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Morphological Characters of Maize (*Zea mays* L.) Genotypes to Elevated Carbon Dioxide and Temperature Regimes

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ABSTRACT

The amount of carbon dioxide (CO_2) of the earth´s atmosphere is increasing, which has the potential of increasing greenhouse effect and air temperature in the future. Plants respond to environment CO_2 and temperature. Therefore climate change may affect agriculture. The purpose of this paper was to study the morphological response of maize genotypes to elevated carbon dioxide and temperature regimes. Most of the morphological, physiological, biochemical and biophysical parameters indicated better performance under elevated CO_2 regime as compared to elevated temperature regime at all growth stages. This was mainly because of exposure of the crop to elevated temperature regime and the heat stress was documented to have detrimental effects 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. Various morphological parameters studied indicated that, the genotypes HTMR-1, 900M-GOLD and HTMR-2 performed better under elevated CO_2 and temperature regime. The maximum reduction with respect to these parameters was observed in ARJUN and NK 6240 genotypes.

Key words: *Climate change, Elevated $CO_{2,}$ Maize genotypes and temperature regimes*

INTRODUCTION

Global atmospheric carbon dioxide concentrations (Ca) are rising (367 ppm in 1999) and are projected to reach between 540 and 970 ppm by the end of the 21st century[13]. Recent climate model projections have also suggested that global surface air temperature may increase 1.4–5.8C in association with this doubling of Ca[3]. Since both Ca and temperature are among the most important environmental variables that regulate physiological and phenological processes in plants, it is critical to evaluate the effects of Ca and air temperature on the growth and yield of key crop plants. Because changes in Ca and temperature are likely to occur concomitantly, it is of particular interest to quantify the interactions of these two climate variables[14].In C_3 plants, enhanced growth and photosynthesis are generally observed in response to elevated Ca. However, plant responses to elevated Ca can be mitigated by various acclimation mechanisms[10, 13].

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Owing to the biochemical and anatomical specialization associated with the CO2 concentrating mechanism, changes in photosynthesis and growth in C_4 plants in response to elevated Ca were thought to be minimal. However, several studies reported that both photosynthesis and plant growth of C_4 species responded positively to elevated Ca[6]. Maize is the most cultivated C4 species in the world. An accurate assessment of the effects of elevated Ca and temperature on plant growth and development is critical in order to forecast potential impacts of climate change on maize productivity. The interactive effects of temperature and CO2 on the growth and photosynthesis of C4 plants may be similar to those of C_3 plants but this requires further examination[9]. In *Amaranthus*, the CO_2 saturation point was increased with temperature indicating that the sensitivity of photosynthesis to CO_2 in C_4 plants might be enhanced by elevated temperature[11]. It is important to better understand the interaction between elevated Ca and higher temperatures in C_4 plants in order to predict plant responses to future climate Change.

High temperature stress at critical developmental stages of maize plants causes (10-15 %) significant yield loss. Plants become susceptible to high temperatures after reaching eight-leaf stage**.** Extremely high temperature causes permanent tissue injury to developing leaves and the injured tissues dry out quickly, a phenomenon called leaf firing. It can also cause desiccation of tassel tissues, a phenomenon called tassel blasting. Plants with severe leaf firing and tassel blasting lose considerable photosynthetic leaf area, produce small ears, and show reduced kernel set and kernel weight. Moderate heat stress occurring at early reproductive stages reduces pollen production, pollination rate, kernel set, and kernel weight, resulting in significant yield loss.

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. Plant height, internodal length, leaf area per plant, total dry matter accumulation at harvest, days to 50 per cent flowering and days maturity, leaf firing percentage, tassel blast per cent (%), 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

In general 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, genotypes, and also interaction effect at all the growth stages. The least plant height was noticed in reference plot. Except 25 and 50 DAS Irrespective of the treatments the HTMR-1 recorded higher plant height followed by 900M-GOLD, NK 6240, and ARJUN and the least plant height was noticed in HTMR-2 genotype. 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 the 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. Increased photosynthesizing area ranging from 15 to 40 per cent was recorded in all five genotypes tested under elevated CO_2 concentration over ambient CO_2 grown plants. So under elevated CO_2 increased leaf area greatly contributed to the higher carbon assimilation rate at canopy level. The plant height, leaf area increased significantly under high CO_2 condition. There are many reports in the literature supported this finding. These results indicated that the growth has increased in the elevated CO_2 in terms of plant height and leaves which may be reasoned to the fact that the carbon dioxide has a direct fertilizing effect on the plant growth[6,8].

Under elevated temperature regimes, plant height, Chl a, Chl b and yield per plant were severally affected in maize genotypes as compared to reference plot and a-CO_2 treatments. Maize genotypes *viz.*, HTMR-2 (20%), ARJUN(60%) , 900M-GOLD (20%) and NK 6240(40%) showed the leaf firing and tassel blast symptoms in e-CO_{2+} e –temp and a-CO_{2+} e –temp treatment . The genotype HTMR-1 did not record leaf firing symptoms under heat stress condition. Whereas, the genotype recorded tassel blast symptoms under the similar conditions. Among the five maize genotypes, tassel blast occurred in ARJUN, NK 6240 (60%) followed by HTMR-1 (40%), HTMR-2 and NK 6240(20%) under e-CO_{2+} e –temp treatment. Under a-CO_{2+} e –temp treatment maximum tassel blast occur in ARJUN and HTMR-2 (40%) followed by HTMR-1, NK 6240 and 900M-GOLD (20%) showed typical leaf firing symptoms accompanied with drastically reduced yield levels. The adverse effect of heat stress[9] on the plant growth, anthesis silking interval and events involved in the growth and development of reproductive organs such as tassel initiation, time of flowering, pollination, fertilization. Similar to our findings they have also recorded leaf firing and tassel blast symptoms leads to drastic reduction in yield of maize genotypes.

Dry matter accumulation in leaves differed significantly at harvest. Irrespective of genotype e-CO_2 treatment recorded maximum dry matter in leaves, followed by e-CO_{2+} e –temp, a-CO_2 and reference plot . Whereas, the least dry matter accumulation in leaves was noticed in a-CO_{2+} e –temp. Among all the genotypes the HTMR-1, 900M-GOLD, ARJUN genotypes had better response under altered environmental conditions, While HTMR-2 and NK 6240 genotype had less or non-responsiveness under altered environmental condition with respect to dry matter accumulation. This was mainly due to the plants grown under e-CO_2 have higher leaf area, plant height and high photosynthetic rates that results in higher dry matter accumulation under altered environmental conditions as compared to ambient treatments. Similarly, in crops like sugarcane[17] indicated that plants grown under elevated CO_2 (~720 ppm) recorded an increase of 30 per cent photosynthesis and 17 per cent in height, and accumulated 40 per cent more biomass in comparison with the plants grown at ambient CO_2 (~370 ppm) and in groundnut[13] crop vegetative biomass, increased by 51% and 54% in the ambient and CO_2 enriched air, respectively. The days to 50 per cent flowering of maize genotypes ranged from 68 days (ARJUN) in e-CO_2 treatment to lowest number of days to 50 per cent flowering was observed in ARJUN and HTMR-1(40 days) genotypes in a-CO$_{2+}$ e –temp and e-CO$_{2+}$ e –temp treatment respectively. Whereas, under heat stress conditions, (a-CO$_{2+}$ e –temp) it ranged from 40 days (ARJUN) to 54 days (HTMR-1 and 900M-GOLD). With an overall mean of 49 days. The days to maturity of maize genotypes ranged from 101 days (900M-GOLD) in reference plot to 82 days (HTMR-2) in a-CO$_{2+}$ e –temp treatment. Generally days to maturity were lower in a-CO$_{2+}$ e–temp treatment in all genotypes except HTMR-1(91 days) genotype. Whereas, under heat stress conditions, (a-CO$_{2+}$ e –temp) days to maturity of maize genotypes ranged from 82 days (HTMR-2) to 91 days (HTMR-1) with an overall mean of 87 days.

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-1 recorded 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. Mung bean[14] crop under elevated CO$_2$ 700 ppm increased total chlorophyll, photosynthetic rate, growth and yield parameters. Higher temperature decreases the plant biomass and yield by decreasing photosynthesis and increasing transpiration and stomatal conductance[16]. Also, plants mitigate overheating by leaf rolling and drooping and vertical leaf orientation or by transient wilting. 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 days to 50 per cent of flowering and days to maturity

Treatment	Days to 50 per cent of flowering						Days to maturity					
	HTMR-1	**HTMR-2**	**ARJUN**	**900 M GOLD**	**NK 6240**	**Mean**	**HTMR-1**	**HTMR-2**	**ARJUN**	**900 M GOLD**	**NK 6240**	**Mean**
T$_1$	55	46	48	56	60	**53**	99	89	94	98	97	**95**
T$_2$	63	46	68	66	55	**60**	91	82	86	88	89	**87**
T$_3$	54	46	40	54	53	**49**	95	91	96	92	93	**93**
T$_4$	40	46	56	59	54	**51**	85	87	92	93	89	**89**
T$_5$	60	47	61	64	62	**59**	97	89	98	101	99	**97**
Mean	**54**	**46**	**55**	**60**	**57**		**93**	**88**	**93**	**94**	**93**	

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)
(-) = not occured

Table 2: Effect of elevated CO_2 and temperature regimes on leaf firing (%) and tassel blast (%) during summer season

Treatment	Leaf firing (%)						Tassel blast (%)					
	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	_	20	20	_	_	**8**
T_2	_	_	40	_	40	16	20	40	40	20	20	**28**
T_3	_	_	_	_	_	0	_	_	20	_	_	**4**
T_4	_	**20**	60	20	_	20	40	20	60	60	20	**40**
T_5	_	_	_	_	_	0	_	40	_	_	_	**8**
Mean	**0**	**4**	**20**	**4**	**8**		**12**	**24**	**28**	**20**	**8**	

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) (-) = not occured

Table 3: Effect of elevated CO_2 and temperature regimes on plant height (cm) at 25, 50 and 75 DAS

Treatment	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 3b. Effect of elevated CO_2 and temperature regimes on plant height (cm) at 100 DAS and at harvest

Treatment	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 4a. Effect of elevated CO_2 and temperature regimes on leaf area per plant (dm^2 $plant^{-1}$) at 25, 50 and 75 DAS

Treatment	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 4b. Effect of elevated CO_2 and temperature regimes on leaf area per plant (dm^2 $plant^{-1}$) 100 DAS and at harvest

Treatment	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)

Table 5: Effect of elevated CO_2 and temperature regimes on total dry matter accumulation (g $plant^{-1}$) at harvest

Treatments	**Total dry matter (g $plant^{-1}$)**					
	HTMR-1	**HTMR-2**	**ARJUN**	**900 M GOLD**	**NK 6240**	**Mean**
T_1	91.8	91.4	72.7	100.1	98.0	**90.8**
T_2	82.8	69.1	79.1	75.8	80.0	**77.3**
T_3	122.3	118.2	105.8	93.0	117.1	**111.3**
T_4	116.6	109.1	99.4	104.3	111.3	**108.2**
T_5	85.7	81.7	69.0	94.0	78.9	**81.9**
Mean	**99.8**	**93.9**	**85.2**	**93.4**	**97.1**	
	S.Em±			**CD @ 1%**		
A	0.280			1.046		
B	0.280			1.046		
A X B	0.626			2.339		

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 6a. 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 6b. 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

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.

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