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Seasonal Variation of Bio-physical Parameters to Elevated Carbon Dioxide and Temperature Regimes in Maize Genotypes

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A B S T R A C T

Increasing atmospheric CO_2 concentration has led to concerns about global changes to the environment. One area of global change that has not been fully addressed is the effect of elevated atmospheric CO_2 and temperature regimes on agriculture production inputs. Maize (*Zea mays L.*) is the most important grain crop is produced throughout the country under diverse environments. A study was conducted to evaluate the seasonal comparison (summer and *Kharif* 2015) of bio-physical parameters (photosynthetic rate, transpiration rate, stomatal conductance and NDVI) to elevated carbon dioxide and temperature regimes raised in open top chamber with different concentrations of CO_2 levels (normal CO_2, 550ppm,) with different temperatures regimes (+2°C). Among the genotypes NK 6240, HTMR-1 and 900 M-GOLD genotype recorded maximum transpiration rate and stomatal conductance whereas, the genotypes HTMR-2 and ARJUN had least transpiration rate and stomatal conductance. The results showed that maize genotypes grown in kharif season performed better compared to summer season with respect to bio-physical parameters.

Keywords

Elevated CO_2 and Temperature, Bio-physical parameters, Maize genotypes etc.

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Introduction

Under the present global scenario of CO_2 increase (IPCC 1996), it has become pertinent for researchers all over the world to find solutions for future. Firstly, research can help to identify the crops which respond to the above situation and those which do not. Secondly, among the crops which respond, those with relatively a higher magnitude are to be identified initially to address the food and feed self-sufficiency followed by the soil improvement. Various reviews on the response of different crops revealed that an increase in CO_2 has a positive effect on the plant biomass. Kimball (1986) obtained an average increase of 21% in biomass in response to elevated CO_2 when he analyzed 94 observations of different plants. Cure (1985) and Cure and Acock (1986) reported that sorghum showed a stimulation of 5% increase in biomass with elevated CO2 levels (scaled to 550 µmol/mol). Venkteshwara Rao (1999) observed that in groundnut cv. TMV-2 biomass production was 29% higher in elevated CO_2 (660 ppm) than in ambient CO_2. In sunflower the growth was affected at elevated CO_2 by increasing net CO_2

assimilation rate (Tezara *et al.,* 2002). It was observed that with elevated levels of CO_2 (using the FACE technology) there was a greater stimulation of belowground than aboveground biomass (Kimball *et al.,* 2002). Under ample water and nutrients the root growth of C3 grasses was stimulated by about 47% as compared with then 12% of shoots whereas in clover (C3 legume) the root growth stimulation (25%) was nearly same as that of shoots (24%).

Plants are directly affected by rising atmospheric CO_2 concentration because it is first the molecular link from atmosphere to biosphere. It serves as substrate to photosynthetic carbon assimilation. There is concomitant decline in photorespiration process and alteration in stomatal activity, C_3 crops. Responce to elevated CO_2 may be due to reduced oxygenase activity of RuBP carboxylase oxygenase enzyme in plants. The elevated CO_2 induced photosynthesis; competitive inhibition of the oxygenase activity of rubisco, and acceleration of carboxylation because the CO_2 binding site is not saturated at the current CO_2, and therefore, C_4 plants showed little or no photosynthetic response to elevated CO_2.

This is because C_4 pathway is not competitively inhibited by O_2 and completely CO_2 saturated. Plants with C_4 photosynthetic pathway showed negligible photosynthetic response to elevated CO_2 because the C_4 cycle increased the CO_2 concentration in bundle sheath cells to the point where very little photorespiration occurs and Calvin cycle is nearly saturated with CO_2

However, there is no consensus on the quantitative effects of increased CO_2 on plant processes and growth because of differences in response at different stages of growth, species of crops and growth limiting environmental factors.

Materials 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. Normalized difference vegetation index (NDVI), leaf temperature, 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

The results indicated that significant difference was observed among the genotypes and treatments in both the season. Photosynthetic rate was maximum at 60 DAS in all the treatments. Photosynthetic rate was maximum between 30 to 60 DAS and later on it is declined. Irrespective of the treatments, mean of all the genotypes showed that e-CO_2 treatment had recorded maximum photosynthetic rate followed by, e-CO_{2+} e –temp, a- CO_2 except 30 and 90 DAS, and reference plot except 90 DAS and the least photosynthetic rate was noticed a-CO_{2+} e –temp treatment. However photosynthetic rate decreased from 60 DAS to 90 DAS. During summer season the highest photosynthetic rate was recorded in HTMR-2 (25.95 µmol$CO_2m^{-2}s^{-1}$) in e-CO_2 treatment which was followed by HTMR-1(25.73 µmolCO_2 $m^{-2}s^{-1}$), NK 6240 (25.08 µmol$CO_2m^{-2}s^{-1}$) in same treatment. The least photosynthetic rate was noticed in 900M-GOLD (17.35 µmol$CO_2m^{-2}s^{-1}$) genotype in reference plot treatment. Whereas kharif season higher photosynthetic rate was observed in HTMR-1 (29.68 µmol$CO_2m^{-2}s^{-1}$) in e-CO_2 treatment, which was on par with HTMR-2 (28.5 µmol$CO_2m^{-2}s^{-1}$), NK 6240 (27.93 µmolCO_2 $m^{-2}s^{-1}$) in same treatment.

But differ significantly at a-CO_2 (24.15 µmol CO_2 $m^{-2}s^{-1}$), a-CO_{2+} e –temp (20.45 µmol CO_2 $m^{-2}s^{-1}$), e-CO_{2+} e –temp (27.30 µmol CO_2 $m^{-2}s^{-1}$) and reference plot (25.48 µmol CO_2 $m^{-2}s^{-1}$). The least photosynthetic rate was recorded in HTMR-2 (19.75 µmol$CO_2m^{-2}s^{-1}$) genotype in a-CO_{2+} e –temp. The maize genotypes grown during kharif season 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. A decrease in Photosynthetic rate in plants grown under higher CO_2 concentration and measured at ambient a level of CO_2 concentration has been reported in many crops. An absolute reduction in assimilation rates in plants exposed to elevated CO_2 for a long period may be caused by the following factors. 1. End product inhibition- accumulation of starch and sucrose 2. Limitation due to pi recycling 3. Decrease in content and activation of RuBisCo.

At summer season 90 DAS, maximum transpiration rate was noticed in NK 6240 (4.42 m mol of $H_2Om^{-2}s^{-1}$) in a-CO_{2+} e –temp treatment, which was followed by HTMR-1 (4.03 m mol of $H_2Om^{-2}s^{-1}$), HTMR-2 (4.10 m mol of $H_2Om^{-2}s^{-1}$) in same treatment. At this stage significant difference was observed among the treatments, genotypes and also interaction effect. But differ significantly at a-CO_2 (4.03 m mol of $H_2Om^{-2}s^{-1}$), e-CO_{2+} e –temp (2.79 m mol of $H_2Om^{-2}s^{-1}$), e-CO_2 (3.47 m mol of $H_2Om^{-2}s^{-1}$) and reference plot (3.26 m mol of $H_2Om^{-2}s^{-1}$). The least transpiration rate was recorded in ARJUN (2.50 m mol of $H_2Om^{-2}s^{-1}$) genotype in reference plot treatment. But during kharif season Maximum transpiration rate was noticed in NK 6240 (4.42 m mol of $H_2Om^{-2}s^{-1}$) in a-CO_{2+} e –temp treatment. But differ significantly at a-CO_2 (2.02 m mol of $H_2Om^{-2}s^{-1}$), e-CO_{2+} e –temp (2.51 m mol of $H_2Om^{-2}s^{-1}$), e-CO_2 (1.92 m mol of $H_2Om^{-2}s^{-1}$) and reference plot (2.14 m mol of $H_2Om^{-2}s^{-1}$). The least transpiration rate was recorded in ARJUN (1.46 m mol of $H_2Om^{-2}s^{-1}$) genotype in e-CO_2 treatment. At 90 DAS, maximum stomatal conductance was recorded in 900M-GOLD (0.224 mmol $CO_2m^{-2}s^{-1}$) in a-CO_{2+} e –temp, which was on par with ARJUN (0.197 mmol $CO_2m^{-2}s^{-1}$), HTMR-2 (0.217 mmol $CO_2m^{-2}s^{-1}$). HTMR-1 (0.200 mmol $CO_2m^{-2}s^{-1}$) in same treatment and also HTMR-1(0.202 mmol $CO_2m^{-2}s^{-1}$) in reference plot treatment.

Table.1 Effect of elevated CO_2 and temperature regimes on photosynthetic rate (μmol$CO_2$$m^{-2}s^{-1}$) during summer season

Treatment	Photosynthetic rate (μmol$CO_2$$m^{-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	29.90	28.83	25.80	26.03	28.25	**27.76**	43.30	42.75	41.10	42.05	41.73	**42.19**	20.30	19.38	19.93	18.03	19.68	**19.46**
T_2	27.83	28.18	26.40	26.30	27.95	**27.33**	41.43	40.48	38.63	39.38	40.25	**40.03**	20.28	20.58	18.73	20.55	20.80	**20.19**
T_3	35.00	33.98	33.03	31.18	33.63	**33.36**	50.45	52.18	48.28	47.70	49.75	**49.67**	25.73	25.95	23.33	22.58	25.08	**24.53**
T_4	33.55	33.63	32.13	32.33	34.63	**33.25**	48.65	46.23	45.45	44.88	49.23	**46.89**	24.63	25.28	24.23	23.60	23.53	**24.25**
T_5	31.35	30.05	30.03	29.98	31.30	**30.54**	39.78	41.63	40.60	39.78	41.15	**40.59**	20.30	20.70	21.30	17.35	20.35	**20.00**
Mean	**31.53**	**30.93**	**29.48**	**29.16**	**31.15**		**44.72**	**44.65**	**42.81**	**42.76**	**44.42**		**22.25**	**22.38**	**21.50**	**20.42**	**21.89**	

	30 DAS S.Em±	30 DAS CD @ 1%	60 DAS S.Em±	60 DAS CD @ 1%	90 DAS S.Em±	90 DAS CD @ 1%
A	0.270	1.007	0.428	1.598	0.283	1.059
B	0.270	1.007	0.428	1.598	0.283	1.059
A X B	0.603	NS	0.956	NS	0.634	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.2 Effect of elevated CO_2 and temperature regimes on photosynthetic rate (μmol$CO_2$$m^{-2}s^{-1}$) during *kharif* season

Treatment	Photosynthetic rate (μmol$CO_2$$m^{-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	31.75	30.33	30.35	30.20	31.85	**30.90**	45.35	43.38	38.25	40.20	43.03	**42.04**	24.15	25.63	24.20	26.33	25.98	**25.26**
T_2	28.90	28.55	26.80	27.23	28.55	**28.01**	42.38	41.60	41.68	40.33	41.53	**41.50**	20.45	19.73	20.90	21.35	21.93	**20.87**
T_3	35.25	34.15	34.05	32.65	33.83	**33.99**	51.10	52.55	49.48	48.20	51.28	**50.52**	29.68	28.50	27.13	26.08	27.93	**27.86**
T_4	33.78	34.00	32.73	33.05	34.80	**33.67**	49.65	47.78	46.70	47.18	51.70	**48.60**	27.30	25.35	24.73	24.75	26.23	**25.67**
T_5	30.23	29.25	26.15	26.73	28.40	**28.15**	41.55	39.78	38.18	43.68	44.13	**41.46**	25.48	25.73	22.10	22.23	25.30	**24.17**
Mean	**31.98**	**31.26**	**30.02**	**29.97**	**31.49**		**46.01**	**45.02**	**42.86**	**43.92**	**46.33**		**25.41**	**24.99**	**23.81**	**24.15**	**25.47**	

	30 DAS S.Em±	30 DAS CD @ 1%	60 DAS S.Em±	60 DAS CD @ 1%	90 DAS S.Em±	90 DAS CD @ 1%
A	0.255	0.953	0.406	1.516	0.246	0.919
B	0.255	0.953	0.406	1.516	0.246	0.919
A X B	0.570	NS	0.907	3.390	0.550	2.056

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 transpiration rate (m mol of $H_2O\ m^{-2}s^{-1}$) during summer season

Treatment	Transpiration rate (m mol of $H_2Om^{-2}s^{-1}$)																	
	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	1.87	1.36	1.48	2.01	2.15	**1.77**	2.33	2.30	2.45	3.15	2.28	**2.50**	3.86	3.36	3.44	3.99	4.03	**3.74**
T_2	2.26	2.05	2.46	1.79	2.78	**2.27**	3.01	3.06	2.56	2.68	3.56	**2.97**	4.03	4.10	3.52	3.78	4.42	**3.97**
T_3	1.31	1.03	0.60	1.10	1.43	**1.09**	2.36	2.07	1.70	2.22	2.41	**2.15**	3.36	2.84	2.75	2.88	3.47	**3.06**
T_4	1.67	0.81	0.75	2.16	2.04	**1.49**	2.34	1.84	1.78	2.88	2.79	**2.33**	3.37	3.06	2.63	3.30	2.79	**3.03**
T_5	1.24	1.38	0.63	1.20	1.28	**1.14**	2.86	2.33	1.52	2.23	3.11	**2.41**	3.33	3.28	2.50	3.29	3.26	**3.13**
Mean	**1.67**	**1.33**	**1.18**	**1.65**	**1.93**		**2.58**	**2.32**	**2.00**	**2.63**	**2.83**		**3.59**	**3.33**	**2.97**	**3.45**	**3.59**	

	S.Em±	CD @ 1%	S.Em±	CD @ 1%	S.Em±	CD @ 1%
A	0.068	0.254	0.033	0.123	0.016	0.061
B	0.068	0.254	0.033	0.123	0.016	0.061
A X B	0.152	0.569	0.073	0.274	0.037	0.137

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 transpiration rate (m mol of $H_2O\ m^{-2}s^{-1}$) during *kharif* season

Treatment	Transpiration rate(m mol of $H_2Om^{-2}s^{-1}$)																	
	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	1.09	1.19	0.49	1.04	1.12	**0.98**	1.79	1.69	1.45	1.71	1.69	**1.66**	1.90	1.78	1.60	1.90	2.02	**1.84**
T_2	2.00	1.78	1.83	1.51	2.33	**1.89**	2.08	2.12	2.05	2.11	2.66	**2.20**	2.21	2.36	2.11	2.27	2.91	**2.37**
T_3	1.23	0.97	0.55	0.96	1.08	**0.96**	1.72	1.42	1.26	1.33	1.59	**1.46**	1.84	1.73	1.46	1.75	1.92	**1.74**
T_4	1.74	1.11	1.30	1.66	1.95	**1.55**	1.97	1.93	1.93	2.18	2.26	**2.05**	2.07	2.25	2.01	2.12	2.51	**2.19**
T_5	1.41	0.70	0.66	1.79	1.93	**1.30**	1.70	1.47	1.33	1.99	2.08	**1.71**	1.93	1.75	1.70	2.11	2.14	**1.92**
Mean	**1.49**	**1.15**	**0.96**	**1.39**	**1.68**		**1.85**	**1.73**	**1.60**	**1.86**	**2.05**		**1.99**	**1.97**	**1.77**	**2.03**	**2.30**	

	S.Em±	CD @ 1%	S.Em±	CD @ 1%	S.Em±	CD @ 1%
A	0.069	0.257	0.030	0.112	0.020	0.074
B	0.069	0.257	0.030	0.112	0.020	0.074
A X B	0.154	0.574	0.067	0.249	0.044	0.165

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_2 $m^{-2}s^{-1}$) during summer season

Treatment	Stomatal conductance (µmol $CO_2 m^{-2} s^{-1}$)																	
	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	0.276	0.268	0.259	0.247	0.292	**0.268**	0.348	0.357	0.362	0.318	0.377	**0.352**	0.157	0.158	0.165	0.180	0.201	**0.172**
T_2	0.299	0.276	0.285	0.278	0.269	**0.281**	0.393	0.372	0.363	0.371	0.361	**0.372**	0.200	0.217	0.197	0.224	0.170	**0.201**
T_3	0.233	0.232	0.224	0.246	0.231	**0.233**	0.317	0.308	0.329	0.319	0.312	**0.317**	0.118	0.118	0.134	0.128	0.133	**0.126**
T_4	0.248	0.239	0.230	0.241	0.251	**0.242**	0.357	0.354	0.337	0.338	0.391	**0.355**	0.148	0.131	0.135	0.163	0.177	**0.151**
T_5	0.399	0.361	0.388	0.356	0.349	**0.370**	0.423	0.425	0.427	0.431	0.395	**0.420**	0.202	0.182	0.163	0.174	0.195	**0.183**
Mean	**0.294**	**0.275**	**0.277**	**0.273**	**0.278**		**0.367**	**0.363**	**0.363**	**0.355**	**0.367**		**0.165**	**0.161**	**0.158**	**0.173**	**0.175**	
	S.Em±			CD @ 1%			S.Em±			CD @ 1%			S.Em±			CD @ 1%		
A	0.005			0.019			0.007			0.027			0.005			0.018		
B	0.005			NS			0.007			NS			0.005			NS		
A X B	0.011			NS			0.016			NS			0.011			0.041		

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 stomatal conductance (mmol CO_2 $m^{-2}s^{-1}$) during *kharif* season

Treatment	Stomatal conductance (mmol $CO_2 m^{-2} s^{-1}$)																	
	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	0.278	0.259	0.263	0.250	0.289	**0.268**	0.370	0.360	0.352	0.348	0.376	**0.361**	0.167	0.156	0.154	0.147	0.179	**0.160**
T_2	0.299	0.275	0.287	0.280	0.321	**0.292**	0.394	0.355	0.402	0.365	0.412	**0.386**	0.191	0.155	0.175	0.165	0.210	**0.179**
T_3	0.235	0.237	0.226	0.243	0.233	**0.235**	0.328	0.339	0.309	0.332	0.315	**0.325**	0.128	0.139	0.109	0.131	0.116	**0.125**
T_4	0.251	0.244	0.231	0.245	0.249	**0.244**	0.336	0.331	0.321	0.331	0.354	**0.335**	0.132	0.130	0.123	0.133	0.154	**0.134**
T_5	0.425	0.363	0.382	0.350	0.340	**0.372**	0.479	0.446	0.449	0.440	0.415	**0.446**	0.276	0.244	0.249	0.236	0.216	**0.244**
Mean	**0.297**	**0.275**	**0.277**	**0.273**	**0.286**		**0.381**	**0.366**	**0.366**	**0.363**	**0.374**		**0.181**	**0.164**	**0.162**	**0.162**	**0.175**	
	S.Em±			CD @ 1%			S.Em±			CD @ 1%			S.Em±			CD @ 1%		
A	0.002			0.008			0.004			0.016			0.005			0.018		
B	0.002			0.008			0.004			NS			0.005			NS		
A X B	0.005			0.018			0.009			0.035			0.011			0.041		

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.7 Effect of elevated CO_2 and temperature regimes on NDVI during summer season

Treatment	NDVI																	
	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	0.57	0.63	0.57	0.69	0.59	**0.61**	0.61	0.63	0.63	0.71	0.62	**0.63**	0.56	0.39	0.46	0.47	0.51	**0.47**
T_2	0.71	0.65	0.61	0.65	0.64	**0.65**	0.74	0.72	0.64	0.68	0.67	**0.69**	0.43	0.37	0.30	0.38	0.36	**0.37**
T_3	0.66	0.73	0.56	0.57	0.65	**0.63**	0.74	0.76	0.71	0.61	0.67	**0.70**	0.67	0.66	0.61	0.63	0.57	**0.63**
T_4	0.67	0.70	0.72	0.67	0.74	**0.70**	0.72	0.73	0.77	0.72	0.77	**0.74**	0.49	0.61	0.49	0.42	0.54	**0.51**
T_5	0.54	0.69	0.49	0.51	0.47	**0.54**	0.71	0.73	0.55	0.64	0.59	**0.64**	0.60	0.52	0.43	0.61	0.54	**0.54**
Mean	**0.63**	**0.68**	**0.59**	**0.62**	**0.62**		**0.70**	**0.71**	**0.66**	**0.67**	**0.66**		**0.55**	**0.51**	**0.46**	**0.50**	**0.50**	
	S.Em±			CD @ 1%			S.Em±			CD @ 1%			S.Em±			CD @ 1%		
A	0.012			0.045			0.008			0.028			0.011			0.043		
B	0.012			0.045			0.008			0.028			0.011			0.043		
A X B	0.027			0.101			0.017			0.063			0.025			0.095		

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.8 Effect of elevated CO_2 and temperature regimes on NDVI during *kharif* season

Treatment	NDVI																	
	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	0.58	0.50	0.46	0.55	0.60	**0.54**	0.66	0.69	0.59	0.62	0.70	**0.65**	0.45	0.57	0.48	0.57	0.53	**0.52**
T_2	0.51	0.69	0.57	0.60	0.51	**0.58**	0.74	0.76	0.66	0.71	0.73	**0.72**	0.69	0.40	0.55	0.40	0.50	**0.51**
T_3	0.74	0.69	0.68	0.73	0.66	**0.70**	0.72	0.74	0.74	0.77	0.69	**0.73**	0.55	0.73	0.71	0.74	0.60	**0.66**
T_4	0.71	0.74	0.72	0.66	0.61	**0.69**	0.74	0.76	0.73	0.75	0.69	**0.73**	0.72	0.71	0.65	0.72	0.66	**0.69**
T_5	0.43	0.66	0.49	0.51	0.53	**0.52**	0.63	0.74	0.70	0.68	0.66	**0.68**	0.55	0.52	0.64	0.63	0.62	**0.59**
Mean	**0.60**	**0.66**	**0.58**	**0.61**	**0.58**		**0.70**	**0.74**	**0.69**	**0.71**	**0.69**		**0.59**	**0.59**	**0.61**	**0.61**	**0.58**	
	S.Em±			CD @ 1%			S.Em±			CD @ 1%			S.Em±			CD @ 1%		
A	0.011			0.040			0.010			0.036			0.012			0.045		
B	0.011			0.040			0.010			0.036			0.012			NS		
A X B	0.024			0.090			0.022			0.081			0.027			0.101		

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)

The least stomatal conductance was recorded in HTMR-1 and HTMR-2 (0.118 mmol $CO_2m^{-2}s^{-1}$) genotypes in e-CO_2 treatment. whereas in kharif season At 90 DAS, the highest stomatal conductance was noticed in HTMR-1 (0.276 mmol $CO_2m^{-2}s^{-1}$) in reference plot, which was on par with HTMR-2 (0.244 mmol $CO_2m^{-2}s^{-1}$), ARJUN(0.249 mmol $CO_2m^{-2}s^{-1}$), 900M-GOLD(0.236 mmol $CO_2m^{-2}s^{-1}$) in same treatment but differ significantly at e-CO_{2+} e–temp (0.132 mmol $CO_2m^{-2}s^{-1}$), a-CO_2 (0.167 mmol $CO_2m^{-2}s^{-1}$), a-CO_{2+} e–temp(0.191 mmol $CO_2m^{-2}s^{-1}$). The lowest stomatal conductance was recorded in ARJUN (0.109 mmol $CO_2m^{-2}s^{-1}$) genotype in e-CO_2 treatment.

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 the 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 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) and due to stomatal closure, and abundant carbon-dioxide concentration raised the intensity of photosynthesis. Elevated CO_2 reduce transpiration by partially closing the stomata and decreasing stomatal conductance. Similar results were obtained by Leakey *et al.,* (2004) and found that growth at elevated CO_2 significantly increased leaf photosynthetic rate by up to 41 per cent and also stomatal conductance is lowered by 23% under elevated CO_2 compared to ambient condition in maize. This was supported by no of authors (Stanciel *et al.,* 2000; Vu 2005 and Rogers *et al.,* 2004).

Irrespective of the genotypes, mean of all the genotypes showed the highest NDVI in e-CO_{2+} e –temp treatment, followed by e-CO_2, reference plot, and a-CO_2 and the least NDVI was observed in a-CO_{2+} e –temp. Irrespective of the treatments, the genotype HTMR-2, HTMR-1, 900M-GOLD recorded maximum NDVI and the least NDVI was noticed in NK 6240 and ARJUN genotype. This is due to every degree increase in day temperature above 30^{o}C would decrease yield by 1 % in optimum conditions and 1.7% in drought conditions (Lobell *et al.*, (2011) and also Rowhani *et al.*, (2011) reported that for every 2^{o}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) Also, plants mitigate overheating by leaf rolling and drooping and vertical leaf orientation (Larcher 2003; Nobel 2005) or by transient wilting (Chiariello *et al.*, 1987 and Nobel, 2005). Such adaptive mechanisms likely reduce leaf exposure to incident light and in turn, may lead to decreased photosynthesis.

The exposure of the crop elevated CO_2 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. Among the genotypes NK 6240, HTMR-1 and 900 M-GOLD genotype recorded maximum transpiration rate and stomatal conductance whereas, the genotypes HTMR-2 and ARJUN had least transpiration rate and stomatal conductance. Among five maize genotypes studied the good response to NDVI was observed in HTMR-2, HTMR-1 and 900M-GOLD whereas, poor response to NDVI was observed in ARJUN and NK 6240 genotypes. The results showed that maize genotypes grown in kharif season was performed better compared to summer season with respect to bio-physical parameters.

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