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Rice Crop Simulation Model Studies

S.A. SASEENDRAN, L.S. RATHORE, G.S.L.H.V. PRASAD RAO[1] AND S.V. SINGH
National Centre for Medium Range Weather Forecasting, Department of Science and Technology, New Delhi

ABSTRACT

Realising the importance of utilising the highly advanced techniques in agricultural research, the CERES-Rice v 3.0 crop growth simulation model has been calibrated and validated for the agroclimatic conditions of Kerala. Validation studies showed that the model is able to predict the phenological occurrence of the crop fairly well to enable the farmers to take crop management decisions related to it. In eight experiments with different planting dates of *Jaya, Jyothi and Triveni* rice cultivars during *virippu* season under rainfed conditions, the flowering dates were predicted within an error of three days and date of crop maturity within an error of six days. The grain yield predicted by the model was within an error of 3.1% less than the observed for all the transplanting dates. The high accuracy of the grain yield prediction shows the ability of the model in simulating the growth of the crop in the agroclimatic conditions of Kerala and as such, the model may be used for making various strategic and tactical decisions related to agricultural planning and management in the state.

Introduction

Through crop growth simulation modelling it became possible to simulate a living plant through the mathematical and conceptual relationships that govern its growth in the soil-plant atmosphere continuum. The advantages of crop modelling were well illustrated in the works of Nix (1976) and Wit (1978). The simulation models of agricultural systems have the potential of taking the agricultural research and development into the age of fast information technology.

The CERES model for upland rice was presented by Alocilja and Ritchie (1988). The CERES-Rice (Singh *et al.*, 1994) model as available in the DSSAT v3. (Tsuji *et al.*, 1995) is a growth and development simulation model of the rice crop under upland and lowland condition. It is a daily time-step model that simulates grain yield and growth components of different varieties in given agroclimatic condition. The model simulates the transformation of seeds, water and fertilizers into grain and straw through the use of land, energy (solar, chemical and biological) and management practices, subject to environmental factors such as solar radiation, maximum and minimum air temperature, precipitation, day length variation, soil properties and soil water conditions. The model takes into account the nitrogen fertilization and water balance inthe soil or irrigation. Jintrawet (1995) used the CERES-Rice model to develop a decision support system for the fast assessment of low land rice based cropping alternatives in Thailand. The study had demonstrated that the CERES-Rice model is able to simulate low yields obtained by farmers in northeast Thailand areas and the relatively higher yields in north-west Thailand areas. The study also proved the validity of the model in finding alternative ways to improve farm performance with regard to rice production.

Keeping in view the potential of the crop simulation models for tactical and strategic decision making in agriculture, in this study an attempt has been made to generate genetic coefficients for some of the commonly used rice crop varieties in the state viz. *Jaya, Jyothi* and *Triveni* and evaluate the CERES-Rice version 3.0 (Tsuji *et al.*, 1994) model for crop growth simulation in the state of Kerala.

Materials and Methods

In this study, the CERES-Rice version 3.0 (Singh *et al.*, 1994) was used. The primary thrust of the models developed so far is to analyze how weather and genetic characteristics affect potential yield given a specified management scheme.

The performance data of the *Jaya, Jyothi* and *Triveni* rice cultivars at Pilicode collected at Regional Research Station, Kerala Agricultural University, Pilicode (12 12'N, 75 10' E), in the year of 1993 and 1994 *virippu* season (June to September/October) have been used for evaluation of the model. The crop mangement details fo the experiment are as follows : transplanting dates - 8, 15, 22 and 29 June in 1993 and 1994 respectively; plants/m^2 - 99.0; row spacing - 20 cm; soil - shallow

1 Regional Research Station, Kerala Agricultural University Pilicode, Kerala, India

sandy loam; fertilizer - 200 kg/ha urea in two applications, one basal and another one at the time of maximum tillering stage; irrigation - unirrigated (rainfed).

Weather data for the parameters viz. maximum temperature (at 4.5 ft.), minimum temperature (4.5 ft), hours of bright sunshine and rainfall collected at the experiment station (Pilicode) in an agrometeorological observatory during the experiment period were used. The incoming solar radiation (Rs) was calculated indirectly from the number of sunshine hours, using the Angstrom standard formula. The soil type in which rice is grown in the state of Kerala is mainly sandy clay loam. Relevant data for this soil type have been used in the model validation studies.

Results and Discussion

A genetic coefficient calculator (Gencalc) was developed by Hunt *et al.*, (1993) to facilitate determination of the genotype specific coefficients that are made use of by the IBSNAT crop models. In the present study the Gencalc was used for calculationof the eight genetic coefficients required in the rice crop simulation runs. Separate coefficients were developed for *Jaya, Jyothi* and *Triveni* cultivars. The coeffcients for the IR8 cultivar was taken as the starting assumption for the calculation. The crop performance data for the 8 June transplanting date have been utilised for the calculation of all the three cultivars. It was observed that, except single grain weight and tillering coefficient, all the other coefficients evolved differ greatly from their assumed values of the IR8 cultivar. The coefficients developed are used for further validation of themodel for seven more transplanting dates viz. 15 June, 22 June and 29 June in 1993 and 8 June, 15 June, 22 June and 29 June in 1994.

Table 1 presents a comparison between the model simulated and the field observed heading date and physiological maturity date, of one of the crop variety studied viz. *Jaya* in units of days after transplantation in four experiments repeated in two consecutive years viz. 1993 and 1994. The results show that, the flowering date was predicted by the model within an error of one day, for 8 June and 2 days each for the 15 June, 22 June and 29 June transplanting dates, respectively in the year 1993. The corresponding error values for 1994 were 3, 0, 2 and 2 days. On an average the flowering dates predictions showed an error of 1.2% more than that measured in the field.

Table 1. Comparison between predicted and observed phenological occurrence of Jyothi for different transplanting dates under rainfed conditions

(O = observed; S = simulated)

Transplanting date	Heading date (days after transplantation)		Physiological maturity (days after transplantation)	
	O	S	O	S
8 June 1993	67	68	104	104
15 June 1993	69	67	105	102
22 June 1993	65	67	102	103
29 June 1993	70	68	106	105
8 June 1993	70	67	100	106
15 June 1993	69	69	101	105
22 June 1993	71	69	105	102
29 June 1993	71	73	102	101

As far as the predictions of the date of Physical maturity are concerned, it can be seen from the table 1 that, the predictions for all the 8 transplanting dates were with in an error of six days. These results show that with the help of the genetic coefficients derived for the *Jaya* rice variety in the state of Kerala, the model is able to predict the phenology of the crop with fairly good accuracy. These predictions are very crucial in the light of the fact that at flowering, it is essential to see that, the crops do not suffer from moisture and fertiliser stress. Also, the good prediction on the date of maturity can help the farmer to plan for harvesting and marketing his crop. As such, the validated CERES v3. model can be utilised to advise the farmer to plan and optimize farm operations.

Table 2 presents a comparison of the grain yield predictions of the model with the observed, for the eight experiments discussed above. The results show that, on an average of all the eight experiments, the grain yield prediction by the model has fallen within an error of 1.2%, 3.1% and 1.7% less than the observed for *Jaya, Jyothi* and *Triveni* cultivars, respectively. The high accuracy of the grain yield prediction shows the ability of the model in simulting the growth of the crop in the agroclimatic conditions of Kerala. In this context,

Table 2. Comparison between predicted and observed grain yield of Jaya, Jyothi and Triveni under rainfed conditions for different transplanting dates

(O = observed; (S = simulated)

Transplanting dates	Grain Yield (kg/ha)					
	Jaya		Jyothi		Triveni	
	O	S	O	S	O	S
8 June 1993	5100	5089	5900	6185	4700	5304
15 June 1993	5300	5312	6400	6030	5900	4461
22 June 1993	4300	4160	5300	4891	4800	4744
29 June 1993	3300	3267	4700	5368	4300	5002
8 June 1993	5200	5380	5742	5989	4651	5214
15 June 1993	5600	5855	5691	6258	4830	4698
22 June 1993	6250	6600	5900	6117	5393	5236
29 June 1993	6500	6760	6102	6200	5196	·5410

Table 3. Simulated crop and soil status at main development stages for 8 June transplanting

Date	Growth stage	Biomass kg/ha	LAI	Leaf No. no.	ET mm	Rain mm	Nitrogen stress	Water stress
8 June	Transplant	59	.42	4	50	280	.00	.00
1 Aug	End Juvenile	3594	6.63	11	306	2094	.00	.03
8 Aug	Panicle initial	4892	7.72	12	348	2123	.00	.28
12 Sep	Heading	9409	6.19	20	529	2571	.00	.49
21 Sep	Beg. grain fill	10725	4.26	20	620	2590	.00	.06
4 Oct	End grain fill	12135	2.03	20	631	2735	.49	.00
7 Oct	Maturity	12135	1.38	20	637	2740	.47	.00
7 Oct	Harvest	12135	1.38	20	637	2740	.00	.00

it may be noted that the yield prediction of the rice crop is very crucial for the economic planning in the state.

In table 3, the simulated crop and soil status at different developmental stages of the crop is shown for the model simulation in respect of *Jaya* for the 8 June 1993 transplanting date. The data show that, a total amount of 2740 mm of rainfall was received during the crop growth period, against an evapotranspiration (ET) requirement of 637 mm. Nonetheless, the crop experienced moderate soil moisture stress during the beginning of grain filling stage and at the end of grain filling stage, due to the uneven distribution of rainfall. This indicates the necessity of harnessing the excess water during the rainy period to cater to the need during the lean periods.

Conclusions

Evaluation of the CERES-Rice model version 3.0 for simulation of crop growth, development and yield inthe state of Kerala, India has been made. The model is found to be able to predict the grain yield and phenological occurrence of the crop fairly well to enable the farmers to take decisions on the crop management operations.

Once a model has been developed, calibrated and tested to the stage it acccounts for the major yield factors in a region, the model can be made part of the whole system of regional agricultural research by adopting a system frame-work for the crop and agrometeorology data collection. To apply a model this way there is a need for a regional experimental program to collect balanced set of crop and environmental data and weather data with which the model can be used. The models have potential scope in use for defining areas and landscape positions suitbale for raising the rice crop as well as double cropping.

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