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ASSESSING THE CLIMATE CHANGE EFFECT ON PRODUCTION OF POTATO CROP USING INFOCROP AND WEATHER GENERATOR CLIMGEN

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ABSTRACT

In the present study, weather generator ClimGen was used to generate daily weather data of maximum temperature, minimum temperature and rainfall from 2020 to 2050 in Prayagraj. The generated weather data was further used to evaluate the impact of changing climate in Potato production using Infocrop model. Calibration and validation of the Infocrop model was done using the field experiment, conducted in rabi season of 2016-17 at three date of sowing (2nd November, 16th November and 1stDecember) with potato variety G4. Results revealed that rise in temperature along with rise in rainfall will result in change in productivity of potato. It was also observed that with shifting of climate the sowing date of potato has also been shifted and delay sowing will give the higher yield compare to timely sowing.

***Keywords**:* Climate change, Infocrop model, ClimGen, Potato etc.

INTRODUCTION

With increasing population in developing countries, potato crop has become a preferable crop in order to meet the demand of this burgeoning problem of population to sustain food security. The role of potato is now well recognized in human nutrition, food security and national economy of developing countries. At global level, India ranks second in potato acreage (1.83 Mha) and production (37.3 Mt) during 2009-10 (DES, 2012). More than 85% of potato area is confined to Indo-Gangetic plains (IGP), where it is grown during autumn (October-February) in irrigated conditions and contributes more than 80% to the total potato production of the country (Pandey and Kang, 2003).Potato is grown in many different environments, but it isbest adapted to temperate climates (Haverkort 1990).It can be resistant to drought and low-fertility conditions, but not tolerant of high temperature or humidity. At high temperatures potato tuberization diminishes, while it is frost sensitive and gets severely damage below 0ºC temperature.

Many studies has shown that agricultural production has been greatly affected by climate and changes in greenhouse gas concentrations, radiation and temperature patterns may have large consequences for the potential and rainfed yields (Hijmans2003;Saue & Juri, 2011 Taheri & Shamabadi, 2013; Dua *et al.,* 2013 and Wang *et al.,* 2015). In the recent past weather generators are widely used in different fields like agriculture, environmental management, hydrology etc. ClimGen weather generator is an effective tool for the parameterization of weather data and the generation of long term weather data (McKague, *et al.,* 2005). This model requires inputs of daily

weather parameters (temperature, rainfall, relative humidity, wind speed *etc*) to calculate long period weather data for a particular location. However Crop growth simulation model can be used to evaluate relationship between crop productivity and environmental factors. In this context, Info crop model has been successfully used for the optimizing date of sowing, pre-harvest yield forecasting, nitrogen management and irrigation scheduling etc. The model has also been used for impact analysis of climate change on potato production in several studies (Singh *et al.,* 2005; Govindrakrishnan, *et al.,* 2007 and Abdul Haris, *et al.,* 2015).Considering the background, a study was undertaken to assess the impact of climate change on potato production using ClimGen and Info crop model on the productivity of potato at different date of sowing in Prayagraj under changing climate.

MATERIALS AND METHODOLOGY

Experimental Details

A field experiment was carried out during rabi season of 2016-17at the field nursery of College of Forestry, Sam Higginbottom University of Agriculture Technology & Sciences, Prayagraj (Uttar Pradesh) to evaluate the effect of climate change on Potato crop with different sowing environments. Prayagraj is situated at Latitude of 25.43º N and longitude of 81.84º E with an altitude of 98 m above mean sea level. The Experiment was conducted on G4 variety of potato for three sowing dates viz. 2nd November, 16th November and 1stDecember.

Software Used

Climgen and Infocrop model were used for the study to analyze the trend of weather variable and also the effect of changing climate on potato production. ClimGen is a weather generator that uses principles similar to those in WGEN (Richardson and Wright, 1984). ClimGen is a daily time step stochastic model that generates daily precipitation, minimum and maximum temperature, solar radiation, humidity and wind speed data series with similar statistics to that of the historical weather data. However Infocrop model is a crop simulation model that simulates the daily growth of a specific crop at a selected weather and soil data.

ClimGen Model processing, evaluation and weather data generation

For climate change study the futuristic data of temperature and rainfall has been predicted with help of ClimGen model. It was first parameterized after geo-locating the location of Prayagraj and using daily maximum temperature, minimum temperature and precipitation for 1985-2015, which were stored in Universal Environmental Database (UED) format. After parameterization, ClimGen was used to generate daily series of maximum temperature, minimum temperature, precipitation from 1985-2015. The generated data then used to evaluate the performance of ClimGen model by comparing with respective observed data. To evaluate the agreement between observed and generated weather data Percent mean difference, root mean square error (RMSE) and wilmott Index were taken as criteria. After model evaluation, the daily rainfall, maximum and minimum temperatures were simulated to generate a long term series data (2011-2050) for trend analysis from past data (1985-2015) by ClimGen weather generator model for climate change and variability.

Calibration and validation of Infocrop model

Data required for calibration and validation of InfoCrop model are crop data, soil data, daily weather data and crop management data. From these data thermal time in degree-days for the vegetative, grain filling, panicle initiation are determined. The values describing growth and grain development were also determined. The soil and plant data collected from the literature were used for calibration of the InfoCrop model and the data generated through field experiment were used to validate the calibrated model. The

performance of the model was evaluated through some statistical parameters, namely, percentage error and root mean square error (RMSE).

Optimization of sowing data

The generated weather data (year of 2020, 2030, 2050) from ClimGen model was used as input weather data in Infocrop model for climate change study over the production of Potato. For the optimization of planting date for potato under Prayagraj region, InfoCrop model was run separately for all the three planting dates as chosen for the present investigation following the recommended package and practices and the timing giving maximum tuber yield was recorded as the optimum date.

RESULTS AND DISCUSSION

Quantitative Evaluation of ClimGen model

ClimGen model was evaluated for studying its performance in generating future daily rainfall, maximum and minimum temperatures by using available data for Prayagraj region. It was found that mean rainfall of Prayagraj during monsoon season 770mm while annual maximum and minimum temperature is 32.6ºC and 19.4ºC respectively. ClimGen model was put to rigorous quantitative evaluation by determining different statistical indices i.e. percentage difference, root mean square error (RMSE) and Willmot Index. Results of comparisons between generated and observed weather, analyzed separately for monthly periods at Prayagraj are given in Table 1.Willmott index showed the good agreement i.e. 0.99 for minimum temperature, maximum temperature and rainfall with RMSE values of 1.12, 2.48 and 11.57 respectively which indicated that ClimGen model performed well in generating weather data. It was also evident that the generated long term series data by ClimGen model was found close to observed series data of maximum temperature, minimum temperature and rainfall at Prayagraj. Since percentage error (Table 1) of rainfall between observed and generated data was somewhat higher compared to temperature, therefore, evaluation of ClimGen model should be done carefully. Overall, the results of this evaluation showed that the generation methods in ClimGen were sound for maximum and minimum temperatures but not as much as rainfall generation at considered weather station. Similar observations were also found by **Safeeq and Fares (2011)** when they evaluated ClimGen model for four tropical watersheds at USA

Trend analysis of futuristic weather data

In order to study the climatic variability at Prayagraj maximum temperature, minimum temperature and rainfall were selected from observed series (1985-2015) and generated series for 2016-2050. It was evident that minimum temperature was increased by 1.04% from 1985-2030 and by 1.56% from 1985-2050. So there is an increasing trend in minimum temperature upto 2050 while in case of maximum temperature there was slight increase. Increase in maximum temperature would result in increased crop water requirements of rainfed crops while increase in minimum temperatures may result in changing date of sowing, adaptation of changing variety and crop and also affect the crop physiology. However, it was observed that the generated long term data of average annual rainfall at Prayagraj was 836.13mm and Standard Deviation of 202.19 mm with Coefficient of Variation of 24.18%. It was observed that there was an increase of 8.9% and 11.5% of annual rainfall from 1985-2050 in Prayagraj respectively by 2030 and 2050 respectively. It was also observed that *Kharif* season receives the maximum amount of rainfall which is useful for agriculture management in the region. The average seasonal rainfall (July to October) at Prayagraj was observed 734.89 mm, with Standard deviation of 60.19 with Coefficient of variation 8.1%. The projected increase in rainfall would provide an opportunity for more on-farm water harvesting in the rainfed areas of Prayagraj.

Table.1 Comparison between the observed and generated monthly weather parameters at Prayagraj

Parameters	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Gen Min. Temp. (°C)	8.6	11.8	16.3	21.6	25.0	26.5	25.5	25.3	24.4	21.0	14.4	10.1
Obs. Min. Temp.(°C)	8.7	11.6	16.4	21.7	25.8	27.2	26.2	25.9	25.0	20.6	14.1	9.8
Min. Temp % difference	-0.7	2.2	-0.7	-0.6	-3.2	-2.6	-2.7	-2.5	-2.1	2.2	2.1	2.9
Gen Max. Temp. (°C)	22.9	27.1	32.7	38.8	40.5	38.7	34.0	33.0	33.3	32.8	30.1	25.7
Obs Max. Temp. (°C)	22.8	27.1	33.3	39.0	41.3	39.1	34.0	33.0	33.3	33.0	30.0	25.2
Max. Temp % difference	0.19	-0.01	-1.59	-0.48	-1.78	-1.19	0.02	0.03	0.02	-0.65	0.57	2.02
Gen Rainfall (mm)	12.5	14.8	7.0	3.0	12.6	95.5	220.9	286.7	167.2	26.2	2.1	7.2
Obs. Rainfall (mm)	14.8	12.9	7.3	2.9	12.3	91.9	196.3	266.2	156.3	30.7	1.9	6.9
Rainfall % difference	-15.5	14.7	-4.1	3.4	2.4	3.9	12.5	7.7	7.0	-14.7	10.5	4.3

Calibration and validation of Infocrop model

The evaluation of the model calibration was performed by Percentage error. Results showed that InfoCrop model was able to simulate value of yield attribute compare to observed crop data. The overall values of yield attribute indicated that Infocrop model has closed prediction of observed values as the percentage error of crop duration, Max LAI, tuber yield and biological yield was 7.84%, 14.81%, 16.47% and 21.45% respectively. On the basis of this statistical indicator (% error) it can be concluded that the model fitted the observed data set very well. Model validation was done between the simulated values from Infocrop model and observed values from field experiment for Potato as presented in Table 2. The RMSE values between simulated and observed data for days to emergence, flowering, tuber initiation and maturity were 21.8%, 1.8%, 6.9% and2% respectively while for tuber yield RMSE was 6.8%.Overall model provide the good estimates for observed field parameters.

Table 2 Comparison between measured and simulated values of phenological parameters for different dates of sowing of Potato during 2016-17

DOS	Emergence (DAS)		Flowering (DAS)		Tuber Initiation (DAS)		Maturity (DAS)		Tuber Yield (Kg/ha)	
	O	S	O	S	O	S	O	S	O	S
1 DOS	21	25	55	54	70	72	110	108	15425.02	14754.25
2 DOS	18	22	55	54	70	68	108	105	18526.42	19645.21
3 DOS	16	20	54	55	70	62	106	105	14256.71	15623.24
% RMSE	21.8		1.8		6.9		2		6.8	

Table 3 Effect of temperature on tuber yield (kg/ha)

Date of sowing	At normal Temp	Average change in temperature by					
		+1°C	+2°C	+3°C	-1°C	-2°C	-3°C
1 DOS	**14754.25**	13561.14	11450.11	10250.81	16450.45	14562.123	12587.45
2 DOS	**19645.21**	18401.56	17925.45	16321.45	19958.11	18250.64	15243.15
3 DOS	**15623.24**	16284.86	14567.12	11235.45	15201.13	13548.41	11012.32

Predicting yield under temperature fluctuation

In this present investigation, InfoCrop model was applied to a growing period of 2016-17 in order to determine its sensitivity on the changes in minimum temperature (°C) and maximum temperature (°C). Temperature variations from ±1 °C to ±3 °C were applied for this purpose. The model output (Table 3) also showed the simulated yield would decrease with increase of temperature. Decrease in temperature by 1°C showed an increase in tuber yield. With decrease in 1°C temperature there is increase in tuber yield, while the further decrease in temperatures leads to tuber yield loss. It can thus be concluded that decrease in temperature would be favourable for potato crop up to some extent but will have a negative impact on the tuber yield, if decreased further depending upon different region.

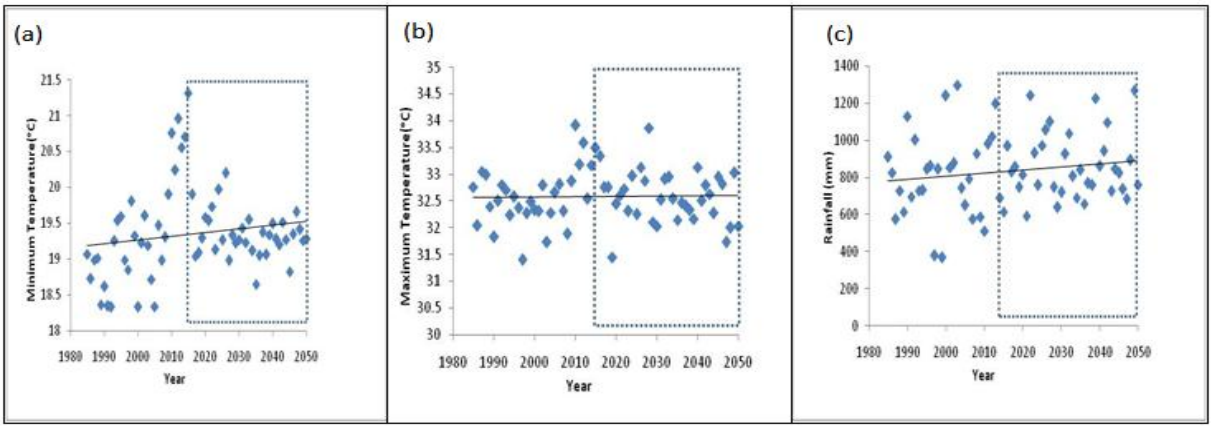

Fig 1 Trends analysis of (a) minimum temperature (b) maximum temperature (c) Rainfall

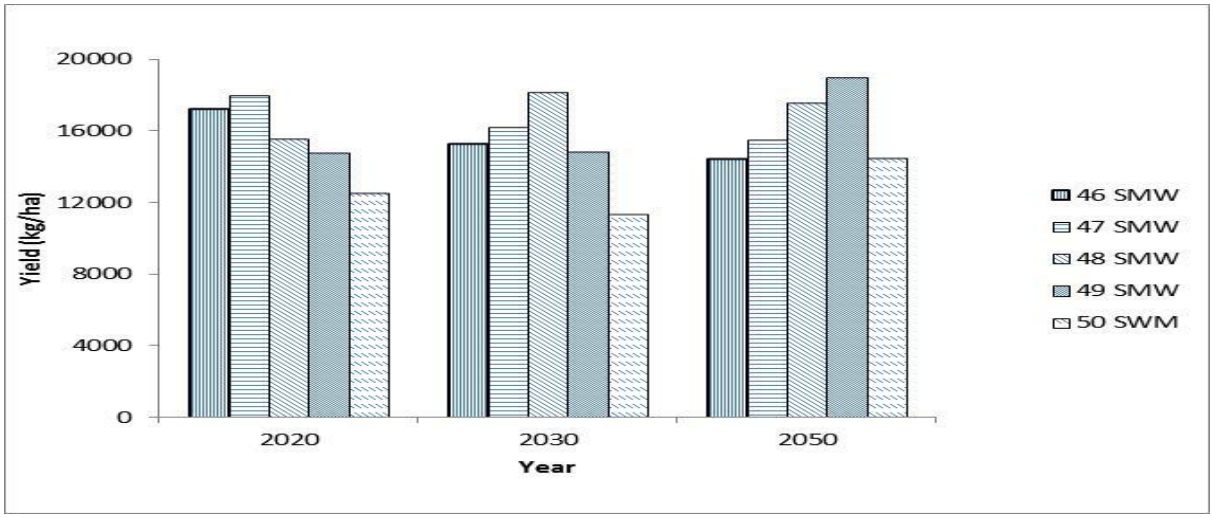

Fig.2 Change in tuber yield (kg/ha) as influenced by different year at different standard meteorological week

Optimization of date of sowing

In this objective the optimum standard meteorological week for growing potato with changing climate has been estimated as presented in Fig. 2. For this the weather data generated from ClimGen model has been used as input file in Infocrop model for prediction of yield in different years. For 2020's the 47th SMW (Standard meteorological week) has shown highest yield. Similarly for 2030's the 48th SMW has shown highest yield, while for 2050's 49thSMW has shown good yield. It can be concluded that the increase in temperature forced the earlier maturity of potato cultivars as the thermal time for different growth stages. Besides decreased photosynthesis rate due to increase in temperature, this is another reason why potato productivity declined under increased temperature situation. The average annual precipitation was also predicted to increase, although the changes through precipitation in potato production appear less certain as change in temperature.

CONCLUSION

The results of the present study indicated that ClimGen weather generator is an effective tool for the generation of long term weather data for Prayagraj region of Uttar Pradesh. Analysis indicated that maximum and minimum temperature had increasing trend in Prayagraj. This increase in temperature could affect future potato yields. In comparison to the present date of planting during the end of October to early December planting will be beneficial under changing climate. Significant differences in crop yield were observed with different planting dates. Therefore, changing potato sowing date to late November will maximize the utilization of climate resources, thereby serving as an effective adaptation strategy of potato planting in response to climate change in that region.

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