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Biochemical changes associated with elevated carbon dioxide in rice (*Oryza sativa* L.)

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Abstract
The environmental change has tremendous effect in crop production in the form of increased stress all through the plant growth and development. Consequently the aim of the investigation was to assess the effect of elevated carbon dioxide under artificially induced carbon dioxide condition utilizing an open top chamber with rice genotype CO 51. Rice could provide less protein, nutrients and minerals fundamental for humans be in response to rising carbon dioxide concentrations that are involved in global warming. Increased concentrations of atmospheric carbon dioxide are anticipated to decrease the content of fundamental component, for example, protein in rice, threatening the nutrition of billions of people in the middle of the century. However, changes in plant-based nutrient substance in response to carbon dioxide have not been elucidated. The results from the present investigation revealed that the increased carbon dioxide have negative effects on soluble protein content (mg g^{-1}) and nitrate reductase activity (µmol NO_2 g^{-1} hr^{-1}) and positive effects on sucrose phosphate synthase (µ mol mg^{-1} protein min^{-1}) and starch content (mg g-1) in different crop developing stages.

Keywords: Rice, elevated carbon dioxide, nutrient quality, enzymes

1. Introduction
The environment is continuously changing as a result of man's activities the present investigation is to anticipate, how agriculture will react to the changing environment condition of tomorrow. One of the real main thrusts for worldwide environmental change is the rapid rise in the greenhouse gas concentration in the environment. The human activities have prompted the change of greenhouse gases, for example, methane, carbon dioxide, water vapor, nitrous oxide and chlorofluorocarbons (Gitz *et al*., 2016; Kizildeniz *et al*., 2018; Vinothini *et al*., 2019) [7, 11, 20]. The sensational raise in human population since the pre-industrial period, raised concentration of these gases because of extensive scale utilization of fossil fuels, deforestation, industrialization and urbanization. The carbon dioxide content of atmosphere had been incredibly steady for a few centuries, striking at a normal concentration of around 280 ppm. With the beginning of industrial revolution 1874 the equilibrium was annoyed and the carbon dioxide content of the air started to rise in this manner to remarkable financial development (IPCC, 2014) [10].
The global climate change due to the increase in greenhouse gases, especially CO_2, is having a direct or indirect effect on sustainable agriculture and food production. For the past 800,000 years, the CO_2 level was maintained up to a level between 180–200 and 250–280 ppm before the beginning of the industrial revolution. Once humans started to burn fossil fuels in the industrial era, things changed rapidly. In 2010, the industrialization changed the condition by rising global annual mean of CO_2 to reach the current level of 400 ppm. The intergovernmental panel on climate change (IPCC) suggests that there will be a rise of atmospheric CO_2 to a concentration of 550 ppm by 2050 due to the anthropogenic emission of greenhouse gases (IPCC, 2014) [10].
Possible upcoming climatic change coming about because of expanded atmospheric carbon dioxide concentration and other greenhouse gases, particularly the increase in temperature, hampers our capacity to anticipate worldwide rice production and raises serious inquiries concerning food security for the near future (Myers *et al*., 2017) [16]. Higher concentrations of carbon dioxide are related with decreases in protein and different key nutrients in rice. Rice is the essential source of nourishment for in excess of 2 billion individuals. Diminishes in the nourishing substance of rice could disproportionate affect wellbeing results in the poorest

rice-dependent countries (Ebi and Zizka, 2018) [3]. This investigation gives important insights into how higher CO_2 concentrations could influence the protein content of rice. Along these lines, this experiment was to study about impact of elevated CO_2 on biochemical changes in rice.

2. Materials and Methods

The field experiments were carried out in open top Chamber (OTC) with elevated CO_2 and ambient condition, established at Wetland Farm, Department of Farm Management, Tamil Nadu Agricultural University, Coimbatore. The air enriched CO_2 is distributed through a circular tube and the uniform distribution of the carbon dioxide within the chamber was ensured by air blowers. The CO_2 analyzer established in the OTC measures the concentration of carbon dioxide within and the computer regulated inlet valves will control the flow of the gas (Vinothini *et al*., 2019) [20].

To study the effect of elevated CO_2 on biochemical parameters, the seeds of rice variety CO 51 were sown in a nursery bed and after 20 days, the seedlings were transplanted in the open top chamber with elevated CO_2 and in ambient condition. The field trial was laid out in Randomized Block Design with eight replications. The following observations were recorded at three stages of crop growth and development *viz*., i) Active tillering stage (24 to 42 DAT), ii) Heading stage (55 to 60 DAT) and iii) Grain filling stage (80 to 85 DAT) in the plants raised in the open top chamber chamber as well as under ambient conditions. The details of the treatments are as follows.

2.1 Treatment details

Environmental condition		Level of CO_2 (ppm)
E_1	Ambient condition	400±9
E_2	Open Top Chamber + Ambient CO_2	400±9
E_3	Open Top Chamber + Elevated CO_2	550

The following biochemical parameters were recorded.

2.2 Starch content

Starch content was determined by the Anthrone method (Mcready *et al*, 1950) [15].

2.3 Soluble protein content (mg g^{-1})

Leaf soluble protein was estimated by the method suggested by Lowry *et al*. (1951) [13].

2.4 Sucrose phosphate synthase (μ mol mg^{-1} protein min^{-1})

Sucrose phosphate synthase activity was measured by the method of Huber (1992) [9].

2.5 Nitrate reductase activity (μmol NO_2 g^{-1} hr^{-1})

Nitrate reductase activity in the leaves at different stages was estimated by the method suggested by Evans and Nason (1953) [4].

2.6 Statistical analysis

The analysis of variance was carried out and comparison was done by Duncan's multiple range test (DMRT). The mean difference is significant at the P-values < 0.05. Statistical analysis was performed using the SPSS 16.0 software (SPSS Inc., Chicago, USA).

3. Result and Discussion

3.1 Soluble protein content (mg g^{-1})

Soluble protein content was showed a significant difference due to a different environmental condition. The increase in soluble protein content was observed from tillering stage to the heading stage and a gradual decrease towards the grain filling stage. The highest soluble protein content (5.07, 8.03 and 7.11) registered in ambient condition at 30, 60 and 85 DAT followed by OTC + ambient CO_2 (4.95, 7.29 and 6.74) and the lowest was registered in OTC + elevated CO_2 (4.52, 6.98 and 6.24) (Table 1). Longer exposure to raised CO_2 results in acclimation of photosynthesis with down-guideline of the degree of Rubisco protein. This coarse control of the degree of Rubisco protein serves to improve CO_2 acquiring with use of the fixed carbon. Notwithstanding coarse control of Rubisco protein, there are fine controls, which react all the more quickly to changes in environmental conditions. In such manner, two important components are known to manage Rubisco action. One includes the reversible carboxylation of lysine buildup in the dynamic site to actuate the enzyme, while the different operates by the reversible binding of 2-carboxyarabinitol-1 phosphate, the Rubisco dark inhibitor, to the carboxylates site (Zhu *et al*., 2018) [21]. Nitrogen deficiency brought about the diminishing in the content of protein, including Rubisco, and chlorophyll, and decrease in photosynthetic capacity and carboxylation effectiveness. Under this hypothesis, diminishes observed in Rubisco may reflect a general decrease of leaf protein, because of reallocation of nitrogen inside the plant (Makino, 2003; Taub, 2008) [14, 19].

Table 1: Changes in soluble protein content (mg g^{-1}) of rice under ambient and elevated CO_2 condition

Treatments	Soluble protein content (mg g^{-1})		
	Tillering stage	Heading stage	Grain filling stage
E_1 - Ambient condition	5.07±0.02 ^{a}	8.03±0.05 ^{a}	7.11±0.05 ^{a}
E_2 – OTC + Ambient CO_2	4.95±0.01 ^{b}	7.29±0.08 ^{b}	6.74±0.06 ^{b}
E_3 - OTC + Elevated CO_2	4.52±0.04 ^{c}	6.98±0.02 ^{c}	6.24±0.03 ^{c}

Data presented are means from eight replicates with standard errors. Within each treatment, different letters at each column indicate significant differences by Duncan's multiple range test at $P<0.05$

3.2 Starch content (mg g^{-1})

The environmental condition had a significant influence on starch content at various growth stages of the plant. Among the environmental condition, the highest starch content was recorded in OTC + elevated CO_2 (52.6, 69.6 and 54.6) followed by OTC + ambient CO_2 (42.4, 54.6 and 46.3), while the lowest was in ambient condition (32.8, 49.5 and 38.7) at 30, 60 and 85 DAT (Table 2). Under elevated CO_2 condition, a major storage carbohydrate starch is also increased in plants (Aranjuelo *et al*., 2008) [2]. This increase in starch likely contributes to the high levels of sucrose observed with elevated CO_2, due to the conversion of starch to sucrose overnight. For normal plant growth conversion of starch to sucrose is essential and increased in starch likely contributes to the high level of sucrose (Zhu *et al*., 2016) [22]. However, under elevated CO_2 it may contribute to the accumulation of sucrose. In plants grown under ambient CO_2 the starch content builds up during the day and disappears overnight. The increased production of starch under elevated CO_2, however, means that not all of the plant's starch reserves are depleted during the night, leading to a gradual accumulation in leaves over time (Aoki *et al*., 2003) [1].

Table 2: Changes in starch content (mg g^{-1}) of rice under ambient and elevated CO_2 condition

Treatments	Starch content (mg g^{-1})		
	Tillering stage	Heading stage	Grain filling stage
E_1 - Ambient condition	32.8±0.09 ^{c}	49.5±0.7 ^{c}	38.7±0.5 ^{c}
E_2 - OTC + Ambient CO_2	42.4±0.09 ^{b}	54.6±0.4 ^{b}	46.3±0.6 ^{b}
E_3 - OTC + Elevated CO_2	52.6±0.04 ^{a}	69.6±0.1 ^{a}	54.6±0.7 ^{a}

Data presented are means from eight replicates with standard errors. Within each treatment, different letters at each column indicate significant differences by Duncan's multiple range test at $P<0.05$

3.3 Sucrose phosphate synthase (μ mol mg^{-1} protein min^{-1})

Sucrose phosphate synthase was significantly influenced by environmental condition. The increase in soluble protein content was observed from tillering stage to the heading stage and a gradual decrease towards the grain filling stage. Highest sucrose phosphate synthase of (23.1, 25.3 and 23.9) in OTC + elevated CO_2 was followed by OTC + ambient CO_2 (20.8, 23.1 and 21.0) and the lowest in ambient condition (20.1, 22.4 and 20.2) at 30, 60 and 85 DAT (Table 3). The raised CO_2 up controlled activities of the sugar metabolizing enzymes, sucrose phosphate synthase (SPS) and adenosine-S'diphosphoglucose pyrophosphorylase (AGP), bringing about more prominent accumulation and export of carbohydrates related with photosynthetic activities, in spite of decrease in rubisco activity and Rubisco protein content (Sun *et al*., 2011). Gesch *et al*. (2002) [18, 6] revealed that raised CO_2 altogether increased the activity of sucrose phosphate synthase (a key protein in the production of sucrose) and ADP glucose phosphorylase (a key enzyme in starch synthesis in rice). Lee *et al*. (2005) [12] likewise revealed an increase in the sucrose phosphate synthase activity in rice at raised CO_2. The increased sucrose phosphate synthase activity was because of the reallocation of nitrogen far from Rubisco and into sucrose phosphate synthase, along these lines prompting a more prominent sucrose synthesis and export of photosynthates from the leaves. These investigations infer that rice responds to increasing CO_2 concentrations by moving the priority of allocation of sugars more towards export than starch storage, thus preventing the feedback inhibition.

Table 3: Changes in sucrose phosphate synthase (μ mol mg^{-1} protein min^{-1}) of rice under ambient and elevated CO_2 condition

Treatments	Sucrose phosphate synthase (μ mol mg^{-1} protein min^{-1})		
	Tillering stage	Heading stage	Grain filling stage
E_1 - Ambient condition	20.1 ± 0.24 ^{c}	22.4 ± 0.30 ^{c}	20.2 ± 0.23 ^{b}
E_2 - OTC + Ambient CO_2	20.8 ± 0.14 ^{b}	23.1 ± 0.07 ^{b}	21.0 ± 0.20 ^{b}
E_3 - OTC + Elevated CO_2	23.1 ± 0.20 ^{a}	25.3 ± 0.31 ^{a}	23.9 ± 0.20 ^{a}

Data presented are means from eight replicates with standard errors. Within each treatment, different letters at each column indicate significant differences by Duncan's multiple range test at $P<0.05$.

3.4 Nitrate reductase activity (μmol NO_2 g^{-1} hr^{-1})

The difference in nitrate reductase activity was significant due to an environmental condition. The gradual decrease in nitrate reductase activity was observed during the grain filling stage. The highest nitrate reductase activity was observed in ambient condition (1.35, 3.42 and 2.62) at 30, 60 and 85 DAT followed by OTC + ambient CO_2 (1.02, 3.11 and 2.13) while the lowest (0.93, 2.38 and 1.42) was registered in OTC + elevated CO_2 (Table 4). Raised CO_2 prolonged accumulation of carbon in various plant parts. In spite of the point that the nitrate reductase action increased, the nitrogen concentration and the soluble protein content in the plant parts were diminished. Raise in temperature decreased the nitrate reductase activity and the accumulation of carbon and nitrogen in various plant parts. Though, this decrease was more under raised CO_2. Raised CO_2 positively influenced the nitrate reductase activity (Fujita *et al*., 2002; Rakshit *et al*., 2012; Hofmann *et al*., 2013) [5, 17, 8].

Table 4: Changes in nitrate reductase activity (μmol NO_2 g^{-1} hr^{-1}) of rice under ambient and elevated CO_2 condition

Treatments	Nitrate reductase activity (μmol NO_2 g^{-1} hr^{-1})		
	Tillering Stage	Heading Stage	Grain filling Stage
E_1 - Ambient condition	1.35 ± 0.004 ^{a}	3.42 ± 0.05 ^{a}	2.62 ± 0.04 ^{a}
E_2 - OTC + Ambient CO_2	1.02 ± 0.007 ^{b}	3.11 ± 0.03 ^{b}	2.13 ± 0.02 ^{b}
E_3 - OTC + Elevated CO_2	0.93 ± 0.001 ^{c}	2.38 ± 0.03 ^{c}	1.42 ± 0.01 ^{c}

Data presented are means from eight replicates with standard errors. Within each treatment, different letters at each column indicate significant differences by Duncan's multiple range test at $P<0.05$.

4. Conclusion

The anthropogenic increase in the atmospheric carbon dioxide concentration will influence the crop growth both by rising the atmospheric temperature in addition to by changing the biological processes in the plant system. Response of rice under elevated CO_2 using the open top chamber exhibited a significant increase in growth and development. The sucrose phosphate synthase along with the content of starch was increased. Elevated CO_2 positively affected the soluble protein content and nitrate reductase activity of the rice.

5. References

1. Aoki N, Ono K, Sasaki H, Seneweera SP, Sakai H, Kobayashi K *et al*. Effects of elevated CO_2 concentration on photosynthetic carbon metabolism in flag-leaf blades of rice before and after heading. Plant production science. 2003; 6(1):52-8.
2. Aranjuelo I, Irigoyen JJ, Sanchez-Diaz M, Nogues S. Carbon partitioning in N_2 fixing Medicago sativa plants exposed to different CO_2 and temperature conditions. Functional Plant Biology. 2008; 26:35(4):306-17.
3. Ebi KL, Ziska LH. Increases in atmospheric carbon dioxide: Anticipated negative effects on food quality. PLoS Med. 2018; 15(7).
4. Evans HJ, Nason A. Pyridine nucleotide-nitrate reductase from extracts of higher plants. Plant Physiology. 1953; 28(2):233.
5. Fujita K, Nobuyasu H, Kuzukawa T, Adu-Gyamfi JJ, Mohapatra PK. Elevated CO_2 concentrations increase leaf nitrate reduction by strengthening sink activity in soybean plants. Soil science and plant nutrition. 2002; 48(5):745-52.
6. Gesch RW, Vu JC, Boote KJ, Allen LH, Bowes G. Sucrose-phosphate synthase activity in mature rice leaves following changes in growth CO_2 is unrelated to sucrose pool size. New Phytologist. 2002; 154(1):77-84.
7. Gitz V, Meybeck A, Lipper L, Young CD, Braatz S. Climate change and food security: risks and responses. Food and Agriculture Organization of the United Nations (FAO) Report, 2016, 110.
8. Hofmann LC, Straub S, Bischof K. Elevated CO_2 levels affect the activity of nitrate reductase and carbonic anhydrase in the calcifying rhodophyte Corallina officinalis. Journal of experimental botany. 2013; 64(4):899-908.
9. Huber PJ. Robust estimation of a location parameter. In Breakthroughs in statistics, Springer, New York, NY, 1992, 492-518.
10. IPCC. Climate change: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 2014.
11. Kizildeniz T, Irigoyen JJ, Pascual I, Morales F. Simulating the impact of climate change (elevated CO2 and temperature, and water deficit) on the growth of red and white Tempranillo grapevine in three consecutive growing seasons (2013–2015). Agricultural water management. 2018; 202:220-30.
12. Lee MH, Yang CC, Su JC, Lee PD. Biochemical characterization of rice sucrose phosphate synthase under illumination and osmotic stress. Botanical Bulletin of Academia Sinica, 2005, 46.
13. Lowry OH, Rosebrough NJ, Farr AL, Randall RJ. Protein measurement with the Folin phenol reagent. Journal of biological chemistry. 1951; 193:265-75.
14. Makino A. Rubisco and nitrogen relationships in rice: leaf photosynthesis and plant growth. Soil Science and Plant Nutrition. 2003; 49(3):319-27.
15. McReady RM, Guggolz JV, Sil V, Owens HS. Determination of starch and amylose in vegetables. Analytical Chemistry. 1950; 22:1156-8.
16. Myers SS, Smith MR, Guth S, Golden CD, Vaitla B, Mueller ND *et al*. Climate change and global food systems: potential impacts on food security and under nutrition. Annual review of public health. 2017; 38:259-77.
17. Rakshit R, Patra AK, Pal D, Kumar M, Singh R. Effect of elevated CO_2 and temperature on nitrogen dynamics and microbial activity during wheat (*Triticum aestivum* L.) growth on a subtropical inceptisol in India. Journal of agronomy and crop science. 2012; 198(6):452-65.
18. Sun J, Zhang J, Larue CT, Huber SC. Decrease in leaf sucrose synthesis leads to increased leaf starch turnover and decreased RuBP regeneration-limited photosynthesis but not Rubisco-limited photosynthesis in Arabidopsis null mutants of SPSA1. Plant, cell & environment. 2011; 34(4):592-604.
19. Taub DR, Miller B, Allen H. Effects of elevated CO_2 on the protein concentration of food crops: a meta-analysis. Global Change Biology. 2008; 14(3):565-75.
20. Vinothini N, Manonmani V, Karthikeyan S. Seed priming to mitigate the impact of elevated carbon dioxide associated temperature stress on germination in rice (*Oryza sativa* L.). Archives of Agronomy and Soil Science, 2019. DOI: 10.1080/03650340.2019.1599864
21. Zhu C, Kobayashi K, Loladze I, Zhu J, Jiang Q, Xu X *et al*. Carbon dioxide levels this century will alter the protein, micronutrients, and vitamin content of rice grains with potential health consequences for the poorest rice-dependent countries. Science advances. 2018; 4(5):1012.
22. Zhu C, Xu X, Wang D, Zhu J, Liu G, Seneweera S. Elevated atmospheric CO_2 stimulates sugar accumulation and cellulose degradation rates of rice straw. Gcb Bioenergy. 2016; 8(3):579-87.