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Climate Variability of Maize (*Zea mays* L.) Crop using DSSATv4.5 Crop Simulation Model in the Effect of Planting Date in Sabour Region of Bihar

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A B S T R A C T

CERES-Maize model calibrated for local conditions of Sabour has been used to evaluate the daily weather data (1985 to 2009) to the maize crop growth period. The procedure is to place the daily weather into the model up to the time the yield prediction is to be made and sequences of historical data after that time until the end of growing season to give yield estimates. A procedure that makes use of historical weather data and different sowing date with the CERES-Maize model was developed to arrive at a probable distribution of predicted yields. The lower temperature and more solar radiation in tassel emergence to dough stage, silk emergence to physiological maturity phase and lower maximum temperature are found favorable to contribute more in increasing the grain yields. The CERES-Maize model correlated for the genetic coefficient predicts the silking dates and physiological maturity very well. The *kharif* maize gave the highest grain yield of 3689 kg/ha in 2007 and the lowest of 2348 kg/ha in 2003. Among eight different sowing dates the lowest average grain yield was 3325 kg/ha for the last sowing date and the highest average grain yield was 3725 kg/ha in 2nd sowing date. The 25 percentiles were less than the mean grain yields and also 75 percentiles.

Introduction

Maize (*Zea mays* L.) is one of the most important cereals both for human and animal consumption. Maize is grown in climates ranging from temperate to tropical during the periods when mean daily temperatures are above 15° C and frost-free. Weather variables affect the crop growth cycle. Maize, being reputed as "Poor Man's Nutricereal" possesses multiuse because of its higher nutritive value, of which its consumption as feed in the livestock sector is very large. The productivity of maize in India has increased from 547 kg/ha during 1950-51 to 1655 kg/ha presently (Anonymous, 2000). In order to enhance and console date the productivity of maize further, Decision Support System for Agrometeorology Transfer (DSSAT) is a valuable tool for making viable decision on technological options and their transfer to suitable region. The CERES –Maize model of DSSAT was developed by Jones and Kiniry (1986) and allows quantitative determination of growth and yield of maize. However, CERES-Maize model has not been evaluated under diverse agro-climatic condition in India. The result evaluated the date of tasseling and grain yield predicted by CERES-Maize model showed good agreement with the observed values and also model poorly predicted the biomass and harvest index maize (Karthikeyan *et al.*, 2005). The performance of CERES model for maize (cv GM-3 and Ganga Safed-2), wheat (cv GW-496) and pearl millet (cv MH-179) crops under sandy loam soils of middle Gujarat agro-climatic zone evaluated by Patel *et al.*, 2005. The CERES-maize model was evaluated to simulate the maize seed yield due to change in environment factors such as daily air temperatures, solar radiation and carbon dioxide concentration individually as well as in combination (Patel *et al.*, 2008).

The present study was undertaken to evaluate CERES –Maize model of DSSAT for south alluvial plain agroclimatic zone of Bihar. Using sensitivity analysis option in DSSAT V 4.5 CERES-Maize model, an attempt was made to develop alternate management strategies decision by changing the experimental file (BGPR8701.MZX) with different sowing dates with an interval of one week and maize grain yields were predicted for these seasons of study. The growth of maize is very responsive to radiation. However, five or six leaves near and above the cob are the source of assimilation for the grain filling and light must penetrate to these leaves.

Materials and Methods

Bihar Agricultural College, Sabour (Bihar) is situated in the Gangetic alluvial plains of Bhagalpur district in Bihar. It is located south of the river Ganga at 25.23° N Latitude, 87.07° E Longitude with an altitude of 37 meters above mean sea level. This region is characterized by hot desiccating summer, cold winter and moderate rainfall. May is the hottest month with an average maximum temperature of 42° C. January is the coldest month with an average minimum temperature of 5 to 10° C. The average annual rainfall is 1150 mm, precipitating mostly between mid June to mid October.

Model description

CERES–Maize model used in this study is a part of the Decision Support System for Agro-technology Transfer (Tsuji *et al.,* 1994) by International Benchmark Sites Network for Agro-technology Transfer (IBSNAT) and share a common input and output data format embedded in DSSAT. Its major components are vegetative and reproductive development, carbon balance, water balance and nitrogen balance modules. The basic structure of the model, including underlying differential equations, has been explained in several other publications (Jones *et al.,* 1991 and Hoogenboom *et al.,* 1992). This model has been used to simulate the growth and productivity of maize crop sown on different dates in present study.

The crop growth simulation model is developed as a simplified representation of the physical, chemical and physiological mechanism underlying maize plant growth processes. Through a better understanding of the basic plant production-processes and distribution of dry matter in relation to water use during different phenophases, derived from the model outputs, the entire response of the plant to local environmental conditions could be simulated.

Model input

Daily weather data, soil albedo, soil drainage constant, field capacity, wilting point, initial soil moisture in different layers, maximum root depth, crop genetic coefficients and management practices such as plant population, plant row spacing and nitrogen application are required to run the model (Tsuji *et al.,* 1994). The long-term observed daily weather data on maximum and minimum temperature, solar radiation (derived from sunshine hour data using Angstrom's formula) and rainfall at Sabour for the period 1985-2009 have been used in this study.

Soil

Sabour is characterized by alluvium soil. Soil pH is 7.4 and filed capacity 17.50 %, permanent wilting point 6.80 % and water holding capacity is 18.00 mm (100 mm) considering evaporation.

Crop

Thee rainfed kharif maize crop is a major crop grown by the farmers of the region. Normal date of sowing taken by farmers is around 15th June, coinciding with the onset of monsoon. In the present study, the simulations of 25 years data were analyzed to generate average, 25 and 75 percentiles values of output factors (grain yield etc.) for each management combination.

Genetic coefficients

Crop genetic input data, which explain how the life cycle of a maize cultivar, responds to its environment has been developed for cultivar Ganga safed-2 (early maturing with life cycle of 80 days) which is one of the currently prevailing varieties in the state and are presented in Table 1. The coefficients were derived iteratively using Hunt's method (Hunt's *et al.,* 1991). The coefficients derived can be satisfactory utilized for evaluation of the growth performances of the crop under the growth management situations in the state. Minimum crop data sets used for the calculations of phenology and growth coefficients included dates of emergence, flowering, silking, beginning of grain filling, maturity and grain yield, above ground biomass, grain number per cob and kennel weight.

Yield prediction procedure

Yield prediction using crop growth simulation models were carried out by many workers (Aggarwal and Kalra 1994, Hundal and Kaur 1997, Singh *et al.,* 1999, Patel *et al.,* 2005 and Karthikeyan and Balasubramanian, 2005 and Patel *et al.,* 2008). In this study a new procedure is developed to predict maize yield during the growing season of prediction year using CERES-Maize, perfect weather forecast, current and historical weather. The daily weather data is put into the model upto date on which, yield predictions are to be made. There upon, weather is used in place of daily weather data which is followed by sequence of historical data until the end of growing season for 25 years data. Using these sequences of weather data, yield estimate is made separately for each of 25 years for the different sowing dates.

Results and Discussion

The CERES-Maize simulation results of grain yields, evapotranspiration and maturity date of maize cv Ganga.safed-2 for eight different sowing dates (Table 2) indicated that grain yields decrease with delay in sowing dates considered from 1st June onwards. Climate of

Sabour clearly indicates that day temperature during hot season is around 40° C and its starts decreasing during 1st week of June and end by 25th June. The risk associated with dates of sowing on 1st June and 6th June is high as rain water is not sufficient with pre-monsoon rain to meet water requirement of the crop in the initial stage and also the crop may suffer during juvenile stage encountered with higher dry temperature (Singh, *et al.*, 2005).

The model predicted the date of tasseling Shekh *et al.*, (1999) reported the close predication of date of silking in maize by CERES-Maize model in Gujarat. The data on CERES – Maize Model predicated grain yields of maize under different dates of sowing are furnished in Table 2. The kharif, maize recorded the highest grain yield of 3689 kg/ha in 2007 and the lowest grain yield is 2348 kg/ha in 2003. Across the different sowing dates the lowest average grain yield is 3325 kg/ha in last sowing date and the highest average grain yield is 3725kg/ha in 2nd sowing date. Under the second date of sowing the lower temperature in silk emergence to physiological maturity phase is found to contribute more in increasing the grain yields. The lower maximum temperature in tassel emergence to dough stage and higher solar radiation in silk emergence to physiological maturity and also the favorable parameters for better grain yields under second date of sowing (Fig. 1). The analysis showed that while under the first sowing date crop evapotranspiration was 366 mm, it increased with delay in sowing and the last sowing date recorded highest evapotranspiration (448 mm).

Table.1 Genetic coefficients used in the CERES-Maize simulation model

Name	Description	Genetic coefficients for Ganga safed-2
P1	Thermal time from seedling emergence to the end of the juvenile phase (expressed in degree days above a base temperature of 80C) during which the plant is not responsive to changes in photoperiod.	310.0
P2	Extent to which development (expressed as days) is delayed for each hour increase in photoperiod above the longest photoperiod at which development proceeds at a maximum rate (which is considered to be 12.5 hours).	0.520
P5	Thermal time from silking to physiological maturity (expressed in degree days above a base temperature of 8°C).	900.0
G2	Maximum possible number of kernels per plant.	600.0
G	Kernel filling rate during the linear grain filling stage and under optimum conditions (mg/day).	7.90
PHINT	Phylochron interval; the interval in thermal time (degree days) between successive leaf tip appearances.	38.90

Table.2 Model Simulation of Maize cultivar Ganga safed-2 for different sowing dates for south alluvial region of Bihar

Date of sowing	Mean ((kg/ha)	25 Percentile ((kg/ha)	75 Percentile ((kg/ha)	Seasonal ET (mm)	Date of maturity
1st June	3321	3157	3658	366	21st August
6th June	3725	3357	3897	387	25th August
11th June	3349	3165	3589	391	2nd September
16th June	3358	3241	3589	401	5th September
21stJune	3315	3151	3529	419	11th September
26th June	3348	3265	3563	424	16th September
1st July	3383	3186	3546	436	22nd September
6th July	3325	3109	3429	448	28th September

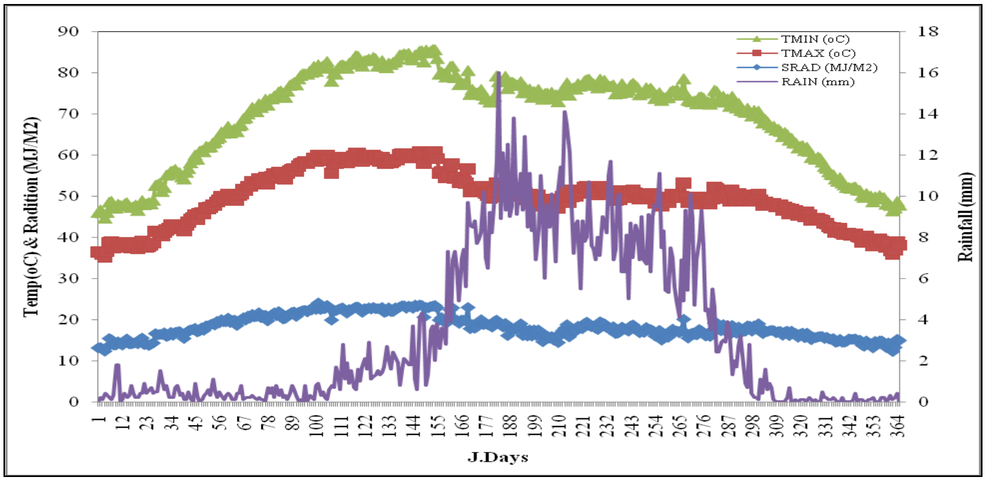
Table.3 Model simulation of Maize cultivar Ganga safed-2 for Nitrogen up take for south alluvial region of Bihar

Date of sowing	Mean ((kg/ha)	25 percentiles ((kg/ha)	75 percentiles ((kg/ha)	Standard Deviation	Date of maturating
1st June	149	146	151	6.1	21st August
6th June	235	211	247	24.9	25th August
11th June	247	232	258	21.6	2nd September
16th June	249	229	261	21.8	5th September
21st June	246	231	256	18.6	11th September
26th June	225	217	238	18.7	16th September
1st July	223	214	233	15.6	22nd September
6th July	225	216	235	16.5	28th September

Table.4 Phenology of Maize crops growth stages for south alluvial region of Bihar

Date of sowing	Crop age	Crop growth
1st June	0	Sowing
6th June	6	Emergence
18th June	18	End Juvenile
24th June	25	Flowering Initiation
24th July	57	Silking
1st August	66	Beginning grain filling
20th August	85	Maturity

Fig.1 Mean of Maximum & minimum temperatures (^{o} C), radiation (MJ/M^{2}) and rainfall (mm) of South Alluvial region of Bihar from (1985 to 2009)



The mean Nitrogen uptake for 1st sowing date is 149 (kg/ha) but 25 percentile is slightly less than 75 percentile. However, for the other dates, the differences are large. Similarly, standard deviation for first date of sowing is very less compared to other sowing dates (Table 3). The lowest standard deviation for 1st sowing date is 6.1 mm and the highest is 2nd sowing date 24.9 mm. The second sowing date is that time the crop under first sowing is in emergence stage. The crop of maize is in silking stage at 57 days, grain-filling stage in 66 days and maturity stage at 85 days in Table 4.

The performance of the model was very useful for the selection of the best sowing date for sowing maize within the season. The performance of CERES- Maize model in maize grain yield predication was well documented earlier by Singh *et al.,* (1993) in Malawi; Shekh and Rao (1996) in Gujarat, India and Parthipan (2000) in Tamil Nadu, India, Karthikeyan and Balasubramanian (2005) in Tamil Nadu, Patel *et al.,* (2005) and Patel *et al.,* (2008) in Gujarat.

In conclusion, the lower temperature in silk emergence to physiological maturity phase is found to contribute more in increasing the grain yields. The lower maximum temperature in tassel emergence to dough stage and higher solar radiation in silk emergence to physiological maturity and also the favorable parameters for better grain yields under second date of sowing. The CERES - Maize model has correlated for the genetic coefficient predicts the silking dates and physiological maturity very well.

Limitation

The model does not include the other nutrient factors *i.e.,* phosphorus, potassium and other plant essential micro-nutrients. These nutrient and micronutrient factors are assumed to be in abundant supply in the soil so as not to cause any stress on crop which is often not true. Similarly loss due to weed, pest and diseases are also not included in the model. Due to favorable weather conditions the pest and diseases infestation may cause loss to the crop, that loss cannot be simulated at present by the model.

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