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Elevated CO_2 influenced morpho-physiological traits and yield of rice (*Oryza sativa* L.) genotypes

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Abstract
Atmospheric greenhouse gases (GHGs) concentration has increased in past few decades by the anthropogenic activities which leads to climate change. This changing climate will certainly have impact on agricultural production. An experiment was conducted to investigate the relationship between morpho-physiology and grain yield of rice genotypes under elevated CO_2 condition. Ten short duration rice genotypes *viz.,* N22, ADT 36, ADT 37, ADT 43, ADT 45, CO 51, ASD 16, MDU 6, TPS 5 and Anna (R) 4 were chosen for this study. This experiment was conducted using Open Top Chambers (OTC). Two treatments were given 1. Ambient CO_2 (400 ppm) and 2. elevated CO_2 (550 ppm) during flowering phase. Elevated CO_2 resulted significant changes in morpho-physiological parameters such as plant height, tiller number, leaf area, SPAD chlorophyll index and 1000 grain weight of rice genotypes. N22 followed by Anna (R) 4 and ASD 16 recorded more yield. Elevated CO_2 condition influenced morpho-physiological parameters, which found to be associated with high grain yield under elevated CO_2 condition than plants grown under ambient CO_2 condition.

Keywords: Rice, elevated CO_2, leaf area, total chlorophyll content, SPAD chlorophyll index

Introduction
Since 1750, concentration of atmospheric CO_2 has increased from 278 ppm (Pearson and Palmer, 2000) [5] to currently 400 ppm (IPCC, 2014) [8]. The CO_2 concentration is projected to rise further for the next 50 years even if various efforts are made to reduce carbon emissions (Fisher *et al.*, 2007). Among the various climate changes expected to occur, an increase in CO_2 is one of the few that will have positive influences on crop production by promoting photosynthetic rates. The mechanisms and magnitude of elevated CO_2 effects on crop productivity have been studied for decades using various research facilities including growth chambers, open-top chambers and free-air CO_2 enrichment (FACE) facilities. Previous studies indicated that major C3 cereals show a similar yield response to elevated CO_2, *i.e.* 10-20% greater yield under 550-660 μmol mol^{-1} CO_2 than under 380-400 μmol mol^{-1} CO_2 (Long *et al.*, 2004). Identifying and developing cultivars that respond well to elevated CO_2 can be an important option for adaptation to climate change (Ziska *et al.*, 2012) and may lead to higher resource use efficiency (Drake *et al.*, 1997). Elevated temperature will harmfully affect crops, but increased CO_2 concentration can have certain positive impacts on crop growth and productivity. There are reports that, increase in atmospheric CO_2 concentration will increase the potential production of C3 crops at higher latitudes (Taylor *et al.*, 2018) [19]. Horie *et al.*, (2000) [6] showed that an average increase in rice yield was about 30% with doubling of CO_2 concentration. Different studies on rice also showed that elevated CO_2 generally increased tiller number, photosynthesis, plant biomass and grain yield (Chakrabarti *et al.*, 2012) [3]. Rice one amongst the foremost noticeable food crops on the globe. As world population increases rapidly, the demand for rice will grow to an estimated 2000 million metric tons by 2030 (Cho and Oki 2012) [4]. The responses to elevated CO_2 of rice (*Oryza sativa* L.) growth and yield have been widely reported and crops respond directly to rising CO_2 through photosynthesis and stomatal conductance (Franks *et al.*, 2013), which hence promotes crop yield (Ainsworth, 2008) [2]. The primary mechanism promoting crop growth is through increased photosynthetic rates (Makino and Mae 1999) [12], which subsequently leads to morphological changes such as leaf area development, tiller production and changes in shoot to root ratios (Seneweera and Conroy 2005). The higher air CO_2 can increase photosynthesis, biomass and yield of C_3 crops, collectively called CO_2 fertilization effect (Sheidollah Kazemi *et al.*, 2018).

Materials and Methods
The present experiment was conducted during October to January 2019, using Open Top Ten short duration rice genotypes namely, N22, ADT 36, Chambers, in the Wetland, Tamil Nadu Agricultural University, Coimbatore.

The location is in North Eastern Agro-Climatic Zone of Tamil Nadu at 11.01°N latitude and 76.39°E longitude and at an altitude of 426.7 m above MSL. ADT 37, ADT 43, ADT 45, CO 51, ASD 16, MDU 6, TPS 5 and Anna (R) 4 were chosen for this study. Seeds were collected from various rice research stations of Tamil Nadu. The experiment was performed in UV protected OTC (diameter 5m and height 4.3m) built with multi-layered polycarbonate sheets. A data logger with software SCADA (Supervisory Control And Data Acquistion) was installed to acquire data on the temperature, relative humidity and CO_2 level in each OTC. The system displayed and recorded the actual and required CO_2 level in each OTC. A feedback loop passing through programmable logic controllers monitored the above said parameters both on the inside and outside the OTCs during the entire study period on a real-time basis. Two chambers were used for this study, one for ambient CO_2 and another one for exposing elevated CO_2 (150 ppm from ambient). By using CO_2 cylinders, infrared source, humidifiers and wireless signal transmission with SCADA integration facility, temperature and relative humidity (RH) were maintained inside the chambers. Two plants per pots were maintained and with four replications. Stress was imposed at anthesis stage to grain filling stage. Two treatments were used in this study for 1. Ambient and 2. Elevated CO_2 condition (ambient + 150 ppm). Observations were recorded after elevated CO_2 imposition and elevated CO_2 imposed plants were compared with plants which grown under ambient CO_2 condition.

Plant height was measured from the base of the shoot to the tip of the leaf and mean plant height was calculated and expressed in cm. Leaf area per plant was measured using a Leaf Area Meter (LICOR, Model LI 3000) and expressed as Cm^2 $plant^{-1}$. Chlorophyll index readings were recorded using chlorophyll meter (SPAD 502) designed by the Soil Plant Analytical Development (SPAD) section, Minolta, Japan, using the method described by Minolta (1989) [13] and Monje and Bughree, (1992) [14]. 1000 grain weight was calculated after harvest by five plants average and expressed in g $plant^{-1}$. For statistical analysis, the data collected from this experiment were statistically analyzed in a CRD (Completely Randomized Design) through SPSS software (Statistical Package for the Social Sciences) base software version11.5 (2001). The critical difference (CD) was computed at 0.05 probability level.

Results and Discussion

Morphological parameters

Plant height is an important parameter which decides biomass of the plant. Plant height was significantly varied between ambient and elevated CO_2 conditions. Plant height is an important trait for growth, since increased plant height would allow greater biomass production and yield potential in crops (Zhang *et al.*, 2004) [21]. According to Maity *et al.* (2019) [11] plant height was varied from 80.7 cm to 88.3 cm in different treatments. N22 followed by Anna (R) 4, MDU 6 and ADT 37 (114.4, 109.2, 107.7 and 105.5cm) had higher plant height among the genotypes under elevated CO_2 conditions (Fig. 1). Elevated CO_2 enhanced plant height significantly in most of the genotypes compared with ambient CO_2 and field conditions (Shaidul haque *et al.*, 2005) [18]. Increased CO_2 concentration significantly increased tiller number in rice plants. Above findings were similar to this present study. The panicle number is a yield component dependent on the tiller number. Hence, the number of tillers is an essential trait to study under stress conditions, which indirectly contribute to grain yield of rice genotypes Leonard *et al.* (2021) [10]. Maity *et al.* (2019) [11] reported that, increased CO_2 concentration significantly increased tiller number in rice plants. In ambient chamber tiller number was 13.5 which increased to 16.1 in elevated CO_2 and chamber control temperature treatment (Fig. 2). Jitla *et al.* (1997) [9] also reported that at high CO_2 from concentration there was 42% increase in tiller number in rice. Seneweera, (2011) [17] reported that elevated CO_2 from substantially increased grain yield of rice, and this is partly due to increases in tiller numbers. The same trend was observed in no. of leaves in plants.

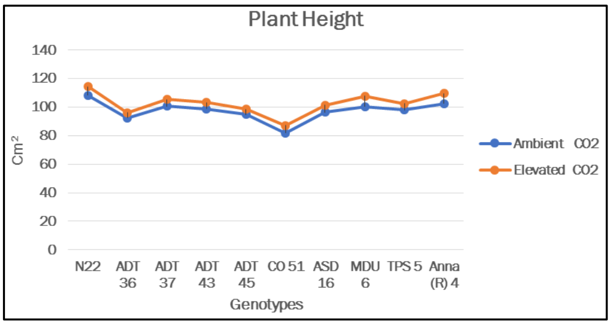

Fig 1: Effect of elevated CO_2 on plant height of rice genotypes

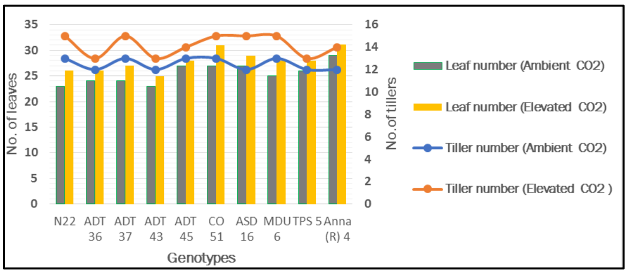

Fig 2: Effect of elevated CO_2 on number of leaves and number of tillers of rice genotypes

Leaf area (Cm^2 $plant^{-1}$)

The time trend of leaf area revealed a gradual increase CO_2 from vegetative to grain filling stage. Increased leaf area was observed under elevated CO_2 condition in rice varieties. Irrespective of the genotypes there was a increase in the leaf area during elevated CO_2 condition compared to ambient condition. Higher leaf area was observed in Anna (R) 4, N22, MDU 6 and ASD 16 (2943, 2613, 2559, 2305 Cm^2 $plant^{-1}$) under elevated CO_2 condition (Fig. 3). Leaf area is a fundamental determinant of the total photosynthesis of a plant. Leaf area always shows a positive relationship with net photosynthetic activity, because leaf enlargement is attributed to increase in number and width of grana and also high degree of stacking of grana (Fortun *et al.*, 1985) [5]. According to Sabine Stuerz and Folkard Asch (2019) [16] an optimum leaf area of 0.33 m^2 to 0.89 m^2 is required to maintain photosynthesis and grain yield. Elevated CO_2 increased significantly the leaf area of mungbean genotypes compared with the ambient CO_2 and field conditions (Shaidul haque *et al.*, 2005) [18].

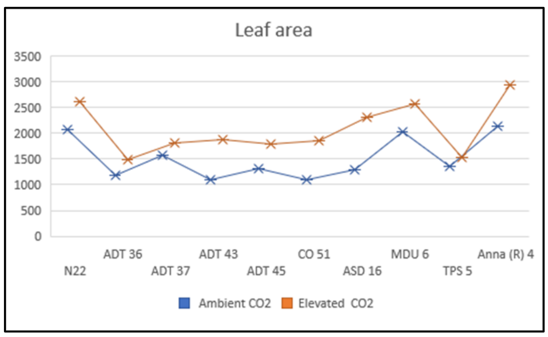

Fig 3: Effect of elevated CO_2 on leaf area chlorophyll index of rice genotypes

SPAD chlorophyll Index

SPAD chlorophyll value is expressed as cholorophyll index. Under elevated CO_2 condition, all the genotypes recorded higher chlorophyll index than ambient condition. Under elevated CO_2 condition N22, Anna (R) 4, ADT 37 and MDU 6 has recorded (13%, 14%, 9% and 7.5%) increased higher SPAD chlorophyll Index than ambient condition (Fig 4). Abdelhamid *et al.*, 2003, reported that, mung bean plants showed a positive correlation with the SPAD readings under elevated CO_2 condition. According to, Shaidul haque *et al.* (2005) [18] plants grown under OTC conditions maintained a higher chlorophyll content compared with those grown under field conditions. Above findings were confirmed with this present study.

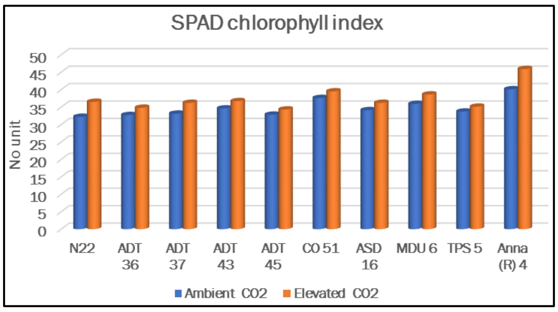

Fig 4: Effect of elevated CO_2 on SPAD chlorophyll index of rice genotypes

1000 grain weight

Irrespective of the genotypes, higher grain yield was observed under elevated CO_2 conditions (ambient + 150 ppm) and showing significant difference between genotypes. More grain yield was observed in N22, Anna (R) 4 and ASD 16 (22.8, 22.9and 20.8 g). Shaidul haque *et al.*, 2005 [18] reported that, elevated CO_2 increased the pod number per plant and 100-grain weight compared with ambient CO_2 and field conditions. Yang *et al* (2009a) [20] found that, elevated CO_2 (570 μmol/mol) slightly accelerates phenological development and substantially enhances grain yield about 30% in rice plants. Elevated CO_2 substantially increased grain yield of rice, and this is partly due to increases in tiller numbers (Seneweera, 2011) [17]. These results were supported to this present study.

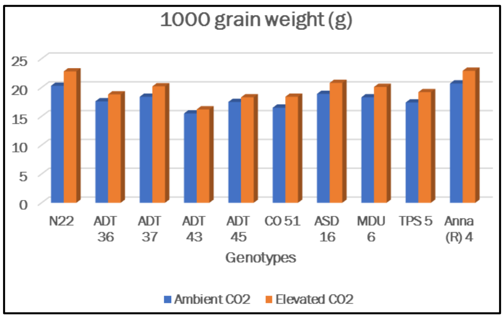

Fig 5: Effect of elevated CO_2 on 1000 Grain weight (g $plant^{-1}$) of rice genotypes

Conclusion

This present experiment concluded that, elevated CO_2 influenced morphophysiological parameters like plant height, number of tillers, leaf area, SPAD chlorophyll index were indirectly involved to increased grain yield of rice genotypes. N22 followed by Anna (R) 4 and ASD 16 were recorded high yield under elevated CO_2 conditions. These genotypes showed a increase in plant height, tiller number, leaf area and SPAD chlorophyll values. Therefore, tiller number, leaf area and SPAD chlorophyll index are ultimately contributed for higher grain yield of rice genotypes. To some extent elevated CO_2 condition is beneficial to all the crops in but too high concentration of CO_2 is detrimental to all the crop yield. In this study Ambient + 150 ppm of CO_2 increased rice yield. Hence, we can recommend this concentration to farmers to grow rice and get benefits.

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