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Interactive effect of elevated carbon dioxide concentration on phosphorus dynamics under low land rice

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Abstract
Carbon dioxide (CO_2) in the atmosphere is rapidly rising year by year. Growth stimulation of plants at elevated CO_2 will have a greater demand for nutrient to sustain their faster growth. The present investigation entitled “Effect of Elevated Carbon Dioxide Concentration on Phosphorus Dynamics under Low Land Rice (Variety - Naveen) in Odisha” was conducted in the institute research farm of ICAR-NRRI Cuttack (Odisha) during the Kharif season of 2016. The test variety taken was “Naveen” which was transplanted in the pots of OTC on 5th August 2016 and harvested on 8th November 2016. Langmuir isotherm predicted that maximum bonding energy (k) was found under ambient condition i.e., (0.155 L mg-^{1}) and minimum value was found under 700 ppm CO_2 concentration i.e., (0.112 L mg-^{1}) it also showed Langmuir adsorption maxima (b) value is maximum in ambient condition i.e., (454.5 mg P kg-^{1}) and minimum value was found under 700 ppm concentration i.e., (370.4 mg P kg-^{1}). Phosphorus desorption was analyzed and it was found that higher amount of desorption of “P” was found in C3P2 treatment given and lowest was found in C1P0 treatment given.

Keywords: Phosphorus dynamics, lowland rice and elevated carbon dioxide

Introduction

Human activities have increased greenhouse gas concentrations in the atmosphere. Anthropogenic factors such as fossil fuel usage and land use changes have increased the concentrations of greenhouse gases in the atmosphere over the last century according to Inter-governmental Panel on Climate Change (IPCC, 2007) [4]. Research has demonstrated this increased concentration will affect our climate by causing increases in temperature and altered weather patterns. Well-mixed greenhouse gases such as CO_2, N_2O, CH_4, and halocarbons, in addition to water–vapour feedback and solar irradiance, contribute to increases in the mean global temperature, which is predicted to continue increasing (IPCC, 2007) [4]. Carbon dioxide (CO_2) in the atmosphere is rapidly rising year by year. It has increased from 270 ppm prior to the Industrial Revolution to 384 ppm in 2009, 388.63 ppm in January 2010, 394 ppm in 2013 (Goufo *et al.*, 2014) [2] and 408.84 ppm in June 2017 (NOAA-NCEI State of the Climate: Global Analysis). The rate of change of CO_2 concentration has accelerated with models predicting that the CO_2 concentration will increase to 550 ppm by the middle of this century and climb up to 800 ppm by the end of this century (Long and Ort, 2010) [7].

Increasing the atmospheric carbon dioxide concentration usually result in a greater plant biomass, in agriculture, horticulture and natural vegetation. Growth stimulation of plants atelevated CO_2 will have a greater demand for nutrient to sustain their faster growth. A greater root biomass and length at elevated CO_2 could improve the plant’s potential to exploit the soil’s available nutrient. The greater increase in nutrient uptake may occur for nutrient that diffuses slowly in the soil solution (e.g. phosphorus), because the average distance of diffusion to the root surface will decrease with greater root length density. Phosphorus, a fascinating essential plant nutrient element is known to be involved in functions in plant growth, membrane synthesis and stability, respiration, photosynthesis, and metabolism. Being an important constituent of nucleic acids, phytins, phospholipids, nucleotides, co-enzymes and enzymes, it is of great importance in the transformation of energy, transfer of hereditary characters, fat and albumin formation and cell organization in plants (McVickar *et al*., 1963) [8]. Several studies have reported that both the magnitude and the direction of the growth response of plants to elevated CO_2 depend on P availability (Jin *et al.*, 2013) [6]. However, only a small proportion of total soil P (generally <1%) is in the form of labile phosphate ions which are available to plants (Richardson *et al.*, 2009) [12]. This means that the plant-available P concentrations in soils are small despite the total P in soils being in the range 200–3000 mg P kg/ha. This presents challenges to plants in acquiring sufficient P from the soil to meet their needs. For some nutrient an improved potential for nutrient uptake under elevated CO_2 might not be realized. Elevated CO_2 increased microbial biomass in the rhizosphere which in turn temporally immobilized P. This study also shows that phosphorus sorption increases with elevated carbon dioxide condition (Jian *et al* 2012) [5]. P is mobilized by desorbing and chelating P from Al–P and Fe–P complexes and from other non-labile pools. However, the extent that elevated CO2 increases P desorption depends on whether elevated CO2 stimulates the release of those carboxylates that are effective immobilizing Pi (Shen *et al*., 2011) [14]. Under elevated CO_2, C3 species (in contrast to C4 species) usually use less water per plant, even if the plants are bigger. The corresponding smaller flow of water through the soil to the root may reduce the uptake of nutrients. Soil microorganisms act as sink and source of phosphorus (P) and mediate key processes in the soil P cycle, e.g., P mineralization and immobilization (Oberson and Joner, 2005) [10]. In the absence of recent carbon inputs, gross organic P mineralization rates of between 1.4 and 2.5 mg P kg day^{-1} have been measured for arable soils (Oehl *et al*., 2004) [11]. As microorganisms in soils regulate the dynamics of organic matter decomposition and P availability, they play a key role in the responses of ecosystems to global climate changes. Elevated CO_2 would affect soil microorganisms indirectly through increased root growth and rhizo-deposition rates (Rouhier *et al*., 1994) [13] because CO_2 concentration in soil is much greater than the atmospheric CO_2. As such, responses of plants such as root dynamics, root-exudates, and litter production and decomposition are of great importance in understanding microbial responses. In recent time the change in rhizosphere environment is likely to affect P acquisition by plant. Question therefore arises as to whether plant P demand on the one hand and P acquisition on the other will be affected more by the increase of atmosphere CO_2 concentration. Understanding this demand and supply balance for labile soil P will be important for developing P management strategies in agricultural system to cope up with increasing atmospheric CO_2 concentration.

Materials and Methods

The present investigation entitled "Effect of Elevated Carbon Dioxide Concentration on Phosphorus Dynamics under Low Land Rice (Variety - Naveen) in Odisha" was conducted in the institute research farm of ICAR-NRRI Cuttack (Odisha) during the Kharif season of 2016. 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 was 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 rhizospheric 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) [16], Acid hydrolyzable carbon content was measured using anthrone method (Haynes and Swift, 1990) [3], Phosphorus sorption was measured using by the (Singh and Jones, 1976) [15] method.

Results and Discussion

Phosphorus dynamics

(a) Phosphorus sorption

Phosphorus sorption properties of the soil were analyzed using both Langmuir (Presented table 1 and Fig 1) and Frendulich (Presented table 2 and fig 2) isotherms. Both the isotherms showed a significant effect on the soil phosphorus sorption properties under elevated carbon dioxide and different phosphorus levels. Phosphorus sorption properties of the soil were analyzed using both Langmuir (Presented Figure 1) isotherms. Both the isotherms showed a significant effect on the soil phosphorus sorption properties under elevated carbon dioxide and different phosphorus levels. Langmuir isotherm predicted that maximum bonding energy (k) was found under ambient condition i.e., (0.155 L mg^{-1}) and minimum value was found under 700 ppm CO_2 concentration i.e., (0.112 L mg^{-1}) it also showed Langmuir adsorption maxima (b) value is maximum in ambient condition i.e., (454.5 mg P kg^{-1}) and minimum value was found under 700 ppm concentration i.e., (370.4 mg P kg^{-1}). After analysis of both the isotherm it can be concluded that phosphorus sorption is gradually decreasing with increase in CO_2 concentration which shows a marked increase in phosphorus availability to the crop under future environmental condition.

Langmuir isotherm $$\frac{c}{s} = \frac{1}{k.b} + \frac{c}{b}$$

Freundlich isotherm $$x = ac^{1/n}$$

Table 1: Phosphorus sorption properties of the soil under different treatments using Langmuir adsorption isotherm

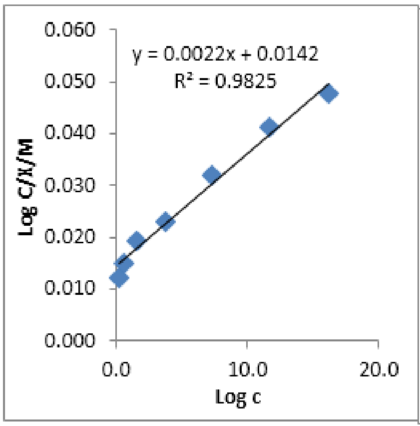
Treatment	Regression equation	R^2	b (mg P kg-1)	k (L mg-1)	mbc (k*b) (L kg-1)
C1P0	y=0.0022x+0.0142	0.98	454.5	0.155	70.4
C1P1	y=0.0023x+0.0184	0.98	434.8	0.125	54.3
C1P2	y=0.0024x+0.0221	0.98	416.7	0.109	45.2
C2P0	y=0.0022x+0.0186	0.98	454.5	0.118	53.8
C2P1	y=0.0024x+0.0247	0.96	416.7	0.097	40.5
C2P2	y=0.0025x+0.0265	0.94	400.0	0.094	37.7
C3P0	y=0.0025x+0.0199	0.96	400.0	0.126	50.3
C3P1	y=0.0027x+0.0230	0.93	370.4	0.117	43.5
C3P2	y=0.0027x+0.0241	0.91	370.4	0.112	41.5

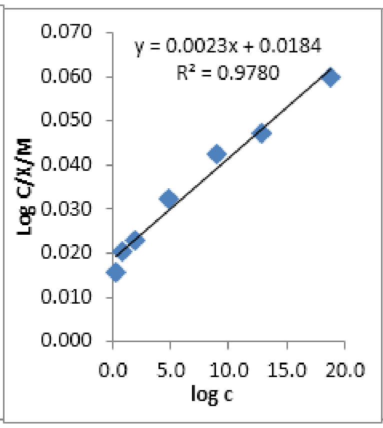
Note: S denotes µg P adsorbed g−1 soil, C the equilibrium P concentration (µg P mL−1), b the Langmuir adsorption maxima (µg P g−1 soil) and k the Langmuir bonding energy constant (ml µg−1).

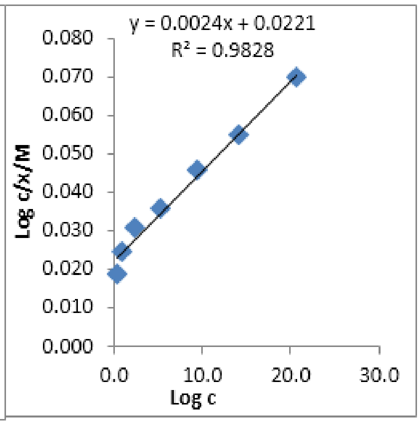
Table 2: Phosphorus sorption properties of the soil under different treatments using Langmuir adsorption isotherm

Treatment	Regression equation	R2	n	A
C1P0	y = 0.5938x + 1.8289	0.9848	1.68	67.437
C1P1	y = 0.5937x + 1.7589	0.9959	1.68	57.398
C1P2	y = 0.6261x + 1.682	0.9816	1.60	48.084
C2P0	y = 0.5753x + 1.7870	0.9863	1.74	61.235
C2P1	y = 0.6339x + 1.6394	0.9763	1.58	43.591
C2P2	y = 0.6388x + 1.6031	0.9731	1.57	40.096
C3P0	y = 0.5816x + 1.7350	0.9762	1.74	54.325
C3P1	y = 0.6134x + 1.6398	0.9863	1.63	43.631
C3P2	y = 0.6382x + 1.6078	0.977	1.57	40.532

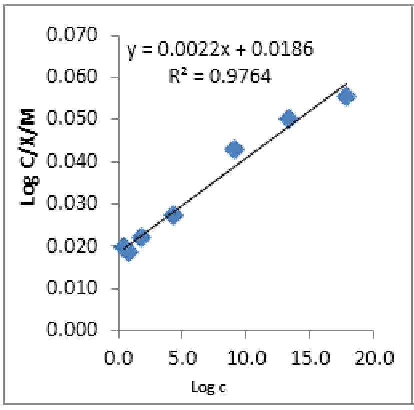
Note: X denotes µg P adsorbed g−1 soil, C the equilibrium P concentration (µg P ml−1), a = the extent of P adsorption (µg P g−1 soil) and n = a constant corresponding to the degree of linearity between the solution equilibrium concentration and adsorption (g ml−1).

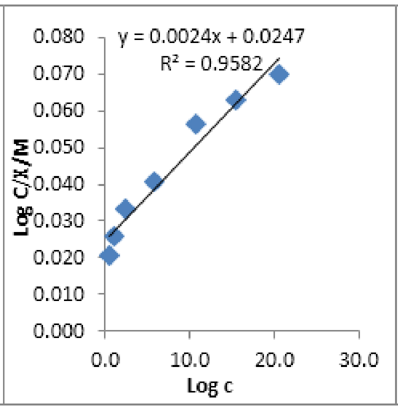


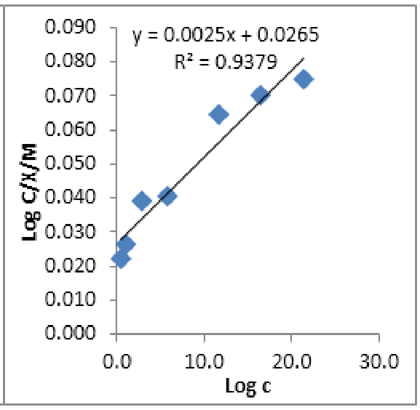




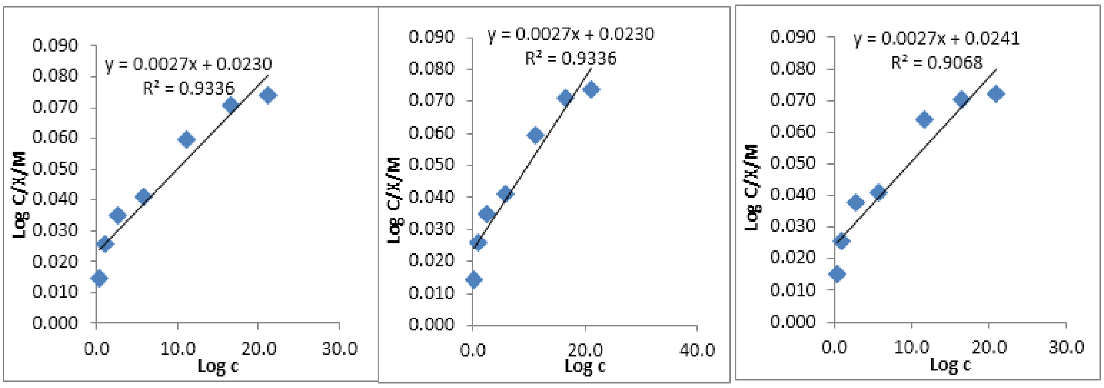
(A) C1P0 (B) C1P1 (C) C1P2





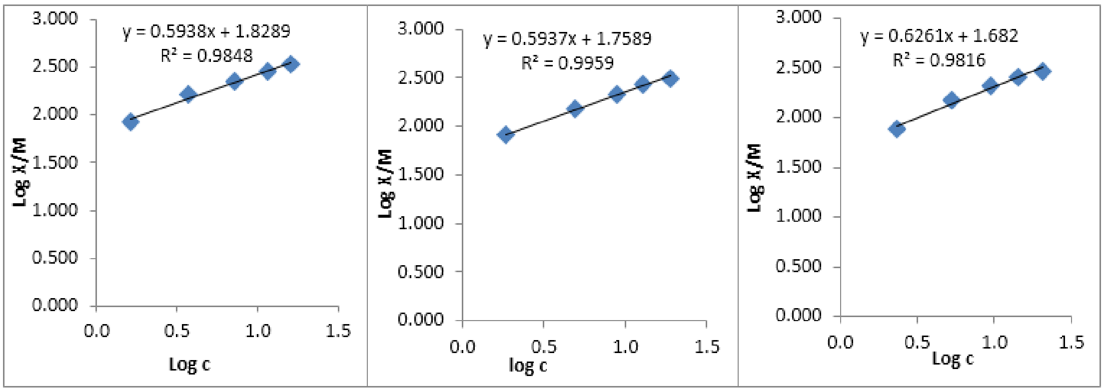


(D) C2P0 (E) C2P1 (F) C2P2

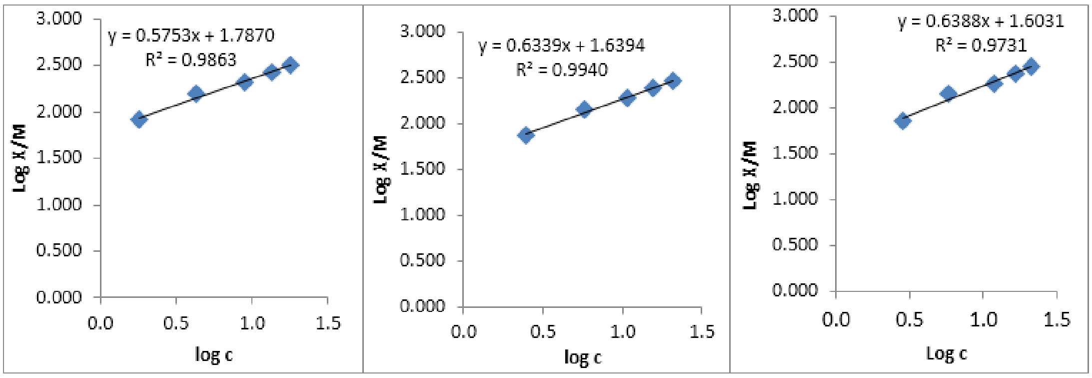


(G) C3P0 (H) C3P1 (I) C3P2

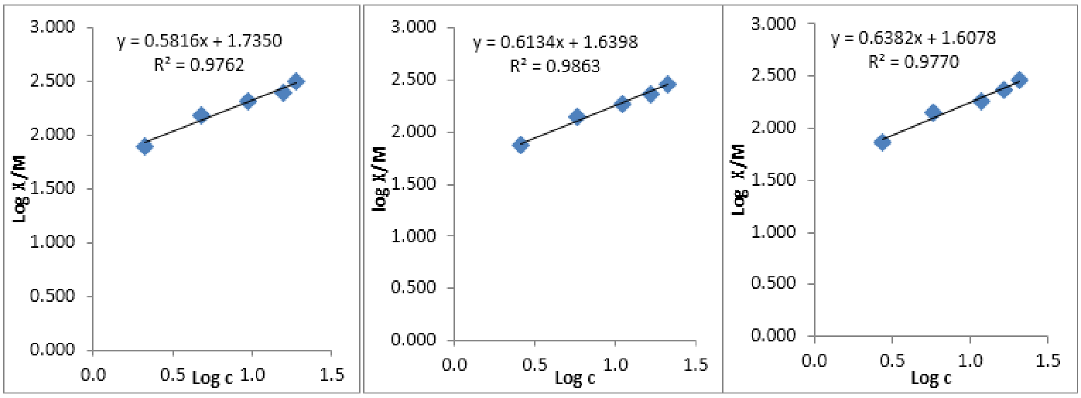
Fig 1: Standard curve of different treatments analyzed with Langmuir isotherm under elevated carbon dioxide and phosphorus doses(C1 - ambient, 390 ppm CO_2; C2 - 550 ppm CO_2; C3 - 700 ppm CO_2; P0- no P; P1 - 25 kg ha^{-1}; P2 - 50 kg ha^{-1}).



(A) C1P0 (B) C1P1 (C) C1P2



(D) C2P0 (E) C2P1 (F) C2P2



(G) C3P0 (H) C3P1 (I) C3P2

Fig 2: Standard curve of different treatments analyzed with Freundlich isotherm 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})

(b) Phosphorus desorption

Phosphorus desorption was analyzed and presented in Fig 3. In the fig it is evident that higher amount of desorption of "P" was found in C3P2 treatment given and lowest was found in C1P0 treatment given. Hence it can be concluded that under elevated carbon dioxide phosphorus desorption i.e., availability of phosphorus will increase to the plant.

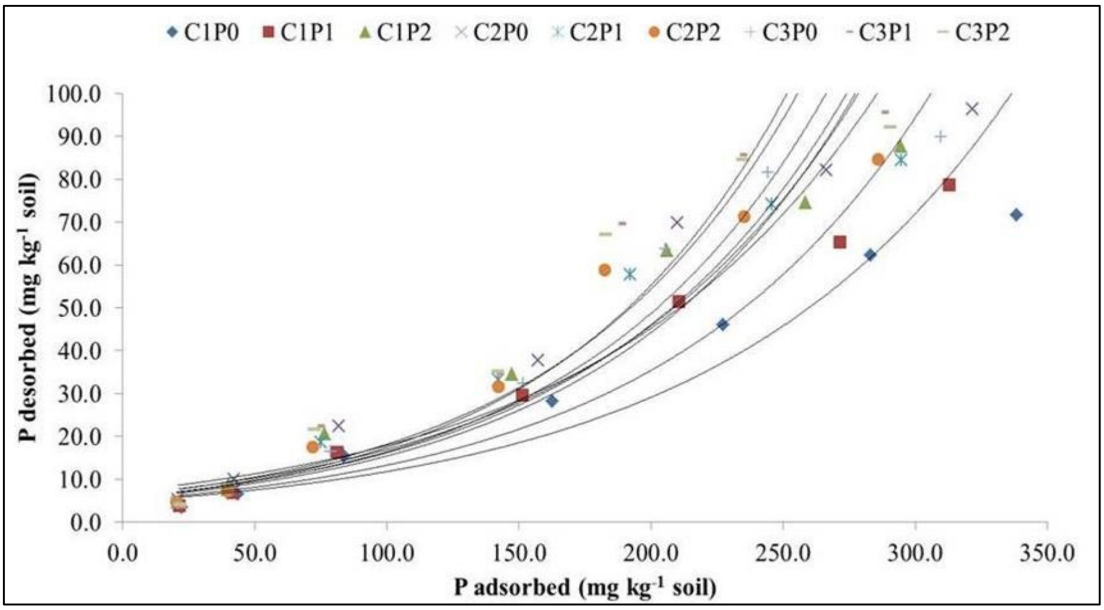


Fig 3: Phosphorus desorption (mg kg^{-1}soil) under elevated carbon dioxide and phosphorus doses. (C1 - ambient, 390 ppm CO_2; C2 - 550 ppm CO_2; C3 - 700 ppm CO_2; P0- P; P1 - 25 kg ha^{-1}; P2 - 50 kg ha^{-1})

Yield

It was 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.

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.

References

1. Bray RH, Kurtz LT. Determination of total, organic and available forms of phosphorous in soils, Soil Sci 1945.
2. Goufoet P, Pereira J, Moutinho-Pereira J. Rice phenolic compounds under elevated carbon dioxide (CO2) concentration. Environmental and Experimental Botany 2014;99:28-37.
3. Haynes RJ, Swift RS. Stability of soil aggregates in relation to organic constituents and soil water content. J. Soil Sci. 1990;41:73-83.
4. IPCC. Climate Change. The Physical Science Basis, Contribution of Work-ing Group-I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge 2007.
5. Jian J, Caixian T, Roger A, Clayton B, Peter S. Elevated CO2 temporally enhances phosphorus immobilization in the rhizosphere of wheat and chickpea. Plant Soil. 2012;368:315-328.
6. Jin J, Tang C, Armstrong R, Butterly C, Sale P. Elevated CO2 temporally enhances phosphorus immobilization in the rhizosphere of wheat and chickpea. Plant and Soil. 2013;368:315-328.
7. Long SP, Ort DR. More than taking the heat: crops and global change Current Opinion in Plant Biology 2010;13:241-248.
8. McVickar MH, Bridger GL, Nelson LB. Advances in phosphate fertilizers. Fertilizer Technology and Usage. Soil Science Society of America, Madison 11, Wisconsin 1963, pp.155-187.
9. National oceanic and atmospheric environmental (NOAA) June. National Centers for Environmental Information (NCEI) is responsible for preserving, monitoring, assessing, and providing public access to the Nation's treasure of climate and historical weather data and information 2017.

10. Oberson A, Joner EJ. Microbial turnover of phosphorus in soil. In: Turner B.L., Frossard, E., Baldwin, D.S. (eds) Organic phosphorus in the environment. CABI, Wallingford. 2005 pp 133-164.
11. Oehl F, Sieverding E, Ineichen K, Mader P, Dubos D, Boller T, Wiemken A. Impact of long-term conventional and organic farming on the diversity of arbuscularmycorrhizalfungi. Oecologia 2004;138:574-583.
12. Richardson AE, Hocking PJ, Simpson RJ, George TS. Plant mechanisms to optimise access to soil phosphorus. Crop & Pasture Science. 2009;60:124-143.
13. Rouhier H, G Billes, El Kohen A, Mousseau M, Bottner P. Effect of elevated CO2 on carbon and nitrogen distribution within a tree (Castaneasativa Mill.)-soil system. Plant Soil 1994;162:281-292.
14. Shen JB, Yuan LX, Zhang JL. Phosphorus dynamics: from soil to plant. Plant Physiology 2011;156:997-1005.
15. Singh BB, Jones JP. Phosphorus sorption and desorption characteristics of soils as affected by organic residues, Soil Sci. Soc. Am. J 1976;40:389-394.
16. Vance ED, Brookes PC, Jenkinson DS. The use of the chloroform fumigation-incubation method in strongly acid soils. Soil. Biol. Biochem 1987;19:697-702.