Original Research Article

Effect of Elevated CO₂ and Temperature on Growth of Rice Crop

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Abstract

Introduction

Since 1750, concentration of atmospheric CO₂ has increased from 278 ppm (Pearson and Palmer, 2000) to currently 400 ppm (IPCC, 2014). The atmospheric CO₂ concentration during 2002 to 2011 has increased at an average rate of 2.0 ± 0.1 ppm year⁻¹.

Changing climate will certainly have impact on agricultural production. Several researchers have reported that growth and yield of crops will be adversely affected due to increased atmospheric temperature (Zacharias et al., 2010; Singh et al., 2013). Although elevated temperature will harmfully affect crops, but increased CO₂ concentration can have certain positive impacts on crop growth and productivity. There are reports that, increase in atmospheric CO₂ concentration will increase the potential production of C3 crops at higher latitudes (Taylor et al., 2018).
Rice (*Oryza sativa* L.) is an important food crop with half of world’s population relying on rice every day (Maclean et al., 2002). It is also the staple food across Asia where around half of the world’s poorest people live and is becoming increasingly important in Africa and Latin America. Horie et al., (2000) showed that an average increase in rice yield was about 30% with doubling of CO₂ concentration. Different studies on rice also showed that elevated CO₂ generally increased tiller number, photosynthesis, plant biomass and grain yield (Kobayashi et al., 1999; Sakai et al., 2001; Chakrabarti et al., 2012).

Although elevated CO₂ concentration has certain positive impacts on the crop but increased temperature will harmfully affect crop growth and productivity. Elevated temperature causes reduction in total dry matter, tiller mortality, reduced number of panicles, decline in number of grains per panicle, floret sterility, and grain weight thus overall reducing the yield of rice crop (Zacharias et al., 2010). Raj et al., (2016) also reported that high temperature stress of 3.9°C significantly reduced grain and biomass yield of rice. Increase in daily mean temperature from 28°C to 32°C, significantly reduced total dry weight, root dry weight, root length, leaf area and specific leaf area of rice crop (Rankoth and De Costa, 2013). Rise in temperature at vegetative stage and early grain filling stage of various rice varieties showed lower photosynthesis rate in the crop (Cao et al., 2009).

Although some work has been reported on effect of elevated CO₂ and temperature on rice but the interactive effect of elevated CO₂ and high temperature on rice is less reported especially under tropical condition. It is therefore important to study the response of rice as influenced by elevated CO₂ and temperature. Hence the following study was undertaken to study the impact of elevated CO₂ and temperature on growth of rice crop.

**Materials and Methods**

**Study site**

The study was conducted during the *kharif* season of year 2017 inside the Open Top Chamber (OTC) at ICAR-Indian Agriculture Research Institute (IARI), New Delhi, India. The climate of the area is semi-arid and subtropical with mean annual maximum and minimum temperature of 35°C and 18°C respectively. Both ambient (400ppm) and elevated CO₂ concentrations (550 ± 25ppm) were maintained inside the OTCs (Table 1). Elevated temperature was maintained by partially covering the upper portion of the OTC. Daily maximum and minimum temperature was recorded for the entire crop growth period using digital thermometer kept within the OTCs.

**Crop management**

Rice crop (variety Pusa basmati 1509) was grown in crates inside the OTCs. Recommended dose of nitrogen was applied in 3 splits i.e. half dose as basal and remaining half in two equal splits at tillering and flowering stage. Phosphorus and potassium were applied during transplanting of the crop. Plant samples were collected at harvesting stage and dry weight of straw and root were recorded. Growth parameters like plant height and no of tillers were also recorded. Statistical analysis of the data was done using SAS software. Factorial CRD design was followed.

**Results and Discussion**

**Temperature gradient inside the open top chambers**

Daily mean temperature was calculated from daily maximum and minimum temperature and then seasonal mean temperature inside all the OTCs was calculated. Temperature inside the partially covered OTC (elevated
temperature treatment) was higher than chamber control OTC (elevated CO₂ treatment) by 2°C (Fig. 1).

**Plant height**

Height of the rice plant was not affected by elevated CO₂ as well as high temperature. Plant height varied from 80.7 cm to 88.3cm in different treatments (Fig. 2).

**Number of tillers**

Increased CO₂ concentration significantly increased tiller number in rice plants. In chamber control treatment tiller number was 13.5 which increased to 16.1 in elevated CO₂ and chamber control temperature treatment (Fig. 3).

**Table.1 Description of treatment combinations**

| Treatments | Description                      |
|------------|---------------------------------|
| OTC 1      | Ambient CO₂ + Chamber control Temperature |
| OTC 2      | Ambient CO₂ + Elevated Temperature |
| OTC 3      | Elevated CO₂ + Ambient Temperature |
| OTC 4      | Elevated CO₂ + Elevated Temperature |

**Fig.1 Mean seasonal temperature inside different OTCs**

![Bar chart showing mean seasonal temperature inside different OTCs](chart1.png)

**Fig.2 Effect of elevated CO₂ and temperature on plant height in rice**

![Bar chart showing effect of elevated CO₂ and temperature on plant height in rice](chart2.png)
Fig. 3 Effect of elevated CO$_2$ and temperature on tiller number in rice

![Graph showing the effect of elevated CO$_2$ and temperature on tiller number in rice.]

Fig. 4 Effect of elevated CO$_2$ and temperature on straw weight in rice

![Graph showing the effect of elevated CO$_2$ and temperature on straw weight in rice.]

Fig. 5 Effect of elevated CO$_2$ and temperature on root weight in rice

![Graph showing the effect of elevated CO$_2$ and temperature on root weight in rice.]

On the other hand increase in temperature reduced tiller number in rice. Tiller number decreased to 12.2 in elevated temperature and ambient CO$_2$ treatment. But elevated CO$_2$ along with high temperature recorded tiller number of 14.4. This showed that the negative
effect of high temperature was compensated by elevated CO$_2$ concentration. Increased photosynthesis rate of rice under elevated CO$_2$ treatment resulted in accumulation of more biomass which was reflected in increased tiller numbers of the crop. Jitla et al., (1997) also reported that at high CO$_2$ concentration there was 42% increase in tiller number in rice. Study conducted by Zacharias et al., (2010) showed that high temperature induced tiller mortality in rice crop.

**Straw weight**

Rise in temperature led to reduced growth of the crop. Straw weight of rice reduced from 44.7 g hill$^{-1}$ to 52.1 g hill$^{-1}$ in high temperature treatment under ambient CO$_2$ concentration (Fig. 4). But increase in CO$_2$ concentration significantly increased straw weight of the crop. Elevated CO$_2$ level along with high temperature was able to compensate the loss of temperature rise due to the CO$_2$ fertilization effect. In elevated CO$_2$ plus elevated temperature treatment straw weight was 59.2 g hill$^{-1}$. Singh et al., (2013) also indicated that elevated CO$_2$ could alleviate the negative impact of high temperature but the effect is crop and region specific.

**Root weight**

Root weight of rice increased in elevated CO$_2$ treatment while high temperature caused reduced root weight of the crop. Root weight reduced from 11.2 to 9.6 g hill$^{-1}$ in high temperature treatment (Fig. 5). In elevated CO$_2$ plus elevated temperature treatment root weight was 13.5 g hill$^{-1}$. Earlier studies also showed that increased root growth contributes to higher root biomass and root dry weight under elevated CO$_2$ condition (Rogers et al., 1994, 1996).

In conclusion, results from the experiment showed that growth of rice crop reduced under high temperature treatment which was observed in terms of reduced tiller number, straw weight and root weight of rice plants. But increased CO$_2$ concentration was able to compensate the loss due to enhance growth of the crop under high CO$_2$ condition.

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