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RESEARCH ARTICLE

EFFECT OF INCREASED LEVEL OF CO_2 ON GROWTH AND YIELD OF WHEAT CROP

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ABSTRACT

The present study was carried out to evaluate the changes in growth and yield in wheat (*Triticum aestivum*) crop when grown under elevated CO2. Different chambers were used: ambient CO2 chamber and elevated CO2 chamber. Crop was grown from seedling to maturity inside the chamber under ambient CO2 and elevated (future) CO2 (500 ± 50 ppm). Crop resulted in greater biomass compared to ambient CO2. The high concentration of CO2 resulted into increase shoot length, root length and number of tillers in terms of their size and weight. Exposure to elevated CO2 cause significant increase in economic yield of wheat per plant. In this study we examine the effect of present and future CO2 concentration on the growth, biomass and yield of wheat crop.

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INTRODUCTION

The rising atmospheric carbon dioxide concentration (CO_2) is one of the best documented global atmospheric changes of the past half century (Prentice, 2001). Climate change and agriculture both are important issue which take place on global scale, and climate change directly or indirectly affects agriculture. The effect of climate change on agriculture may be related to unpredictable weather conditions. Local or regional studies assume greater significance to understand the impact of climate change on agriculture and also for developing mitigation strategies (Kalra *et al*., 2008). The percentage increase in total biomass at 700 and 550 ppm CO_2 was 65.4% and 39%, respectively compared to the ambient chamber (M. Vanaja, 2007). For some regions and crops, there will be opportunities for increased production, but all in all, there is no doubt that net agriculture production will adversely affected by climate change (IPCC, 2007a). Open top chambers used mostly and comprise main source of information for the field study of crops under elevated level of CO_2. Lobell *et al*. (2011) showed that climate trends since 1980 were large enough in many countries to offset a significant proportion of the potential increases in average crop yields due to technological advances, CO_2 fertilization and other factors (Xinyou Yin, 2012).

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Elevated CO_2 leads plants to produce a larger number of mesophyll cell, chloroplasts, longer stems and extended length, diameter and number of large roots, forming good lateral root production with different branching patterns; in some agricultural food crops, resulting in increasing root to shoot ratios under elevated (CO_2) (Qaderi and Reid, 2009**)**. Analysis of short term experiments in growth chambers show that leaf photosynthetic rate in wheat increases asymptotically with CO_2 concentration (Farquhar *et al*. 1980; Allen 1990).

Research on the effects of elevated CO_2 on wheat is of particular relevance because wheat is most important food crop worldwide. Currently, India stands first in area and second in production after China in the world with about 12% contribution in total world wheat production. Wheat is grown in India in an area of about 30 million ha with a production of 93 million tonnes. The major wheat producing States in India are Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Rajasthan, Bihar, Maharashtra, Gujarat, Karnataka, West Bengal, Uttarakhand, Himachal Pradesh and Jammu and Kashmir, contributes about 99.5% of total wheat production in the country. The India's contribution in world wheat area is about 12.40%, whereas 11.77 % share in the total world wheat production. (http://farmer.gov.in/imagedefault/pestanddiseases crops/wheat.pdf). The increase in CO_2 affected the plant growth and photosynthesis. Elevated CO_2 is likely to stimulate the growth of many plant species (Poorter, 1998; Sakurai *et al*., 2014).

Most of the relevant studies focused on the effects of CO_2 enrichment on biomass accumulation in plants **(**Drake *et al.* 1997). Kimball (1983, 1986), Kimball *et al*. (2002) and Poorter (1993) on the basis of their evaluation of several hundreds of studies of this kind showed an average increment in biomass production in C3 plants more in response to a doubling of CO_2 concentrations. Cure (1985) and Cure and Acock (1986) conducted a literature survey and tabulated the results of a doubling of CO_2 on the response of 10 major agricultural crops under 550 μmol/mol CO_2 and they reported yield increase of wheat, rice, cotton and potato by 19, 8, 113 and 28%, respectively. The current trend of increasing atmospheric CO_2 indicates that the level might be doubled from the present level, around 350 ppm, by the middle of this century **(**Watson *et al*., 1990; Houghton *et al*., 1996). The global mean temperature will also rise to 3–4^{o}C with doubling of the CO_2 concentration (Reddy *et al*., 1995). Such a change of the atmosphere will obviously bring a shift in overall agriculture globally. Strong evidences indicated that increase in atmospheric CO_2 concentration has challenged physiologists to predict the responses of plants. The present study generally involved exposing wheat to elevated CO_2 and observing response of crops. This study was conducted to determine the effect of expected future level of CO_2 on growth and dry matter of wheat.

MATERIALS AND METHODS

The chamber experiment was conducted in C6 block of the N. E. Borlaug Crop Research Centre of the G.B.P.U.A. and T., Pantnagar, district, Udham Singh Nagar (Uttarakhand). Pantnagar is situated in the *Tarai* region of Uttarakhand at latitude of 29.2^{o}N, 79^{o}E longitude and at an altitude of 243.80 m above the mean sea level. May is the hottest month of the year and temperature generally rises up to 45.5±1.5^{o}C. However, minimum temperature can be low as 1.5±1.0^{o}C in the month of January. Maximum relative humidity remains in the range of 90-95 percent. The reference meteorological data used for the study (i.e. minimum and maximum temperature and relative humidity) were taken from the Meteorological Observatory located at Crop Research Centre, Pantnagar.

Two sets of experiment were conducted. In this study period we used two different climate chambers. Chamber one exposed to ambient temperature and ambient CO_2 concentration, second chamber continuously exposed to +100 ppm CO_2 above ambient climate, Henceforth referred "*future climate*". The different experimental chambers had different climatic conditions. All the chambers were facing towards south and placed in an open area in the field where mutual shading or shading by other object was avoided. Each chamber had equal dimension of 1.5m×1.5m×2.0m (Length × Width × Height), covered with transparent polyethylene sheet (0.2 mm thick) that was UV-transparent and allow upto 86% light transmission. All the chambers had circular opening at the top of the chamber (15cm diameter). The chamber exposed to ambient condition having multiple opening. Under elevated CO_2 chamber (i.e. +100 ppm from ambient condition), CO_2 was continuously injected inside the chambers.

The daily minimum and maximum temperature inside and outside chamber was continuously measured with the help of thermo-hygrometer. The soil used in this experiment was loamy in texture. The important physical and chemical properties of experimental soil collected from the top 0-15 cm. pH was 7.10, bulk density was 1.45 g/cm3, organic carbon was 0.82 %, Total Nitrogen was 0.08%, available phosphorous was 76.17 kgP_2O_5/ha, exchangeable potassium was 141.12 kgK_2O/ha.

Statistical analysis

All recorded data was interpreted and was analyzed statistically to determine different levels of significance at 0.05, 0.01 and 0.001. The experimental data were analyzed by using analysis of variance in SAS software (randomized block design). The critical difference at 5% level of probability was calculated for testing the significance difference between two means.

RESULTS AND DISCUSSION

Climate

During the experiment, the average air temperature of the ambient chamber (T_{amb}) was 0.24°C higher than average outside chambers which was taken as a reference temperature. In both 2013 and 2014, sowing was done in the month of December. In Fig. 1, average minimum-maximum temperature and carbon dioxide concentration inside and outside of the chambers during the experiment are presented as mean value. The CO_2 concentration in the ambient chamber was 397 ppm, outside CO_2 was taken as a reference CO_2, while in the elevated CO_2 chambers it was maintained to 500±20 ppm in the both experimental year (Fig. 2).

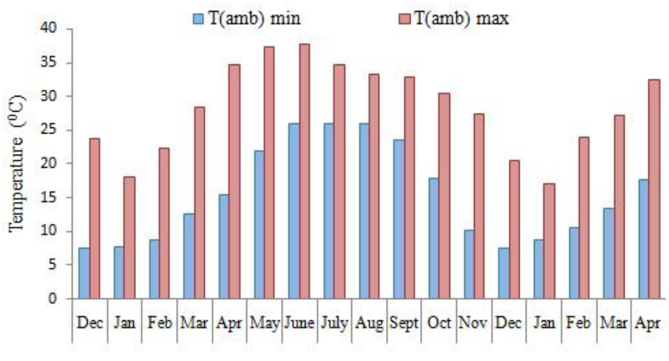

Figure 1. Monthly average minimum and maximum value of ambient and elevated temperature (˚C) throughout the experimental period

Plant growth

Winter wheat variety UP-2526 sown for two years. Wheat shows a statistically significant effect of elevated CO_2 on growth and yield of wheat crop, in terms of shoot length, root length, number of tillers, biomass production and weight of grains per plant. Fig. 3 shows the effect of elevated CO_2 on shoot length of wheat is significantly different from ambient CO_2 in first and second season ($p \leq 0.05$ and 0.01).

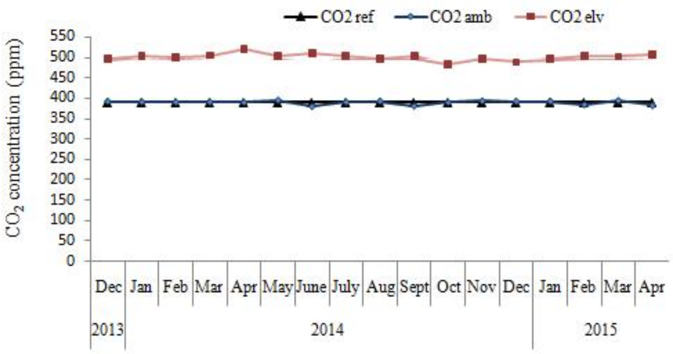

Figure 2. Monthly average CO_2 concentration (ppm) of reference, ambient and elevated CO_2 through the experimental period

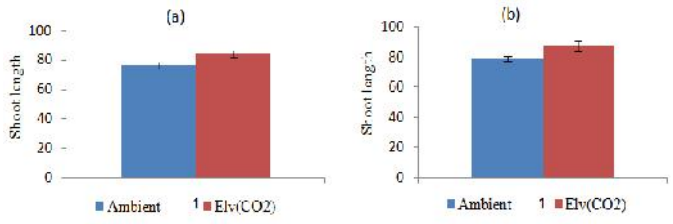

Figure 3. Shoot length (cm) of wheat crop under ambient and elevated CO2 condition (a) for first year; (b) for second year

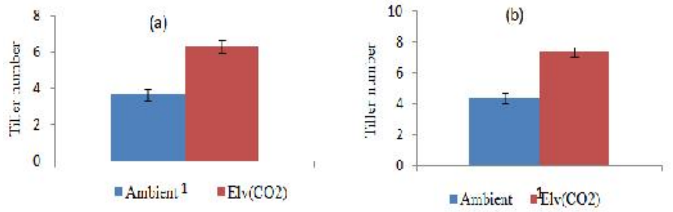

Figure 4. Number of tillers per plant of wheat crop under ambient and elevated CO_2 condition (a) for first year; (b) for second year

Graph shows that the more number of leaves were calculate under elevated CO_2 condition in both seasons. Similar trend in results have been observed in number of tillers/plant (Fig. 4). Maximum numbers of tiller were found at 86 DAS in elevated CO_2 condition in both seasons ($p \leq 0.001$). CO_2 enrichment promotes the development of the tillers, especially during early stage of growth. Comparing both chambers, shoot length was greatly influenced under elevated CO_2 condition. This was in agreement with various authors. According to Madhu and Jerry (2015) high CO_2 might have inhibited the growth at early stage of crop but due to adoptive mechanism of plants to high CO_2 plants were recovered and responded physiologically at later stage. Root length of crops was measured after harvesting and increase in root length under elevated CO_2 condition was found maximum (Fig. 5). Total biomass (Fig. 6) was found significant for both crops in both growing seasons. Maximum was observed under elevated CO_2. Elevated CO_2 affect root and shoot of crop proportionally. Wheat roots become more numerous, longer, thicker exposed to high CO_2 with increased root length. Branching and extension of roots in elevated CO_2 condition may lead to altered root structural and ability of roots to gain water and nutrients from the soil.

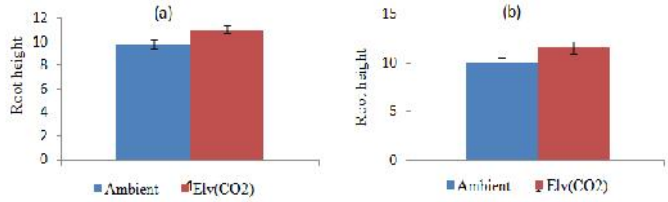

Figure 5. Root length (cm) of wheat crop under ambient and elevated CO_2 condition (a) for first year; (b) for second year

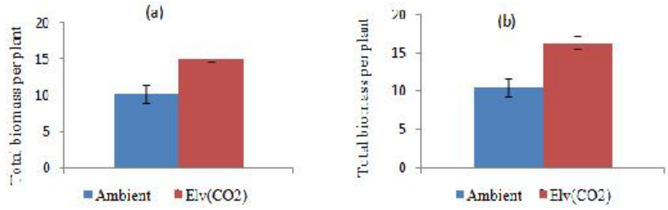

Figure 6. Total biomass per plant of wheat crop under ambient CO2 and elevated CO2 condition (a) for first year, (b) for second year

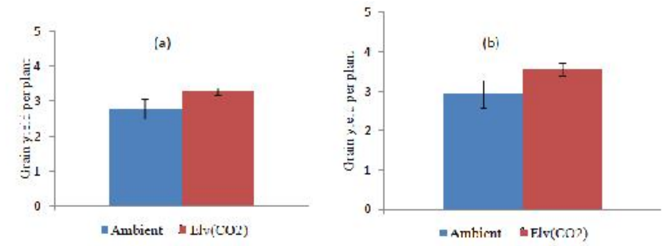

Figure 7. Grain yield per plant of wheat crop under ambient and elevated CO_2 (a) for first year, (b) for second year

Root and shoot growth are so interdependent, in fact above ground growth and biomass yield of most crops are influenced by the capacity of the root system to take up water and nutrients from the soil (Hammer *et al*., 2009). Yang *et al*. (2007) showed that compared with ambient CO_2 (350 mL L^{-1}), 550 mL L^{-1} increased root biomass by 45 %, root volume by 44 %, number of adventitious roots by 31 % and overall root length by 37 % when rice plants were grown in a Stagnic Anthrosol soil. Thus, it appears that root growth positively responds to elevated CO_2, enabling the roots to explore a larger volume of soil, and this will increase the plant's ability to take up nutrients (Nie, *et al*., 2013).

The effect of elevated CO_2 concentration on yield parameters (weight of grains per plant) was smaller in both years, as evident from Fig. 7. The increase in grain yield was only 18% in first year and 21% in second year under elevated CO_2 compared with ambient CO_2. The result was a statistically significant under elevated CO_2 on growth, biomass, grain yield in both years.. The increase in grain yield under elevated CO_2 was might be associated with a higher number of ears per plants, which is in agreement with the (H. Pleijel, *et al*. 2000). The elevated CO_2 concentration seems to have stimulated the development of productive tillers, which might produce the more number of grains per plant under elevated CO_2 when compared to ambient condition. Spike number is most important yield contributing character. Maximum number of spikes was observed under elevated CO_2.

Similar trends were found in chickpea, soybean, field pea, wheat, sorghum and cotton (Del Castillo *et al*., 1989; Rogers *et al*., 1992, 1994; Jin *et al*., 2013, 2015). According to Hamid Reza Miri, *et al*. (2012) stated that the under elevated CO_2 vegetative growth of C3 plants increases. The effects of (CO_2) on biomass (increased by 50%) and seed yield (increased by 24% to 30%) observed by P. Madan (2012). Tubiello and Fischer (2007) used the ultra-simple model AEZ to simulate crop response to elevated (CO_2), i.e. as a multiplier of the harvest yield obtained under current (CO_2). The multiplier was derived from experiments under controlled conditions, which indicated a 25% increase in yield for a doubling of the current atmospheric (CO_2).

Conclusion

Increases in atmospheric carbon dioxide concentration (CO_2) and temperature associated with future climates are expected to affect wheat growth and grain yield. The overall experiment reveals that under elevated CO_2 there were increases in plant growth and yield. From this study results suggested that in wheat grown at elevated CO_2 had positive effects on main shoot length, root length and total biomass. Maximum growth was found under elevated CO_2 condition. Crop yield (weight of grains per plant and number of tillers per plant) was increased due to increase in CO_2 concentration when compared to ambient condition.

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