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Research Article

Impact of Elevated Carbon Dioxide (CO_2) Concentration on Yield of Maize Crop

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ABSTRACT

The increasing atmospheric carbon dioxide (CO_2) concentration is causing change in the earth's climate which will affect the growth and productivity of crops. A study was undertaken to quantify the impact of elevated CO_2 on yield of maize crop. Maize crop (variety PEHM 5) was grown both inside and outside the Free Air Carbon Dioxide Enrichment (FACE) facility under ambient and elevated CO_2 concentration of 550 ppm ± 25 ppm. After harvest, biomass and grain yield were recorded and different yield parameters were also studied. Results showed that grain weight of maize increased by 16.1% while straw weight increased by 11.9% under elevated CO_2 condition. Among different yield parameters, number of grains per row in maize cob increased thereby increasing grain weight under elevated CO_2 condition. The CO_2 fertilization effect will be able to alleviate the negative effects of rising temperature in maize to certain extent.

Key words: Elevated CO_2, Maize, Yield parameters

Introduction

Global climate change is one of the most important environmental challenges and it affects the living organisms on earth. It is mainly caused by the increasing concentration of atmospheric greenhouse gases (GHGs). The concentration of carbon dioxide (CO_2) in the earth's atmosphere has increased from 280 ppm during preindustrial time and has crossed 400 ppm in year 2012 (IPCC 2014). Due to the increase in atmospheric CO_2 concentration, earth's surface temperature is increasing and there is a change in the precipitation pattern. High temperature hastens maturity in crops and reduces crop yield (Chakrabarti *et al*., 2013; Raj *et al*., 2016; Sandhu *et al.*, 2017). But increase in atmospheric CO_2 concentration increases photosynthetic rate, growth and yield of crops (Ainsworth and Long, 2005; Dey *et al*., 2017b, Pramanik *et al.,* 2018). Hence this CO_2 fertilization effect can alleviate the negative effects of increasing temperature on crops to certain extent (Singh *et al*., 2013).

Maize is one of the important cereal crops globally cultivated in 150 million hectares area contributing to 36% of the foodgrain production (FAO, 2010). In India, it is the third most important crop after rice and wheat and grown mostly during the kharif season contributing to 9% of total foodgrain production (Abebe *et al.*, 2016; Venkata *et al*., 2014). Elevated CO_2 and temperature will affect the growth and productivity of maize crop. Yield and quality of maize will be negatively affected by high temperature (Mendelsohn and Dinar, 2009; Pathak

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et al., 2012). Several researchers have studied the effect of elevated CO_2 on maize crop. Some of the studies suggested yield increase by 50% while others showed very less positive impact (Rogers, 1983; Leakey *et al*., 2004; Vanaja *et al*., 2015). There are very few studies on the effects of elevated CO_2 on maize crop under open field condition. Hence the following study was undertaken to quantify the effect of elevated CO_2 on yield of maize crop.

Materials and Methods

An experiment was conducted inside and outside the Free Air Carbon Dioxide Enrichment (FACE) facility in Genetic H field of in ICAR-Indian Agriculture Research Institute (IARI), during the *kharif* season (July to October) of year 2015. The FACE was made up of eight horizontal pipes through which CO_2 enriched air was released at the crop canopy level (Chakrabarti *et al*., 2012). Maize crop (variety PEHM 5) was grown inside the FACE facility under elevated CO_2 concentration of 550 ppm ± 25 ppm. On the other hand, maize grown outside the FACE facility was under ambient CO_2 concentrations of 400 ppm. The crop was sown during third week of July and harvested in first week of November. Average maximum and minimum temperature during the crop growth period was 33.6°C and 21.9°C respectively (Fig 1). Total rainfall received during the period was 352 mm. The experimental soil was mildly alkaline (pH 7.8) in nature with soil organic carbon content of 0.45%. The crop was fertilized with 120, 60 and 60 kg ha^{-1} N, P and K, respectively. Three irrigations were applied to the crop at early knee height, tasselling and silking stages.

Yield parameters

The crop was harvested on first week of November. After harvesting, plant samples were collected and dry weight of grain and straw were recorded. Yield parameters like cob length, number of rows per cob, number of grains per row and hundred grain weight was also recorded. Harvest Index (HI) was calculated using the formula:

$$\text{Harvest index} = (\text{Grain yield} / \text{Total dry matter}) \times 100 \quad \ldots(1)$$

Statistical analysis

The design of the experiment was completely randomized design (CRD). Statistical analysis of the data was done using analysis of variance (ANOVA) technique recommended for the design (Gomez and Gomez, 1984).

Results and Discussion

Results from the experiment showed that plant height in maize was not affected by CO_2 concentration. In ambient CO_2 treatment plant

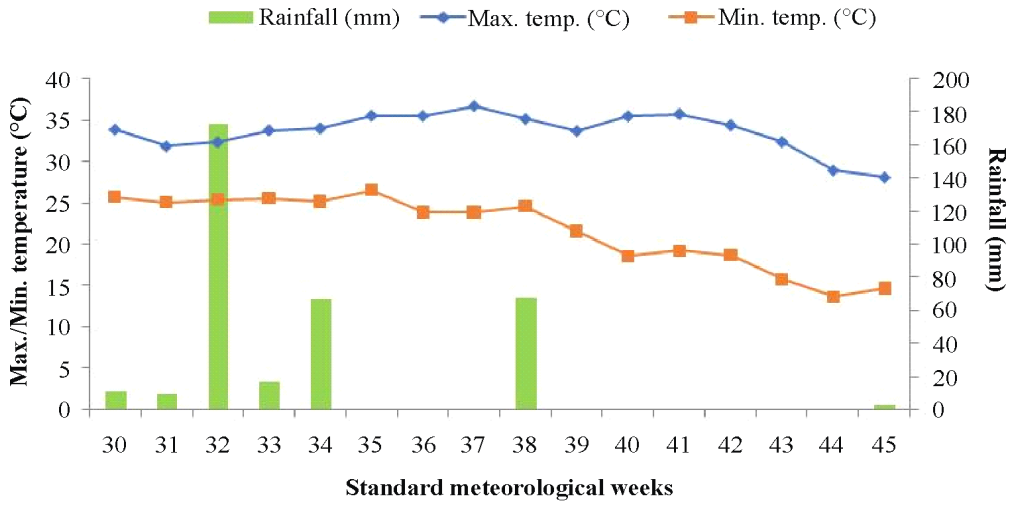

Fig. 1. Variation in air temperature and rainfall during the crop growth period

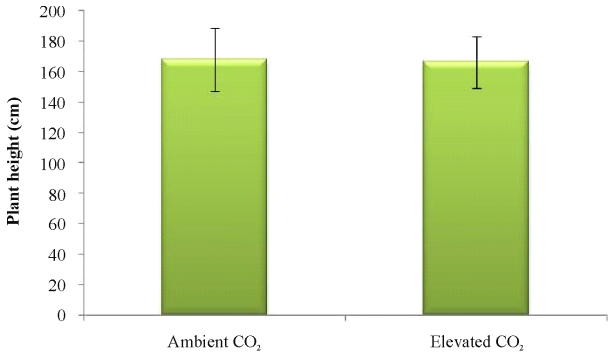

Fig. 2. Plant height of maize under ambient and elevated CO_2 condition

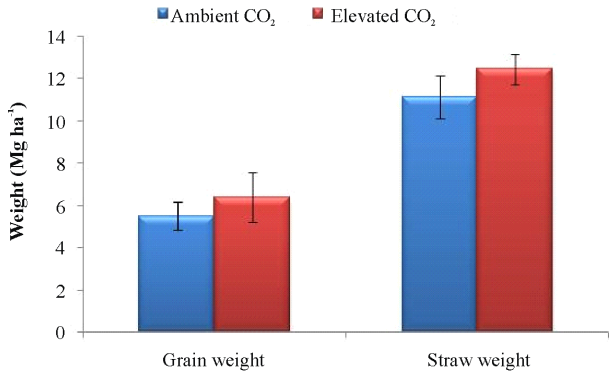

Fig. 3. Effect of elevated CO_2 on grain and straw yield of maize crop

height of maize was 167.5 cm while in elevated CO_2 treatment it was 166 cm (Fig. 2). Grain weight of maize increased by 16.1% while straw weight increased by 11.9% under elevated CO_2 condition as compared to ambient. Grain yield of maize was 5.5 Mg ha^{-1} under ambient treatment which increased to 6.4 Mg ha^{-1} in elevated CO_2 treatment (Fig 3). Straw yield of maize was 11.1 Mg ha^{-1} in ambient treatment which increased to 12.4 Mg ha^{-1} in elevated CO_2 treatment. Earlier studies also showed that elevated CO_2 increases the photosynthesis rate thereby increasing growth and biomass in different crops (Maity *et al.*, 2020; Raj *et al.*, 2019; Dey *et al.*, 2017a; Abebe *et al.*, 2016; Dey *et al.*, 2015). Meng *et al.* (2014) reported yield increase of maize by 22.9% under CO_2 concentration of 700 ppm.

In the current study yield increase in maize was attributed to more number of grains in maize cob under elevated CO_2 condition. Although cob length and number of rows per cob was not affected by the elevated CO_2 level, but number of grains per row significantly increased from 27.1 to 30.5 in elevated CO_2 treatment (Table 1). Hundred grain weight ranged from 18.4 to 18.7 g and was not affected by the elevated CO_2 concentration. Ziska and Bunce (2006) reported that elevated CO_2 level increased flower number, grain number and grain weight in plants. Maize being a C4 crop utilized the elevated CO_2 concentration more efficiently (Abebe *et al.*, 2016) thereby increasing grain number and grain weight than ambient condition.

Table 1. Yield parameters in maize as affected by elevated CO_2 concentration

	Ambient CO_2	Elevated CO_2	LSD (P≤0.05)
Cob length (cm)	15.4	15.5	NS
Rows/cob	14	14	NS
Grains/row	27.1	30.5	2.1
100 grain wt. (g)	18.4	18.7	NS
Harvest index	0.33	0.34	NS

Conclusion

Carbon dioxide concentration in the atmosphere is increasing leading to the climate change affecting the production of agricultural crops. The present study illustrated that grain and straw yield in maize crop increased under elevated CO_2 condition. Among different yield parameters, number of grains per row in maize cob increased in elevated CO_2 treatment thereby increasing grain weight of the crop. Hence it can be concluded that the CO_2 fertilization effect will be able to alleviate the negative effects of rising temperature in maize crop to certain extent.

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