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Short Communication

Assessment of maize (*Zea mays L.*) productivity using CERES-maize model in South Alluvial Plain Zone of Bihar, India

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Maize (Zea mays L.) is cultivated widely throughout the world and has the highest production of all the cereals. Worldwide, production of maize was more than 844.36 MT (FAO, 2017) and productivity of 5.22 t ha^{-1}. It is an important staple food in many countries and also used as animal feed and has many industrial applications. Owing to its tremendous genetic variability, the maize crop thrives well in a wide range of environments from tropical to temperate climate (Anon., 2014). Maize is grown in climates ranging from temperate to tropical during the periods when mean daily temperatures are above 15°C and frost-free. The productivity of maize in India has been reported to 1566 kg ha^{-1} during 2015-16 which has doubled since 2006 (DES, 2015-16).

The CERES –Maize model of DSSAT was developed (*Jones et al*., 1986) and allows quantitative determination of growth and yield of maize. The CERES-Maize model showed good agreement with the observed values of phenology and yield of maize 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 were evaluated by Patel *et al*. (2008). The performance of CERES- Maize model in maize grain yield predication was well documented earlier (Singh *et al*., 1993; Singh *et al*., 2005; Karthikeyan *et al*., 2005; Patel *et al*., 2005 and Patel *et al*., 2008). The present investigation was undertaken to calibrate and validate CERES–Maize model under different sowing dates in south alluvial plain agroclimatic zone of Bihar.

The study was conducted at Research Farm of Bihar Agriculture University, Sabour (25.23° N, 87.07° E, 37 m amsl), Bihar during three consecutive *rabi* (winter) seasons from 2016-17 to 2018-19 with three dates of sowing, *viz*. 5[th] November, 15[th] November and 19[th] November, which is widely followed by the farmers of the region for sowing of maize. The crop was raised following recommended package of practices for the area under irrigated conditions by applying fertilizer (nitrogen–phosphorus–potassium at 120-60-40 kg ha^{-1}) to ensure unlimited nutrient and water supply.

Detailed soil and weather information from Sabour location and season were collected according to the minimum data sets required for calibration of CERES–maize model. Model calibration is adjustment of model parameters or coefficient in a functional relationship so that the model behavior matches with observed data. Model validation is a simplest comparison between the model simulated and observed values obtained from actual or field experiment. If the simulated values lie within the predicted confluence, the model is considered as valid. Thus, validation was used as estimation of the model for its efficacy. For validation of model field experimental data collected during 2017-18 at Sabour was used. Cultivar's coefficients for the test cultivar (DHM117) in terms of genetic, physiological and phenological behaviour were evolved through run of GLUE sub-routine of DSSAT. The details of the coefficients derived and further used in the model for validation and other applications were P1 (160.0), P2 (0.700), P3 (850.0), G2 (640.0), G3 (8.50) and PHINT (38.92). The performance of

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Table 1: Calibration and validation of the growth and development in maize by using DSSAT model south alluvial Agroclimatic zone of Sabour, Bihar

Parameters	Biomass ($t\ ha^{-1}$)		Yield ($t\ ha^{-1}$)		Tasseling (days)		Silking (days)		Physiological maturity (days)	
	S	O	S	O	S	O	S	O	S	O
Mean	14.2	13.3	8.8	8.4	106.3	104.2	109.0	108.2	167.1	156.8
SD	1.1	1.0	0.2	0.2	3.2	0.7	4.5	0.7	3.37	1.30
CV (%)	7.7	7.5	2.7	2.8	3.0	0.6	4.1	0.6	2.02	0.83
r^2	0.91		0.92		0.45		0.63		0.18	
RMSE	0.94		0.38		3.35		3.82		11.03	
MBE	0.89		0.38		2.11		0.78		10.33	
MAE	0.89		0.38		2.11		0.78		10.30	

S-Simulated & O- Observed, SD- Standard Deviation, CV-Coefficient of variation

Table 2 : Statistical analysis of the different growth and development from years 1980 to 2018 at south alluvial Agroclimatic zone of Sabour, Bihar

Parameters	Yield ($t\ ha^{-1}$)				Biomass yield ($t\ ha^{-1}$)			
	5 Nov	12 Nov	19 Nov	Mean	5 Nov	12 Nov	19 Nov	Mean
Mean	9.0	8.7	8.7	8.8	14.3	14.4	14.2	14.3
Max	10.9	10.4	12.0	10.7	17.6	18.0	17.6	17.7
Min	4.9	4.6	3.7	5.2	9.9	10.4	8.3	10.2
SD	1.1	1.1	1.5	1.1	1.4	1.4	1.8	1.5
CV (%)	11.9	13.2	17.6	12.8	9.5	9.8	12.4	10.2

the model was tested using the statistical procedures viz., mean, standard deviation, mean absolute error (MAE), mean bias error (MBE), root mean square error (RMSE), percent error (PE) and correlation coefficient (r) were used to evaluate the performance of model as suggested by Willmott *et al*., (2012).

The model simulated the days to tasseling to the tune of 106.3 and 104.2 days respectively with reasonably good accuracy for cultivar and three dates of sowing. The error percent varied between -3.0 to 4.6 per cent sown on 5th November to 19th November but average error percent is 0.7 per cent. The standard deviation & coefficient variation of simulated and observed tasseling was 3.2 and 0.7 days and 3.0 & 0.6 per cent. The MAE (2.11), MBE 2.11) and RMSE (3.35) analysis was presented and also supported that the model slightly overestimated in all the cases (Table 1).

Observed data on silking days was underestimated by the simulated model for cultivar in all dates of sowing. The error percent varied between -4.9 to 4.4 per cent sown on 5th November to 19th November but average error percent was 0.6 per cent. The standard deviation & coefficient variation of simulated and observed silking was 4.5 and 0.7 days and 4.1 and 0.6 per cent. The other statistical parameters like MAE (0.78), MBE (0.78) and RMSE (3.82) also suggested underestimation (Table 1).

The model simulated the days to physiological maturity with reasonably good accuracy for cultivar grown under three dates of sowing. The error percent varied between -3.0 to 4.6 per cent sowing on 5th November to 19th November in cultivar DHM 117 but average error percent was 6.1. The standard deviation & coefficient variation of simulated and observed maturity day was 3.40 and 1.30 days and 2.02 and 0.83 per cent. The MAE (10.3), MBE (10.3) and RMSE (11.03) (Table 2) analysis also supported that the model slightly overestimated all the cases value. Mohanty *et al*., (2017) also found the model to overestimate days to physiological maturity stage in maize. The lower maximum temperature during tasseling to dough stage and higher solar radiation at silk emergence to physiological maturity could be favorable parameters for better grain yields under second date of sowing (Singh *et al*., 2013).

DSSAT v 4.6 model simulated biomass yield quite close to observed biomass yield for DHM 117 variety and slightly overestimated under present investigation among the sowing for all sowing dates (Table 1). The error percent varied between 6.3 to 7.7 per cent for crop sown on 5th November to 19th November (cultivar DHM 117) but average error percent was 6.9. The standard deviation and coefficient variation of simulated and observed biomass yield was 1.1 and 1.0 $t\ ha^{-1}$ days and 7.7 and 7.5 per cent. The MAE (0.89), MBE (0.89) and RMSE (0.94) analysis also supported that the model slightly overestimated for all the cases (Table 1).

The model quite satisfactorily simulated the grain yield with error percent ranged 3.3 to 5.5 per cent in all treatment with an average error percent was 4.3 per cent (Table 1). It was found that the model overestimated the grain yield in all the cases of variety and dates of sowing within the acceptable range of error percentage. The standard deviation & coefficient variation of simulated and observed grain yield was 0.2 and 0.2 $t\ ha^{-1}$ days and 2.7 and 2.8 per cent. Based on MAE (2.11), MBE (2.11) and RMSE (3.35) it was concluded that the yield simulation was found well with an accepted level for the cultivar and sowing dates.

The CERES-maize (DSSATV4.6) model was run for ruling cultivar DHM117 during the *rabi* seasons of 1980 to 2018 (39 years) at Sabour, Bhagalpur of Bihar under irrigated condition in different sowing dates i.e., 5th November, 12th November and 19th November. The highest average grain yield was 10.7 t ha^{-1} and average biomass yield was 17.7 t ha^{-1} and the lowest average grain yield is 5.2 t ha^{-1} and average biomass yield is 10.2 t ha^{-1} (Table 2).

The grain yield of SD and CV was 1.1 t ha^{-1} and 12.8 % with biomass yield of SD and CV was 1.5 t ha^{-1} and 10.2 % (Table 2). Under the second date of sowing the lower temperature in silk emergence to physiological maturity phase was found to contribute more in increasing the grain yields. The lower maximum temperature during tasseling to dough stage and higher solar radiation at silk emergence to physiological maturity and also the favorable parameters for better grain yields under second date of sowing.

The results on calibration and validation of different yield and growth parameters were found in good agreement and hence the model can be used to simulate genetic coefficient of maize in Bihar. Thus, the calibrated model can be used effectively for decision making.

Conflict of Interest Statement: The author (s) declares (s) that there is no conflict of interest.

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