387	0.379	0.195	0.186	0.186	0.194	0.190	0.190
T_2	0.253	0.251	0.240	0.247	0.254	0.249	0.338	0.348	0.335	0.325	0.346	0.338	0.142	0.148	0.137	0.155	0.158	0.148
T_3	0.251	0.242	0.231	0.242	0.248	0.243	0.347	0.342	0.329	0.335	0.372	0.345	0.140	0.131	0.129	0.148	0.166	0.143
T_4	0.263	0.251	0.250	0.249	0.270	0.257	0.344	0.334	0.341	0.333	0.344	0.339	0.142	0.137	0.144	0.137	0.156	0.143
T_5	0.420	0.360	0.384	0.354	0.342	0.372	0.439	0.435	0.438	0.435	0.405	0.430	0.239	0.213	0.206	0.205	0.206	0.214

Mean	0.297	0.276	0.278	0.274	0.286		0.372	0.364	0.365	0.359	0.370		0.171	0.163	0.160	0.167	0.175	
	S.Em±			CD @ 1%			S.Em±			CD @ 1%			S.Em±			CD @ 1%		
A	0.003			0.011			0.004			0.016			0.004			0.013		
B	0.003			0.011			0.004			NS			0.004			NS		
A X B	0.007			0.026			0.010			NS			0.008			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)

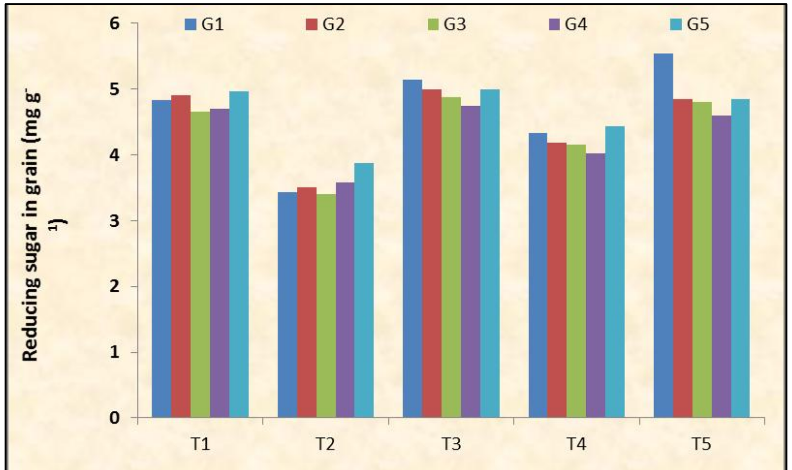

Fig. 2. Effect of elevated CO_2 and temperature regimes on reducing sugar in grain (mg g^{-1})

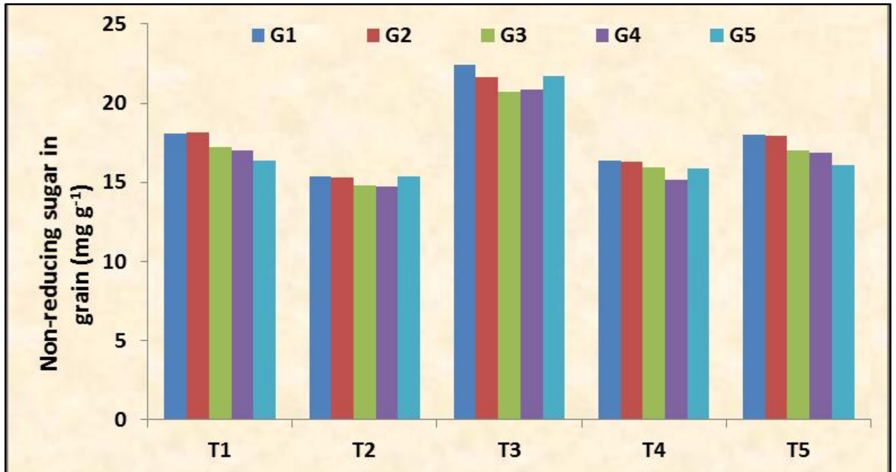

Fig. 3. Effect of elevated CO_2 and temperature regimes on non-reducing sugar in grain (mg g^{-1})

Table 6a: Effect of elevated CO_2 and temperature regimes on yield components (pooled data).

Treatments	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 6b: Effect of elevated CO_2 and temperature regimes on yield components (pooled data).

Treatments	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

Based on the work presented, the following conclusions can be drawn about the effects of an elevated CO_2 concentration on vegetation yield of maize genotypes. There appears to be a strong positive interaction between CO_2 concentration and temperature, which could greatly increase the CO_2 growth stimulation under some conditions, but decreased it under other conditions. Stomatal conductance will probably be reduced at higher CO_2 concentration which will reduce transpiration per unit of leaf area and consequently increase leaf temperature. But with increased leaf area, seasonal water use per unit of land area may be minimally affected. Various parameters studied indicated that, the genotypes HTMR-1, 900M-GOLD and HTMR-2 performed better under elevated CO2 and temperature regime. The maximum reduction with respect to these parameters was observed in ARJUN and NK 6240 genotypes.

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