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Evaluation of CERES-Rice Model under Various Plant Densities and Age of Seedlings in Transplanted Rice of Southern Telangana Zone of Telangana State, India

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A B S T R A C T

Field experiment was conducted during *kharif*, 2013 at college farm, Prof. Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad. The soil of experimental field was sandy loam in texture, alkaline in reaction (pH 8.02), free from salts (EC 0.39 dsm^{-1}), low in organic carbon (0.88%), available nitrogen (210kg ha^{-1}), available phosphorus (14.14 kg ha^{-1}) and potassium (249.76 kg ha^{-1}). The investigation was carried out with three plant densities (1, 3 and 5 seedlings hill^{-1}) and four age of seedlings (15, 25, 35 and 45 days old seedlings). Model evaluation revealed that simulation of phenology at heading and physiological maturity was considered as excellent with NRMSE of 3% and 3%, with lesser RMSE values of 2.0 days and 3 days respectively. However, simulation of total biomass and grain yield was good with NRMSE of 14% and 12%, having RMSE values of 1711 and 683 kg ha^{-1} respectively. So model can be used as a research tool in the variable agro-environments of Telangana State to suggest suitable management practices to rice under low land transplanted conditions.

Introduction

Rice is the staple food for more than half of the world's population and plays a pivotal role in food security of many countries. More than 90% of the global production and consumption of rice is in Asia (IRRI, 1997). As for India, rice is not only a food commodity but also a source of foreign exchange earning about 11,000 cores annually. At the current rate of population growth (1.5%), the rice requirement by the year 2025 would be about 120 million tons

by 2025 as against 104.32 million tons to feed its one and a half billion plus population by then (RKMP, 2013).

Rice producers of Telangana State often encounter circumstances that result in delayed transplanting due to late release of water in the canals, tanks due to delayed onset of monsoon lead to transplanting of aged seedlings and more number of seedlings hill^{-1} as a part of management

practice under delayed transplanting. This ultimately resulted in lower yields. So maintenance of optimum plant densities (no. of seedlings hill-1) and age of seedlings are the two key management practices for rice production (Sarwa *et al.,* 2011,).

At present, information required for the rice production improvement with suitable management practices is a need of hour. The generation of new data through agronomic research methods is insufficient and time consuming to meet these needs. So crop simulation models are considered as potentially useful tools in agricultural decision making (Rinaldi *et al.,* 2007).

So there is need to generate data to validate the previously calibrated model under varied plant densities and age of seedlings of Southern Telangana zone by using short term field experiment to validate DSSAT v 4.5. Keeping these facts in view, the present investigation was carried out to validate the CERES Rice model with experimental data for further applications without resorting to vigorous experimentation.

Materials and Methods

The experiment was conducted during *kharif*, 2013 at Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad having an altitude of 542.3 m above mean sea level at $17^o19'$ N latitude and $78^o23'$ E longitude. The soil of the experimental site was sandy loam in texture, alkaline in reaction, low in available nitrogen, available phosphorus and available potassium. The experiment was carried out with three plant densities *viz.,* 1, 3 and 5 seedlings hill^{-1} as factor one and four age of seedlings 15, 25, 35, 45 days old seedlings as factor two in RBD (factorial), replicated thrice. The data collected from the experiment was used to validate the CERES-

Rice model. Statistical indices like RMSE and Normalized RMSE were used for model evaluation.

CERES Rice Model Description

CERES-Rice model (Ritchie *et al.,* 1986) was selected as a tool for simulating growth and yield of rice under different environment and management strategies. The CERES-Rice model simulates rice crop growth and development from either planting or transplanting to physiological maturity and is based on the physiological processes that describe the response of rice to local soil and weather conditions. Potential growth is mainly dependent upon photosynthetically active radiation (PAR), light interception and the light conversion efficiency, while actual growth is a constraint of crop management, soil and weather interactions.

Input Requirements to run CERES–Rice Model

The input data required to run the DSSAT models include daily weather data, i.e. maximum and minimum temperature, rainfall, and solar radiation; soil characterization data, genetic coefficients and crop management information, such as date of planting, age of seedlings, row and plant spacing, rates and dates and amount of fertilizer and irrigation applied. Input data files of CERES-Rice model are as per IBSNAT standard input/output formats and file structure described in DSSAT v 4.5 (Hoogenboom *et al.,* 2003).

Simulation Studies

After the weather, soil, genotype and crop management input files were created for a specified simulation experiment, the CERES -Rice model was run and output files were

generated. These simulation results were compared with observed data.

Model Validation

To check the accuracy of model simulations it was validated with data recorded for three plant densities and four age of seedlings during the year 2013. The genetic coefficients of MTU-1010 needed to run the model were furnished in the Table 1 (Swarna, 2013). During all this process available data on heading, physiological maturity, grain yield and total crop biomass was compared with simulated values.

Statistical Analysis

Statistical based criteria provide a more objective method for evaluation of the performance of the models (Ducheyne, 2000). RMSE and NRMSE are common statistical tools to test the goodness of fit of simulation models (Wallach and Goffinet, 1989). The computed values of RMSE determine the degree of agreement between the simulated values with their respective observed values and a low RMSE value that approaches zero is desirable. The RMSE was calculated according to equation

RMSE (root mean square error)

$$= \left[\sum_{i=1}^{n} (p_i - o_i)^2 / n \right]^{0.5}$$

In addition to this overall performance of model was estimated using Normalized RMSE (RMSEn), which gives a measure (%) of the relative difference of simulated verses observed data. The simulation is considered excellent with a normalized RMSE less than 10 %, good if the normalized RMSE is greater than 10 and less than 20%, fair if the normalized RMSE is greater than 20% and less than 30%, and poor if the normalized RMSE is greater than

30% (Loague and Green, 1991). The RMSEn was calculated following Equation.

Normalized root mean square error =

$$\left[\frac{RMSE}{\bar{O}} \right] x100$$

The Coefficient of Residual Mass (CRM) was also used to measure the tendency of the model to overestimate or under estimate the measured values. The CRM is defined by

Coefficient of Residual Mass (CRM) =

$$\frac{\sum_{i=1}^{n} O_i - \sum_{i=1}^{n} P_i}{\sum_{i=1}^{n} O_i}$$

Where O_i and P_i, are the observed and predicted values respectively for the ith data point of n observations. A negative CRM indicates a tendency of the model towards over estimation (Xevi *et al.,* 1996).

Results and Discussion

Model simulation efficiency was evaluated with the data obtained from three plant densities and four age of seedlings during the year 2013. During this process the collected data on phenology, biomass, grain yield and nitrogen uptake by grain were compared with the simulated values using statistical indices.

Days to Heading

Simulated values of days to heading was closer to the observed data, with RMSE value of 2.0 days, CRM value of 2.2 and NRMSE value of 3%. This clearly idicates that, CERES-Rice model under estimated the days to heading to the extent of 2.2%. However, under present study simulation of days to heading was considered excellent as the normalized RMSE (NRMSE) value was less than 10% (Table 2)

Days to Physiological Maturity

A difference of 3 days was noticed between observed and simulated values to attain physiological maturity with RMSE, NRMSE and the CRM values of 3 days, 3 and -2.5% respectively (Table 3), showed the tendency of model to overestimate the days to physiological maturity by 2.5%. However, the simulation was considered as excellent with NRMSE value was being less than 10%. Similar results obtained from validation of different rice models by Wikarmpapraharn and Kositsakulchai (2010) who observed the closer simulated values from ORYZA 2000 model than those obtained from CERES-Rice model.

Table.1 Genetic Coefficients of MTU1010 used for CERES-Rice Model

S.No.	Description of coefficients	Value
1	P_1: time period (expressed as growing degree days (GDD) in ^{o}c above a base temperature of 9^{0}C) from seedling emergence during which the rice plant is not responsive to changes in photoperiod. This period is also referred as the basic vegetative phase of the plant.	450
2	$P_2 0$: Critical photoperiod or the longest day length (in hours) at which the development occurs at a maximum rate. At values higher than P20 developmental rate is slowed, hence there is delay due to longer day lengths.	12
3	P_2R: Extent to which phasic development leading to panicle initiation is delayed (expressed as ^{0}C) for each hour increase in photoperiod above P20.	160
4	**P5**: Time period in GDD (^{o}C) from beginning of grain filling (3 to 4 days after flowering) to physiological maturity with a base temperature of 9°c.	350
5	G_1: Potential spikelet number co-efficient as estimated from the number of spikelets per g of main culm dry weight (less leaf blades and sheaths plus spikes) at anthesis. A typical value is 55.	55
6	G2: Single grain weight (g) under ideal growing conditions, i.e. non-limiting light, water, nutrients and absence of pests and diseases.	0.0250
7	**G3**: Tillering co-efficients (scalor value) relative to IR64 cultivar under ideal conditions. A higher tillering cultivar would have co-efficient greater than 1.0.	1
8	**G4**: Temperature tolerance co-efficient. Usually 1.0 for varieties grown in normal environments. G4 for japonica type rice growing in a warmer environment would be 1.0 or greater. Likewise, the G4 value for Indica type rice in very cool environments or season would be less than 1.0	1

Figure.1 Observed and Simulated Biomass (kg ha-1) at Heading of Rice using CERES-Rice Model at Different Plant Densities and Age of Seedlings
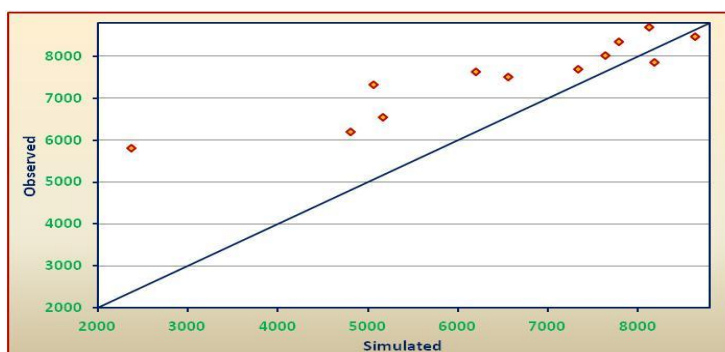
Table.2 Comparison of Simulated and Observed Days to Attain Heading of Rice under Varied Plant Densities and Age of Seedlings

Treatments	Simulated	Observed	Difference
D_1S_1	72	75	-3
D_1S_2	72	75	-3
D_1S_3	72	73	-1
D_2S_1	66	69	-3
D_2S_2	66	69	-3
D_2S_3	66	68	-2
D_3S_1	61	62	0
D_3S_2	61	61	0
D_3S_3	61	60	-1
D_4S_1	55	56	-1
D_4S_2	55	56	-1
D_4S_3	55	55	0
RMSE	2		
NRMSE	3		
CRM	2.2		

Figure.2 Observed and Simulated Biomass (kg ha-1) at Physiological Maturity of Rice using CERES-Rice Model at Different Plant Densities and Age of Seedlings
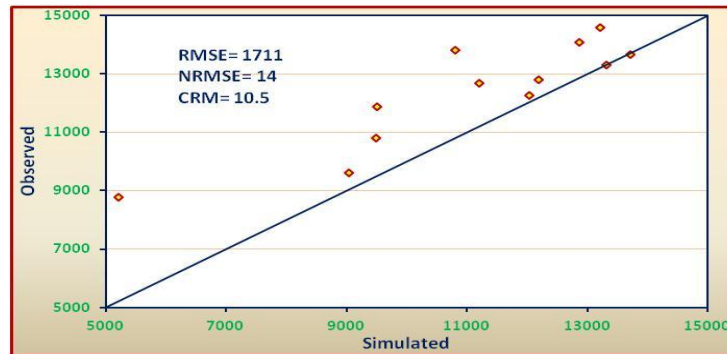

Figure.3 Observed and Simulated Grain Yield (kg ha-1) of Rice using CERES- Rice Model at Different Plant Densities and Age of Seedlings
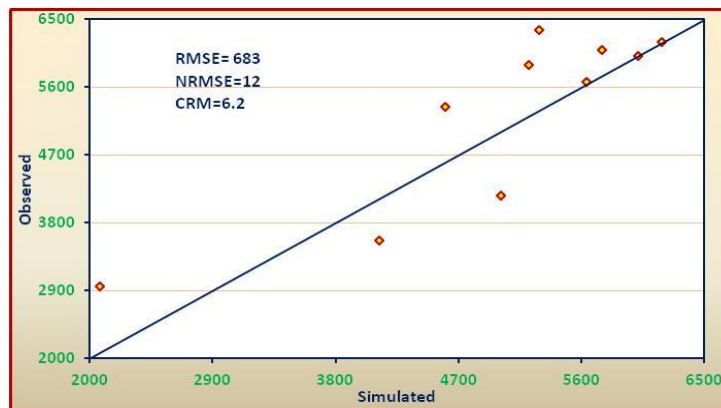
Table.3 Comparison of Simulated and Observed Days to Attain Physiological Maturity of Rice under Varied Plant Densities and Age of Seedlings

Treatments	Simulated	Observed	Difference
D_1S_1	108	107	1
D_1S_2	108	106	2
D_1S_3	108	105	3
D_2S_1	105	99	6
D_2S_2	101	98	3
D_2S_3	101	97	4
D_3S_1	97	93	4
D_3S_2	93	92	1
D_3S_3	93	91	2
D_4S_1	87	86	1
D_4S_2	86	85	1
D_4S_3	86	85	1
RMSE	3		
NRMSE	3		
CRM	-2.5		

Figure.4 Observed and Simulated N uptake by Grain (kg ha-1) of Rice using CERES- Rice Model at Different Plant Densities and Age of Seedlings
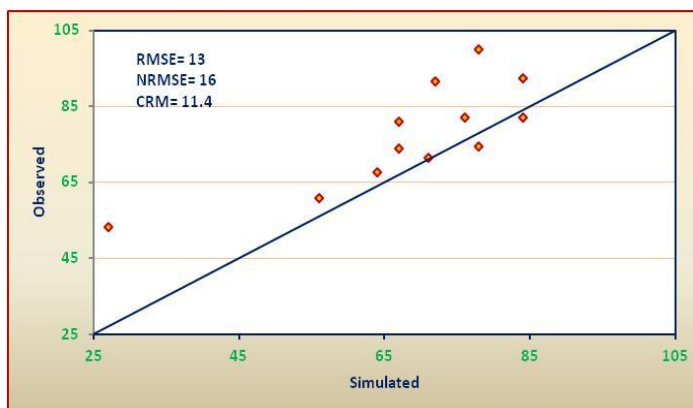
Biomass at Heading Physiological Maturity

The simulation of biomass at heading was considered good with NRMSE value of 19% due to underestimation of biomass by 13.6% with CRM value of 13.6 (Figure 1&2). The higher value of RMSE reflected that the model predicted above-ground biomass was quite good.

Biomass simulation at physiological maturity stage with observed data was similar to the heading stage with RMSE, NRMSE and CRM value of 1711 kg ha^{-1}, 14% and 10.5 respectively, which showed the model tendency to under predict the total biomass by 10.5%. The higher RMSE and NRMSE values indicated the good simulation of biomass at physiological maturity.

Grain Yield

Simulated grain yield was closely related to the observed data with RMSE, NRMSE and

CRM value of 683 kg, 12% and 6.2 respectively, showed the tendency of the model to under predict the grain yield by 6.2%. With respect to simulation here it was considered as good as the NRMSE values was 12%. The lower value for RMSE reflected that the model predicted grain yield quite well (Figure 3).

Nitrogen uptake by grain

Observed values of nitrogen uptake was closer to the simulated values with RMSE of 13 kg ha^{-1}. The positive CRM value of 11.4 showed the tendency of model to under predict the nitrogen uptake by 11.4%. However, the simulation was considered as good with NRMSE value of 16 % (Figure 4).

In conclusion, CERES-Rice model can be used as a tool to identify suitable management strategies to improve the rice yield under transplanted conditions as the simulation of phenology was considered as excellent and for biomass and grain yield the simulation was considered as good.

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