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Validation of Oryza 2000 Model with Irrigated Low Land Field Experiment of Rice

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Abstract: Biophysical models predict the behavior of the land use system in physical terms such as crop yields, environmental effects, and effect on management. Oryza 2000 model is an eco-physiological crop model to simulate the growth and development of a rice crop in situations of potential production, water limitations, and nitrogen limitations. This paper reports on the calibration and validation of the model using independent data sets of kharif rice crop. Data are originated from the nitrogen balance experiment conducted by Directorate of Rice Research (DRR), Hyderabad during 2001 .The calibration of the model was performed by deriving the crop growth parameters for DRRH1 and Vikas varieties. Results show that there was overestimation of Leaf Area Index (LAI) in all our observations and there was slight overestimation between simulated and observed weights of the total aboveground dry matter (WAGT and WAGT_OBS) of DRRH1 (13.7%) and Vikas (10.5%) varieties. At maturity date, with respect to grain yield (WRR14) parameter, model has shown slight overestimation with average of observed values of DRRH1 (9.5%) and Vikas (4.3%). But in each case one of the replications of observed values very nearer to simulated values. Model simulations can be further improved by calibrating other parameters of crop. Hence, calibration to the model at different levels with more intensive field experimental data will improve the performance of the model and it can be effectively used for different management practices for irrigated rice grown in dry season or wet season.

Keywords: Rice, Oryza model, validation, calibration, simulation, LAI, rice yield.

INTRODUCTION

Advanced estimation of rice production is required for various policy decisions. An optimum crop production estimation becomes more complex, involving several factors like fertilizer, pest control, genotype, environment and cultural practices. Greater use of crop simulation models is being suggested to increase the efficiency of different trials. Further, the models can help to compare experimental research findings across sites, extrapolate experimental field data to wider environments, develop management recommendations and decision support systems, explore effects of climatic change, and make yield predictions (Bouman *et al.*, 1996; Jones *et al.*, 2003). A suitably validated crop simulation model could be used to test hundreds of such combinations in a brief time at limited expense. Such simulations can adequately describe relative trends in yields caused by environment variation (Penning de Vries *et al.*, 1989). Model simulations frequently assume the rice yield is not reduced by diseases, pests, and weeds. Several comprehensive mechanistic and detailed process based rice models, such as SIMRIW (Horie, 1987), CERES- RICE (Godwin *et al.*, 1990), Oryza1 for potential production (Kropff *et al.*, 1994), Oryza_W for water limited production (Wopereis *et al.*, 1996), and Oryza 2000 (Bouman *et al.*, 2001) are available. Hence, this study aimed to derive crop growth parameters and validate the model by comparing with experimental data.

MATERIALS AND METHODS

Model and Parameters

Oryza 2000 (Bouman *et al.*, 2001) model is an eco-physiological crop model to simulate the growth and development of a rice crop in situations of potential production, water limitations, and nitrogen limitations (de Wit and Penning de Vries 1982).

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The basic input requirements of the model are daily weather data (radiation, minimum and maximum temperature), experimental data (plant density, date of crop emergence and transplanting) and crop data (cultivar specific, morphophysiologic character of plant species). Most of the crop parameters are generic and can be used for all varieties. However some parameters and functions are best calibrated specifically for the variety and environment under consideration, namely development rates, partitioning factors, relative leaf growth rate, specific leaf area, leaf death rate and fraction of stem reserves. The life cycle of rice crop is divided into four main phonological phases. Hence, four variety specific development rates have to be estimated for the effect of temperature in the different stages.

DVRJ (^{0}C d)$^{-1}$: for the basic vegetative, from seedling emergence to start of photoperiod sensitivity.

DVRI (^{0}C d)$^{-1}$: for photoperiod sensitive phase, from the end of basic vegetative phase to panicle initiation. DVRI is the development rate at optimum photoperiod.

DVRP (^{0}C d)$^{-1}$: for the panicle formation phase, from panicle initiation to first flowering.

DVRR (^{0}C d)$^{-1}$: for the grain filling phase, from first flowering to physiological maturity.

There are two programs to help in deriving these parameters: DRATES for development rates and PARAM for others. The dates of sowing, transplanting, panicle initiation, flowering and maturity for each genotype in each experiment were used to determine the specific pre and post flowering development rates using program DRATES (Kropff *et al.*, 1994). These four development rates were estimated using dates of crop growing phases and weather data for each variety.

The additional input requirements for Oryza-N component of Oryza2000 model are the N supply that included the indigenous N from soil flood water system and N applied from the fertilizer. It assumes that a constant amount of indigenous N is added to the soil N pool everyday. Although N uptake is sensitive to soil type, climate, and management practices, the N recovery efficiency increases from a relatively lower value from basal N application at transplanting to higher recoveries at panicle initiation. The N fertilizer application was provided as input table corresponding to the date and amount of N application. Above four crop development rates were calibrated and Leaf Area Index (LAI) and above ground dry matter production (WAGT) were simulated for long and mid duration varieties.

Data Sets

An irrigated low land field experiment data with one hybrid DRRH1 (142 days) and one variety VIKAS (135 days) was used as validation data set to examine the relative influence of genotype on crop parameters and simulate LAI and dry matter weight. This experiment was conducted during 2001 Kharif season at DRR farm with 4 replicates and was fully irrigated and kept as free from weeds, pests, and diseases as possible. Rice was fertilised with a total of 90 Kg N in three splits. Twenty day old seedlings were transplanted at 5 seedlings per hill and 25 hills per square meter.

Input and Output Files

Input data was entered into three files weather, experimental and crop data file. Day wise weather data, such as maximum and minimum temperature, sunshine hours, rainfall, vapour pressure and wind speed were collected from Agricultural Research Institute, Rajendranagar, Hyderabad and entered into weather file of oryza model. Day wise crop samples were taken during the growing season to determine biomass of green leaves, dead leaves, stems and panicles. The leaf area was determined soon after the hills were collected. Grain Yield components were measured at harvest time. Data on dry weights of above parameters and dates of transplanting, panicle initiation, flowering and maturity were entered into experimental file of the model. The model was validated under nitrogen limited situation. Crop data file is always needed and contains parameters that describe the rice variety under consideration.

Crop growth and development was simulated for each replication using emergence dates, seedbed duration, transplanting densities and daily weather data. The output file contains weight of storage organs, stems and leaves, weight of rough rice and total above ground dry matter (WAGT).

RESULTS AND DISCUSSION

Results were divided into two aspects generating crop growth parameters and comparison of simulated and observed LAI and dry matter production of above specified varieties.

Generating Crop Growth Parameters

Four variety specific development rates were estimated for the effect of temperature in the different stages. These development rates vary with the duration of the crop. In first data set crop growing parameters were generated for variety Vikas and hybrid DRRh1 (Table 1). The variation was more in more in basic vegetative phase compare to other 3 phases. Differences between varieties in total crop duration are usually caused by differences in the duration of the vegetative phase (DVRJ) rather than other phases (Vergara and Chang, 1985).

Table 1
Calibrated Development Rates for Vikas and DRRH1

Variety	*N Level (kgs)*	*DVRJ*	*DVRI*	*DVRP*	*DVRR*
Vikas	90	0.001046	0.000758	0.000354	0.001954
DRRH1	90	0.000430	0.000758	0.000666	0.001942

Comparison of Simulated and Observed LAI and WAGT

The model was run for 90 kg N and it was observed that there was overestimation of LAI values for DRRH1 (Figure 1) and Vikas (Figure 3) and there was slight overestimation between simulated and observed weights of the total aboveground dry matter (WAGT and WAGT_OBS) of DRRH1(13.7%) and Vikas (10.5%) varieties (Figure 2 & 4). At maturity date, with respect to grain yield (WRR14) parameter, model has shown slight overestimation with average of observed values of DRRH1 (9.5%) and Vikas (4.3%). But in each case one of the replications of observed values very nearer to simulated values.

Table 2
Simulated and Observed Values of DRRH1 Variety, Experiment Conducted at DRR, Hyderabad during Kharif 2001

Name of the parameter	*Explanation*	*Sim-Value (kgs)*	*Obs Val R1 (kgs)*	*Obs Val R2 (kgs)*	*Obs Val R3 (kgs)*	*Obs Val R4 (kgs)*	*Average AVG (kgs)*
WRR14	Weight of rough rice	6403	5200	6040	6690	5450	5845
WAGT	Total Weight	10846	8150	9200	9600	11200	9537.5
DAE	Growth Duration	142	142	142	142	142	142
Emergence Date (0)		191	191	191	191	191	191
Panicle Initiation Date (0.65)		246	246	246	246	246	246
Flowering Date (1.01)		276	276	276	276	276	276
Maturity Date (2.01)		307	307	307	307	307	307

Table 3
Simulated and Observed Values of Vikas Variety, Experiment Conducted at DRR, Hyderabad during Kharif 2001

Name of the parameter	*Explanation*	*Sim-Value (kgs)*	*Obs Val R1 (kgs)*	*Obs Val R2 (kgs)*	*Obs Val R3 (kgs)*	*Obs Val R4 (kgs)*	*Average AVG (kgs)*
WRR14	Weight of rough rice	5236	4390	5180	5800	4720	5022.5
WAGT	Total Weight	9872	8000	11500	8000	8250	8937.5
DAE	Growth Duration	135	135	135	135	135	135
Emergence Date (0)		191	191	191	191	191	191
Panicle Initiation Date (0.65)		214	214	214	214	214	214
Flowering Date (1.01)		270	270	270	270	270	270
Maturity Date (2.01)		300	300	300	300	300	300

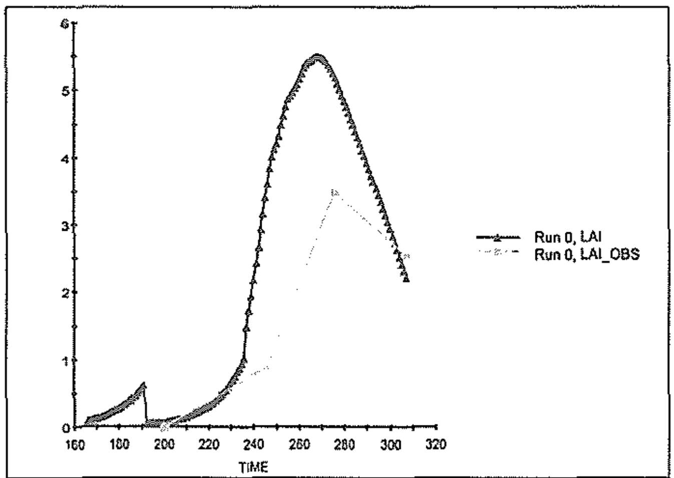

Figure 1: **Simulated and Observed Leaf Area Index (LAI) DRRH1 Variety with Estimated Development Rates Grown Under Potential Production Conditions, DRR, 2001.**

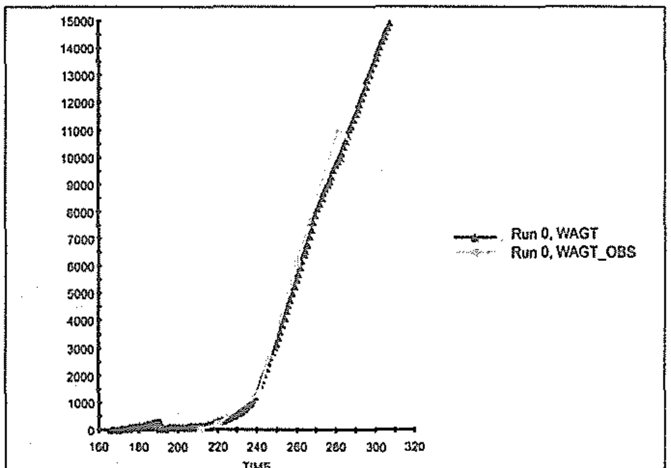

Figure 2: **Simulated and Observed WAGT for DRRH1 Variety with Estimated Development Rates Grown Under Potential Production Conditions, DRR, 2001.**

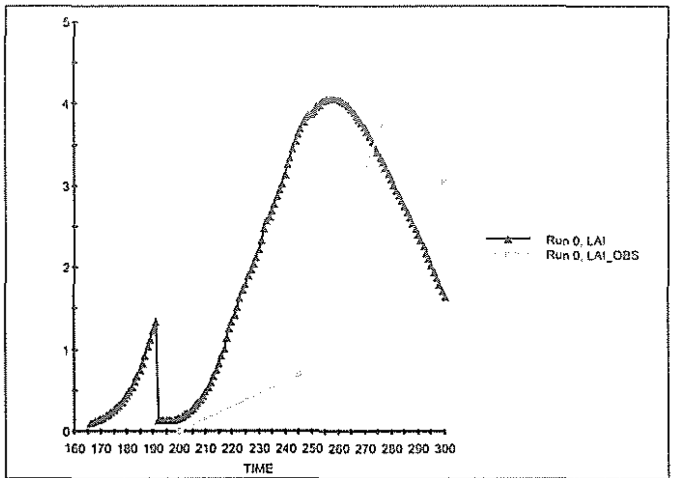

Figure 3: **Simulated and Observed Leaf Area Index (LAI) Vikas Variety with Estimated Development Rates Grown Under Potential Production Conditions, DRR, 2001.**

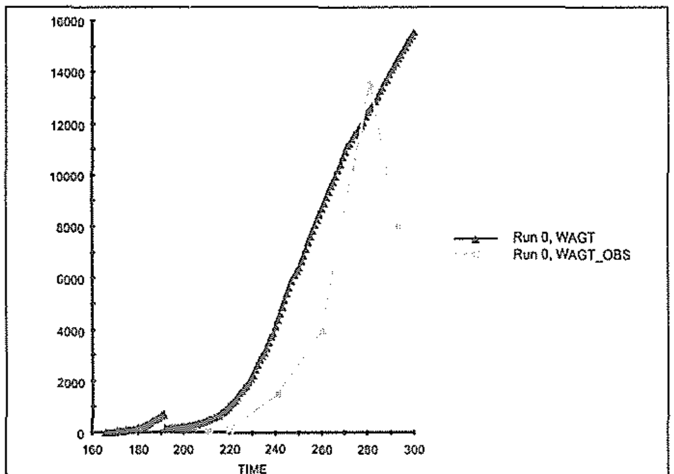

Figure 4: **Simulated and Observed Leaf Area Index (LAI) Vikas Variety with Estimated Development Rates Grown Under Potential Production Conditions, DRR, 2001.**

DISCUSSION

No absolute values for goodness of fit parameters define whether a model is "good" or "bad". Mitchell (1997) demonstrated that even the achievement of close-to-ideal goodness-of-fit parameters such as in linear regression does not prove that a model is theoretically correct. Nonetheless, repeated and well-documented comparisons between model simulations and real world measurements can increase our confidence in suitability of a model for a certain purpose.

It was observed from our results that there was overestimation of LAI in all our observations. As reported by Bouman (2006) that simulation of LAI was relatively poor and that LAI values were generally overestimated by the model. The relative difficulty of modeling LAI is well known and simulation errors have been reported for other models as well, for example, for CERES-Rice (underestimation of LAI by the model, Timsina and Humphreys, 2003) and WOFOST (over estimation of LAI by the model, Roetter *et al.*, 1998).

There was slight underestimation of WAGT up to flowering stage and after that the results were overestimated. With respect to grain yield the model values were overestimated. Above mentioned differences can be adjusted by calibrating other parameters like leaf area growth rate and partition of biomass to stem and leaves. Hence there is a scope for improving this model by LAI and phonological development computations. Further, the improved model can be used effectively to predict rice production for low land irrigated areas. Interestingly there is no significant difference in simulated values of Variety and Hybrid. The variation observed between variety and hybrid is in development growth rates at basic vegetative phase. Oryza model can be used to predict rice production for hybrid rice varieties also.

CONCLUSION

The crop growth simulation model ORYZA 2000 can replace the need for years of costly multi location, on station and on farm trials to select rice varieties. The results of this validation suggest us that there is ample scope for application of the calibrated model to identify better cultivars and management practices for irrigated rice grown in dry season or wet season.

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