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EFFECT OF CLIMATE CHANGE ON WHEAT PRODUCTIVITY AND POSSIBLE MITIGATION STRATEGIES USING APSIM-WHEAT IN WESTERN DISTRICT OF UTTAR-PRADESH, INDIA

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Abstract

Climate change is expected to affect agriculture differently in different parts of the world. Temperature and CO_2 are two important parameters related to climate change, which affect crop yield of a particular region. In the present study, an attempt has been made to assess impact of these two parameters on the productivity of wheat in western district of Uttar Pradesh, India. In this study, APSIM-Wheat model 7.7 was used. The wheat varieties UP-2565 were sown on three different dates (20 December, 30 December, 9 January). As per IPCC (2001) recommendation projected CO_2 concentrations were applied 414,522 and 622 ppm and temperature projections were applied 1.3, 2.9 and 5.2^{0}C during the years 2020, 2050 and 2080. It was found that days taken to attain anthesis was found to be decreased as temperature increased at all levels (*i.e.* 1.3 in 2020s, 2.9 in 2050s and 5.2^{0}C in 2080s). Increase in temperature will adversely influence the crop performance and these negative impacts of temperature are not compensated enough by elevated CO_2 concentration.

Key words :APSIM-Wheat, anthesis, wheat, IPCC, projections.

Introduction

Climate influences plant life in many ways and can exhibit, simulate, alter or modify crop performance. Various modeling approach has been applied for optimization of natural resources to assess the impact of future climate change on crop production. In this study an attempt has been made to evaluate the likely impact of climate change on wheat yield in sub humid climate of Meerut. For this study user friendly model APSIM-Wheat model vs 7.7 was used (Kneating *et al*., 2003), which is a generic model. Various crop models have been widely used over the globe for assessing the effect of climate change and in developing adaptation strategies. Crop weather models are one of the convenient tool to assess the impact of climate change. It saves time as well as cost incurred in cumbersome field experiment. The APSIM model has been widely used in Australia to study productivity, nutrient cycling and environmental impacts of farming systems as influenced by climate variability, management interventions and future climate change (Van Ittersum *et al*., 2003; Wang *et al*., 2009). It provides the functionality needed to predict soil C change as affected by environmental and management. However, it is also performing well in Indian condition after proper calibration.

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Materials and Methods

Field experiments were conducted during 2014-15 at Crop Research Centre, Sardar Vallabh Bhai Patel University of Agriculture & Technology (29^0 01' North latitude and 77^0 75' East longitudes). The experiment was laid in randomized block design. The wheat varietie UP-2565 were sown on three different dates (15 November, 30 December, 15 January). Periodical observations were recorded on plant biometrics *viz*., dry matter, plant height, leaf area index (LAI), biomass, leaf area index (LAI), dry matter different phenological stages *viz*., days taken to emergence, crown root initiation (CRI), heading, flowering and maturity. Data on weather parameters maximum, minimum temperature, relative humidity, evaporation and bright sun shine hours were procured from a class "B" Agrometeorological observatory of Sardar Vallabh Bhai Patel University of Agriculture & Technology. Recommended package of practices was adopted during both years of study. Wheat crop was sown with row spacing of 22.5 cm. Three irrigations were applied at critical phenological stages. In regards to fertilizer application of crop 120 kg N, 60 kg P_2O_5 and K_2O were applied as basal dose at the time of sowing by broadcasting method. The remaining 2/3rd dose of N were applied in two splits at CRI and late tillering stage. In this study Apsim-Wheat model vs 7.7 was applied for cropping season 2014-15. As per IPCC (2001) recommendation projected CO_2 concentrations were applied 414, 522 and 622 ppm and temperature projections were applied 1.3, 2.9 and 5.2^{0}C during the years 2020, 2050 and 2080.

Results and Discussion

Calibration of model

The APSIM model was calibrated using the field trial data of 2014-15 and validated with the corresponding data of different treatments in the same year for the wheat cultivar UP-2565. The APSIM wheat module has been used to parameterise the wheat cultivar UP-2565, coefficients generated to match the Days to 50% flowering, observed yield, LAI and biomass are given in table 1.1.

For datasets used to determine the genetic and phenotypic coefficients for the cultivar good agreement was obtained between the predicted and observed values (fig. 1). There was a good agreement between the observed grain and biomass yield of wheat as compared to the predicted ones. The error in prediction of days to flowering and date to physiological maturity for both crops was within 1 day. The measured grain yield of wheat at harvest was 4.1 t ha^{-1} compared to the simulated grain yield of 4.3 t ha^{-1}. The measured total biomass and the predicted biomass values were also comparable (table 1). Therefore, in this parameterization study, the APSIM wheat module was able to simulate the observed days to 50% flowering, physiological maturity, total biomass and grain yield for the wheat crop reasonably well for Western district of Uttar Pradesh, India.

Effect of projected temperature

Increases in temperature affects both vegetative and reproductive phase and may cause reduction in yield as projected in many studies. Temperature is the prime factor,in absence of other limiting factor, which drives plant growth rates. For this study temperature is projected to be increased by as 1.3^{O}C and 2.9^{O}C in the years 2020 and 2050, respectively.

Effect of projected temperature on days taken to anthesis

The increase in temperature is accompanied by reduction in crop growth duration. From the experiment, it was found that there was linear decrease in duration of phenological phases with increase in temperature levels. Maximum reduction in days taken to anthesis was observed for rise in temperature by 2.9^{O}C in the year 2050. The reduction was 8.8 to 16.6%, 8.1 to 17.4% and

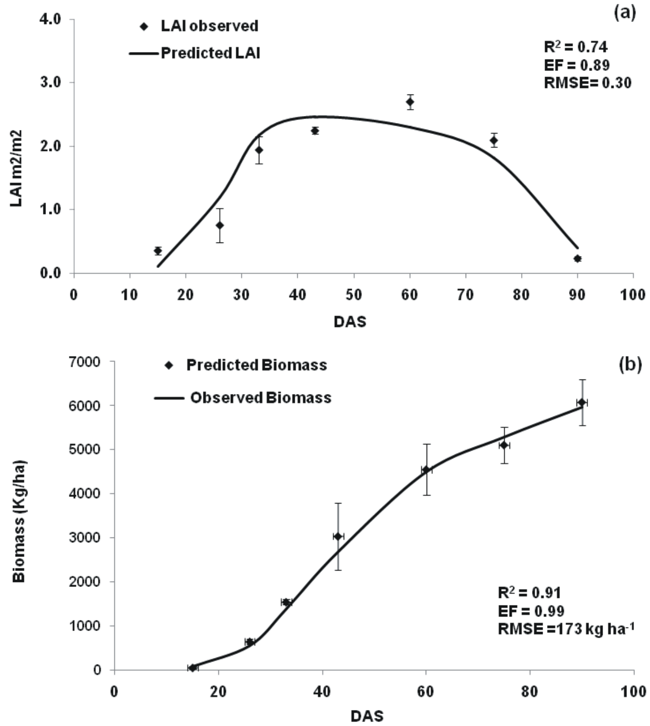

Fig. 1 : Parameterization of APSIM model for wheat cultivar (UP-2565) showing observed and predicted values for (a) LAI and (b) total biomass yield. Vertical bar represents standard deviation. DAS: days after sowing.

Table 1.1 : APSIM model predicted and observed values for wheat cultivar, UP-2565

Parameters	UP-2565	
	Observed	Predicted
Days to 50% flowering	37	36
Total DM (t ha^{-1})	5.8	6.1
Date to physiological maturity	130	132
Grain yield (t ha^{-1})	4.1	4.3

Table 1.2 : Effect of increase in temperature (^{0}C) on anthesis (DAS) of wheat under different treatments.

Dates of sowing	Simulated anthesis (DAS)		
	Projected increase in temperature(^{0}C)		
	At present (23.2^{0}C)	In year 2020 (+1.6^{0}C)	In year 2050 (+2.9^{0}C)
20 December	90	82	75
30 December	86	79	71
09 January	81	76	71

6.1 to 12.3% for the crop on 20 December, 30 December and 09 January, respectively. Similar tend has been observed for days taken to physiological maturity. The reduction was 2.4 to 5.6%, 6.5 to 8.9% and 2.5 to 6.08% for the crops sown on 20 December, 30 December and 09 January, respectively. The reduction in duration of phenological stages was more for late sown crop. Decrease in phenological duration of crops was probably due to rapid accumulation of growing degree days (GDD), which enhance the rate of growth and development resulting in shortening of life span. Approximately 5 days reduction in flowering and 4 days reduction in days taken to maturity was reported in Northwest India by 1^{O}C increase in temperature (Attri and Rathore, 2003). Similar findings have been reported by Lobell *et al.* (2012). They carried out their study on three sites (9 years) over north India and reported a decrease in wheat yield due to shortening of growing period.

Effect of projected temperature on leaf area index (LAI)

The effect of increase in temperature at different projected levels on leaf area index of rice as influenced by different treatments has been presented in fig. 2. Leaf area index decreased as temperature increased from current year temperature level. The decrease is from 3.07 to 2.3, 2.09 to 1.47 and 1.66 to 1.15 for crop sown on 20 December, 30 December and 09 January, respectively.

Effect of projected temperature on dry matter

The effect of increase in temperature at different projected levels on total dry matter of wheat as influenced by different treatments has been presented in table 1.2. Total dry matter decreased as temperature increased from current temperature level; from 12954 to 12035(kg/ha), 12000 to 11156 (kg/ha) and 9285 to 8045 (kg/ha) with crop sown on 20 December, 30 December and 09 January in the case of year 2020.

Total dry matter decreased as temperature increased from current temperature level; from 12954 to 10665(kg/ha), 12000 to 10229 (kg/ha) and 9285 to 6564 (kg/ha) with crop sown on 20 December, 30 December and 09 January in the case of year 2050. Crop sown on 09 January recorded the lowest value for total dry matter compared to current year temperature levels than sowing with increased temperature projections, while the difference was less with other sowing dates.Total dry matter decreased as the temperature increased over current temperature level with crop sown on 20 December, 30 December and 09 January. Similar results were reported by Haris *et al.* (2013).

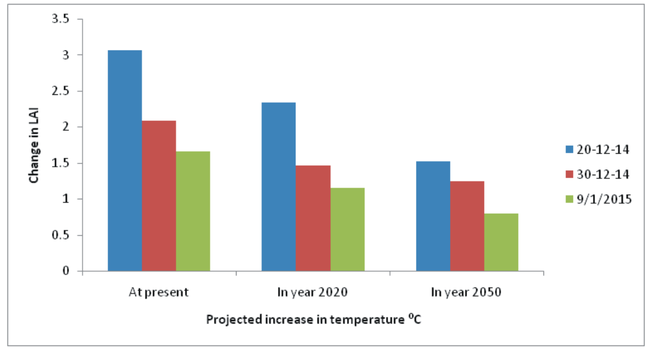

Fig. 2 : LAI as influenced under different cliamatic scenarios based on temperature.

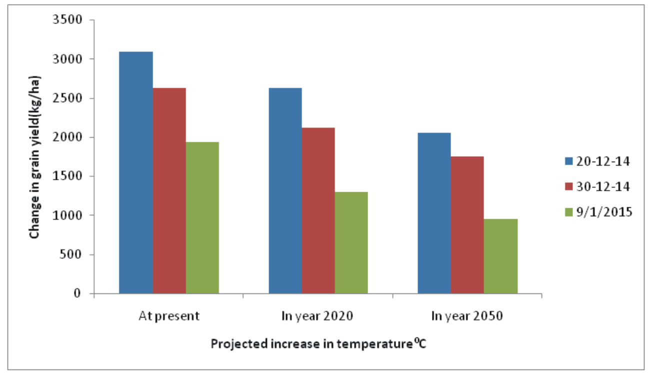

Fig. 3 : Effect of increase in temperature (°C) on grain yield under different sowing dates.

Table 1.3 : Effect of increase in temperature (^{0}C) on days to physiological maturity (DAS) of wheat under different treatments.

Dates of sowing	Simulated physiological maturity (DAS)		
	Projected increase in temperature(^{0}C)		
	At present (23.2^{0}C)	In year 2020 (+1.6^{0}C)	In year 2050 (+2.9^{0}C)
20 December	125	122	118
30 December	123	115	112
09 January	116	113	109

Table 1.2 : Total dry matter as influenced in different climatic scenarios (only temperature).

Dates of sowing	Simulated dry matter at harvest(kg/ha)		
	Projected increase in temperature(^{0}C)		
	At present	In year 2020 (+1.6^{0}C)	In year 2050 (+3.9^{0}C)
20 December	12954	12035	10665
30 December	12000	11156	10229
09 January	9285	8045	6564

Effect of projected temperature on grain yield

It has been found that crop yield decreases with increase in temperature. It has been presented in fig. 3.

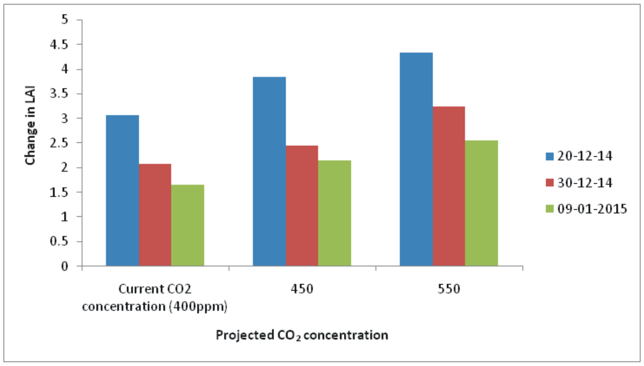

Fig. 4 : Effect of increase in CO_2 on average LAI under different sowing dates.

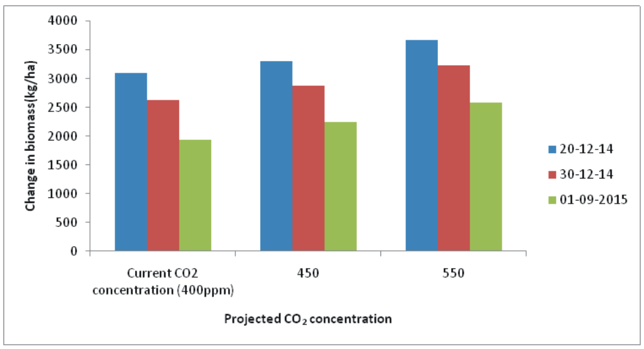

Fig. 5 : Effect of increase in CO_2 on grain yield under different sowing dates.

The decrease is from 3095.7 to 2633 (kg/ha), 2629.40 to 2126 (kg/ha) and 1945 to 1303 (kg/ha) for crop sown on 20 December, 30 December and 09 January respectively in the case of the year 2020 (+1.6^{0}C). The decrease is from 3095.7 to 2056 (kg/ha), 2629 to 1756(kg/ha) and 1945 to 956 (kg/ha) for crop sown on 20 December, 30 December and 09 January respectively in the case of the year 2050 (+3.9^{0}C). The decrease was highest in the case of 09 January sowing and also 09 January sowing recorded the lowest grain yield index compared to other sowing dates. Grain yield decreased as temperature increased over current temperature level with crop sown on 20 December, 30 December and 09 January, respectively. This may be due to due to high temperature the plants complete life cycle quickly and they cannot convert their food resources to grain.

Effect of CO_2 concentration

CO_2 is projected to be increase by 450ppm and 550ppm in the year 2020 and 2050, respectively (IPCC, 2007). Crop weather simulation models (CWSM) seek to predict the phenology and yield of wheat crop from input of weather data and would thus serve as an essential tool to study the effect of climate change on crop production.

Table 1.3 : Dry matter at harvest as influenced in different climatic scenarios (only CO_2).

Date of sowing	At current CO_2 concentration (400ppm) dry matter	Simulated dry matter (kg/ha)	
		Projected CO_2 Concentration (ppm)	
		450(2020)	550(2050)
20 December	12954	13145	13504
30 December	12000	12356	12583
09 January	9285	9605	9860

Effect of CO_2 concentration on leaf Area Index

The effect of increase in CO_2 at different projected levels on leaf area index of wheat as influenced by different treatments has been presented in fig. 4. Leaf area index increased as CO_2 increased from current year CO_2 level. The increase is from 3.07 to 3.85, 2.09 to 2.45 and 1.66 to 2.15 for crop sown on 20 December, 30 December and 09 January respectively in the case of the year 2020 (450ppm CO_2). The increase is from 3.07 to 4.35, 2.09 to 3.25 and 1.66 to 2.56 for crop sown on 20 December, 30 December and 09 January respectively in the case of the year 2050 (550ppm CO_2). The increase was highest in the case of 20 December sowing and also 20 December sowing recorded the highest leaf area index compared to other sowing dates.

Leaf area index increased as CO_2 increased over current CO_2 level with crop sown on 20 December, 30 December and 09 January, respectively. This may be due to increase in CO_2 during the vegetative period of wheat the photosynthesis rate increases resulting in higher LAI.

Effect of CO_2 concentration on total dry matter

The effect of increase in dry matter at different projected levels on total dry matter of wheat as influenced by different treatments has been presented in table 1.3. Total dry matter increased as CO_2 increased from current CO_2 level from 12954 to 13145 (kg/ha), 12000 to 12356 (kg/ha) and 9285to 8045(kg/ha) with crop sown on 20 December, 30 December and 09 January for 2020 (450ppm CO_2). Total dry matter increased as CO_2 increased from current CO_2 level from 12954 to 13504kg/ha), 12000 to 12583 (kg/ha) and 9285 to 9860 (kg/ha) with crop sown on 20 December, 30 December and 09 January for 2050 (550ppm CO_2).Total dry matter increased as the CO_2 increased over current CO_2 level with crop sown on 20 December, 30 December and 09 January.

Effect of CO_2 concentration on total grain yield

The effect of increase in grain yield at different projected levels on total grain yield of wheat as influenced by different treatments has been depicted in fig. 5. Total grain yield increased as CO_2 increased from current CO_2 level from 3095.4 3307 (kg/ha), 2629.40 to 2885.4 (kg/ha) and 1945 to 2255 (kg/ha) with crop sown on 20 December, 30 December and 09 January for 2020 (450ppm CO_2). Total grain yield increased as CO_2 increased from current CO_2 level from 3095.4 to 3675.7 (kg/ha), 2689 to 3239.4 (kg/ha) and 1945 to 2595 (kg/ha) with crop sown on 20 December, 30 December and 09 January for 2050 (550ppm CO_2). Total grain yield increased as the CO_2 increased over current CO_2 level with crop sown on 20 December, 30 December and 09 January.

Conclusion

The performance of APSIM-Wheat model was well and it correctly predicted almost all the wheat crop characters. It is clear from the results that increase in temperature will adversely influence the crop performance and these negative impacts of temperature are not compensated enough by elevated CO_2 concentration. Hence, in climate change scenario by adapting optimized package of practices (like shifting in date of sowing) we can minimize yield losses upto certain extent. In this study impact of the weeds, diseases and insect pests on crop growth, development and final yield are not considered so there is need to incorporate these parameter in future studies for better assessment of final yield.

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