Modeling the effect of planting date on Maize (*Zea mays L.*) crop in Sabour region of Bihar using DSSATv3.5 crop simulation model

P. K. SINGH, L. S. RATHORE, K. K. SINGH, A. K. BAXLA and R. K. MALL*

Agromet Service Cell, Ministry of Earth Sciences, New Delhi – 110 003, India

* *National Institute of Disaster Management, IIPA Campus Ring Road, New Delhi – 110 002, India*

(*Received 4 March 2009, Modified 10 September 2009*)

e mail : pksingh@ncmrwf.gov.in

सार – सबौर की स्थानी स्थितियों के लिए अशांकित सी. ई. आर. ई. एस. - मक्का मॉडल का मक्का की फसल की बढ़ोतरी के संबंध में मध्यम अवधि मौसम पूर्वानुमान का आकलन करने के लिए उपयोग किया गया है। इस प्रक्रिया में उपज का आकलन करने के लिए जिस समय तक उपज का पूर्वानुमान किया जाना है तब तक के और उसके बाद के बढ़ोतरी के अंत तक के ऐतिहासिक आँकड़ों की श्रृंखला (प्रतिवर्ष एक श्रृंखला) और विचाराधीन वर्ष के दैनिक मौसम के आँकड़ों को इस मॉडल में शामिल किया जाता है। पूर्वानुमानित उपज का संभावित वितरण प्राप्त करने के लिए सी. ई. आर. ई. एस. मक्का मॉडल के साथ संयुक्त रूप से ऐतिहासिक मौसम आँकड़ों, मध्यम अवधि मौसम पूर्वानुमान (एम. आर. डब्ल्यू. एफ.) तथा वर्तमान मौसम के आँकड़ों के उपयोग के लिए एक प्रक्रिया का विकास किया गया। नर मंजरी मक्का से दाने के पकने की अवस्था तक और फिर रेशे बनने से फसल के पकने की अवस्था में निम्न तापमान और अधिक सौर विकिरण तथा निम्न अधिकतम तापमान फसल की वृद्धि के अनुकूल पाए गए हैं। अनुवांशिक गुणांक के लिए सुसंबद्ध सी. ई. आर. ई .एस. - मक्का मौडल ऐसे बनने की तारीखों और फसल में पकने की अवस्था का बेहतर ढंग से पूर्वानुमान कर रहा है। वर्ष 1999 में खरीफ की मक्का की फसल की 3490 कि. ग्रा./हैक्टेयर पैदावार हुई और वर्ष 1979 में सबसे कम 2474 कि. ग्रा./हैक्टेयर हुई। आठ विभिन्न बुआई की तारीखों में से पिछली बुआई की तारीख की सबसे कम औसतन 3190 कि. ग्रा./हैक्टेयर पैदावार हुई और दूसरी बुआई की तारीख की अधिकतम औसतन 3313 कि. ग्रा./हैक्टेयर पैदावार हुई। फसल की माध्य पैदावार 25 शतमक से 75 शतमक तक कम थी।

ABSTRACT. CERES-Maize model calibrated for local conditions of Sabour has been used to evaluate the relevance medium range weather forecast relative to the maize crop growth period. The procedure is to place the reference year's daily weather into the model up to the time the yield prediction is to be made and sequences of historical data (one sequence per year) after that time until the end of growing season to give yield estimates. A procedure that makes use of historical weather data, medium range weather forecast (mrwf) and current weather data in conjunction 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. Kharif maize gave the highest grain yield of 3490 kg/ha in 1999 and the lowest of 2474 kg/ha in 1979. Among eight different sowing dates the lowest average grain yield was 3190 kg/ha for the last sowing date and the highest average grain yield was 3313 kg/ha in 2nd sowing date. The 25 percentiles were less than the mean grain yields and also 75 percentiles.

Key words – DSSAT Maize v 3.5, CERES-Maize & Weather data (Maximum Temperature & Minimum Temperature, Solar radiation and rainfall).

1. 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 agroclimatic condition 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 Safedd-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 3.5 CERES-Maize model, an attempt was made to develop alternate management strategies decision by changing the experimental file (SABR7501.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.

2. Material and methodology

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.

3. Model description

CERES–Maize model used in this study is a part of the Decision Support System for Agro-technology Transfer (DSSAT) (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.

3.1. *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 1975-2005 have been used in this study.

3.2. *Soils*

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.

3.3. *Crops*

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 30 years data were analyzed to generate average, 25 and 75 percentiles values of output factors (grain yield etc.) for each management combination.

3.4. *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

Genetic coefficients used in the CERES-Maize simulation model

Name	Description	Genetic coefficients for Proagro
P1	Thermal time from seedling emergence to the end of the juvenile phase (expressed in degree days above a base temperature of 8^0C) 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
G3	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

Date of sowing	Grain yields (kg/ha)			Seasonal ET (mm)	Date of maturity
	Mean	25 percentiles	75 percentiles		
1st June	3212	3041	3400	361	22nd August
6th June	3313	3143	3516	371	27th August
11th June	3242	3079	3449	385	2nd September
16th June	3279	3110	3453	396	7th September
21st June	3249	3069	3412	409	12th September
26th June	3284	3060	3536	413	15th September
1st July	3238	3068	3441	425	20th September
6th July	3190	3119	3392	439	26th September

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.

3.5. *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 (reference year) using CERES-Maize, perfect weather forecast, current and historical weather. The reference year's daily weather data is put into the model upto date on which, yield predictions are to be made. Thereupon, weather forecast for next 5 days is used in place of daily weather data which is followed by sequence of historical data until the end of growing season for 30 years data (one sequence per year data). Using these sequences of weather data, yield estimate is made separately for each of 30 years. The mean of distribution of yield estimates during this period is taken as the prediction for the reference year.

4. Results and discussion

On the basis of the marked differences in the yield values, the years 1986 and 1999 were selected as reference years for Sabour. The CERES-Maize simulation
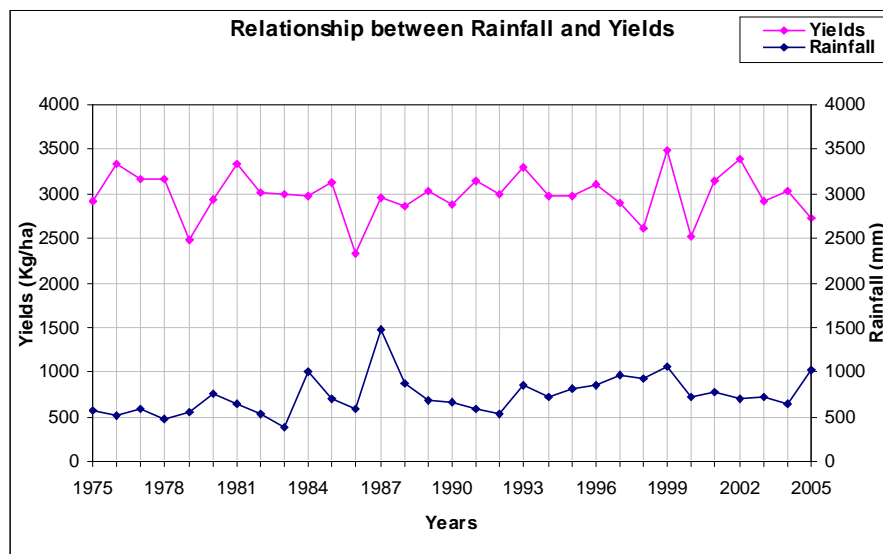
Fig. 1. Relationship between predicted yield (kg/ha) and rainfall (mm) of south Bihar Alluvial Plain Zone (Sabour)

TABLE 3

Model simulation of Maize cultivar Ganga safed-2 for Nitrogen up take

Date of sowing	N uptake (kg/ha)			Standard Deviation	Date of maturating
	Mean	25 percentiles	75 percentiles		
1st June	146	144	148	5.7	22nd August
6th June	223	209	237	25	27th August
11th June	237	229	249	22	2nd September
16th June	235	226	252	22	7th September
21st June	236	227	246	19	12th September
26th June	220	213	231	19	15th September
1st July	219	210	228	16	20th September
6th July	222	212	231	17	26th September

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 and the pattern of second rainfall and predicted yields for the 30 year period is presented in Fig. 1. The kharif, maize recorded the highest grain yield of 3490 kg/ha in 1999 and the lowest grain yield is 2474 kg/ha in 1986. Across the different sowing dates the lowest average grain yield is 3190 kg/ha in last sowing date and the highest average grain yield is 3313 kg/ha in 2nd sowing date. Under the second date of sowing the

TABLE 4

Phenology of Maize crops for different sowing dates

Date of sowing	Crop age	Crop growth
1st June	0	Sowing
6th June	5	Emergence
18th June	17	End Juvenile
24th June	23	Flowering Initiation
24th July	53	Silking
1st August	61	Beginning grain filling
20th August	80	Maturity

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 analysis showed that while under the first sowing date crop evapotranspiration was 361 mm, it increased with delay in sowing and the last sowing date recorded highest evapotranspiration (439 mm).

The mean Nitrogen uptake for 1st sowing date is 146 (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 5.7 mm and the highest is 2nd sowing date 25 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 53 days, grain-filling stage in 61 days and maturity stage at 80 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.

5. 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 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.

References

Aggarwal, P. K. and Kalra, N., 1994. "Simulating the effect of climatic factors, genotypes ands management on productivity of wheat in India" (eds), Division of Environmental Sciences, IARI, New Delhi. p155.

Anonymous, 2000, Department of Statistics, Government of Tamil Nadu, Chennai, p46.

Hoogenboom, G., Jones, J. W. and Boote, K. J., 1992, "Modeling growth, development and yield of grain legumes using SOYGRO, PINTGRO and BEANGRO - A Review", Transaction of American Society of Agriculture Engineers, **35**, 6, 2043-2056.

Hundal, S. S. and Kaur, Prabhiyot, 1997, "Application of the CERES – wheat model to yield predictions in the irrigated plains of Indian Punjab", *Journal of Agricultural Sciences*, Cambridge.

Hunt, I. A., Parajasingham, S., Jones, J. W., Hoogenboom, G., Imamura, D. T. and Ogoshi, R. M., 1991, "General : Software to facilitate the use of crop models to analyze field experiments", *Agronomy Journal*, **85**, 1090-1094.

Jones, C. A. and Kiniry, J. R., 1986, "CERES- Maize: A simulation model of maize growth and development", Texas A & M University press, College Station, Texas, USA. p194.

Jones, J. W., Boote, K. J., Jagtap, S. S. and Mishoe, J. W., 1991, "Soybean development. (in) Modeling Soil and Plant Systems", (eds. J. Hanks and J. T. Ritchie) American Society of Agronomy, Madison, WI, p425.

Karthikeyan, R. and Balasubramanian, T. N., 2005, "Evaluation of DSSAT v3.5 CERES-Maize model for Western Zone of Tamil Nadu", *Journal of Agrometeorolgy*, **7**, 2, 190-198.

Parthipan, T., 2000, "Nitrogen management strategies in hybrid maize (COH3) using SPAD meter and predictions using CERES-Maize Model", M.Sc. (Agri). Thesis Tamil Nadu Agricultural University, Coimbatore.

Patel, V. J., Vyas Pandey, Vadoderia, R. P., Patel, H. R. and Shekh, A. M., 2005 "Performance of CERES model for maize, wheat and red millet crops under sandy loam soils of middle Gujarat for climatic zone" *GAU, Research Journal*, **30**, 1-2, 67-73.

Patel, H. R., Patel, V. J. and Vyas Pandey, 2008, "Impact assessment of climate change on maize cultivars in middle Gujarat agro climatic region using CERES-maize model", *Jr. of Agro Meteorology special issue 2008*, **10**, Part II, 292-295.

Shekh, A. M., Patel, H. R., Parmar, R. S. and Reddy, D. R., 1999, "Evaluation and comparison of CERES- Maize model with regression model under middle Gujarat agroclimatic region", In: Proc. National workshop on dynamic crop simulation modeling for agrometeorological advisory services. New Delhi. NCMRWF and DST, 55-66.

Shekh, A. M. and Rao, B. B., 1996, "Crop growth modeling: Possibilities and limitations-an Indian perspective", In Climate variability and Agriculture, Y. P. Abrol, Sulochana Gadgil and G. B. Pant (Eds.). Narosa Publishing House, New Delhi. 356-374.

Singh, K. K., Kumar, Rajesh, Mall, R. K., Rathore, L. S., Sanker, U. and Gupta, B. R. D., 1999, "Soybean yield prediction from current and Historical weather data using CROPGROW model", *Indian Journal of Agricultural Sciences*, **69**, 9, 639-643.

Singh, K. K., Baxla, A. K., Chaudhary, J. L., Kaushik, S. and Gupta, Akhilesh, 2005, "Exploring the possibility of second crop in Bastar Plateau region of Chhattisgrah using DSSAT crop simulation model", *Journal of Agrometeorolgy*, **7**, 2, 149-160.

Singh, U., Thornton, P. K., Saka, A. R. and Dent, J. B., 1993, "Maize modeling in Malawi; tool for soil fertility research and development", In system Approaches for Agricultural Development. F. W. T. Penning De Vries *et al*. (Eds.) Kluwer Academic Publishers. The Netherlands. 253-273.

Tsuji, G.Y., Uehara, G. and Balas, S. S., 1994, "Decision support system for agro technology transfer", University of Hawaii, Honolulu, Hawaii.