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Yield and duration of potato crop in Bihar under projected climate scenarios

A.ABDUL HARIS*, V. CHHABRA, B.P. BHATT and A. K. SIKKA[1]

ICAR Research Complex for Eastern Region, Patna-800014

[1] NRM Division, KAB-II, Pusa, New-Delhi-110012

**Email : abdulharis123@rediffmail.com*

ABSTRACT

The impact of projected climate during 2020-2080 on the potential yield of potato in Bihar has been analysed using InfoCrop model. Data from field experiments conducted at Patna, with popular potato variety Kufri Ashoka grown in *rabi* season of 2008-09 through 2010-11, was used for calibration and validation of model. It is indicated that increased minimum and maximum temperature projected for future time periods, however, almost no change in rainfall is projected for the stations under studied. The crop planted on 2nd December, showed projected decline in yield ranging from 3.3-5.9% for 2020, 12.5-15% for 2050 and 19.3-24.8% for 2080 time period across the locations studied. Delayed planting by 10 days successively from 2nd December through 22nd December showed a progressively lower decline in the projected yield at different locations. However, advancing the planting time by 10 days resulted in higher decline in projected yield. Weather data analysis performed for the crop season (November-February).

Key words: Climate change, crop yield, crop duration, potato

Since agricultural production is greatly affected by climate, any changes in climate which may result from increasing concentrations of greenhouse gases in the atmosphere could have serious consequences for agricultural yield potential (Mearns, 2000). Food and energy security of India are crucially dependent on favourable weather. According to the estimates by IPCC (2007) earth's linearly averaged surface temperature has increased by 0.74°C during the period 1901-2005. Increasing trends of rainfall and minimum temperature in Gangetic plains of Bihar was observed (Haris *et al*., 2010a). Crop growth simulation models, combining knowledge of crop characteristics and their interactions with the environmental variables have been developed for calculating yield levels of crops under well specified conditions. Simulation studies are useful in predicting future climate scenario based on changing trends in temperature, CO_2 and rainfall etc (Haris *et al*., 2010b; Haris *et al*., 2012). Wheat yield in Patna and Ranchi showed a declining trend due to increased temperature (thermal stress) coinciding with grain filling stage of crop (Haris *et al*., 2011). Predicted increase in temperature for future time periods may prove to be detrimental in future time periods for *rabi* crops, however, crop like winter maize may be benefitted due to increase in temperature upto some extent (Haris *et al*., 2013; Haris *et al*., 2014; Chhabra and Haris, 2014). Sarquis *et al*. (1996) stated that the magnitude of the effect of elevated temperatures on potato growth and final yield is determined by an interaction between soil temperature, air temperature, solar radiation flux density, and photoperiod duration. Kadaja and Tooming (2004) proposed a relatively simple model POMOD to calculate potato yield, which permits generalization of the knowledge in different disciplines on the potato crop yield levels, using the measured physiological, ecological, agro meteorological, and agronomical parameters of the plant.

Potato is a temperate crop and prefers mild temperatures. Along with direct impacts of climate change (i.e. rainfall and temperature), potatoes will also be particularly sensitive to various indirect effects, including changes in the agricultural potential of soils, as this effects the availability of water to plants and impinges on other land management practices. CO_2 concentration and assimilation of photosynthates in potato are positively correlated and 10% increase in tuber yield is estimated for every 100 ppm increase in CO_2 concentration (Miglietta *et al.,* 1998). These positive effects are attributed to increased photosynthesis by 10–40% (Katny *et al.,* 2005) and decreased evapotranspiration (Magliulo *et al*., 2003). High temperature is reported to reduce tuber numbers and size leading to decreased total biomass production and tuber yield (Peet and Wolfe, 2000). CO_2 enrichment does not appear to compensate for the detrimental effects of higher temperatures

Table 1: Geographical position of representative centres in Bihar

Center	Agro-ecological zone	Latitude	Longitude	Altitude (m)
Pusa (Samastipur)[a]	Zone INorth West Alluvial Plains	25.85^{0}N	85.78^{0}E	38
Madhepura (Madhepura)[a]	Zone IINorth East Alluvial Plains	26.11^{0}N	86.23^{0}E	53.95
Sabour (Bhagalpur)[a]	Zone III ASouth Bihar Alluvial Plains	25.33^{0}N	87.17^{0}E	11
Patna (Patna)[a]	Zone III BSouth Bihar Alluvial Plains	25.58^{0}N	85.25^{0}E	41

a- name of the district

Table 2: Generic coefficients used for InfoCrop potato model calibration

Sl. No.	Parameters used for simulation	Potato
1.	Thermal time (^{0}C d)	
a	Planting to germination	226^{0}C d (12 days)
b	Germination to 50% tuber initiation	317^{0}Cd (45 days)
c	50% Tuber initiation to physiological maturity	385^{0}Cd (30 days)
2.	Radiation use efficiency (gm $MJ^{-1}day^{-1}$)	3.5
3.	Specific leaf area (dm^2mg^{-1})	0.0027
4.	Potential storage organ weight (mg per tuber)	200000
5.	Date of sowing	02 December
6.	Date of harvesting	28 February

on tuber yield (Singh *et al*., 2010). At low latitudes, shifting planting time or location is less feasible, and in these regions global warming could have a strong negative effect on potato production.

In this study the effects of projected temperature change in changing climatic scenarios on the yield potential of potato in Bihar have been analysed using InfoCrop model. Simulation studies are carried out with four dates of sowing for potato to get the ideal planting window in future temperature scenarios.

MATERIALS AND METHODS

For this study, four stations in different agroclimatic zones are selected (Table 1), representing each zone, on the basis of availability of meteorological, soil and crop data.

Experimental data

Daily data for air temperature and rainfall from four centers representative of each zone is collected for the period 1961-1990 (except for Sabour, for which the data period was 1972-1990). Missing values of solar radiation vapour pressure and wind speed were worked out (Allen *et al*., 1998). Vapour pressure was derived from maximum and minimum relative humidity. Wind speed (2 ms^{-1}) used as a temporary estimate where no wind data were available (FAO, 1998). This is justified as wind speed during the crop duration of from November to February is mostly calm and potato being a tuber crop with foliage on the soil surface is not much affected by wind. Meteorological data for the simulation studies were collected from Rajendra Agricultural University (Pusa, Samastipur) Bihar Agriculture College (Sabour, Bhagalpur) and Krishi Vigyan Kendra Madhepura RAU Krishi Vigyan Kendra, Madhepura, ICAR-Research Complex for Eastern Region, Patna, RAU Rice Research Station, Mithapur (Patna). Crop and soil data were taken from experimental records at ICAR-RCER, Patna.

Intergovernmental Panel on Climate Change (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 data used in this study is the output of UK Hadley Center for Climate Prediction and Research model ver. 3 (HadCM3) for the A2 storyline. The 30 year averaged monthly changes obtained from Data Distribution Centers (DDC) of IPCC is incorporated into individual years according to the equations 1 and 2. The outputs of minimum, maximum temperature and rainfall were used to generate future scenarios and solar radiation was then calculated from the temperature values (maximum and minimum), extraterrestrial radiation and adjustment coefficient by using Hargreaves's radiation formula (FAO, 1998).

Projected changes in Temperature = Baseline temperature + Expected change in temperature obtained from HadCM3 outputs... (1)

Projected changes in Precipitation = Baseline daily rainfall x (1+ % change in rainfall) ... (2)

Calibration and Validation of InfoCrop model

The generic crop model InfoCrop, developed at IARI, by Aggarwal *et al*. (2004) is used in this study. InfoCrop is a decision support system (DSS) tool, designed to simulate

Table 3: Validation for potato crop

Crop	Years	Observed yield (kg ha^{-1})	Predicted yield (kg ha^{-1})	Coefficient of Efficiency (%)	RMSE (kg ha^{-1})	MAE (kg ha^{-1})	R^2
Potato	2008	1900	2019	67	79.30	71.67	0.99
(Kufri	2009	2000	2055				
Ashoka)	2010	2230	2189				

Table 4: Temperature and rainfall for baseline and future time periods during crop season (November-February)

Period	Pusa (Zone I)			Madhepura (Zone II)		
	Tmin (°C)	Tmax (°C)	Rainfall (mm)	Tmin (°C)	Tmax (°C)	Rainfall (mm)
Baseline	10.1	25.5	34.3	10.3	25.3	33.4
2020s	11.5	26.2	34.4	11.8	26.0	33.4
2050s	13.4	27.7	34.4	13.7	27.5	33.4
2080s	14.9	30.1	34.4	15.1	29.9	33.4
		Sabour (Zone IIIA)			Patna (Zone IIIB)	
Baseline	10.7	25.3	37.4	10.8	25.2	38.8
2020s	12.1	26.0	37.5	12.2	25.9	38.9
2050s	14.0	27.5	37.5	14.2	27.4	38.9
2080s	15.4	29.9	37.4	19.9	32.6	38.9

the effects of weather, soils, agronomic management (including planting, nitrogen, residues and irrigation) and major pests on crop growth and yield. The model is designed to use a minimum set of soil (soil type, pH, organic matter, bulk density etc.), weather, genetic and management information (sowing date, sowing depth, transplanting date, irrigation, fertilizer, etc.). It integrates on a daily basis and therefore requires daily weather data (maximum temperature, minimum temperature, rainfall, solar radiation, vapour pressure and wind speed). The model calculates the crop development phases and morphological development as a function of temperature, day length and genetic characteristics (Table 2).

The model calibrated by comparing the simulated yield with the observed yield for three years. Calibration in case of potato variety Kufri Ashoka for Patna location was done on the basis of data available from experimental records. Simulation for other three stations (Pusa, Madhepura and Sabour) was performed based on the calibration and validation of Patna. Crop specific thermal time is calculated as per the equation 4 adapted from Mavi (1986). The results of validation are presented in Table 3. The coefficient of efficiency is calculated by the model listed by Hubbard *et al*. (2003). MAE, RMSE and R^2 were calculated by the formulas as given by Cochran (1977).

After calibrating, the model was run for the baseline and scenarios based on the practices used for validation purposes.

RESULTS AND DISCUSSION

Variability of temperature and rainfall of selected stations during crop season (Nov-Feb.)

Analysis of weather data during the study period showed the variation in temperature as well as rainfall for baseline and future time periods viz. 2020s, 2050s and 2080s. Lowest minimum temperature (10.1^{0}C) is for Pusa (zone I). Patna station lying in zone III B witnessed higher minimum temperature and rainfall during baseline and future periods as compared to other stations. As far as rainfall projection is concerned, no change is observed from baseline to different time periods; however, temperature varies significantly (Table 4).

Effect on yield

With the current cultivars, cultivation and management practices, the impacts of temperature regimes in future scenarios on potato yield under A2 scenario are explored at the selected centers for four dates of planting viz. 22nd November, 2nd December, 12th December and 22nd December. All the results are taken by comparing the simulated yields (Table 5) between A2 climate change scenarios for the time scales, i.e., 2020's, 2050's and 2080's, and baseline (1961-1990).

Table 5: Simulated duration and yield of potato for different dates of sowing and time periods

Potato	22 November		2 December		12 December		22 December	
	Crop duration (Days)	Crop yield (kg ha^{-1})	Crop duration (Days)	Crop yield (kg ha^{-1})	Crop duration (Days)	Crop yield (kg ha^{-1})	Crop duration (Days)	Crop yield (kg ha^{-1})
Pusa								
Baseline	80.1	26241	79.8	25413	77.8	24638	75.1	23834
2020	73.8	23430	75.2	24390	73.8	24392	71.7	23316
2050	66.9	21223	67.7	22251	67.4	22618	66.2	22071
2080	61.7	19435	62.3	20415	62.5	21999	61.8	21427
LSD$_{.01}$		1316**		1611**		1715**		1650**
Madhepura								
Baseline	78.8	28568	78.9	28599	77.6	27499	74.8	26086
2020	72.6	25556	74.1	26909	73.4	27094	71.3	25614
2050	65.6	23404	66.7	24301	66.7	25286	66.0	24728
2080	60.8	21206	61.7	22431	62.6	25297	62.0	24370
LSD$_{.01}$		1129**		1242**		1244**		1281**
Patna								
Baseline	78.5	22382	78.2	22398	76.8	21995	74.2	21411
2020	73.1	20674	73.9	21656	73.1	21824	71.2	21096
2050	65.8	18580	66.9	19600	66.9	20128	65.5	19756
2080	60.7	16187	62.1	16832	62.3	19685	61.2	18699
LSD$_{.01}$		1950**		2018**		1777**		1616**
Sabour								
Baseline	79.1	26134	78.7	25561	77.4	25332	74.5	23902
2020	73.4	23373	74.2	24282	73.3	24648	71.2	24040
2050	66.5	21398	67.0	22264	66.9	22638	66.0	22980
2080	61.2	19325	62.1	20627	62.4	22358	61.5	21911
LSD$_{.01}$		1404**		1394**		1251**		1746**

**=Significant at 1% level

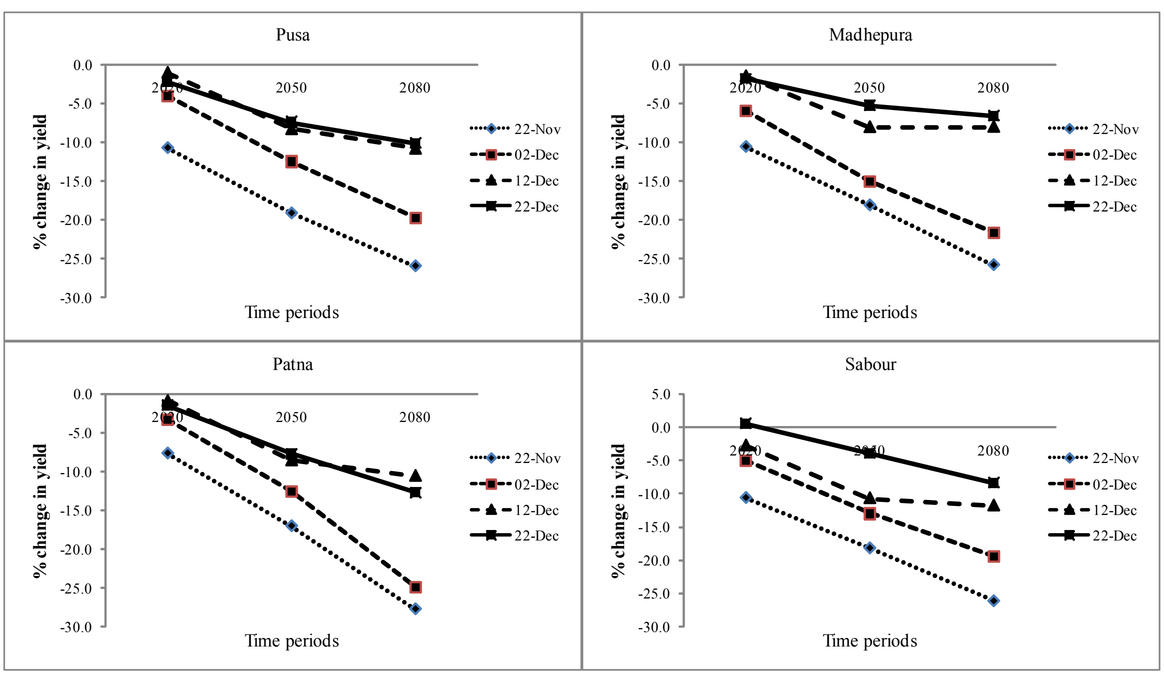

Fig 1: Percent change in simulated potato yield at selected stations in Bihar for different dates of sowing and time periods

For 22nd November planting, reduction in percentage yield of potato from the baseline yield ranged from 7.6 to 27.7 % for Patna that is also maximum range of reduction when other stations were compared. Analysis of variance test was performed for all stations which showed significant difference of yield from baseline yield for all future time periods (2020's, 2050's and 2080's) except Patna, where simulated yield showed non-significant difference for 2020's.

For 2nd December planted crop, simulated yield of potato decreased from the baseline ranged from 3.3 to 24.8% for 2020 to 2080 respectively at Patna. At Pusa, a decline of 4 to 19.7% in simulated yield of potato was observed. At Madhepura, a decrease to the tune of 21.6% and at Sabour 19.3 % were projected upto 2080s. All stations showed significant difference of yield from baseline yield for 2050's and 2080's, however for 2020's non-significant change in yield was observed from baseline except Madhepura station.

When simulation is done for 12th December and 22nd December, potato yield reduction is lesser as compared to other two dates of planting mentioned above. For Patna and Pusa, there is marginal difference in yield change percentage for these two dates of planting, whereas for Madhepura and Sabour planting of crop on 22nd December had lesser reduction percentage from baseline as compared to 12th December of planting as presented (Fig.1). All stations showed significant difference of yield from baseline yield for 2050's and 2080's except Patna for 12th December sowing and except Sabour for 22nd December sowing during 2050's.

Effect on duration

Potato var. Kufri Ashoka has duration of 75-90 days. It has been observed that crop duration also decreased with time due to increase in mean temperature. For baseline, crop duration varied from 78-80 days for 2020, 2050 and 2080 time periods, it varied from 74-75, 67-68 and 62 days respectively for future periods.

Proper planting makes all the environmental factors suitable from time of emergence and seedling establishment. The proper planting time for crop growth synchronizing with climatic conditions, characteristics of cultivars and planting, is important as suggested by Kochki *et al.,* (1995). In the potato growing belt of Indo-Gangetic plains the likelihood of reducing the crop duration due to climate change has already been reported elsewhere (Annual Report, 2010-11) and hence, adjustment of planting date is crucial. Reduction in duration is due to increase in mean temperature during future time periods and thereby early attainment of thermal time required for crop growth. This itself is reason for reduced yield due to lesser number of days available for tuberization and growth.

CONCLUSION

The results of the present study indicates that for the short duration varieties like Kufri Ashoka , it is essential to identify the right planting window for realizing optimum yield in changing temperature regimes of future climate. In comparison to the present date of planting during the end of November to early December, late December planting will be beneficial under changing temperature regimes. Thus, late sowing is beneficial with lower percentage of reduction in yield in future time periods. Duration of crop is also reduced due to increase in temperature in future time periods. Temperature dependent planting time is major factor in determining growth and yield in the major potato growing regions of Indo –Gangetic plains.

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