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# Assessment of climate change on wheat (*Triticum aestivum*) production using crop simulation under Indo-Gangetic Plains

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India is the second most populous country in the world after China. It accounts for 2.4% of world area with 16.9% share in world population. About 54.6% population of our country is engaged in agriculture and allied activities (Census 2011) and it contributes 17.2% to the country's gross value added (Indian economic survey report, 2016–17 series). Agriculture continues to play a pivotal role in sustainable growth and development of the Indian economy. Not only does it meet the food and nutritional requirements of 1.3 billion Indians, it contributes significantly to production, employment and demand generation through various backward and forward linkages. The areas under wheat has steadily gone up since the start of the green revolution in 1965 and its production and productivity have increased tremendously. The wheat area has increased from 12.8 million-ha in 1966–67 to 30.42 million ha in 2017–18 (Agricultural Statistics at a Glance 2018).

Since the year 1850, each of the last three decades has been warmer than any preceding decade (Jayaraman and Murari 2014). The evidences have unequivocally established that global warming is the result of unprecedented greenhouse gas emissions with in the last two centuries (IPCC 2013). Therefore to see the impact of climate change a modeling based study was carried out to know the effect of graded level of $CO_2$ and temperature on the productivity of wheat.

*Data Set*: Weather data used for crop simulation modelling for impact assessment was taken for the period of 1985–2016 and data related to genotypes of wheat was collected from annual reports of Institute of Wheat and Barley Research, Karnal, India. The present study was carried out during 2021 at Banaras Hindu University Varanasi, Uttar Pradesh. Weather variables used in the study are maximum temperature ($T_{max}$), minimum temperature ($T_{min}$), rainfall and solar radiation. Climate data for the rainfall (0.25° latitude × 0.25° longitude) and temperature (0.5° latitude × 0.5° longitude) for the period 1981–2016 was obtained from the India Meteorological Department (IMD). With the help of weather generator (WGEN) monthly weather statistics can be computed from daily data for a number of years, preferably five or more complete historical weather years. Baseline regional circulation model (RCM) climate data (1971–2000) were obtained from RegCM4.0 model which has been developed by the National Centre for Atmospheric Research (NCAR) in 2010 with a 50 km horizontal resolution.

*Modelling Approach*

DSSAT: This model is developed by International Benchmark Sites Network for Agro technology Transfer (*IBSNAT*) in USA. It is a software tool that enables sub – models to be linked to simulate agricultural systems.

CERES: Wheat is a yield simulation model that was originally developed under the auspices of the USDA-ARSWheat Yield Project and the U.S. government multiagency AGRI-STARS program (Ritchie and Otter, 1985). The model is also one of the main models that have been incorporated in DSSAT (Hoogenboom *et al.* 1994). The CERES-Wheat model simulates the impacts of the main environmental factors such as weather, soil type; and major soil characteristics and crop management on wheat growth, development and yield (Ritchie *et al.* 1998).

Input requirements for CERES-Wheat include weather and soil conditions, plant characteristics and crop management (Hunt *et al.* 2001). The minimum weather input requirements of the model were daily solar radiation, $T_{max}$ and $T_{min}$, precipitation and solar radiation. This model required soil inputs like drainage and runoff coefficients, evaporation, soil albedo, water-holding characteristics for each individual soil layer as well as rooting preference coefficients. The model requires saturated soil water condition, and precipitation and initial soil water content for the first day of simulation. Crop genetic inputs like photo-period sensitivity, duration of grain filling, conversion of mass to grain number, grain-filling rates, vernalization etc. also needed to run this model (Hunt *et al.* 1993). Check

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management input information including plant population, planting depth and date of planting had also been used. Latitude was required for calculating day length.

*Impact Assessment*

Carbon dioxide sensitivity: For the study of carbon-dioxide sensitivity on the production of the crop, different concentrations of carbon-dioxide, viz. 450 ppm, 500 ppm, 550 ppm and 380 ppm were used as control. At different concentrations of carbon-dioxide the continuous increase in production was observed in all wheat growing agro-climatic zones of India. For the study of temperature sensitivity on the wheat crop production different levels of temperature were used. Different combinations of carbon-dioxide and temperature were also used for the study of climate change impact on wheat production.

*Impact of carbon dioxide on wheat yield*: To assess the impact of carbon dioxide on crop production different levels of carbon dioxides i.e. 70 ppm, 120 ppm and 170 ppm were used. Since wheat is a $C_3$ crop, the increased yield was observed from elevated levels of carbon dioxide. Result revealed that wheat yield was increased with respect to graded level of $CO_2$ concentration, and 7.91% enhancement was observed at 550 ppm concentration as compared to control (Table 1). Aggarwal (2008) reported that increased level of ambient $CO_2$ is beneficial which leads to enhanced photosynthesis in different crops, particularly those having $C_3$ mechanism of photosynthesis, like wheat. Meta-data analysis on field study of $CO_2$ enrichment experiments indicates that, 550 ppm $CO_2$ concentration enhances wheat yield by 8–10% (Long *et al.* 2005, Aggarwal 2008). Similar results have been reported by Kimball (1983) and Taub (2010).

*Impact of temperature on wheat production*: Based on the modeling approach it has been observed that yield reduction of 10.12 and 17.24% was noticed due to 1 and 2°C increment in the normal temperature respectively (Table 2). Similar findings have also been reported by Aggarwal (2008).

*Interaction effect of graded level of $CO_2$ and temperature*: Interaction effect of elevated $CO_2$ and temperature had negative impact on wheat productivity. Higher yield reduction 16.21% was noticed with higher concentration of $CO_2$ (550 ppm) along with 2°C enhancement in mean normal temperature (Table 3). That means graded level of $CO_2$ along with temperature is detrimental to the growth and productivity of wheat crop.

From the present study, it can be concluded that enhancement of $CO_2$ up to 550 ppm is helpful in getting higher productivity of wheat while increased temperature even 1°C from the normal mean temperature is detrimental for the growth and development of wheat crop.

Table 1 Impact Assessment of carbon dioxide on wheat crop production

| Carbon dioxide | Percent (%) change in wheat yield |
|---|---|
| Control | - |
| + 70 ppm | 2.85 |
| + 120 ppm | 5.11 |
| + 170 ppm | 7.91 |

Table 2 Effect of temperature on wheat production with different levels

| Temperature | Per cent (%) Change in wheat Yield |
|---|---|
| + 1 Degree | -10.12 |
| + 2 Degree | -17.24 |

Table 3 Interaction effect of $CO_2$ and temperature

| CO2 level (ppm) | Per cent (%) yield reduction | |
|---|---|---|
| | +1 °C | +1 °C |
| +70 | -1.35 | -11.25 |
| +120 | -4.12 | -13.95 |
| +170 | -7.05 | -16.21 |

## SUMMARY

Climate change has very wide impact on different crops and cropping system. In north India crop like wheat also affected due to climate change. To assess the impact of climate change a study using CERES (Crop Environment Resource Synthesis) model was carried out at Kanpur, India. Three different levels of carbon dioxide ($CO_2$) i.e. 450 ppm, 500 ppm and 550 ppm and two different levels of temperature (1̊C and 2̊C) and their interaction were used to study the impact of climate change on wheat production. The results revealed that different elevated levels of carbon dioxide concentration recorded higher production of wheat which ranges from 3–8%. Graded levels of temperatures caused drastic reduction in yield which ranges from 10–17%. Conjoint effect of temperature and carbon dioxide recorded yield losses from 1–16%.

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