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Calibration and Validation of DSSAT Model v4.6 for *Kharif* Rice in Agro-Climatic Zone (IIIB) of Bihar

Koushik Sar[1*] and S. S. Mahdi[2]

[1]Institute of Agriculture, Visva Bharati, Sriiniketan-731236, West Bengal, India

[2]Department of Agronomy, sher-e-kashmir University of agricultural sciences and technology, J&K-180009

*Corresponding Author E-mail: koushiksar1@gmail.com

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ABSTRACT

The DSSAT model v4.6 was calibrated and validated for Kharif rice (cv. Rajendra Mahsuri-1) using the experimental data of 6 years (2008-2014) of Research Farm, ARI, Patna for rice with sowing date range of 13-22 July for rice . The yield attributes, phenological stages as simulated by model were compared with the observed data. The result revealed that the model underestimated the yields of the cultivar and overestimated rest of the parameters. The average error percent of pod yield, anthesis and maturity for cv. Rajendra Mahsuri-1 as simulated by DSSAT model were 1.46, 1.94 and 1.62 respectively. Simulated growth and development (anthesis, physiological maturity and grain yield) were close to observed and measured parameters for all the years of study. Based on these results it can be concluded that the model was very robust in predicting the critical phenological growth stages and yield of rice cultivar Rajendra Mahsuri-1 in agro-climatic zone (IIIB) of Bihar.

Key words: *Rice, Simulation modeling, Crop growth, Yield and Validation*

INTRODUCTION

Rice (*Oryza sativa L.)* is a grain plant belonging to the family Poaceae and genus *Oryza* with chromosome no. = 24. Rice is one of the most important food grains produced and consumed all over the world. It is a subsistence crop for most farmers[7]. Rice is the longest continuously grown cereal crop in the world and according to the International Rice Research Institute (IRRI) it is "one of the most important developments in history"[5]. In India, rice is cultivated in diverse ecosystems spread over 43.97 million ha with a production of 104.32 million tonnes of milled rice and with average productivity of 2.37 tonnes ha^{-1} (G.O.I. 2013). India has to produce 114 million tons of rice by the year 2030 to meet the food grain requirement of burgeoning population. In state Bihar, *Kharif* is the predominant season with rice cultivated in 3.2 m ha. On the other hand the rice is cultivated in about 1 lakh ha during *Rabi* season. The state production of rice is 6.04 m t with productivity of 1.95 t ha^{-1}.The productivity of the crop rice decrease due to biotic and abiotic stresses.

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Weather is one of the important factor, which affects all stages of rice growth and finally the yield. The process-based dynamic simulation crop models based on soil, crop and weather factors could be effective research tools for planning alternative strategies for crop management, land use and water management and also a useful tool for planning and developing technological interventions in diverse areas like India[1].The crop growth simulation models show considerable pattern and genetic potential pattern for yield[2]. In this paper has been made to calibrate and validate the DSSAT model for rice in Bihar.

MATERIAL AND METHODS

Data sets

As of model (DSSAT v4.6) requirement, the following sets of data were collected and generated for the smooth running of the model:

Weather data

The weather data (daily basis) on maximum and minimum temperatures, rainfall, solar radiation and relative humidity of six years (2008-2014) for centre Patna was obtained from National Data Centre, Indian Meteorological Department, Pune. Solar radiation was calculated by the model based on Hargreaves method, which is reported to be best suited for Indian conditions.

Soil data (layer wise)

The layer wise data on soil parameters such as texture, organic carbon, cation exchange capacity, water-holding characteristics, bulk density, soil pH were obtained from National Bureau of Soil Survey & Land Use Planning (NBSS & LUP), Nagpur and also from the database maintained by Department of Soil Science and Agricultural Chemistry, Bihar Agricultural University, Sabour.

Crop management and experimental data (Field experiments)

The six years (2008-2014) experimental data conducted at the experiment stations, Patna centre (for rice) of the Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India was used for the calibration and validation of model.

These experiments were carried out to assess the effect of different amounts of nitrogen fertilizer on yield and yield components rice under irrigated conditions. Treatments included 6 levels of nitrogen fertilizer (0, 40, 60, 80, 120 and 150 kg ha^{-1}) which the experiments were conducted based on a randomized complete block design with three replications. Planting dates was mid July (18-27) for rice using Rajendra Mahsuri-I. Some of the measured factors such as, grain yield, biological yield, leaf area index, plant height, 100 seed weight, days to anthesis and days to maturity, harvest index and N content in straw and grain were provided for the model as observed data for the calibration and validation of model.

Crop model calibration

CERES-Rice model was calibrated by an experimental data of six years (2008-2014), conducted at the experiment stations, Patna centre (for rice) of the Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India.

Crop model validation and test criteria

Validation is the comparison of the results of model simulations with observations from crops that were not used for the calibration. A model should be rigorously validated under widely differing environmental conditions to evaluate the performance of major processes in addition to its ability to predict the phenology and yield[8]. Before any model can be used with confidence, adequate validation or assessment of the magnitude of the errors that may result from its use should be performed. Model validation, in its simplest form is a comparison between simulated and observed values.

Several criteria were used to quantify the differences between observed and simulated data. Test criteria have been separated into two groups, called summary measures and difference measures. Summary measures include the mean of observed values (Obs) and simulated values (Sim), the standard deviation of observations (So) and the simulation (Ss), the slope (b) and intercept (a) of the least square regression ($Sim_i = a + b + Obs_i$). Willmott (1982) calculated an index of agreement (D) as follows:-

The summary measures describe the quality of simulation while the difference measures try to locate and quantify errors. The latter include the mean absolute error (MAE) and the root mean square error (RMSE). They were calculated according to Willmott as follows and were based on the terms (Sim_i – Obs_i)

$$\text{RMSE} = \sqrt{\frac{\sum_{i-1}^{n}(X_{\text{obs}_i} - X_{\text{sim}_i})^2}{n}}$$

$$\text{MAE} = \sqrt{\frac{\sum_{i-1}^{n}(1X_{\text{obs}_i} - 1X_{\text{sim}_i})}{n}}$$

MAE and RMSE indicate the magnitude of the average error, but provide no information on the relative size of the average difference between (Sim) and (Obs). Varshneya (1999), who gave a simple indication of error in prediction, defined the percent Error (PE). PE is defined as ratio of RMSE to mean observed value expressed as percentage and was calculated as follows:

$$\text{Error Percent} = \sqrt{\frac{(X_{\text{sim}_i} - X_{\text{obs}_i})}{X_{\text{sim}_i}}} \times 100$$

Note: In all equations, X_{obs_i} is observed values and X_{sim_i} is modelled (simulated) values at time/place *i*.

Another criterion was the test of difference between simulated and observed data which was 1:1 line. Under best simulation, the simulated and observed data should be the same so its regression equation is $y = x$ (1:1 line). Fitted regression equation between simulated and observed data (Simulated = $a + b \times$ Observed) with 1:1 line (Simulated = Observed) was tested by *t-test*. Hypothesis 0 (H0) is b = 1 and so hypothesis 1 (H1) is b ≠ 1 in the *t-test*. If H0 is accepted, this means that the difference between simulated and observed data is not significant.

RESULTS AND DISCUSSION

Phenological development

The accurate simulation of phasic development of a crop is crucial for accurate simulation of crop growth and yield. Thus, evaluation of the phasic development is the most important and the first step in any study aimed at assessment of the performance of a simulation crop model. CERES-Rice (DSSAT v4.6) model was calibrated and validated for Patna (rice) based up on the experimental data of six years.

Rice

Days to anthesis

The observed duration of days to anthesis varied between 92 to 95 days and that simulated by CERES-Rice model from 90 to 98 days during the six years (2008-2014) of crop cycle. The range of magnitude of deviation between simulated and observed days to anthesis varied between 2 to 4 days over the years. The results showed that the model underestimated the days to anthesis during the year 2008 whereas, it was overestimated during 2009, 2010, 2011, 2012 and 2013 by the model. The values of errors as computed in terms of RMSE (2.61), MAE (2.50) and average percent error were 1.94 over six years of simulation which indicated that model performed well in all the years (Figure 1).

Days to maturity

The observed duration of days to physiological maturity varied between 130 to 135 days. Similarly the corresponding values as the simulated by the model ranged between 133 to 138 days. The range of magnitude of deviation between simulated and observed days to physiological maturity varied between 1 to 3 days over six years. The results showed that the model does not underestimated the days to physiological maturity during the crop season of six years. However, it was overestimated during all the six years by the model. The values of errors as computed in terms of RMSE (2.34), MAE (2.16) and average percent error was 1.62 over the 6 years of simulation which indicated that model performed well in all the years in predicting the physiological maturity dates of a rice crop (Figure 2).

Grain yield

Measured grain yield of rice varied from 4850 to 6230 kg ha^{-1} while, model simulated grain yield ranged between 4900 to 5640 kg ha^{-1}. Over the 6 years of simulation, the model overestimated the grain yield in all the years of simulation except during the year 2009 and 2013, where model underestimated yield. The range of magnitude of deviation between simulated and observed grain yield varied between 20 to 590 kg ha^{-1}. The values of errors as computed in terms of RMSE (266.72), MAE (181.16) with average percent error (1.46) which indicated that model performed well in all the years in predicting the grain yield of rice (Figure 3).

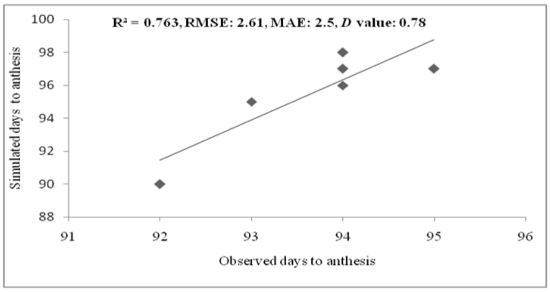

Fig. 1: Observed and simulated days to anthesis of rice crop at Patna Station

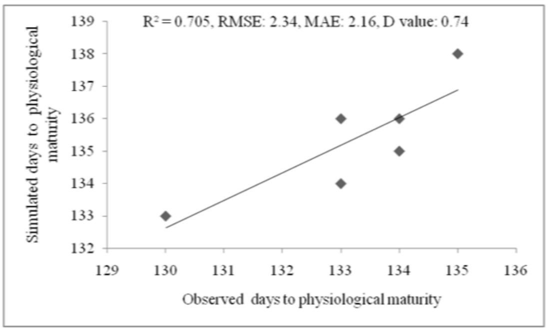

Fig. 2: Observed and simulated days to physiological maturity of rice crop at Patna Station

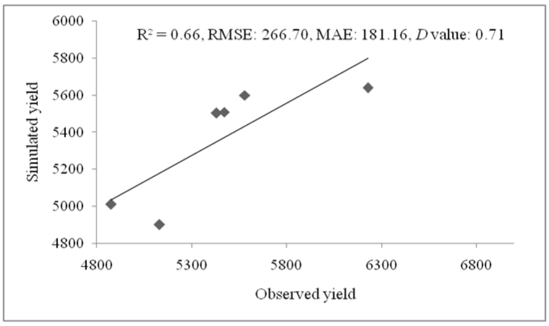

Fig. 3: Observed and simulated grain yield of rice crop at Patna Station

SUMMARY AND CONCLUSION

The salient findings related to calibration and validations are The CERES-RICE model (v4.6) was used to simulate the growth, development and yield of RICE crop sown in mid july with one varity Rajendra Mahsuri-1. The model successfully predicted growth, phenology and yield of crop with error values within 10%.In nutshell, the model prediction was reasonably good for predicting crop duration, leaf area index and grain yield for rice varity Rajendra Mahsuri-1. In fact this study provides an insight into the complex issue of evaluation and model performance.

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