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Assessment of impact of climate change on rice and wheat yield in sub humid climate of Bihar

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ABSTARCT

The present study deals with the impact of temperature and CO_2 projection obtained for different time periods 2020, 2050 and 2080 using HADCM3 factors on the productivity of rice and wheat crop at four stations viz. Pusa, Purnea, Sabour and Patna of Bihar using InfoCrop model performed. The results showed that the simulated yield of rice and wheat decreased in the range of 1.1-9.2 %, 6.1-13.2 % and 15.9-22.4 % from baseline in 2020, 2050 and 2080 respectively over the stations. Decrease in simulated yield in wheat was observed in the range of 3.5-21.1 %, 14.0-37.9 % for 2050 and 2080 for all the stations.

Key words : Climate change, rice, wheat, simulation studies, CO_2 conc., temperature rise

The climate sensitivity of agriculture is uncertain, as there is regional variation of extreme temperature and rainfall, the crop and cropping system, soils and management practices.Inter-Governmental Panel on Climate change (IPCC) Fifth Assessment Report concludes that increasing numbers of warm days and decreasing numbers of cold days have been observed, with the warming trend continuing into the new millennium (IPCC 2014).General Circulation Models (GCMs) and Special Report on Emission Scenarios (SRES), show that higher temperatures will lead to lower rice yields as a result of shorter growing periods. However, carbon dioxide (CO_2) fertilization may at least in part offset yield losses in rice and other crops. In the Indo-Gangetic Plains of South Asia there could be a decrease of about 50% in the most favourable and high-yielding wheat area as a result of heat stress at two times CO_2 (IPCC 2014). Elevated CO_2 besides affecting the crop also affects the environment, which in turn may either beneficial or damaging effect on agricultural production (Rosenzweig *et al.,* 1998). Changes in temperature play a crucial role in determining crop productivity (Fiscus *et al.,* 1997). Decline in potential yield of wheat and rice is linked to negative trend in solar radiation and an increase in minimum temperature in the Indo-Gangetic Plains of India (Pathak *et al.,* 2003). With subsequent rise in temperature reduced the yield of wheat and enhanced CO_2 was unable to counter balance the decline in wheat yield (Abdul Haris *et al.,* 2013). Decision support systems (DSS) or crop models provide a way, where the relative effects of these variables on crop growth and yield can be studied in particular combinations on regional basis. The present study deals with the effects of climate change on *kharif* and *rabi* season crops (Rice and wheat) for Bihar which might help to adopt suitable farming techniques to maximise agricultural production in this high potential region. It also provides insights into possible changes in the cropping pattern and adaptation options for future.

MATERIALS AND METHODS

Bihar is located in the alluvial plains of India and is situated between 24^0 N and 27^0N, 83^0E and 88^0E with a height of 52 m amsl having normal rainfall of 1243.7 mm. Four different station stations were selected representing different zones (Pusa zone I; Purnea zone II; Sabour zone III A; Patna zone III B).Daily data for air temperature and rainfall from four representative centres were collected for the period 1955-2010 for Pusa and Sabour and 1969-2010 for Patna and Purnea. Meteorological, crop and soil data used for the simulation studies were collected from India Meteorological Department, Pune; Rajendra Agricultural University, Pusa and Bihar Agricultural University, Sabour.

IPCC describes future scenarios for the period 2010-2039, 2040-2069 and 2070-2099 referred to as $2020_{s,}$ 2050_s and 2080_s respectively. The General Circulation Model was used in the study ($HADCM_3$) for the A_2 scenarios (The A_2 scenario describes a heterogeneous world with a focus on self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population). The generic crop

Table 1: Study area representing different agro-ecological zones of Bihar

Station	Agro- ecological zone	Latitude(^{0}N)	Longitude(^{0}E)	Elevation (m)
Pusa	I	25.85	85.78	47
Purnea	II	25.98	87.80	53
Sabour	III A	26.10	87.70	37
Patna	III B	25.58	85.25	41

Table 2: Validation results for rice and wheat crops

Crop	Coefficient of efficiency (%)	RMSE(kg ha^{-1})	MAE(kg ha^{-1})	R^2
Rice (var. Swarna)	70	291.5	236	0.87
Wheat (var. HD 2733)	85	105.2	71	0.90
Wheat (var. PBW 343)	84	162.1	132	0.89

RMSE= Root mean square error; MAE= Mean absolute error.

Table 3: Percentage change in yield ofrice and wheatcrop due to climate change

	Rice			Wheat		
Stations	2020	2050	2080	2020	2050	2080
Pusa	-1.3	-8.6	-19.1	2.6	-3.5	-14.0
Purnea	-1.4	-11.4	-22.4	-5.0	-13.0	-20.0
Sabour	-1.1	-6.1	-15.9	-3.7	-18.7	-35.4
Patna	-9.2	-13.2	-19.9	-11.0	-21.1	-37.9

model Info Crop ver. 2.1 developed at IARI, Pusa (Aggarwal, et al., 2004) was used. Info Crop is a DSS, designed to simulate the effects of weather, soil, agronomic management and major pests on crop growth and yield. The model was calibrated by comparing the simulation yield with the observed yield for three years. Calibration in the case of rice for var. Swarna and for two different varieties of wheatHD 2733 and PBW 343 for different locations, viz. Pusa, Purnea, Sabour and Patna respectively was done according to crop yield data availability.Generic coefficients were derived for rice var. Swarna and for wheat var. HD 2733 and PBW 343 growing in the major area. The results of validation are presented in Table 1. After calibration, the model was run for the baseline and scenarios based on the practices used for validation purposes.Sensitivity analysis was performed for Swarna var. of rice and HD 2733 and PBW 343 varieties of wheat crop to know the role of projected changes of temperature in various combinations. The growth and yield of rice and wheat under different changing scenarios was simulated using the model. Potential yields of rice and wheat were first simulated at current level of CO_2 for the baseline period (1961-1990). Further the different scenarios were given for 2020, 2050 and 2080 respectively, as incremental variable scenarios have the capacity of capturing a wide range of possible changes in the near future.

RESULTS AND DISCUSSION

Change in yield of rice and wheat crop due to climate change

Simulated yield of rice in different scenario decreased the yield in all the periods. This decrease was in the range of 1.1-9.2 %, 6.1-13.2 %, 19.1-22.2 % for 2020, 2050 and 2080 respectively for all the stations (Table 3). Maximum decrease in yield was observed in Patna for 2020 and 2050 but in 2080, it was maximum in Purnea.These results are in line with those of other researchers. For instance, Peng *et al.* (2004) observed that yield of rice decreased by 10 % for every 1^0 C rise in growing season T_{min}.

Simulated yield of wheat decreased from the baseline in 2050 and 2080 to3.5-14 %, 13-20 %, 18.7-35.4 % and 21.1-37.9 % for Pusa, Purnea, Sabour and Patna respectively. Simulated yield was also decreased for 2020 by 5 %, 3.7 % and 11 % for Purnea, Sabour and Patna respectively.A decline of 0.45 tonne ha^{-1} in wheat yield, with increase in temperature from 0.5^0 C to 1.5^{0}C has been reported by Kalra *et al.*(2003). The impact of climate change was more on wheat than rice. This may be ascribed to the increased projected T_{min} and T_{max} and decreased rainfall in the months of Feb to March synchronizing reproductive and grain development stages of wheat. All these conditions reduce both duration to anthesis and to maturity, leading to poor grain fill in wheat (Arora *et al*. 1998). Moreover, at high temperature, energy is lost through the process of transpiration by the plant and reduced energy results in poor grain formation and yield. Such effects are less in rice because of relatively lower temperature at maturity and these may not aggravate in future as the projected temperature rise is also less. In the present study, a strong correspondence between reduction in yield and shortening of crop duration under higher temperature was observed in scenarios.

CONCLUSION

The study indicates losses in the yield of rice and wheat with subsequent rise in temperature. However, the percentage decline was more in zone II and III B in case of rice, probably due to more decline of rainfall in future. In case of wheat, decline in yield was more in zone III A and III B, probably due to more increase of minimum temperature in these zones. Notwithstanding these uncertainties, climate change will drive reductions in crop yield. Adaptation options, such as adopting new agronomic practices and delineating favourable areas for rice and wheat production, need to be looked into for sustainability of food security in this region.

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