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SIMULATION MODELING OF RICE CULTIVARS FOR PHENOLOGICAL EVENTS AT DIFFERENT DATES OF TRANSPLANTING AND NITROGEN LEVELS USING CERES 4.6v AT SOUTH GUJARAT CONDITION

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Abstract: The present investigation, CERES-Rice v.4.6 model was used to develop genetic coefficients and validate it under Navsari conditions by conducting a field experiment was conducted on college farm, Navsari Agricultural University, Navsari (Gujarat) during the *kharif* season of the year 2015. The experiment was laid out in a split plot design with four dates of transplanting as main plot treatment, three genotypes (*cv*. Jaya, Gurjari and GNR-2) and two nitrogen levels as sub-plot treatment with three replications. The model was validated with field experimental data of 2015. The model predicted the occurrence of phenophases like panicle initiation, anthesis, beginning of grain filling and physiological maturity (DAT) at different dates of transplanting and nitrogen levels within ±1 to 3 days of observed values at Navsari location. The good agreement was recorded between observed and simulated panicle initiation (DAT), anthesis (DAT), and physiological maturity (DAT) in all the cultivars and various dates of transplanting at 75 and 100 kg nitrogen levels. From the results we can conclude that the DSSAT model gave high performance in 1st and 2nd dates of transplanting than the 3rd and 4th date of transplanting for all phenological events. Majority of the results were overestimated by model. Various test criteria revealed that the model performance in terms of phenological events were under satisfactory. Results further showed that all the phenological days taken by crop decreased from first to fourth date of transplanting.
Keywords: Rice, simulation model, DSSAT 4.6, CERES-Rice, Phenological events.

INTRODUCTION

Rice is an essential food for more than two billion people (Juliano and Villareal, 1993). Globally rice is planted to about 163.1 million ha with a total production of 744.4 million tons annually (Anon., 2014), out of which Asia accounts about 90 per cent of the production and consumption. Rice export contributes nearly 25 per cent of total agricultural exports from the country. DSSAT is major product of IBSNAT (International Benchmark Sites Network for Agro-technology Transfer). The DSSAT is being used as a business tool to enhance profitability to input marketing (Murthy, 2002). DSSAT (version 4.5) is an

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application software program that includes crop simulation models for more than 25 crops to make more reliable predictions. It has been used in over 100 countries by agronomists for evaluating farming methods (Jones *et al.*, 2003). DSSAT requires daily precipitation, maximum and minimum air temperatures, and solar radiation as standard weather inputs. These inputs were taken from a regional climate model that was driven by a global model (Thorp *et al.*, 2008). Crop Environment Resources Synthesis (CERES) models is one of the inbuilt module of the DSSAT model. CERES-Rice model is a process based management-oriented model that can simulate the growth and development of rice crop (Ritchie *et al.*, 1998). The model can recognize gaps between potential, on-station farm yield and yield contributing characters *etc*. The relationship between climate change, crop growth and yield are complicated. Hence, a crop growth model which is able to simulate a specific growth pattern of a crop and its interaction with environmental condition is required. The model helps to pinpoint the difference between expected possible crop yield and tangible yields in a given environment. Model can calculate crop retort to environmental change (Angus and Zandastra, 1984).

MATERIALS AND METHODS

Crop growth simulation models, if properly validated against data have the potential for tactical and strategic decision making in agriculture. However, before using model for any purpose, it needs to be calibrated andvalidated for the location/crop/variety. To generate required crop management data, a field experiment was conducted at College Farm of N. M. College of Agriculture, Navsari Agricultural University, Navsari (20° 57′ N, 72° 54′ E and 10 m above mean sea level), Gujarat, India, during *kharif* season of the year 2015. The experiment was laid out in a split plot design with four dates of transplanting (D_1-10th July, D_2-25th July, D_3-9th August and D_4-24th August) as main plot treatment, three genotypes (*cv.* Jaya, Gurjari and GNR-2) and two nitrogen levels (N_1-75 kg ha^{-1} and N_2-100 kg ha^{-1}) as sub-plot treatment with three replications.For the present study CERES-Rice model was calibrated based on past five years experimental crop data (2009 to 2013) and subsequently validated with crop data of the year 2015. In the present investigation genetic coefficients (Table 1) were developed with past three year data of rice genotypes. The different test criteria, *viz*., mean of observed and simulated values, root mean square error (RMSE), mean bias error (MBE), mean per cent error (PE), and chi square test (X^2) were used to evaluate the performance of model for phenological characters of all three rice cultivars.

Table-1: Genetic coefficients of CERES-Rice for three different cultivars of rice at Navsari

Genetic Coefficient	Description	Genotypes of rice		
		Jaya	Jaya	Jaya
P1	Time period (expressed as growing degree days [GDD] in ˚C above a base temperature of 9˚C) from seedling emergence to end of juvenile phase during which the rice plant is not responsive to changes in photoperiod. This period is also referred to as the basic vegetative phase of the plant.	740	710	700
P2R	Extent to which phasic development leading to panicle initiation is delayed (expressed as GDD in ˚C) for each hour increase in photoperiod above P2O.	100	150	150
P2O	Critical photoperiod or longest day length (in hours) at which the development occurs at maximum rate. At values higher than P2O the development rate is slowed (depending on P2R), there is delay due to longer day length.	550	500	550
P5	Time period in GDD in ˚C from beginning of grain-filling (3-4 days after flowering) to physiological maturity with base temperature of 9˚C	11.5	11	11.5
G1	Potential spikelet number coefficient as estimated from number of spikelets per g of main culm dry weight (less lead blades and sheaths plus spikes at anthesis. A typical value is 55.	58	55	55
G2	Single dry grain weight (g) under ideal growing conditions. *i.e*., non-limiting light, water, nutrients, and absence of pests and diseases.	0.024	0.025	0.028
G3	Tillering coefficient (scalar value) relative to cultivars under ideal conditions. A higher tillering cultivar would have coefficient greater than 1.	1	1	1
G4	Temperature tolerance coefficient. Usually 1.0 for cultivars grown in normal environment. G4 for japonica type rice grown in warmer environments would be ≥ 1.0. Tropical rice grown in cooler environments or season will have G4 < 1.0	740	710	700

RESULT AND DISCUSSION

Validation of simulation modeling was done on the parameter of panicle initiation (DAT), anthesis (DAT) and physiological maturity (DAT). The findings of experiment have been categorized and presented as follows:

Panicle initiation (DAT)

The observed and CERES model simulated data on days taken to panicle initiation (DAT) at differentdates of transplanting and nitrogen levels of rice genotypes have been presented in Table-2. It was observed that in 10th July transplanting in *cv.* Jaya at 75 kg Nitrogen level lowest deviation was observed (+1.96%) and higher deviation was observed in *cv.* GNR-2 at 100 kg nitrogen level. In 25th July transplanting in cv. Jaya and *cv.* GNR-2 at 100 kg nitrogen level no scattering was observed (+0.0%). At 9th August transplanting in *cv.*Gurjari at 75 and 100 kg nitrogen level the close prediction was observed (+4.08%). At 24th August close percent difference observed in *cv.*Gurjari and *cv.* GNR-2 at 100 kg nitrogen level was0.0%.

The simulated days to panicle initiation were in good agreement with the observed values in *cv.* Gurjari and *cv.* GNR-2 at 75 kg nitrogen level with relatively low in root mean square error (RMSE) of 1.32. The lower mean bias error was observed in *cv.* GNR-2 at 75 kg nitrogen level. *cv.* Gurjari also has lowest percent error (2.44%). The non-significant difference of X^2 test showed high accuracy of the model.

Table 2: Comparison of observed with CERES model simulated value for panicle initiation (DAT) at different dates of transplanting and nitrogen levels

Varieties	Nitrogen levels	Transplanting dates								RMSE	MBE	PE	$X^2_{(0.05)}$
		D_1		D_2		D_3		D_4					
		O_i	S_i	O_i	S_i	O_i	S_i	O_i	S_i				
Jaya	N_1	51	52 (+1.96%)	48	51 (+6.25%)	49	51 (+4.08%)	46	49 (+6.52%)	2.4	2.25	4.94	5.75 (NS)
	N_2	50	52 (+4.0%)	48	51 (+6.25%)	48	51 (+6.25%)	45	49 (+8.89%)	3.08	3	6.45	9.5 (S)
Gurjari	N_1	58	56 (-3.45%)	56	55 (-1.79%)	52	53 (+1.92%)	51	50 (-1.96%)	1.32	-0.75	2.44	1.75 (NS)
	N_2	59	56 (-5.08%)	55	55 0.0%	52	53 (+1.92%)	50	50 0.00%	1.58	-0.5	2.92	2.5(NS)
GNR-2	N_1	50	52 (+4.0%)	50	51 (+2.00%)	50	49 (-2.00%)	47	46 (-2.13%)	1.32	0.25	2.68	1.75(NS)
	N_2	55	52 (-5.45%)	51	51 0.0%	51	49 (-3.92%)	46	46 0.0%	1.8	-1.25	3.55	3.25(NS)

RMSE : Root mean square error, MBE : Mean bias error, PE : Percent error, X^2: Chi square test value at 5% probability level, NS : Non significant, S : Significant, N_1: 75 kg/ha, N_2: 100 kg/ha, O_i: Observed value, S_i: Simulated value

Anthesis

The observed and simulated value on days taken to anthesis (DAT) at different dates of transplanting and nitrogen levels of rice genotypes have been presented in Table-3.The simulated anthesis (DAT) were in good agreement with the observed values in *cv.* Gurjari at 100 kg nitrogen level with relatively low in root mean square error (RMSE) (3.53), mean bias error (-1.5) and percent error (3.99%). In *cv.* Jaya and *cv.* Gurjari the positive values of MBE showed that the model predicted values were overestimated and in *cv.* GNR-2 the negative value of MBE showed that the simulated values were underestimated.The overall results showed that days to anthesis decreased date wise irrespective of cultivars from first to third date of transplanting, both in case of observed and simulated values. This decreasing trend could be explained in terms of the rate of development (inverse of duration) as related to temperature and photoperiod (Marcellos and Single, 1971 and Saini*et al.*, 1986).

Table 3: Comparison of observed with CERES model simulated values for anthesis (DAT) at different dates of transplanting and nitrogen levels

Varieties	Nitrogen levels	Transplanting dates								RMSE	MBE	PE	$X^2_{(0.05)}$
		D_1		D_2		D_3		D_4					
		O_i	S_i	O_i	S_i	O_i	S_i	O_i	S_i				
Jaya	N_1	79	86 (+8.86%)	78	84 (+7.69%)	79	83 (+5.06%)	82	82 (0.00%)	5.02	4.25	6.32	25.25 (S)
	N_2	80	86 (+7.50%)	78	84 (+7.69%)	81	83 (+2.47%)	81	82 (+1.23%)	4.38	3.75	5.48	19.25 (S)
Gurjari	N_1	88	90 (-2.27%)	84	89 (-5.95%)	82	86 (-4.88%)	87	83 (-4.60%)	3.9	1.75	4.58	15.25 (S)
	N_2	92	90 (-2.17%)	86	89 (-3.49%)	87	86 (-1.15%)	89	83 (-6.74%)	3.53	-1.5	3.99	12.5 (S)
GNR-2	N_1	88	86 (-2.27%)	83	83 (0.00%)	82	79 (-3.66%)	87	77 (-11.49%)	5.31	-3.75	6.25	28.25 (S)
	N_2	86	86 (0.00%)	85	83 (-2.35%)	83	79 (-4.82%)	88	77 (-12.50%)	5.93	-4.25	6.94	35.25 (S)

RMSE : Root mean square error, MBE : Mean bias error, PE : Percent error, X^2: Chi square test value at 5% probability level, NS : Non significant, S : Significant, N_1: 75 kg/ha, N_2: 100 kg/ha, O_i: Observed value, S_i: Simulated value

Physiological maturity

The observed and simulated data on days taken to physiological maturity (DAT) at different dates of transplanting and nitrogen levels of rice genotypes have been presented in Table-4. The closer average accuracy between observed and simulated value was seen in *cv.* Gurjari at 100 kg nitrogen level with comparatively lower root mean error square (2.87), mean bias error (+2.75), and percent error (2.46%). The mean bias error values were recorded positive in *cv.* Jaya and *cv.* Gurjari at both the nitrogen levels and it was recorded negative in *cv.* GNR-2 at both the nitrogen levels. The average performance by cultivar was overestimated for *cv.* Jaya and *cv.* Gurjari and underestimated for *cv.* GNR-2 at both the nitrogen levels.Among the all the cultivars the chi square (X^2) values showed significantly difference between observed values and simulated values. The lower significant difference was observed in *cv.* Jaya at 100 kg nitrogen level.Less number of days taken physiological maturity by late date of transplanting. The reason could be that too early and too late transplanting effect the photoperiod, assimilation of photosynthats and dry matter portioning which delay physiological maturity (Soomro*et al.*, 2001).

Table 4: Comparison of observed with CERES model simulated values for physiological maturity (DAT) at different date of transplanting and nitrogen levels

Varieties	Nitrogen levels	Transplanting dates								RMSE	MBE	PE	$X^2_{(0.05)}$
		D_1		D_2		D_3		D_4					
		O_i	S_i	O_i	S_i	O_i	S_i	O_i	S_i				
Jaya	N_1	112	113 (+0.89%)	110	113 (+2.73%)	105	113 (+7.62%)	109	114 (+4.59%)	4.97	4.25	4.56%	24.75 (S)
	N_2	115	113 (-1.74%)	113	113 0.00%	104	113 (+8.65%)	109	114 (+4.59%)	5.24	3	4.75%	27.5 (S)
Gurjari	N_1	122	120 (-1.64%)	116	120 (+3.45%)	112	117 (+4.46%)	116	119 (+2.59%)	3.67	2.5	3.15%	13.5 (S)
	N_2	116	120 (+3.45%)	119	121 (+1.68%)	115	118 (+2.61%)	117	119 (+1.71%)	2.87	2.75	2.46%	8.25 (S)
GNR-2	N_1	116	111 (-4.31%)	116	110 (-5.17%)	107	108 (+0.93%)	110	106 (-3.64%)	4.41	-3.5	3.93%	19.5 (S)
	N_2	119	111 (-6.72%)	117	111 (-5.13%)	108	108 0.00%	109	106 (-2.75%)	5.22	-4.25	4.60%	27.25 (S)

RMSE : Root mean square error, MBE : Mean bias error, PE : Percent error, X^2: Chi square test value at 5% probability level, NS : Non significant, S : Significant, N_1: 75 kg/ha, N_2: 100 kg/ha, O_i: Observed value, S_i: Simulated value

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