Impact of Temperature and Solar Radiation on Wheat Crop for Varanasi Region of Uttar Pradesh

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ABSTRACT

Agriculture production is depended upon the weather phenomena of any particular place. The crop growth and phenology during its growing season are entirely determined by the climatic condition of the location. Possible changes in temperature and solar radiation are expected to significantly impact the crop growth and yields. In this study, CERES wheat model was used to assess the impact of temperature and solar radiation on physiology and productivity of wheat crop at Varanasi region, Uttar Pradesh. The simulation of anthesis days, maturity days, grain yield and straw yield were carried out for the range of temperature (maximum and minimum both) -3°C and +3°C with an interval of 1°C temperature from normal, alone or in combination with solar radiation ±1, ±2 and ±3MJ $m^{-2}day^{-1}$ while keeping the other climate variables constant. Anthesis days and maturity days reduced with increasing temperature. At increase of 3°C temperature, anthesis and maturity occurred 10 days and 11 days earlier from normal, respectively. Grain yield decreased by 33.1% and straw yield increased by 10.8% concurrently with an increase in temperature by 3°C and an increase in solar radiation (up to 3MJ m^{-2} day^{-1}) in comparison with the normal conditions. It is inferred that increasing temperature and decreasing solar radiation hampers the crop phenology and the productivity in Varanasi region.

Keywords: *CERES wheat model, Crop yield, Increasing temperature and Decreasing solar radiation.*

1. Introduction

Wheat (*Triticumaestivum* L.) is the second most important food grain crop of India and is associated with the food security of the country. Uttar Pradesh ranks first in respect of wheat crop coverage, with area of 9.67 million ha and production of 33.66 million tons but average productivity is much lower 3.41(t ha^{-1}) (DAC, 2013-14). The wheat production in the country is highly variable due to different agro-climatic conditions. Wheat is a cool-season crop. Cool weather during vegetative growth and warm weather for maturity is ideal for wheat crop. Warm temperature during the growth of wheat may retard heading (Reddy and Reddi, 2008). During the heading and flowering stages, excess high or low temperatures and moisture stress are harmful to wheat crop. Low soil moisture, high temperature and higher bright sun shine hours hasten maturity and shorten the reproductive period from flowering to maturity time. Day temperature above 25ºC during the development and grain filling period tends to decrease grain weight. Intergovernmental Panel on Climate Change (IPCC) has predicted 3-4ºC increase in average temperature by 2080 A.D. and winter may be warmer as compared of monsoon period. If so, winter crop production will be adversely affected due to increased temperature. Therefore, adaptability to impact of climate change on wheat production through varietals management and agronomic practices is required. A crop simulation model has the possibility to use them under various weather and soil conditions and under different environment regions of the world, which is not usually possible when models based on the statistical analysis are used. The model, Decision Support System for Agrotechnology Transfer (DSSAT) Version 4.6 is a software application program that comprises crop simulation models (Hoogenboom*et al.*, 2015). The CERES (Crop Environment REsource Synthesis)-Wheat (Ritchie et al., 1988) is a process-based, management-oriented model that can simulate the growth and development of wheat crop.

2. Materials and Method

Study area: The present study was carried out taking into account the anticipated regional climatic changes for Varanasi region, Uttar Pradesh. The climate of Varanasi has a subtropical, controlled by south-west monsoon, characterized by a moderate to extreme condition. (Singh, et al., 2012). This region falls in semi-arid to sub-humid type of climate. Varanasi soils lay alluvial of Indo-Gangetic plain with mostly soil order *Inceptisols.* Generally, soil texture has sandy loam to sandy clay loam (Rai et al., 2011).

Software used: The DSSAT-CERES wheat model is widely used to simulate the effect of weather, soil characteristics, genotype and management factors on the growth and development of dry and wet irrigated wheat (Arora, et al., 2007).

Methodology: The effects of changes in temperature and solar radiation on phenology (anthesis and maturity days) and productivity (grain and straw yield) of wheat under climatic condition of district Varanasi have been studied here using DSSAT-CERES wheat model v4.6. The genetic coefficients of wheat cultivar HUW-510 developed by Patel et al. (2017) were used. The model was calibrated and validated with conducted field experimental data under FASAL project of two years 2011-12 and 2012-13. Daily historical weather data of Varanasi (25°18' N latitude, 83°1' E longitude and 76 meter above mean sea level) were analysed to determine climate variability trends using regression. The widely accepted approach to analyse possible effects of different climatic parameters on crop growth and yield by specifying the incremental changes to climatic parameter and applying these changes uniformly to baseline/normal climate was also employed in the present study (Hundal and Kaur, 2007). The simulation of anthesis days, maturity days, grain yield and straw yield were carried out for the range of temperature (maximum and minimum both) -3°C and +3°C with an interval of 1°C temperature from normal, alone or in combination with solar radiation ±1, ±2 and ±3MJ $m^{-2}day^{-1}$ while keeping the other climate variables constant. The major reason for using incremental variable scenarios is that they capture a wide range of potential changes. Subsequently, the combination of two variables was interactively modified to assess their combination effect on wheat crop.

3. Results and Discussion

3.1 Impact of temperature and solar radiation on phenology of wheat crop

3.1.1 Effect on anthesis day

The days of anthesis were simulated with various combinations of temperature and solar radiation. The anthesis days were simulated at 69 days after sowing in normal weather condition (no environment modification) (Table 1). While increasing the temperature by 1°C, 2°C and 3°C along with the combination of solar radiation i.e .±1, ±2 and ±3MJ m^{-2} day^{-1} respectively, the anthesis days are proportionally decreased by 3 day, 7 days and 10 days respectively (Fig. 1). Patel et al (2017) reported the same result that increasing in temperature above normal decreased the anthesis days. Higher temperatures could also accelerate plant development and therefore, shorten the growth period Lal et al. (1998).

3.1.2 Effect on maturity days

The days of maturity were simulated with various combinations of temperature and solar radiation. The maturity days were simulated at 104 days after sowing in normal weather condition (no environment modification) (Table 1). While increasing the temperature by 1°C, 2°C and 3°C along with the combination of solar radiation i.e. ±1 ±2 and ±3MJ m^{-2} day^{-1}, respectively, the maturity days proportionally decreased by 3 day, 7 days and 11 days respectively (Fig. 1). Patel, *et al* (2017) reported the same that increasing in temperature below normal decreased the maturity days. Higher temperatures could also accelerate plant development and therefore, shorten the growth period Lal et al., (1998).

3.2 Impact of temperature and solar radiation on productivity of wheat crop

3.2.1 Effect on grain yield

The grain yield was simulated 3254 kg ha^{-1} under normal weather parameters (no environment modification) (Table 1). The decrease in temperature from 1 to 3°C increased

Table 1. Days After Showing (DAS) to simulate anthesis days and maturity days with grain yield and straw yield under normal weather condition (no modification in weather data)

Anthesis days (DAS)	Maturity days (DAS)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
69	104	3254	5346

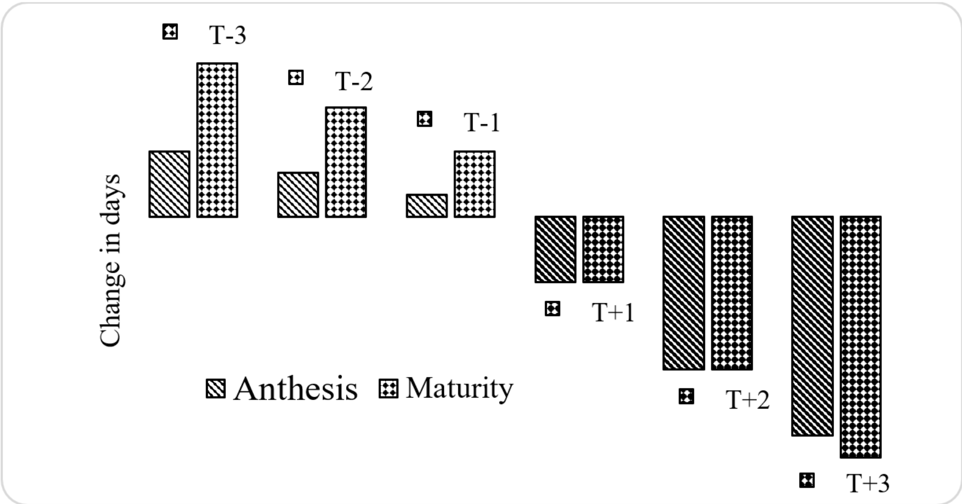

Figure 1: Effect of change in temperature on anthesis days and maturity days

productivity by 1.5 to 5.8% (Fig 2a). Contrary to this, increase in temperature from 1 to 3°C decreased productivity by 9.4 to 33.1%. Increase in radiation from 1 to 3 MJ m^{-2} day^{-1} increased productivity by 0.9 to 3.1%. Contrary to this, decrease in radiation from 1 to 3 MJ m^{-2} day^{-1} decrease productivity by 1.2 to 3.6 % (Fig 2b).

The changes in temperature and solar radiation simultaneously below and above normal weather condition have affected grain yield. In case of increasing temperature as well as increasing solar radiation with different combinations simultaneously above the normal condition decreased grain yield by 6.3 to 32.1%. While, in case of decreasing temperature as well as decreasing solar radiation with different combinations decreased grain yield by 0.5 to 2.9% except in case of decreasing 1°C and 2°C temperature with decreasing 1 MJ m^{-2} day^{-1} solar radiation which has increased 0.3 and 1.8% grain yield respectively. Further, grain yield increased by 0.4% with decreasing 2°C temperature and 2 MJ m^{-2} day^{-1}. Hundal and Kaur (2007) and Yadav *et al.*, (2015) also reported similar findings.

3.2.2 Effect on straw yield

The straw yield was simulated at 5346 kg ha^{-1} in normal weather parameters (no environment modification) (Table 1). The decrease in temperature (maximum and minimum both) from 1 to 3°C decreased straw yield by 1.9 to 5.8%. Contrary to this, increase in temperature (maximum and minimum both) from 1 to 3°C increased straw yield by 3.2 to 8.2% above normal. Increase in solar radiation from 1 to 3 MJ m^{-2} day^{-1} increased straw by 0.2 to 0.8 %. Contrary to this, decrease in radiation from 1 to 3MJ m^{-2} day^{-1} decreased straw yield by 0.5 to 1.1% from normal.

In case of increasing temperature as well as increasing solar radiation with different combinations simultaneously, straw yield increased by 3.6 to 10.8%. Whereas, decreasing temperature as well as decreasing solar radiation simultaneously, straw yield decreased by 2.1 to 6.4%. Similar findings were also reported by Bachelet and Gay (1993), Hundal and Kaur (2007) and Byjesh et al. (2010).

4. Conclusions

Temperature is directly related to plant development. Hence, an increase or decrease in temperature directly affect the length of days of anthesis and maturity. The interactive effects of increasing temperature and solar radiation simultaneously revealed a cumulative adverse effect on productivity of wheat. Productivity of crop is expected to counteract the negative

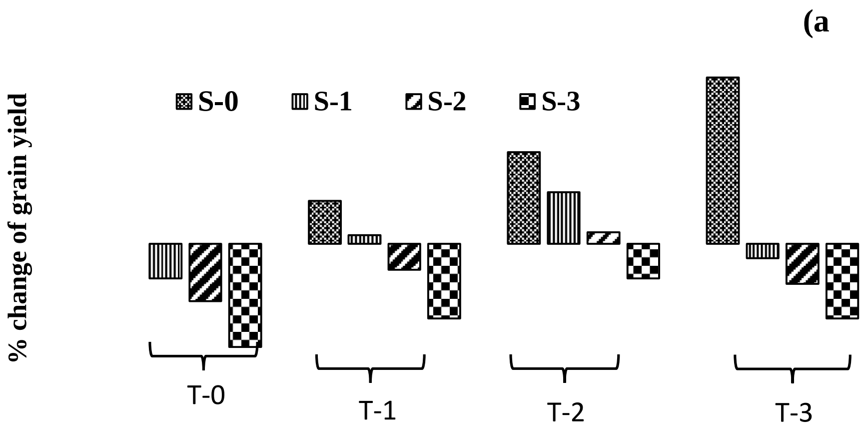

Figure 2 (a): Interactive effect of decreasing in solar radiation and temperature on grain yield

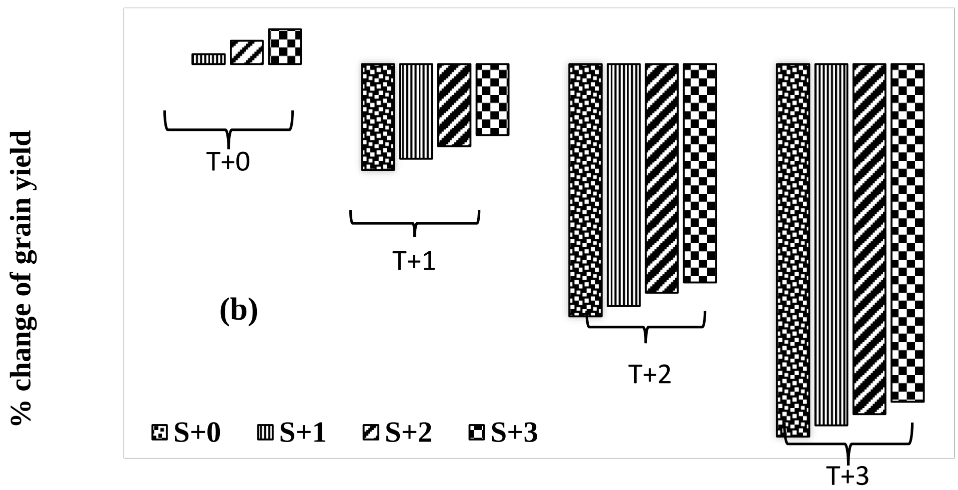

Figure 2b: Interactive effect of increasing in solar radiation and temperature on grain yield

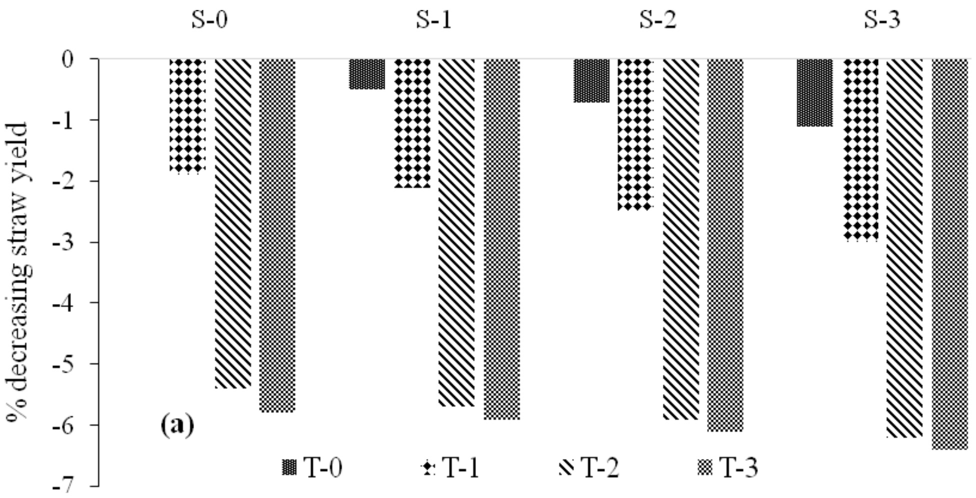

Figure 3a: Interactive effect of decreasing in solar radiation and temperature on straw yield

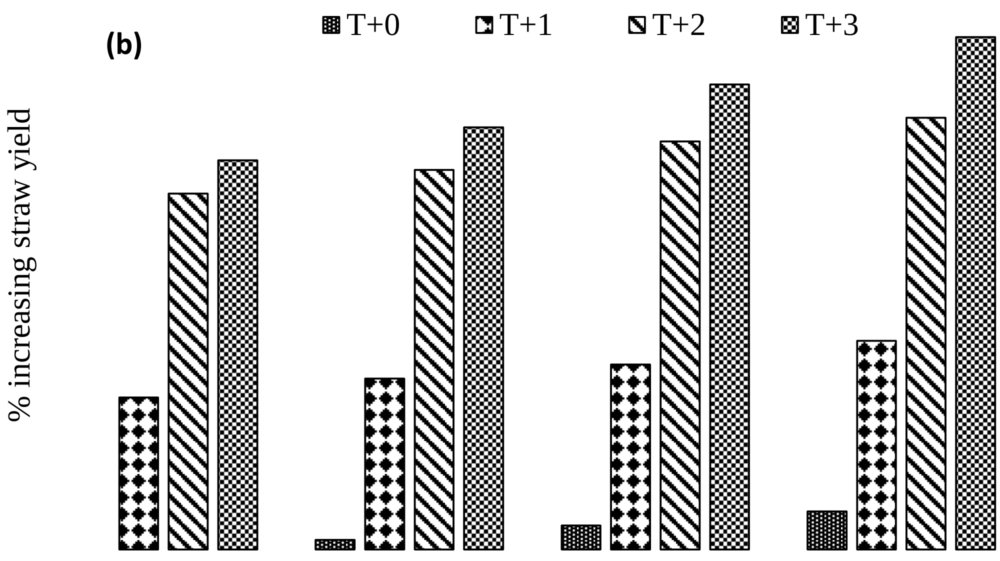

Figure 3b: Interactive effect of increasing in solar radiation and temperature on straw yield

effects of increase in temperature and decrease in solar radiation.

The results of this simulation indicate that solar radiation directly affects crop yield. Highest potential productivity of a crop is therefore obtained in regions where crop duration is more under relatively low temperatures and more radiation received as compared to the normal. Such simulation studies can guide us in determining the effect of climate variability and changes on productivity of wheat crop and can be used for crop yield forecasting and further policy planning by the government.

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