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Effect of elevated carbon dioxide concentration on phosphorus fractionation and phosphorus use efficiency in low land transplanted rice crop

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Abstract
Phosphorus being an immobile nutrient element in soil its availability to plants is less despite the total P in soils being in the range 200–3000mg P kg/ha. Further in elevated CO_2 concentration, the soil P concentration is influenced. The present investigation entitled “Effect of Elevated Carbon Dioxide Concentration on Phosphorus fractionation and Phosphorus use efficiency in low land transplanted Rice crop” was conducted in the institute research farm of ICAR-NRRI Cuttack (Odisha) during the Kharif season of 2016. The total experiment was laid out inside open top chambers (OTC) in the field. The chambers were laid in the field with a common room for controlling the amount of CO_2 to be supplied to various OTCs. Inside the OTC the crop were transplanted inside six pots containing various doses of phosphorus. It was seen that phosphorus sorption decreased and desorption increases with increase in CO_2 concentration with minimum and maximum values respectively under treatment T9 (C3P2). The various agronomical parameters including plant height, tiller numbers, biomass, and yield also shows significant results with increased CO_2 concentration. Plant height and tiller numbers were found to be maximum under treatment T9 (C3P2) and so do the yield also increased with increased CO_2 concentration with maximum yield under treatment T9 (C3P2).Available phosphorus and different soil physiochemical parameters and soil phosphorus fraction was analyzed. Available phosphorus was highly correlated with organic carbon followed by AHC, Followed by POSC, followed by alkaline and acid phosphates and organic phosphorus respectively. It can be observed that PUE is increasing with increase in carbon dioxide concentration. This directs the effect of elevated atmospheric CO_2 is typically increases in above-ground and below ground productivity of C3 and sometimes C4 plants. Plant physiological processes like C metabolism, water-use efficiency (WUE) and nutrient-use-efficiency (NUE) are enhanced with elevated CO_2.

Keywords: Elevated, carbon, concentration, phosphorus, phosphorus

Introduction
Reported that physiological P efficiency (PPE) and P utilization efficiency (PutE) are the measures of plant’s ability to convert the absorbed P into total biomass yield and grain yield, respectively. PPE of wheat was reduced by 15% under elevated CO_2. However, increased harvest index under elevated carbon (EC) restricted the decline in PutE to a non-significant 9.5% (P=0.35) Kumar *et al.*, (2011). Alteration in specific P uptake efficiency (SPUE) is an adaptation mechanism to cope with the conditions of P deficiency. A moderate increase in SPUE of wheat (~21%) under elevated CO_2 might have been induced by the higher P requirement of plant grown there under. Wand *et al.*, (1999) [33] and Lee (2011) reported that the growth response to elevated CO_2 is greater in C_3 species than C_4 species, and the photosynthetic capability can be greatly enhanced in C_3 species under elevated CO_2. Fohse *et al.*, (1988) [11] and Veneklaas *et al.*, (2012) [32] reported that external and internal P requirements represent the P-acquisition efficiency and P-use efficiency for yield production, respectively. The external P requirement is likely to increase with increased plant growth under elevated CO_2. However, the extent of this requirement will depend on the plant species. Mauney *et al.*, (1994) [17] and Amthor (2001) [2] reported that, the yield of wheat (C_3) increased by 31% with elevated CO_2 at 500–700 ppm in a Free Air CO_2 enrichment (FACE) facility and Ottman *et al.*, (2001) [21] reported that sorghum (C_4) yield was not increased in the same environment. Dalton *et al.*, (1986) [8] and Schwanz *et al.*, (1996) reported that to minimize cellular oxidative damage, plants produce anti-oxidative enzymes including super

oxide dismutase (SOD), catalases, peroxidases, ascorbate peroxidase, glutathione peroxidase and glutathione reductase these molecules catalyse reactions that directly or indirectly detoxify reactive oxygen species (ROS). These enzymes occur in both the chloroplast and cytoplasm. Leaves from various plant species grown under elevated CO_2 concentration contained lower activities of superoxide distmutase or catalase than foliage from plants grown under ambient CO_2 concentrations in tobacco. Satapathy *et al.*, (2015) [25] reported that the effect of environmental variation on organic carbon was non-significant. However the OC content was marginally increased under elevated CO_2 compared to ambient environment under OTC. The elevated CO_2 gave lower available N content than the ambient environment in the OTC. Among the environment, the open field shows the highest available P in all wet and dry seasons. It was not significantly different from that under elevated CO_2 but significantly higher than that under ambient environmental condition in the OTC as compared to the ambient environment. In general, the open field gave lower available K content than elevated environment**.** The change in rhizosphere enzyme activity in response to elevated CO_2 is likely to affect P mineralization in the rhizosphere. Niu *et al.*, (2013) reported that elevated CO_2 is likely to affect the internal P requirement of plants because elevated CO_2 alters P utilization within plant tissue. Sattar *et al.*, (2011) reported that the external P requirement is the available P in soil that is required to produce 90% of the maximum plant yield. Sattar *et al.*, (2011), Loneragan and Asher, (1967) and reported that the internal P requirement is the P concentration in the plant to achieve 90% of maximum yield. Mafakheri *et al.*, (2010) reported that proline content of the leaf, however, increased at both growth stages in all varieties of chickpea in response to drought. The increase in proline content due to drought stress was more severe at flowering stage than at the vegetative stage. Chiang and Drissner *et al.*, (2007) reported that the activities of many enzymes were stimulated by root proliferation under elevated CO_2 including invertase (48%), xylanase (23%), urease (24%), protease (40%) and alkaline phosphor mono esterase (54%). Verbruggen and Hermans (2008) suggested that under vegetative stage, drought stress increased proline content about tenfold, this increasing roles as an osmotic compatible and adjust osmotic potential which resulted in drought stress avoidance in chickpea. Dandekar (1995) reported that the proline content depends on plant age, leaf age, leaf position or leaf part. Staddon*et al.*, (1999) demonstrated that *Plantagolanceolata* and *Trifoliumrepens* effectively increased their phosphorus-use efficiency under elevated CO_2 conditions by reducing shoot phosphorus contents as a component of CO_2 induced photosynthetic acclimation. Niklaus *et al.*, (1998) [18] reported the effects of elevated CO_2 nitrogen and phosphorus supply on calcareous grassland communities. At low phosphorus concentrations, biomass nitrogen contents were unaffected by elevated CO_2 (600 ppm) while at high phosphorus concentrations, community biomass-nitrogen increased by 28%, suggesting that community biomass nitrogen will increase in the future only if soil phosphorus contents are increased as well. Cure *et al.*, (1988) [6] reported a 22% decline in P uptake efficiency of soybean under doubled CO_2 concentration, the finding, however, came out of a solution culture experiment with relatively higher levels of P supply. Plant P requirement can be divided into the need for external soil P and the need for internal P within the plant tissues.

Materials and Methods

The present investigation entitled “Effect of Elevated Carbon Dioxide Concentration on Phosphorus fractionation and Phosphorus use efficiency in low land transplanted Rice crop” was conducted in the institute research farm of ICAR-NRRI Cuttack (Odisha) during the Kharif season of 2016 in lowland rice. The rice variety used in the experiment was Naveen. The design followed in the experiment was Factorial CRD which is laid out under nine treatment and four replication combinations namely T1 (C1PO), T2 (C1P1), T3 (C1P2), T4 (C2P0), T5 (C2P1), T6 (C2P2), T7 (C3P0), T8 (C3P1), and T9 (C3P2) where C1, C2, and C3 are ambient, 550 ppm, 700 ppm concentration of carbon dioxide respectively and P0, P1, and P2 are no application of phosphorus, phosphorus applied @ 25 kg ha-^{1} and phosphorus applied @ 50 kg ha^{-1}. The test variety taken was “Naveen” which was transplanted in the pots of OTC on 5th August 2016 and harvested on 8th November 2016. Rice plants were grown inside OTCs installed in the field, with CO_2 fumigation from transplanting to harvest. Standard agronomic practices as commonly followed in Eastern India were followed. 21 days old rice seedlings were transplanted manually with plant geometry of 20 cm × 15 cm in tanks. The soil puddled to maintain 3 ± 2 cm standing water in the tanks. Three levels of phosphatic fertilizers were applied: P0- no application of phosphorus, P1 – P applied @ 25 kg ha^{-1}(4 g P pot^{-1}), P2 –P applied @ kg ha^{-1} (8.1 g P pot^{-1}). Phosphatic fertilizer in the form of SSP was applied. Nitrogen was applied in the form of urea @ 3.1g pot^{-1}, about 50% of the total N was applied as a basal dressing one day prior to transplanting and 25% at MT stage and rest 25% at PI stage and potassium were applied as basal in the form of MOP @ 2.1g pot^{-1}. In the OTCs the experiment will laid out with eighteen treatments combination as follows: Carbon dioxide concentration - C1: Ambient CO_2, C2: Elevated CO_2 (550 ppm), C3: Elevated CO_2 (700 ppm). Phosphorus levels- P0: No application of phosphorus, P1: P applied @ 25 kg/ha (4 g P/pot), P2: P applied @ 50 kg/ha (8.1g P/pot)

The soil samples were collected from the rhizosphere region (0-15 cm) of the rice plant (Naveen variety) planted in the OTCs at the ICAR-NRRI campus. The soil samples from each treatment site were sampled from 2 spots using Agar and were put in sterile polythene bags. The soil samples were collected at all the growth stages of rice plant (AT, MT, PI and HS) and were analyzed for available N (alkaline potassium permanganate method), available P (Bray’s-I method), available K (ammonium acetate method), Microbial biomass carbon was determined using the chloroform fumigation extraction methods of Vance *et al.*, (1987) [31], Acid hydrolyzable carbon content was measured using anthrone method (Haynes and Swift, 1990), Phosphorus sorption was measured using by the (Singh and Jones, 1976) method.

Results and Discussion

Phosphorus fractionation

Phosphorus fractionation was analyzed and presented in Table 1. In NH_4Cl maximum value was found in the treatment C3P2 (34.9 mg kg^{-1}) and minimum was found in C1P0 treatment (23.0 mg kg^{-1}), In Pi-NaHCO3 maximum value was found under the treatment C2P2 (65.5 mg kg^{-1}) and minimum was found in C1P0 (29.9 mg kg^{-1}), in Po-NaHCO3 maximum value was found under the treatment C3P2 (64.8 mg/kg) and minimum was found in C2P0 (29.0 mg kg^{-1}), in Microbial p maximum value was found under the treatment C3P2 (71.09

mg kg^{-1}) and minimum was found in C1P0 (30.5 mg kg^{-1}), in Pi-NaOH I maximum value was found under the treatment C3P0 (99.4 mg kg^{-1}) and minimum was found in C1P1 (68.7 mg kg^{-1}), in Po NaOH I maximum value was found under the treatment C3P2 (187 mg/kg) and minimum was found in C1P0 (118.3 mg kg^{-1}), in Pi-HCl maximum value was found under the treatment C3P2 (88.7 mg kg^{-1}) and minimum was found in C2P0 (31.9 mg kg^{-1}), in Pi-NaOH II maximum value was found under the treatment C3P2 (184.3 mg/kg) and minimum was found in C2P1 (103.2 mg kg^{-1}), in Po-NaOH II maximum value was found under the treatment C3P2 (218.8 mg kg^{-1}) and minimum was found in C1P1 (174.9 mg kg^{-1}), in P residual maximum value was found under the treatment C2P1 (201.7 mg kg^{-1}) and minimum was found in C1P1 (182.2 mg kg^{-1}).

The P fractions in the rhizosphere have been reported to be altered by elevated CO2. Following 5 years of exposure to elevatedCO_2 in a FACE experiment, Khan *et al.*, (2008) demonstrated that the NaOH- and HCl-extractable P increased in the rhizosphere, rather than becoming depleted. With chickpea and wheat grown under elevated CO_2 for 6 weeks, Jin *et al.*, (2013) found that elevated CO_2 significantly increased NaHCO3- and NaOH-extractable Po in the rhizosphere. This indicated that P immobilization had occurred in the rhizosphere under elevated CO_2.

Table 1: Phosphorus fractionation (mg kg^{-1}soil^{-1}) at under elevated carbon dioxide and phosphorus doses

	NH4Cl	Pi-NaHCO3	Po-NaHCO3	Microbial P	Pi-NaOH I	Po-NaOH I	Pi-HCl	Pi-NaOH II	Po-NaOH II	P residual	Total P (sum)
	mg/kg										
C1P0	23.0	29.9	29.0	30.5	69.7	118.3	42.2	164.4	185.6	192.7	885.3
C1P1	25.5	42.7	32.6	53.2	68.7	136.4	60.4	148.6	174.9	182.2	925.3
C1P2	26.9	55.2	44.3	56.4	78.7	153.3	79.6	136.3	187.7	182.5	1000.9
C2P0	24.8	21.7	32.0	36.1	87.2	129.4	31.9	143.5	192.1	184.7	883.5
C2P1	28.5	33.5	45.8	65.5	75.3	148.3	50.4	103.2	207.0	201.7	959.3
C2P2	34.8	65.5	57.8	60.8	86.0	164.5	72.1	179.9	206.5	186.0	1113.9
C3P0	25.6	36.2	29.8	46.0	99.4	140.1	36.3	168.8	200.5	183.2	965.7
C3P1	29.6	40.8	45.4	66.7	82.1	163.7	55.8	123.2	211.6	186.3	1005.3
C3P2	34.9	51.9	64.8	71.9	93.1	187.0	88.7	184.3	218.8	194.5	1190.0

Note: (C1 - ambient, 390 ppm CO_2; C2 - 550 ppm CO_2; C3 - 700 ppm CO_2; P0- no P; P1- 25 kg ha^{-1}; P2 - 50 kg ha^{-1})

Relationship of phosphorus dynamics with different soil parameters under elevated carbon dioxide

The correlation between Available phosphorus and different soil physiochemical parameters and soil phosphorus fraction was analyzed and presented in the table (2). From the table it can be concluded that available phosphorus was highly correlated with organic carbon (0.970**) followed by AHC (0.957**), Followed by POSC (0.937**), followed by alkaline and acid phosphates (0.917**) and (0.887**) Followed by organic phosphorus (0.917**) respectively at 1% level of significance. High correlation was also found with RMC (0.871**), NH4Cl (0.860**), inorganic phosphorus(0.801**) this correlations are also significant at 1% level of significance however the analysis showed that AP is not significantly correlated with phosphorus residual. They have no significant effect on availability of phosphorus to plant.

Table 2: Correlation of available phosphorus with different soil parameters

	NH_4Cl	Inorganic P	Organic P	P residual	POSC	AHC	RMC	OC	Acid Phos	Alk. Phos	Aval. P	CEC
NH_4Cl	1											
Inorganic P	0.779*	1										
Organic P	0.941**	0.704*	1									
residual p	0.240^{NS}	-0.056^{NS}	0.218^{NS}	1								
POSC	0.955**	0.787*	0.955**	0.328^{NS}	1							
AHC	0.879**	0.677*	0.955**	0.179^{NS}	0.924**	1						
RMC	0.764*	0.583^{NS}	0.785*	0.203^{NS}	0.774*	0.909**	1					
OC	0.839**	0.664^{NS}	0.897**	0.222^{NS}	0.906**	0.962**	0.902**	1				
Acid Phos	0.756*	0.580^{NS}	0.826**	0.179^{NS}	0.777*	0.885**	0.903**	0.918**	1			
Alk. Phos	0.813**	0.599^{NS}	0.878**	0.149^{NS}	0.834**	0.944**	0.935**	0.956**	0.982**	1		
Aval. P	0.860**	0.801**	0.914**	0.192^{NS}	0.937**	0.957**	0.871**	0.970**	0.887**	0.917**	1	
CEC	-0.231^{NS}	-0.002^{NS}	-0.147^{NS}	-0.110^{NS}	-0.087^{NS}	-0.177^{NS}	-0.287^{NS}	-0.011^{NS}	0.048^{NS}	-0.031^{NS}	-0.005^{NS}	1

Note: Where, NS= non-significant,*= Significant at 5%, ** = Significant at 1

P-use efficiency of rice plant (Naveen variety)

P-use efficiency was analyzed at harvest stage of the rice plant and the findings are presented in fig 4.6.1. It can be observed that PUE is increasing with increase in carbon dioxide concentration and maximum value is observed in C_3 (17.6%) under P1. However the interactive effect of CO_2+P is non-significant for the same. The direct effects of elevated atmospheric CO_2 are typically increases in above-ground and below ground productivity of C_3 and sometimes C_4 plants (Curtis *et al.*, (1989), Dippery *et al.*, (1995) and Owensby *et al.*, (1999). Plant physiological processes like C metabolism, water-use efficiency (WUE) and nutrient-use-efficiency (NUE) are enhanced with elevated CO_2 Knapp *et al.*, (1993), Larigauderie *et al.*, (1988) and Owensby *et al.*, 1993).

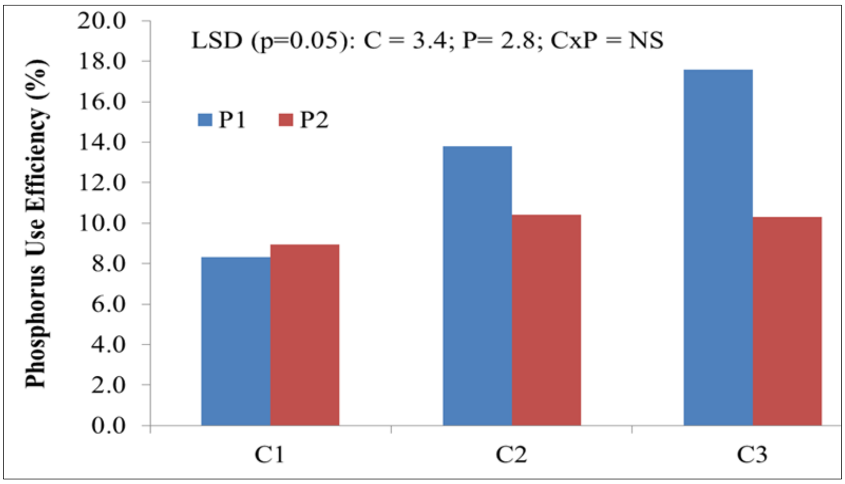

Fig 1: P-use efficiency at harvest stage (HS) under elevated carbon dioxide and phosphorus doses. (C1 - ambient, 390 ppm CO_2; C2 - 550 ppm CO_2; C3 - 700 ppm CO_2; P0- no P; P1- 25 kg ha^{-1}; P2- 50 kg ha^{-1}

Yield attributes

Plant height

Plant height was analyzed at different growth stages of the rice plant and presented in table 4.7.1. Which shows a gradual increase in plant height with each advancing stage However for a particular stage plant height was maximum under C3, similarly a significant increase in plant height was also observed under P2 treatment given. Hence it can be concluded that a significant increase in plant height can be achieved under eCO_2 and higher phosphorus doses. However, thecombined effect of carbon dioxide and phosphorus treatment found to be significant for the panicle initiation stage. Attipalli R. Reddy (2010) [3] similarly reported that Plant height increase (209.45 cm under ambient) with increase CO_2 level (359.92 cm under elevated CO_2). Singh *et al.*, (2017) [29] report that "phosphorus deficiency significantly decreased soybean vegetative growth and developmental rates of main-stem elongation, node addition and leaf area expansion, whereas elevated CO_2 stimulated. Girish K *et al.*, (2010) [12] A two-season (spring and summer) experiment conducted in our experimental field at the University of Hyderabad for three consecutive years (2006–2008), using a tree species *Gmelina arborea* Roxb (Verbenaceae) under CO_2-enriched atmosphere in open altered branching pattern and significant increase in plant height.

No of tillers

The plant tillers numbers were analyzed at different growth stages of the rice plant and presented in the table 3. From the table it can be concluded that the no. Of tillers increased gradually with each advancing stage. In a particular stage the no. Of tillers found to be varying significantly under different carbon dioxide and phosphorus treatments applied. The mean no. of tillers is found to be highest at PI stage under C3 (10.30) and P2 (9.62). However, the combined effect of carbon dioxide and phosphorus treatments found to be non-significantly affect the tiller no. at maximum tillering stage however it is found to be significant at active tillering and panicle initiation stage.

Seneweera (2011) [24] in his experiment showed that the partitioning of dry mass between the roots and shoots was dramatically altered by elevated CO_2 with a large proportion of the dry mass being partitioned to the roots at the expense of the sheaths and blades. This stimulation of root growth was partly due to the increase in tiller number elevated CO_2 because root mass per tiller was increased significantly. The biggest increase in root growth appeared to be in the adventitious roots.

Table 3: Plant height (cm) at active tillering (AT), maximum tillering (MT) and panicle initiation (PI) under elevated carbon dioxide and phosphorus doses

	Active tillering				Maximum tillering				Panicle Initiation			
	PO	P1	P2	Mean	PO	P1	P2	Mean	PO	P1	P2	Mean
Cl	37.9	38.8	40.2	39.0	80.6	82.1	83.5	82.0	90.5	95.1	97.9	94.5
C2	38.8	40.0	41.3	40.0	82.5	84.3	86.0	84.2	98.8	99.9	101.3	100.0
C3	40.8	41.4	42.3	41.5	84.4	87.3	88.7	86.8	103.5	105.1	107.0	105.2
Mean CD (p< 0.05)	39.2	40.1	41.2		82.5	84.5	86.1		97.6	100.1	102.1	
C				0 9				1.4				1.1
P				0.9				1.4				1.1
CxP				N/A				N/A				2.0

Note: (C1 - ambient, 390 ppm CO_2; C2 - 550 ppm CO_2; C3 - 700 ppm CO_2; P0- no P; P1- 25 kg ha^{-1}; P2- 50 kg ha^{-1})

Table 4: No. of tillers at active tillering (AT), maximum tillering (MT) and panicle initiation (PI) under elevated carbon dioxide and phosphorus doses

	Active Tillering				Maximum Tillering				Panicle Initiation			
	P0	P1	P2	Mean	P0	P1	P2	Mean	P0	P1	P2	Mean
C1	5.00	5.38	5.78	5.39	6.92	7.81	8.31	7.68	7.03	8.13	8.47	7.87
C2	6.15	6.32	6.58	6.35	8.58	8.88	9.35	8.94	8.73	9.04	9.41	9.06
C3	7.00	7.35	7.67	7.34	9.67	10.04	10.94	10.22	9.77	10.14	10.98	10.30
Mean CD (p< 0.05)	6.05	6.35	6.68		8.39	8.91	9.53		8.51	9.10	9.62	

C			0.087					0.321				0.213
P			0.087					0.321				0.213
CxP			0.150					N/A				0.370

Note: (C1 - ambient, 390 ppm CO_2; C2 - 550 ppm CO_2; C3 - 700 ppm CO_2; P0- no P; P1- 25 kg ha^{-1}; P2- 50 kg ha^{-1})

Biomass

The agronomical parameters such as no.of panicles, fresh weight, dry weight, fresh weight grain, and dry weight grain were analyzed at harvest stage and the findings are depicted in table No 5. The mean no. of panicle was found to be highest under C3+P2treatment (74.8). Similarly, the fresh straw weight was found to be highest under C3+P2 treatment (515.5g). Dry straw weight was also found to be highest at C3+P2treatment (216.8g). Looking into the grain fresh weight and dry weight both found to be highest under C3 + P2 treatment (133.3g and 105.1g) respectively.

Increases in the present atmospheric CO_2 concentration predicted for the end of this century will increase crop growth, development and grain yield Kimball 1983; Conroy *et al.*, 1994, Poorter and Perez-Soba 2001; Leakey (2009). Increase CO_2 concentration in the atmosphere has positively effect on crop production, but its net effect on rice yield depend on possible yield reductions associated with increasing temperature. For every 75 ppm increasing in CO_2 concentration rice yield will increase by 0.5 t/ha but yield will decrease by 0.6 t/ha for 1°c increase temperature (Sheehy *et al.*, 2005) [26]. Increasing CO_2 in the OTC increase panicle number by 6% (Satapathy S.S. *et al.*, 2015) [25].

Yield

Biological yield was analyzed at harvest stage of the rice plant and presented in table 6.It can be observed that grain yield is highest under C3 (509.4g/m^2) as compare to C1 and C2, similarly phosphorus treatment had also a significant effect on grain yield and it is found to be maximum under P_3 (566.6g/m^2) treatment given. The straw yield was also analyzed at harvest stage and it is found to be maximum under C3 (566.6g/m^2) as compared to C1and C2treatment given. That straw yield is also significantly affected by the phosphorus treatments given and found to be highest under P2 (555.4g/m^2) treatment given. The harvest index thus analyzed at harvest stage and found to vary non-significant under different carbon dioxide and phosphorus treatments given. Harvest index acquires a maximum value under C3(0.48) and combined effect of carbon dioxide level and phosphorus levels found also to be non-significant for all the three parameters discussed above.

Elevated CO_2 accelerated rice development, increased leaf photosynthesis by 30–70%, canopy Photosynthesis by 30–40% and crop biomass yield by 15–30%, depending on genotype and environment. (Erda *et al.*, 2005) [10]. Data based on average across several species under unstressed conditions, revealed that, compared to current atmospheric CO_2concentrations, crop yields increase at 550 ppm CO_2 in the range of 10-20% for C_3 crops and 0-10% for C_4crops (Ainsworth *et al.*, 2004; Gifford, 2004 and Long *et al.*, 2004). FACE studies indicate that, at 550 ppm atmospheric CO_2 concentrations, yields increase under unstressed conditions by 10-25% for C_3 crops, and by 0-10% for C4 crops consistent with previous TAR estimates (Easterling *et al.*, 2007). The 2-year FACE study showed that elevated CO_2 significantly increased rice yield, as has been reported previously (Kim *et al.*, 2001; Yang *et al.*, 2006 and Shimono *et al.*, 2008) [15]. The magnitude of the observed increase was within the range (0–23%) reported in previous rice FACE studies (Kim *et al.*, 2001, Yang *et al.*, 2006 and Shimono *et al.*, 2008) [15].

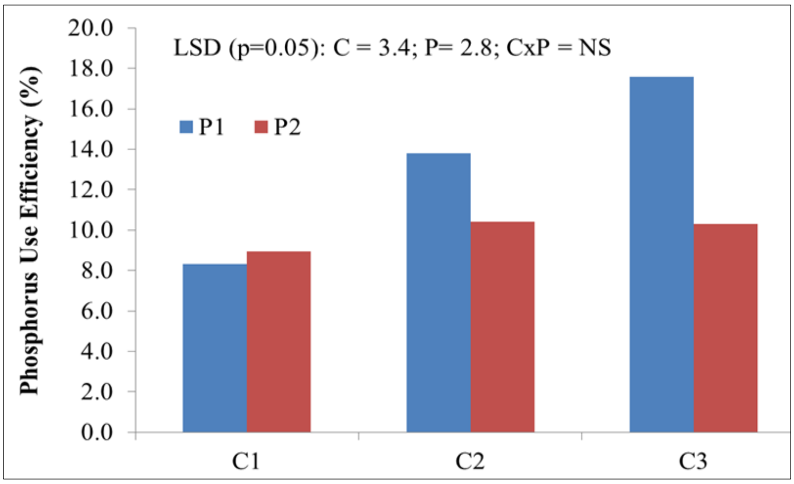

Fig 2: Biomass at harvest stage (HS) under elevated carbon dioxide and phosphorus doses (C1 - ambient, 390 ppm CO_2; C2 - 550 ppm CO_2; C3 - 700 ppm CO_2; P0- no P; P1- 25 kg ha^{-1}; P2- 50 kg ha^{-1})

Table 5: Biomass at harvest stage (HS) under elevated carbon dioxide and phosphorus doses

CO_2 level	Phosphorus level	No of panicle	Fresh straw weight (in gram)	Dry straw weight (in gram)	Fresh grain weight (in gram)	Dry grain weight (in gram)
C1	P0	28.0	222.8	85.5	47.5	36.0
	P1	59.0	312.0	177.5	104.5	81.4
	P2	70.5	519.3	193.0	123.3	97.8
C2	P0	32.0	218.3	78.0	51.3	51.3
	P1	62.8	465.8	177.5	119.8	95.7
	P2	71.3	547.5	227.5	128.5	101.1

C3	P0	31.3	226.3	89.5	52.0	39.0
	P1	60.5	460.0	169.3	107.3	105.1
	P2	74.8	515.5	216.8	133.3	105.1

Note: (C1 - ambient, 390 ppm CO_2; C2 - 550 ppm CO_2; C3 - 700 ppm CO_2; P0- no P; P1- 25 kg ha^{-1}; P2- 50 kg ha^{-1})

Table 6: Yield at harvest stage (HS) under elevated carbon dioxide and phosphorus doses

	Grain yield (g/m2)				**Straw yield (g/m2)**				**HI**			
	P0	**P1**	**P2**	**Mean**	**P0**	**P1**	**P2**	**Mean**	**P0**	**P1**	**P2**	**Mean**
C1	321.8	440.6	533.2	431.8	357.0	515.9	578.1	483.6	0.47	0.46	0.48	0.47
C2	382.4	541.7	571.9	498.7	435.6	599.0	622.3	552.3	0.47	0.47	0.48	0.47
C3	386.3	547.2	594.6	509.4	426.8	600.3	639.1	555.4	0.47	0.48	0.48	0.48
Mean	363.5	509.8	566.6		406.5	571.7	613.2		0.47	0.47	0.48	
CD (p< 0.05)												
C				38.8				36.8				NS
P				38.8				36.8				NS
CxP				NS				NS				NS

Conclusion

After all the analysis the result of the experiment reveled that increase in CO_2 concentration and phosphorus doses significantly increase soil EC, soil AN, AP, TN, TP, soil carbon fraction, soil enzymatic fractions, plant enzymatic fractions, phosphorus desorption activities. However the opposite effect is seen for soil pH and phosphorus sorption capacity of the soil. Among different growth stages of rice plant all the values were found to be maximum under panicle initiation (PI) stage and minimum values were found under the harvest stage. It can also be concluded that the yield is increasing with increased CO_2 concentration and phosphorus doses. Under elevated CO_2 condition higher amount of biomass was found and plant height also significantly varies under elevated CO_2 concentration and found to be maximum under 700 ppm CO_2 concentration. Under elevated CO_2 the phosphorus sorption is decreasing and desorption is gradually increasing which shows that in future if CO_2 concentration is increasing more phosphorus will be available to plant.

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