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Impact of elevated Carbon Dioxide on two groundnut genotypes (Arachis hypogaea L.) under Open Top Chamber facility

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***Abstract*— *The impact of enhanced atmospheric CO_2 concentration (550ppm) was assessed in Open Top Chambers (OTCs) facility to identify the growth and yield parameters at different growth stages of two popular groundnut (Arachis hypogaea L.) genotypes- Dharani, K-9. The results showed significant differences between genotypes, CO_2 levels and time intervals for all the characters studied. The experiments revealed that the genotype Dharani recorded higher response for seed weight, harvest index at eCO_2 while K-9 recorded higher response for total biomass.This study is necessary if we are to realize the potential genotype for maximum yield in the future climate change scenario.*

Keywords— *Arachis hypogaea L., Elevated CO_2,Yield, Biomass,Open Top Chamber.*

I. INTRODUCTION

The carbon dioxide (CO_2) concentration in the atmosphere is increasing due to human activities, fossil fuel combustion and energy use scenario [1]. The increased levels of CO_2 have led to an increased threat of global warming and climate change. Changes in climate factors such as increasing CO_2 concentration, increased temperature and changed precipitation pattern may have significant impacts on plant development and metabolism. The concentration of atmospheric CO_2 has been progressively increasing from 280 ppm (pre-industrial era) in the year 1850 to 407 ppm in 2017 [2]. This created an attention towards the crop responses to enhanced CO_2 levels and also to identify the responsive high yielding genotypes in order to enhance the productivity and production.

The agricultural productivity need to be increased to meet the demand for protein-rich diets due to rising global population. The pre-historic records shows legumes are the oldest cultivated crops and at present they are considered as the major nutrient supplying crops for a balanced human diet [3]. Groundnut seed is chiefly used for edible oil and contains nearly half of the essential vitamins and one-third of the essential minerals. So, for the resource poor farmer's groundnut play an important role in nutritional security [4]. Furthermore it is an excellent fodder for livestock. The productivity of groundnut in Andhra Pradesh is very low against Indian productivity (1615 kg ha^{-1}) and world productivity (1676 kg ha^{-1}). The low productivity can be due to erratic rainfall, incidence of pests and diseases in addition to cultivation of low yielding varieties etc. [5].

Keeping in view the climate change scenario and high yielding groundnut crop varieties, an experiment was conducted in Open Top Chamber facility. The present study was conducted:

- To realize the potential genotype of groundnut for maximum yield to elevated/enhanced Carbon Dioxide concentration (550ppm) when compare with ambient CO_2 (400ppm) in Andhra Pradesh.
- To conduct the experimentin Open Top Chambers (OTCs) facility for evaluating the best groundnut genotype.
- To identify the growth and yield parameters at different growth stages of two popular groundnut (*Arachis hypogaea L.*) genotypes- Dharani and K-9.

II. MATERIALS AND METHODS

2.1 **Materials:** The field investigations were carried to study the impact of elevated carbon dioxide on growth, biomass and yield of groundnut crop under the open top chamber (OTC) facility at Central Research Institute for Dryland Agriculture (ICAR-CRIDA), Hyderabad.

The seeds of the groundnut genotypes- Dharani and K-9 were obtained from the Regional Agricultural Research Station, Ananthapur. The seeds were sown and raised in open top chambers (OTCs) at ambient (aCO_2-400ppm) and elevated (eCO_2-550ppm) CO_2 levels during Kharif season 2016. The seeds of two genotypes were sown

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directly in the soil and the observations were recorded at regular intervals from sowing to harvest.

2.2 **Open Top Chamber facility:** The OTCs are lined with transparent (90% transmittance of light) PVC (polyvinyl chloride) sheet having 3m x 3m x 3m dimensions. Six OTCs were used for the experimental purpose. Four OTCs were maintained with eCO2 of 550ppm and the other two OTCs served as an ambient control without any additional CO2 supply. Throughout the day within the OTCs, eCO2 concentration was maintained and monitored continuously during the experimental period. Continuous injecting of 100% CO2 from a compressed CO2 cylinder into plenum of OTCs was done to maintain the eCO_2 in OTCs at crop canopy level, where it was mixed with air from air compressor before entering into the chamber. From the centre point of OTCs the air sample from each chamber was drawn at three-minute interval into non-dispersive infrared (NDIR) CO_2 analyzer (California Analytical) and the CO_2 concentration was maintained with an automatic switching solenoid, rotameters, Program Logic Control (PLC) and Supervisory Control and Data Acquisition (SCADA) software [6].But gentle washing was frequently done to maintain the transparency of polythene cover.

Inside the OTCs, the maximum temperatures were 1 to 1.5°C higher than outside except for few days following rainfall while the minimum temperatures remained nearly the same. However, there was no significant difference in their maximum temperatures among the aCO_2 and eCO_2. Likewise, inside the chambers relative humidity (RH) was higher as compared to outside. The light intensity in chambers was 80-95% of outside environment. Continuous growth measurements were made at 30, 60, 75, 90 and 110 days i.e. flowering, pegging, poding and at harvest respectively. The recommended agricultural practices were followed during the crop growth period in the OTCs and also the crop was maintained free from moisture stress, pests and diseases.

The characteristics of the test field includes sandy loam in texture, neutral in pH (6.8), low in available nitrogen (225 kg ha^{-1}), medium to high in available potassium (300 kg K_2O ha^{-1}) and phosphorus (10 kg ha^{-1}). The crop received 662.8 mm rainfall during the crop growth period. Relative humidity and temperature was continuously measured using the sensors fitted inside the chambers throughout the experimental period.

Destructive samples of two groundnut genotypes were drawn from both CO_2 levels at 30, 60, 75, 90, DAS and at harvest (110 DAS) in order to record plant height, leaf area, root length, root volume, pod number and biomass of leaf, stem and root.

The plant height was measured from base of the plant to the tip of main shoot and root length was recorded on main root of plant and expressed in centimetres. The root volume was quantified by water displacement method and expressed as ml. The leaf area at different intervals was measured with photo-electronic leaf area meter (LI-3100, LI-COR) and expressed as cm^2/plant. The dry weights of stem, root and leaf were recorded after thorough drying of plant material in hot air oven at 65°C and expressed as g/plant.

The groundnut crop was harvested at 110 days. Three replications with five plants for each replication in each CO_2 concentration were harvested and used for recording final biomass, fodder yield, seed yield and its components *viz.*, pod number, pod weight, seed number and 100 seed weight. The HI (%) was calculated as (seed yield)/ (total above ground dry mass) * 100.

The data were statistically analyzed using a three way analysis of variance (ANOVA) to test the significance of variability between the genotypes, CO_2 concentrations, time intervals and their interactions using star software.

III. RESULTS & DISCUSSION

The impact of eCO_2 on growth and yield of two groundnut genotypes was found significant. The results of the investigations have revealed that the response of two groundnut genotypes differed at two concentrations of CO_2 namely- aCO_2 and eCO_2 in terms of growth, biomass, yield and harvest index. The mean per se values and analysis of variance of groundnut genotypes (Dharani & K-9) under aCO_2 and eCO_2 conditions at different growth stages were tabulated Table 1, biomass parameters in Table 2 and yield parameters in Table 3. The mean performance of different morphological and biomass parameters was presented in Fig. 1and yield parameters in Fig. 2. The percentage increase of the morphological, biomass and yield parameters due to eCO_2 over aCO_2 was presented in Fig. 3.

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Table 1: The mean per se values and analysis of variance of morphological parameters of groundnut genotypes (Dharani & K-9) under aCO_2 and eCO_2 conditions at different growth stages

		Plant height (cm)		**Branches/pl**		**Root length (cm)**		**Root volume (ml/pl)**		**Leaf area (cm^2/pl)**	
		Dharani	K-9	Dharani	K-9	Dharani	K-9	Dharani	K-9	Dharani	K-9
30 DAS	aCO_2	11.8	13.2	3.7	4.0	6.9	6.0	0.5	0.5	180	148
	eCO_2	16.2	16.2	4.3	4.7	11.0	8.7	0.5	0.5	272	159
60 DAS	aCO_2	45.7	44.3	4.3	4.3	11.8	10.7	1.4	0.6	712	265
	eCO_2	61.7	58.9	5.3	5.7	12.7	10.6	1.3	1.5	1120	993
75 DAS	aCO_2	63.0	44.3	5.7	5.7	13.0	12.0	1.4	0.8	1026	772
	eCO_2	64.0	60.0	5.7	6.3	13.7	12.3	1.7	1.5	1682	1286
90 DAS	aCO_2	64.3	46.0	6.3	6.0	13.7	12.0	1.6	0.8	1227	910
	eCO_2	67.3	60.3	5.7	6.3	14.3	12.7	1.7	1.5	2214	1469
110 DAS	aCO_2	71.0	66.3	7.0	6.3	13.8	12.5	1.6	0.9	-	-
	eCO_2	68.8	70.5	7.3	7.0	14.8	14.0	1.9	1.7	-	-
	df										
Time intervals (T)	4	**		n.s.		**		**		**	
CO_2 levels (C)	1	**		n.s.		*		**		**	
Genotypes (G)	1	**		n.s.		*		**		**	
T * C	4	**		n.s.		n.s.		**		**	
T * G	4	**		n.s.		n.s.		*		**	
C * G	1	**		n.s.		n.s.		**		n.s.	
T * C * G	4	n.s.		n.s.		n.s.		n.s.		n.s.	
Error	38	31.5		1.1		5.5		0.0		24392	

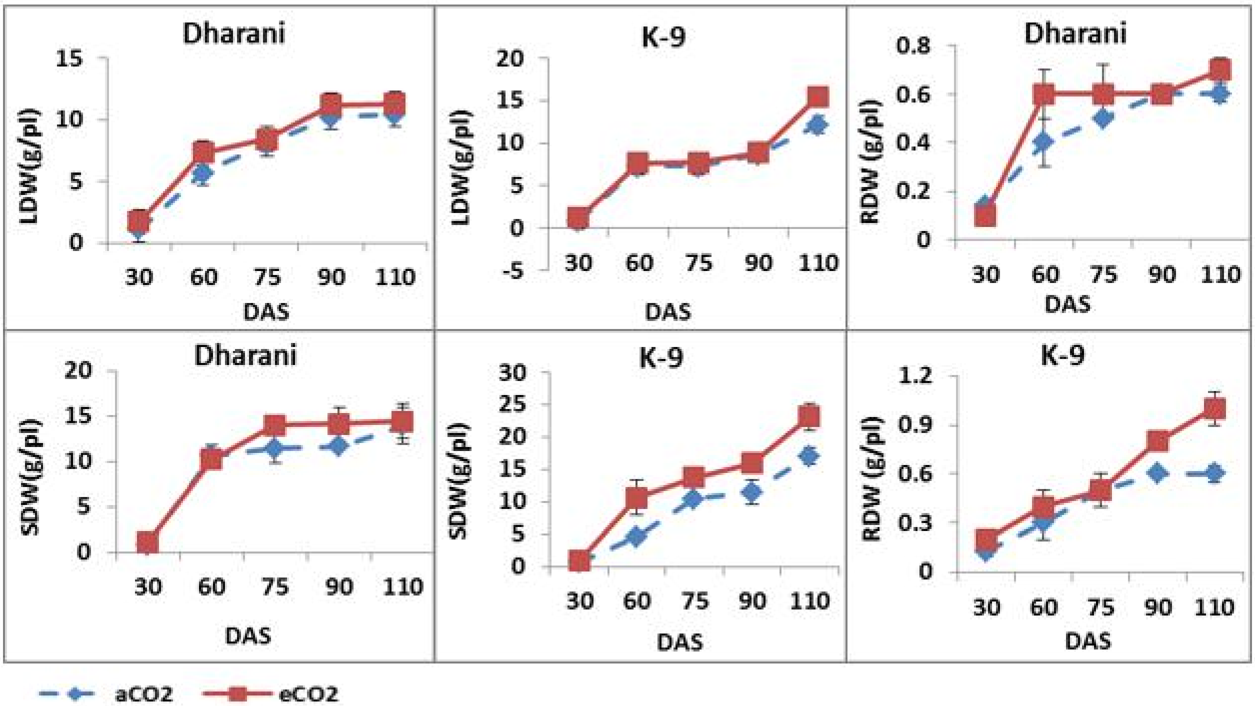

Fig.1: Biomass parameters of two groundnut genotypes at different growth stages under eCO_2& eCO_2 conditions

Table 2: The mean per se values and analysis of variance of biomass parameters of groundnut genotypes (Dharani & K-9)under $aCO_2$and eCO_2conditions atdifferentgrowth stages

		Leaf dry weight (g/pl		**Stem dry weight (g/pl)**		**Root dry weight (g/pl)**		**Total biomass (g/pl)**	
		Dharani	K-9	Dharani	K-9	Dharani	K-9	Dharani	K-9
30 DAS	aCO_2	1.1	0.8	0.8	0.7	0.14	0.13	2.1	1.6
	eCO_2	1.7	1.2	1.1	0.9	0.10	0.20	2.9	2.3
60 DAS	aCO_2	5.7	7.2	10.2	4.6	0.4	0.3	16.7	12.1
	eCO_2	7.3	7.6	10.2	10.7	0.6	0.4	18.1	18.7
75 DAS	aCO_2	8.0	7.2	11.4	10.5	0.5	0.5	28.6	21.9
	eCO_2	8.4	7.7	14.0	13.8	0.63	0.41	33.4	27.7
90 DAS	aCO_2	10.2	8.6	11.6	11.5	0.6	0.6	33.1	21.8
	eCO_2	11.2	8.8	14.1	16.0	0.65	0.81	37.9	32.1
110 DAS	aCO_2	10.4	12.1	13.9	17.1	0.6	0.6	44.2	50.1
	eCO_2	11.3	15.5	14.4	23.2	0.7	1.0	48.4	55.9
	df								
Time intervals (T)	4	**		**		*		**	
CO_2 levels (C)	1	n.s.		n.s.		n.s.		**	
Genotypes (G)	1	**		*		**		**	
T * C	4	**		**		**		**	
T * G	4	n.s.		**		n.s.		**	
C * G	1	**		n.s.		n.s.		**	
T * C * G	4	n.s.		n.s.		n.s.		n.s.	
Error	38	0.5		3.3		0.0		5.5	

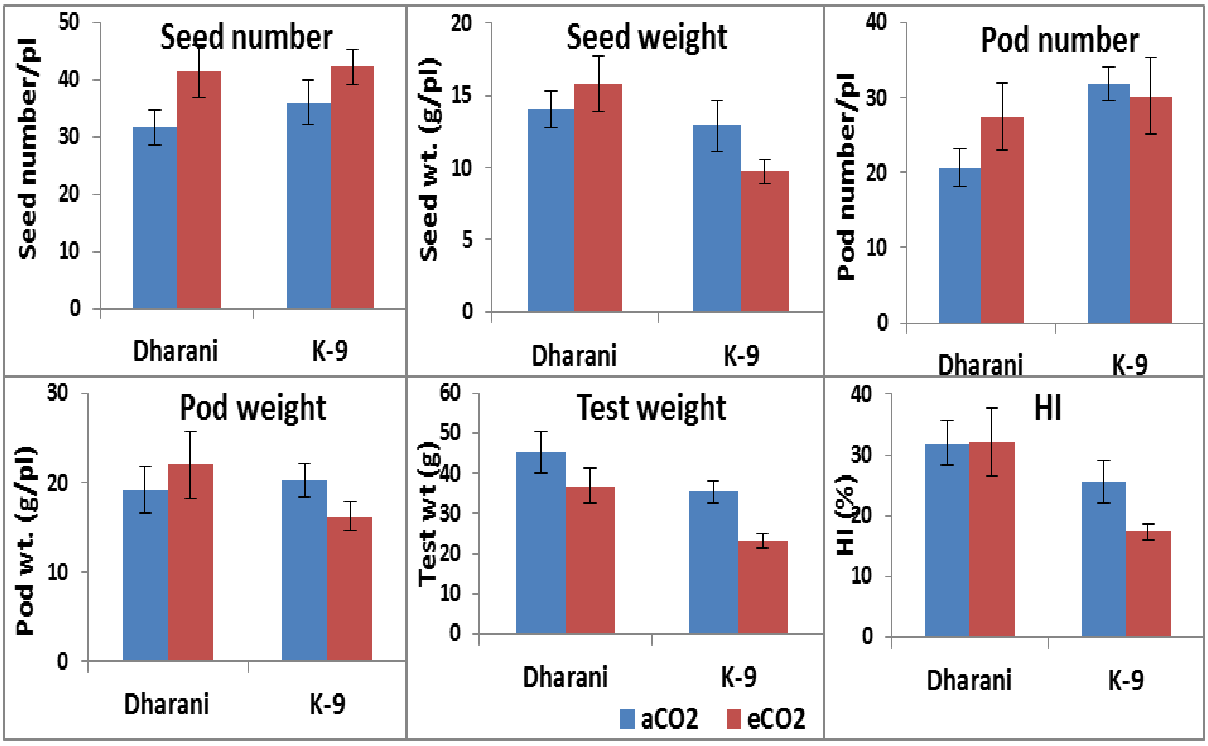

Fig.2: Yield and yield contributing parameters of two groundnut genotypes at eCO_2 and aCO_2 conditions

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3.1 Shoot parameters: The maximum plant height of both the genotypes recorded at the harvest stage. The maximum plant height in Dharani was 71cm at aCO_2 and 68.8cm at eCO_2, whereas it was 66.25cm and 70.5cmrespectively with K-9. The maximum increment in plant height with eCO_2 was at 30 DAS in Dharani (37%), at 75 DAS in K-9 (35%) when compared with aCO_2. A significant increase in plant height, leaf expansion in sweet potato and cowpea was reported by Bhattacharya et al. under eCO_2 [7].

At harvest, the mean stem dry weight was 13.9g/plant and 14.4g/plant in Dharani while 17.1g/plant and 23.2g/plant in K-9 at aCO_2 and eCO_2 respectively. The maximum percentage increment in stem dry weight with eCO_2 was observed as 44.6% at 30DAS in Dharani while 131.9% at 60 DAS in K-9. The genotype K-9 showed better response of stem dry weight than Dharani at eCO_2. Similar increase in stem dry weight throughout the crop growth period with eCO_2 in castor was reported by Vanaja et al.[8].

Table 3: The mean per se values and analysis of variance of yield parameters of groundnut genotypes (Dharani & K-9) under aCO_2 and eCO_2 conditions at harvest

Parameters	Dharani		K-9		Mean sum of square			
	aCO_2	eCO_2	aCO_2	eCO_2	CO_2 levels (C) df (1)	Genotypes (G) df (1)	C * G df (1)	Error df (6)
Pod number/pl	20.6	27.4	31.8	30.2	n.s.	n.s.	n.s.	58.1
Pod weight (g/pl)	19.2	22.0	20.3	16.3	n.s.	n.s.	n.s.	8.5
Seed number/pl	31.6	41.4	36.0	42.2	*	n.s.	n.s.	37.9
Seed weight (g/pl)	14.0	15.7	12.9	9.7	n.s.	*	*	5.4
Test weight (g)	45.4	36.7	35.3	23.2	n.s.	n.s.	n.s.	80.5
Harvest Index (%)	32.0	32.2	25.4	17.3	n.s.	**	*	18.6

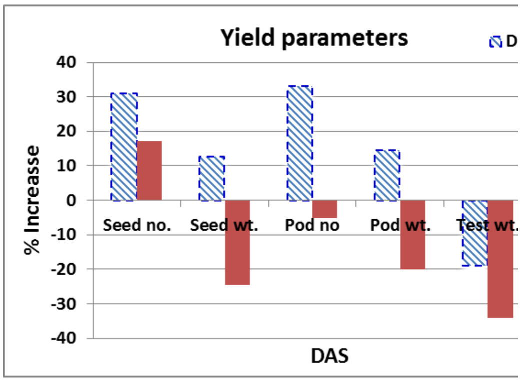

Fig.4: Percentage increase of the yield parameters of two groundnut genotypes due to eCO_2 over aCO_2

3.2 Root parameters: The percentage increment of root length varied from 4 to 59% in Dharani, 3 to 44% in K-9 with eCO_2 and the highest increment in root length was noticed at 30DAS. The root length was 13.8cm and 14.8cm in Dharani whereas 12.5cm and 14cm in K-9 at aCO_2 and eCO_2.The CO_2 enrichment enhances the root growth much more by increasing its length, volume and weight. Increased root length was observed by Madhu et al. with increased CO_2 conditions in groundnut crop [9].

The improved response due to eCO_2 was more significant at initial growth stages of K-9 while a linear increase recorded with Dharani. Higher increment in root volume than root length was observed by Vanaja et al. in rainfed crops [10] under eCO_2. Vanaja et al. observed and reported that eCO_2 significantly increased root volume in sunflower (C3) and maize (C4) crops [11].

The response of root dry weight to eCO_2 was more significant at later growth stages in both the genotypes and the increment was higher in K-9 as compared with Dharani. The maximum increase in root dry weight due to eCO_2 was at 60 DAS in Dharani (50%), whereas it was at harvest in K-9 (66.7%). The increased root volume, root length under eCO_2 infers the possibility of deeper soil penetration and spread to more volume of soil, which would be an advantage in a drier climate. In general enhanced CO_2 strongly enhanced the root growth by increasing its length, volume and weight. Vaidya et al. [12]testified that the biomass of stem, root, leaf and total biomass of groundnut genotypes recorded significant increase at eCO_2.

3.3 Leaf parameters: The maximum incrementin leaf area with $eCO_2$was 80.4% in Dharani while it was 274.5% in K-9. Increased CO_2 tends to accelerate the growth and leaf area per plant, which may increase the total biomass. Leaf area was increased by 46% at eCO_2 compared to ambient grown by Jyothilakshmi et al. in *Vigna mungo* L.[13].

The maximum increase in leaf dry weight was at 30 DAS and it was 47.8% in Dharani, 54.7% in K-9. The leaf biomass increased under eCO_2 was reported in groundnut. Increased leaf area and leaf biomass are expected to improve total biomass as well as yield of a crop as it can improve the photo assimilation of the plant.

3.4 Total Biomass: Among the two genotypes, Dharani recorded higher total biomass at all growth stages as well as under both aCO_2 and eCO_2 than K-9 while K-9 recorded higher response to eCO_2. It is interesting to observe that the eCO_2 impact on total biomass was more at initial growth stages as total biomass increased by 42.4% in Dharani at 30DAS whereas 53% in K-9 at 60 DAS. The increased total biomass at eCO_2 in both the genotypes was mainly contributed by enhanced stem and leaf biomass at initial growth stages. An increased above ground biomass in pigeon pea under elevated CO_2 conditions wasdetectedby Saha et al. [14].

3.5 Yield parameters: Higher numbers of pods were observed at eCO_2 in Dharani while at aCO_2 in K-9. Similar trend was recorded for pod weight and seed weight. It is excited to perceive that among the yield parameters, eCO_2 improved only seed number with K-9 and this response could not improve seed weight as the seed filling in this genotype was poor which reflected in reduced test weight. It is also noted that in both the genotypes the test weight decreased under eCO_2 and it could be due to the prolonged peg initiation and pod formation with poor seed filling.

Among all the yield parameters, Dharani recorded improved performance for pod number, pod weight, seed number, seed weight with eCO_2 while only seed number improved with K-9. Under aCO_2 more number of pods per plant was recorded with K-9 while higher improvement with eCO_2 was registered with Dharani. The increased pod number in Dharani contributed to increased pod weight and seed weight at eCO_2 while no response was recorded with K-9. The reduced test weight in K-9 indicating poor seed filling at eCO_2 though higher seed number was recorded. It clearly indicating the response of vegetative and reproductive biomass at eCO_2 differed with selected genotypes, as higher improvement in vegetative biomass with K-9 and reproductive biomass with Dharani was observed.

3.6 Harvest index (%) (H): The genotype Dharani maintained similar HI at both aCO_2 and eCO_2 as this genotype was able to proportionate the increased biomass to reproductive components. However the response of K-9 was entirely different and the increased total biomass at eCO_2 was mainly due to improved performance of vegetative components specially leaf and stem biomass and the yield components failed to respond to the eCO_2. This resulted in decreased HI of K-9 at eCO_2 revealing that this genotype was not able to take the advantage of enhanced CO_2 environment in terms of yield. The results which are in tune with previously reported findings revealed a significant increase in the HI in black gram due to their improved partitioning efficiency under eCO_2 conditionby Vanaja et al. [15].

The results obtained from the present study showed an increase in the dry matter production as well as economic yield at eCO_2 level. The seed yield improved by 12.59% in Dharani, whereas the harvest index (HI) increased only by 0.7%. This clearly shows that the eCO_2 improved both biomass and economic yield. Thus it may be concluded that the groundnut genotype Dharani is positively responding to increasing CO_2 not only for biomass but also for seed yield.It was also conveyed by Krishna Reddy et al. that Dharani produced significantly higher pod yield than other genotypes on sandy loam soils of Tirupati, Andhra Pradesh, during early kharif under irrigated conditions [16].

To conclude, the present study reveals that the importance of legume crops which are protein rich could also sustain under climate change to meet the demand. Overall results revealed that the highest response to eCO_2 in terms of seed weight, harvest index was shown by Dharani, biomass in K-9. Hence identification of traits and genotypes to fit in the future predicted climatic conditions is required to sustain and improve the yield.

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