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Effect of elevated carbon dioxide (eCO_2) on yield and yield components of different rice cultivars in Odisha

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Abstract
The present study was conducted in collaboration with Department of Agricultural Meteorology, OUAT and Central Research Farm, Bhubaneswar by undertaking a pot experiment in Open Top Chamber (OTC) to study yield and yield attributes of seven kharif rice cultivators to eCO_2 (476 ppm) during Kharif season, 2012. The experiment was explained by three yield components; panicle numbers/hill, filled grain numbers/panicle and 1000-grain weight under eCO_2 conditions. Yield in eCO_2 OTC was found to be more than open field by 2.08 $ghill^{-1}$ (14.5%) associated with increased number of filled grains/panicle (58.8%) and 3.1 $ghill^{-1}$ more dry matter production compared to open field. However, decreased panicle numbers/hill (40%) and increased grain chaffyness (147%) attributed towards smaller increase in yield under eCO_2 than open field condition. So, early and medium maturity cultivars produced more grain yield than the late maturity cultivars and eCO_2 produced less grain yield than ambient CO_2 by 5.76 $ghill^{-1}$.

Keywords: carbon dioxide, yield, harvest index, rice cultivar, dry matter

1. Introduction

Rice, with an annual production of 0.6 Billion Tonne (BT) is most important cereal crop for feeding world population [1]. More than half of the world population (about 63%) in Asia depends on rice as their staple food. In India, rice is the most important cereal crop with an area of 44.8 Million Hector (MH) and producing about 91.8 Million Tonne (MT) which is contributing about 21% of the global rice production next to China [2]. Odisha is a major rice growing state of India having rice grown area of about 4.4 MH [3]. Carbon dioxide (CO_2) is one of the key inputs required for photosynthesis, biomass production and yield formation in all agricultural crops. The energy production from fossil fuels has increased atmospheric CO_2 concentration from 280 $\mu molmole^{-1}$ to 370 $\mu molmol^{-1}$since 1750 and may reach 550 $\mu molmol^{-1}$ by middle of 21st century [4]. The direct effect of increased CO_2 concentration is expected to enhance the growth and yield of many C_3 agricultural crops including rice [5]. So, to meet the future rice demand due to increasing population, it is therefore essential to produce rice more efficiently under elevated CO_2. According to laboratory experiment, rice grown at a higher CO_2 level has more vegetative growth than rice grown at an ambient level of CO_2 and open field [6]. However, Razzaque *et al.* [7] discovered that growth and yield responses of rice to eCO_2 differed with genotype. The high yield varieties generally responded less than local varieties.

Reliable criteria for rice cultivators and eCO_2 studies were not so developed in India neither in Odisha even though it is counted as a rice growing state of the country. So, we have undertaken a pot experiment in Open Top Chamber (OTC) at Central Research Farm, Bhubaneswar during Kharif season of 2012 to study yield and yield attributes of seven kharif rice cultivators to eCO_2.

2. Materials and Methods

The experiment conducted in Open Top Chamber (OTC) in Central research Station, Orissa University of Agriculture and Technology, Bhubaneswar situated at 20° 15'N and85°'52 E, 65 km west of Bay of Bengal during kharif season from July-October month of 2012. Top soil 0 to 30 cm depth from commercially cultivated rice plot of 5 year was used to fill pots. Physiochemical analysis of composite soil was found to be loamy, sandy, acidic soil with available Nitrogen (N) and Potassium oxide (K_2O) was also available with low organic carbon content. The soil was also consists of medium amount of available Phosphorus Pentoxide (P_2O_5) content, The climatic condition of Central research station was considered to be warm and moist with hot humid summer and a short mild winter.

The region falls in moist hot group with an average rainfall coded as $D_1E_3(B_1A_2B_1)C_1D_1E_2$ as established by Lenka [8]. The region gets rainfall through south-west monsoon which usually sets on 10^{th}June and recede by 15^{th} October having an average rain fall of about 1240 mm. The pot experiment conducted in seven varieties Mandakini (95-100 days average grain yield 2583 $kgha^{-1}$), Jyotirmayee (95 days average grain yield 4387 $kgha^{-1}$), Khandagiri (95 days average grain yield 3220 $kgha^{-1}$), Tejaswani (130 days average grain yield 4898 $kgha^{-1}$), Hiranmayee (130 days average grain yield 5453 $kgha^{-1}$), Ramchandi (150-155 days average grain yield 4151 $kgha^{-1}$) and Swarna (140 days average grain yield 3728 $kgha^{-1}$).

Eight OTC in two rows separated by 3.3 m distance in between in East-West direction of circular shape was made up of weather resistant heavy duty UV filtered polycarbonate sheets (100% transmission), 4 m height along with diameter. From a height of 3.5 m CO_2 was supplied to OTCs through micropipeline from 47 Litres (l) gas cylinder containing 22 kg CO_2 at 8 bar pressure in the control room located near OTCs. The temperature and relative humidity sensors inside the OTCs were direct capacitance type according to Ambetronics Company. The center was provided with digital panel output display which was supported by software packages for analysis. Air temperature measured at 1.2 m height by thermometer shielded from direct solar radiation. The gate of first row of OTC s was faced towards south and other towards north.

The pot experiment was conducted in seven variety in Open field, OTCs with ambient CO_2 (380 ppm) concentration and elevated CO_2 (476 ppm) concentration. Seasonal weather in open field was having 20 rainy days with 252.8 mm rainfall. Mean temperature was found to be maximum at 2 PM as 30.8°C and minimum at 7 AM as 19.1°C. The mean maximum temperature in Open field, OTCs with ambient CO_2 (380ppm) concentration and elevated CO_2 (476 ppm) concentration was established to be 30.8 °C, 31.3 °C and 33.3°C respectively. However, the CO_2 content in ambient OTC (341.9 ppm) was close to outside air (355.3 ppm) but it was revealed that eCO_2 OTC had 24.8% CO_2 more than outside. Pot filling, transplanting, cultural operation and harvesting were done as per normal procedure.

One hill was destructively sampled from each combination for panicle numbers per hill, total grain numbers per panicle (including filled grains and chaffy grains) and 1000-grain weight. Panicle number was counted pot wise by detaching it from first node, total grain number of a panicle and 1000-grain weight was counted by selecting a healthy mature panicle. Harvest index was calculated by the ratio of grain yield per pot to total above ground biomass of the pot weighted before weighing for yield.

3. Statistical Analysis

The observed value for growth, yield and yield components were subjected to analysis of variance (ANOVA) following standard statistical procedure for randomized complete block design for interaction effect and completely randomized design for environmental effect [9]. All the statistical analyses were conducted using SAS 9.2 software [10].

4. Results

The increase in temperature under eCO_2 was higher 2.3ºC during whole cropping period. The increased temp was as high as 5.4°C during flowering in medium maturity cultivars and 2.6-3ºC during Panicle Initiation (PI) to flowering stage in late maturity cultivar. In ambient OTC the cultivar Khandagiri had higher 1000-grain weight (24.67 g) than Jyotirmayee, Ramchandi and Swarana. Under elevated CO_2 OTC cultivar Ramchandi had higher 1000-grain weight (27.29 g) than all other cultivar. Khandagiri had higher number of total grains per panicle under open field (161) and ambient OTC conditions (261) than all other cultivar. Under eCO_2 condition, the cultivar Khandagiri had higher number of total grains per panicle (230) than all other cultivars except Hiranmayee. Across the environments, varieties differed in total grain number per panicle. The cultivar Khandagiri had higher number of total grains per panicle (202) than all other cultivar. Elevated CO_2 OTC produced significantly higher number of total grains per panicle (185) than the open field condition (103) and ambient OTC. In interaction of variety and envioronment ambient OTC produced highest number of total grain per panicle with Khandagiri (216) than open field condition with cultivar Swrana. Under open field and eCO_2 conditions, Khandagiri had higher number of filled grain per panicle (130 and 184) than all other cultivars respectively. Under ambient OTC Khandagiri and Hiranmayee produced 191 filled grains per panicle. Across environment cutivar Khandagiri had higher number of filled grain per panicle (169) than other cultivars. Number of filled grains per panicle was higher under ambient OTC (135) and almost same under eCO_2 condition (127) than open field condition (80). Variety of environmental effects was compared with ambient CO_2. OTC produced highest number of filled grains per panicle (193) with the cultivar Khanadagiri and under open field condition swarna had lowest number of filled grains per panicle (62). Environment effect was not significant at maturity stage. Across three environments, the cultivar Jyotirmayee had higher productive panicle numbers per hill (10) than the cultivars Khandagiri (6) and Ramchandi (7). All other cultivar did not differ in productive panicle number. The harvest index of cultivar khandagiri was highest (0.59) across the three environments, but Hiranmayee had the highest HI (0.76) under ambient OTC condition than other cultivars. When yield was considered, ambient OTC produced higher yield (22.13 $ghill^{-1}$) than eCO2 OTC (16.37 $ghill^{-1}$) and open field condition (14.29 $ghill^{-1}$). However, the cultivar Hiranmayee produced highest grain yield (40.29 $ghill^{-1}$) under ambient OTC condition than all other cultivars.

5. Discussion

Rice grain yield under eCO2 was 14.5% higher across the varieties than under open field condition. This result is in agreement with the previous research works showing that increased CO_2 concentration under controlled environment chambers increased the grain yield of rice [11, 12, 13]. The increase in yield was primarily influenced by an increase in harvest index (HI, 67%) under eCO_2 [13, 14]. In the present study a larger increase in HI but smaller increase in yield can be explained by the three yield components, namely panicle numbers per hill, filled grain numbers per panicle and 1000-grain weight. There was a significant increase in filled grain number per panicle (58%) and a similar increase in 1000 grain weight (13%). Similar result for slight increase in 1000-grain weight was also reported by others [15, 16, 17]). However, Shimono *et al*. [18] reported a small decrease in 1000-grain weight under eCO_2 (570±35 μmol mol-1). In case of filled grains per panicle, the former researchers reported a small increase in filled grain percentage under eCO_2 [11, 18]. On the other hand, Cheng *et al*. [14] reported a higher increase in filled grain percentage (29%) under eCO_2, and it was influenced by lower night temperature. In the present study, increase in HI was greatly contributed by increased number of filled grain per panicle.

One of the major yield components, panicle number per hill decreased (40%) under eCO_2 than open field condition. Although tiller number per hill was little higher under eCO_2, but the increased total grain chaffyness (sterility) decreased the productive panicle numbers per hill under eCO_2. Such increase in grain sterility was associated with the higher night temperature (2.3ºC higher) and humidity (84%) under eCO_2 compared with outside thermal regimes. The results were almost the similar with the earlier results that spikelet sterility percentage was associated with higher temperature (1 to 2ºC) under eCO_2 [15].

Moreover, ambient CO_2 produced higher grain yield than eCO_2 or open field. The main reasons attributed to higher yield under ambient CO_2 were more panicle numbers per hill than eCO_2, higher filled grains per panicle than eCO_2 and open field and lower chaffy grains per panicle than eCO_2 with higher HI both from eCO_2 and open field conditions [16]. The Dry matter production in the present experiment was higher under eCO_2 than under open field. The results are inline of findings of several coworkers that total dry matter per stem was greater under eCO_2 [18, 19, 20].

6. Conclusion

Elevated CO2 increased yield 2.08 g $hill^{-1}$ i.e 14.5% in rice cultivar than open field condition but elevated CO_2 produced 5.76 g $hill^{-1}$ less grain yield than ambient CO_2. Harvest index more under eCO_2 (0.57) than from open field (0.34). Harvest indices of early and medium maturity cultivars were more than in open field condition. 82% and 58% increase in total grains per panicle and number of filled grain per panicle under eCO_2. Panicle number per hill decreased 40% in under eCO_2 than open field and ambient field condition. Grain chaffyness increased 147% than from open field condition. Medium maturity cultivar produced more number of chaffy grains than early and late maturity cultivars.

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8. References

1. IRRI. International Rice Research Institute. Rice almanac: source book for the most important economic activity on earth, Oxon, UK: CABI publishing. 2002; 71-74.
2. FAO. Food and Agriculture Organization of United Nations. 2006-07. faostat.fao.org.
3. State-wise Area, Production and Productivity of Rice during 2007-08 to 2009-10. Directorate of rice development, Patna, Government of India, Ministry of Agriculture. 2011; 5.
4. McCarthy JJ, Canziani OF, Leary NA, Dokken DJ, Whiteseeds KS. Climate change 2001: Impacts, Adaptation and Vulnerability. 3rd Assessment Report of the Intergovernmental Panel for climate change. Cambridge University Press, Cambridge. 2001; 106-113.
5. Kimball BA, Idso SB, Jhonson S, Rilling MT. Seventeen years of carbon dioxide enrichment of sour orange trees: Final results. Global change biology. 2007; 13:2171-2183.
6. Da Matta FM, Adriana G, Bruna A, Marcos S, Buckeridge E. Impacts of climate changes on crop physiology and food reality. Journal of Food Research. 2009; 34:1-10.
7. Razzaque MA, Haque MM, Khaliq QA, Soliman ARM, Hamid A. Effect of CO_2 and Nitrogen levels on yield and yield attributes of rice cultivars. Bangladesh Journal of Agricultural Research. 2011; 36(2):213-221.
8. Lenka D. Classification of rainfall zones and drought prone areas (in) water requirement of crops in Orissa. Publisher Directorate of Agriculture, Govt. of Orissa. 1976; 4-5.
9. Gomez KA, Gomez AA. Statistical procedures for agricultural research. A Willey inter-science publication, New York. 1984; 76-83.
10. SAS. Base SAS 9.4 Utilities: Reference. Cary, NC, USA, SAS Institute Inc, 2013.
11. Kim HY, Lieffering M, Miura S, Kobayashi K, Okada M. Growth and nitrogen uptake of CO_2-enriched rice under field condition. New Phytologist. 2001; 150:223-229.
12. De Costa WAJM, Weerakon WMW, Herath HMLK, Abeywardena RMI. Response of growth and yield of rice (*Oryza sativa*) to Elevated atmospheric Carbon Dioxide in the sub-humid zone of Sri lanka. Journal of Agronomy and Crop science. 2003; 189:83-95.
13. Anisworth EA, Beier C, Calfapietra C. Next generation of elevated CO_2experiments with crops: a critical investment for feeding the future world. Plant, Cell and Environment. 2008; 31:1317-1324.
14. Cheng W, Sakai H, Yagi K, Hasegawa T. Interaction of elevated CO_2 and night temperature on rice growth and yield. Agricultural and Forest Meteorology. 2009; 149:51-58.
15. Madan P, Jagdish SVK, Craufurd PQ, Fitzgerald M, Lafarage T, Wheeler TR. Effect of elevated CO_2 and high temperature on seed set and grain quality of rice. Journal of experimental botany. 2012; 63(10):3843-3852.
16. Weerakon WMW, Ingram KT, Moss DN. Atmospheric CO_2 concentration on N partitioning and fertilizer N recovery in field grown rice (*Oryza sativa L*). Agriculture, Ecosystems and Environment. 2004; 108:342-349.
17. Yang L, Huang J, Yang H, Zhu J, Liu H, Dong G, *et al*. The impact of free- air CO_2 enrichment (FACE) and N supply on yield formation of rice crops with large panicle. Field crop research. 2006; 98:141-150.
18. Shimono H, Okada M, Yamakawa Y, Nakamura H, Kobayashi K, Hasegawa T. Rice yield enhancement by elevated CO_2 is reduced in cool weather. Global change biology. 2008; 14:276-284.
19. Yang L, Liu H, Wang Y, Zhu J, Huang J, Liu G, *et al*. Yield formation of CO_2-enriched inter-sub specific hybrid rice cultivar Liangyoupeijiu under fully open-air filled conditions in a warm sub-tropical climate. Agriculture, Ecosystem and Environment. 2009; 129(1):193-200.
20. Sakai H, Yagi K, Kobayashi K, Kawashima S. Rice Carbon Balance under Elevated CO_2. New Phytologist. 2001; 150:241-249.