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ORIGINAL ARTICLE

Validation of Oryza2000 model under combined nitrogen and water limited situations

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Abstract Oryza2000 is an eco-physiological crop model to simulate growth and development of rice in situations of potential production, water limitations, and nitrogen limitations. In the present investigation, unlike independent situation, the applicability under conditions of both water and N limitations has been investigated using data generated from field experiments over 5 years on long and short duration rice varieties. At higher N level model performs better for TDM and yield performance long duration varieties compared to short (Rasi) and medium duration (Ajaya) varieties. On the other, overestimation of leaf area index (LAI) at all nitrogen levels was consistent indicating a need in this area for further improvement of the model. In this context, model performance was also assessed by statistical analysis (R^2, D-index and NOF). D-index is ~0.8–0.9 for two varieties at 3 nitrogen application levels for Ajaya and BPT varieties. The results indicated applicability of model Oryza2000 can be extended to rice genotypes varying in their growth periods and situations like fertilizer, water limited conditions.

Keywords Rice · Crop model · Oryza2000 · Validation · Simulation · LAI · Rice yield · Nitrogen limited · Water limited · Irrigated

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Introduction

Management of the rice crop involves several factors like fertilizer, pest control, genotype, environment and cultural practices and their interactions. Designing and conducting research trials with various combinations is therefore, complex and expensive. Crop simulation models are inexpensive and can adequately describe environmental influences of variation in yields (Penning de Vries et al. 1989). Crop models have also been used 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). 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 Oryza2000 (Bouman et al. 2001) are available. Bachelet and Gay (1993) compared the performance of four rice crop simulation models and determined that ORYZA1 and CERES-RICE simulated more realistic responses to temperature than RICEMOD (Mc Mennamy and O'Toole 1983) and RICESYS (Graf et al. 1990). It is reasoned that a model containing details of processes at the leaf level would be appropriate where much of knowledge of CO_2 and temperature effects on growth processes are available (Matthews and Wassmann 2003).

Oryza2000 is an update of the previous oryza models which are products of the modeling "School of De Wit" (Bouman et al. 1996; Van Ittersum et al. 2003). It follows a daily calculation scheme for the rate of dry matter production of the plant organs and phenological development.

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By integrating these rates over time, dry matter production and development stages are simulated throughout the growing season. The calculation procedures for dry matter production are well documented (Spitters et al. 1989; Goudriaan and Van Laar 1994; Van Laar et al. 1997).

Wade (1995) suggested that the use of simulation models could not be divorced from the experimental process and Swain et al. (2006) stated that results of simulations are sensitive to input values of several parameters. For example, long duration (135–150 days) varieties have different morphology and height than medium duration (115–130 days) varieties. These tall (>1.0 m), long duration varieties usually have less tillering and lower nitrogen (N) responsiveness than high-yielding, medium-duration, semi-dwarf varieties (Tanaka et al. 1964; Wada and Sta Cruiz 1989, 1990; De Datta and Broadbent 1990; Sta Cruiz and Wada 1994).

Oryza2000 was tested under conditions of limiting water (Boling et al. 2000) and limiting N (Bouman and van Laar, 2006) separately. Sailaja et al. (2009) used independent data sets of kharif (wet) rice grown under irrigated conditions to test Oryza2000 and reported that model simulated values were nearer to observed values. Even though, Oryza2000 was validated independently under various situations, its applicability under both nitrogen and water limited situations has not been known. The objectives of this study was to derive crop growth parameters of Oryza2000 for different varieties and validate the model by comparing model simulated results with results of an irrigated low land field experiment for both nitrogen and water limited situations.

Materials and methods

Oryza2000 (Bouman 2001) simulates the growth and development of rice in the following three situations:

- Potential production: Growth occurs in conditions with an ample supply of water and nutrients; growth rates are determined by varietal characteristics and weather conditions only (radiation and temperature).
- Water-limited production (Oryza_W): Growth is limited by a water shortage in at least part of the growing period; nutrients are in ample supply.
- Nitrogen-limited production (Oryza_N): Growth is limited by a shortage of nitrogen (N) in at least part of the growing season; water supply is adequate.

The basic input requirements of the model are data of daily weather (maximum and minimum temperature, sunshine hours, rainfall, vapour pressure and wind speed), experimental conditions (transplanting, plant density, and date of crop emergence) and crop (cultivar specific, morpho physiological characters of plant species). The additional input requirements for Oryza-N component of Oryza2000 model are the N supply that includes 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 every day. Although N uptake is sensitive to soil type, climate, and management practices, the N recovery efficiency increases from a relatively lower value at basal N application at transplanting to higher recoveries at panicle initiation. The N fertilizer application data is provided as an input table corresponding to the date and amount of N application. The additional input requirements for Oryza-W component of Oryza2000 model are the amount and timing of irrigation applied to the crop.

Datasets

The data sets to validate the crop model were derived from field experiments conducted at the research farm of Directorate of Rice Research at Rajendranagar, Hyderabad (17.32 N, 78.38 E). The varieties used were BPT 5204 (135–145 days), Ajaya (120–132 days) and Rasi (115–120 days) (duration). Twenty day old seedlings were transplanted at 5 seedlings per hill and 50 hills per square meter with 10×20 spacing. Plant samples of the above varieties were collected at different growth stages: transplanting, panicle initiation, flowering and maturity. The leaf area was determined soon after the hills were collected. The dry weight of sample tillers, leaves and rest of the leaves were determined separately, and the leaf area index (LAI) was calculated (Yoshida et al. 1976). Grain Yield components were measured at harvest time. 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 (WRR14-Grain Yield) and total above ground dry matter (WAGT).

Input data were entered into three files: weather, experimental and crop data files. Data on dry weights of above said parameters and dates of transplanting; panicle initiation, flowering and maturity were entered into experiment data file of model. The crop data file contains parameters that describe the rice variety under consideration.

Irrigation data was entered in the input file at alternate days. The amount of irrigation applied was 20 mm. The soil texture of DRR farm is mostly clay. Field and available water capacities and wilting points were entered into the PADDY soil data file, input to water balance model of Oryza. Paddy file was used for entering soil attributes. Soil field capacity (0.53 m^3) and available water capacity (0.04 m^3), wilting point (0.49 m^3) and depth (10 mm) of experimental field in DRR, were entered in the PADDY file. Day wise weather data, were collected and entered into weather file of the model. First data set was used for validation at different nitrogen levels while second set served the purpose of validation over time.

First dataset

The experiment was conducted during 2006 wet season at DRR. The experiment was laid out in split plot design with four replications, two varieties (main plot) and three nitrogen (0, 100, 200 kg N ha^{-1}) levels (sub plot). One long duration variety BPT 5204 (135–145 days) and mid duration variety Ajaya (120–132 days) were used in this experiment to examine the relative influence of genotype on crop parameters. Standard cultural practices were followed to raise the crop. The N fertilizer application was provided as input table corresponding to the date and amount of N application in the experiment file. Variety specific crop files were created for BPT 5204 and Ajaya.

Second dataset

An irrigated low land field experiment data with one short duration variety Rasi (120 days) was used as validation data set to simulate dry matter weight over 5 years. The experiment was laid out in randomized block design with four replications. Experiment data from 2001 to 2005 wet season at DRR farm was used. Rice was fertilized with a total of 90 kg N ha^{-1} in three equal splits and this data was provided as input table corresponding to date and amount of N application in the experimental file. Year wise experimental and weather files were created. Variety specific crop file was created for Rasi variety.

Deriving variety specific development rate parameters

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 phenological phases. Hence, four variety specific developmental rates have to be estimated for the effect of temperature in the different stages.

DVRJ (°C $day)^{-1}$: for the basic vegetative, from seedling emergence to start of photoperiod sensitivity
DVRI (°C $day)^{-1}$: for photoperiod sensitive phase, from the end of basic vegetative phase to panicle initiation. DVRI is the development rate at optimum photoperiod
DVRP (°C $day)^{-1}$: for the panicle formation phase, from panicle initiation to first flowering
DVRR (°C $day)^{-1}$: for the grain filling phase, from first flowering to physiological maturity

There were two programs to help in deriving these parameters: DRATES for development rates and PARAM for others (Leaf Area Index, fraction of stem reserves etc.). 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.

Comparison of simulated and observed LAI and WAGT

The LAI and dry matter production of first data set at different N levels were simulated and compared with observed values by calculating percentage differences over observed values. Year wise simulated dry matter production and yield of second data set for 5 years were compared with observed values by calculating percentage differences over observed values. Model performance evaluation was presented by D-index (Eq. 1), and a normalized objective function (*NOF*-Eq. 2) proposed by Ahuja et al. (2002). The D-index is defined as:

$$D = 1 - \sum_{i=1}^{n} (S_i - Ob_i)^2 \div \sum_{i=1}^{n} \left(\left| (S_i - Ob_{Avg}) \right| + \left| (Ob - Ob_{Avg}) \right| \right)^2, \qquad (1)$$

where Ob_{Avg} is the average of observed values that could be from one treatment or multiple treatments (Ahuja et al. 2002); S_i and Ob_i are simulated and observed values respectively. D-index is a measure of the deviation between model prediction and measurement in relationship to the scattering of the observed data. It has a values ranging from 0 to 1, where = 1 means perfect simulation. The normalized objective function is defined as:

$$NOF = RMSE/Ob_{Avg}, \qquad (2)$$

where RMSE is the Root Mean Square Error and NOF = 0 indicates a perfect match between experiment and modeling results. NOF < 1 may be interpreted as simulation errors of less than one standard deviation around the experiment mean (Wikarmpapraharn and Kositsakulchai 2010).

Results

Crop growing dates for different varieties used for the model application and validation are presented as: (i) for deriving variety specific development rates and (ii) validation through comparison of simulated and observed LAI and dry matter production using above specified varieties (Tables 1, 2).

Deriving variety specific development rate parameters

The variety specific development rates were estimated for the effect of temperature in the different stages. These development rates varied with the duration of the crop. In the first data set crop growing parameters were generated for varieties Ajaya, BPT 5204 and Rasi (Table 3). Differences in Table 3 for developmental rates such as DVRJ, DVRI, DVRP and DVRR indicate various phases of life cycle of a rice crop. Among these, calibrated values of DVRI are constant and also consistent with fertilizer application in these varieties while variations in the calibrated developmental rates for the remaining phases varied, has a greater physiological significance.

The variation in parameter is more in basic vegetative phase compared to other 3 phases. Similar results were observed with Rasi variety. 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). There is a slight variation in crop growing periods of observed values for different N applications (Table 3). This has influenced the variation in the development growth rates of varieties at different N application levels. Generally N is applied in 3 splits viz., transplanting, panicle initiation (PI) and flowering phases. Among the three, N applied at PI stage significantly influenced growth rates.

Table 1 Duration for different stages of Ajaya and BPT 5204 varieties used to validate Oryza under nitrogen and water limited situations

Stages	Ajaya	BPT 5204
Transplanting	25	25
Panicle initiation	67	76
Flowering	97	106
Maturity	129	138

Fig. 1 Simulated and observed leaf area index (LAI) and weight of above ground dry matter weight (WAGT) values for 4 replications (R1, R2, R3, R4) of Ajaya variety under at 3 N levels (200, 100, 0 N) and 20 mm irrigation at 1 day interval (experiment conducted at DRR, Kharif, 2006)

Comparison of simulated and observed LAI and WAGT and WRR14

The growth rate parameters given in Table 3 used for the simulation under nitrogen and water limited situations for the 3 varieties and the above two data sets for the corresponding Simulation with first data set. Simulated and observed values of LAI and WAGT of Ajaya (Fig. 1) and BPT 5204 varieties (Fig. 2) were compared under nitrogen and water limited situation. The varieties were grown at 3 N levels (i) 200 kg/ha to represent potential production, (ii) 100 kg/ha and (iii) 0 kg/ha (no applied N) to represent nitrogen limited production. There was no water stress as irrigation was applied on alternate days. The simulated and observed values of weight of dry matter (WAGT) and rough rice (WRR) of the two varieties at maturity for these conditions are given in Tables 4 and 5.

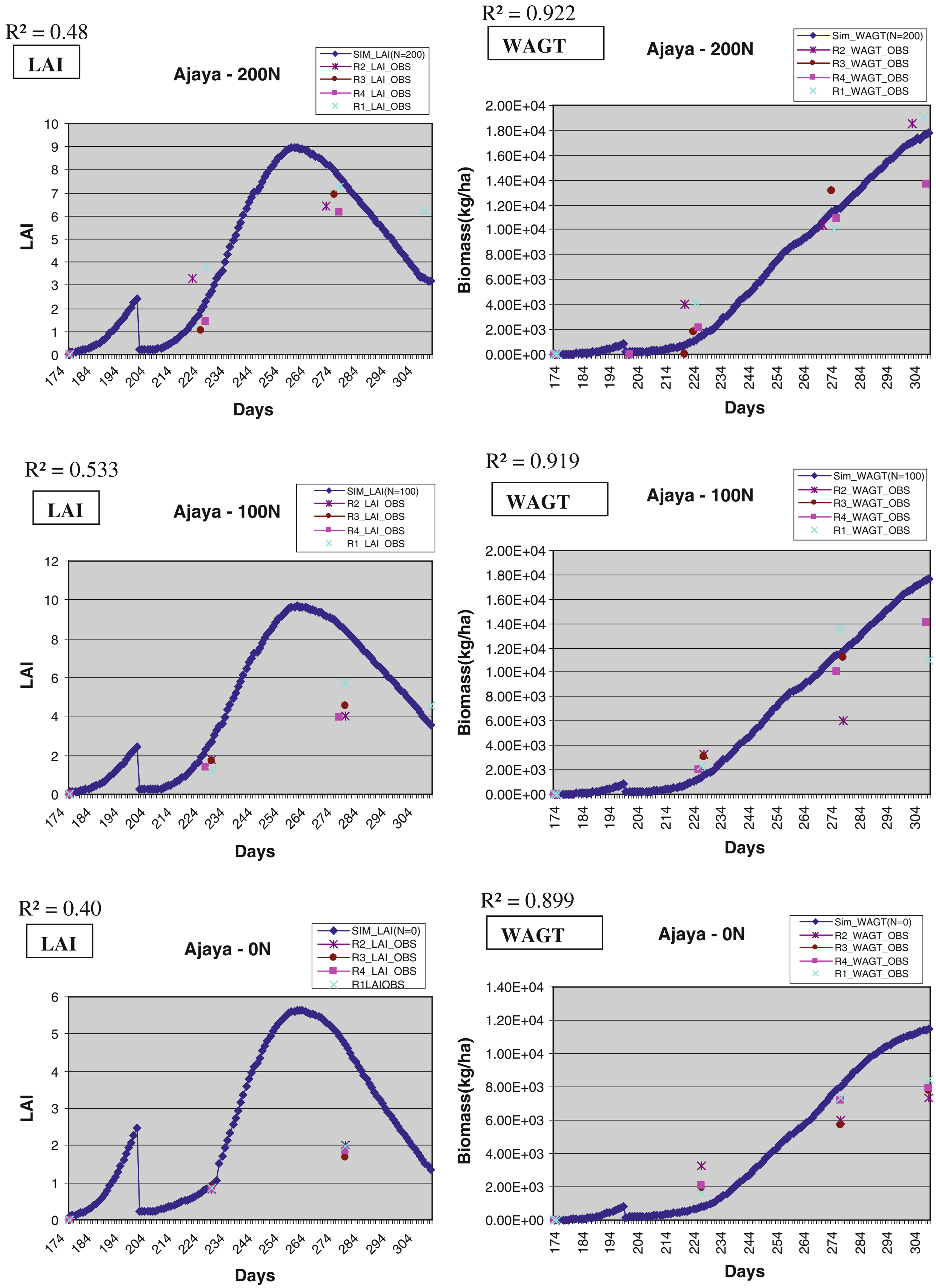
Scatter plots were compared for observed and simulated above-ground dry matter with coefficient of determination (R^2) 0.93 at 200 and 100 kg/ha nitrogen and 0.9 at no applied nitrogen for both Ajaya and BPT varieties (Figs. 1, 2). Coefficient of determination of Leaf Area Index (LAI) were 0.37, 0.53 and 0.48 for two varieties at 0, 100, 200 kg/ha nitrogen levels. Normalized objective function (Eq. 2) is 0.1 for Ajaya and 0.15–0.17 for BPT at 200 kg/ha nitrogen for grain yield and weight of above

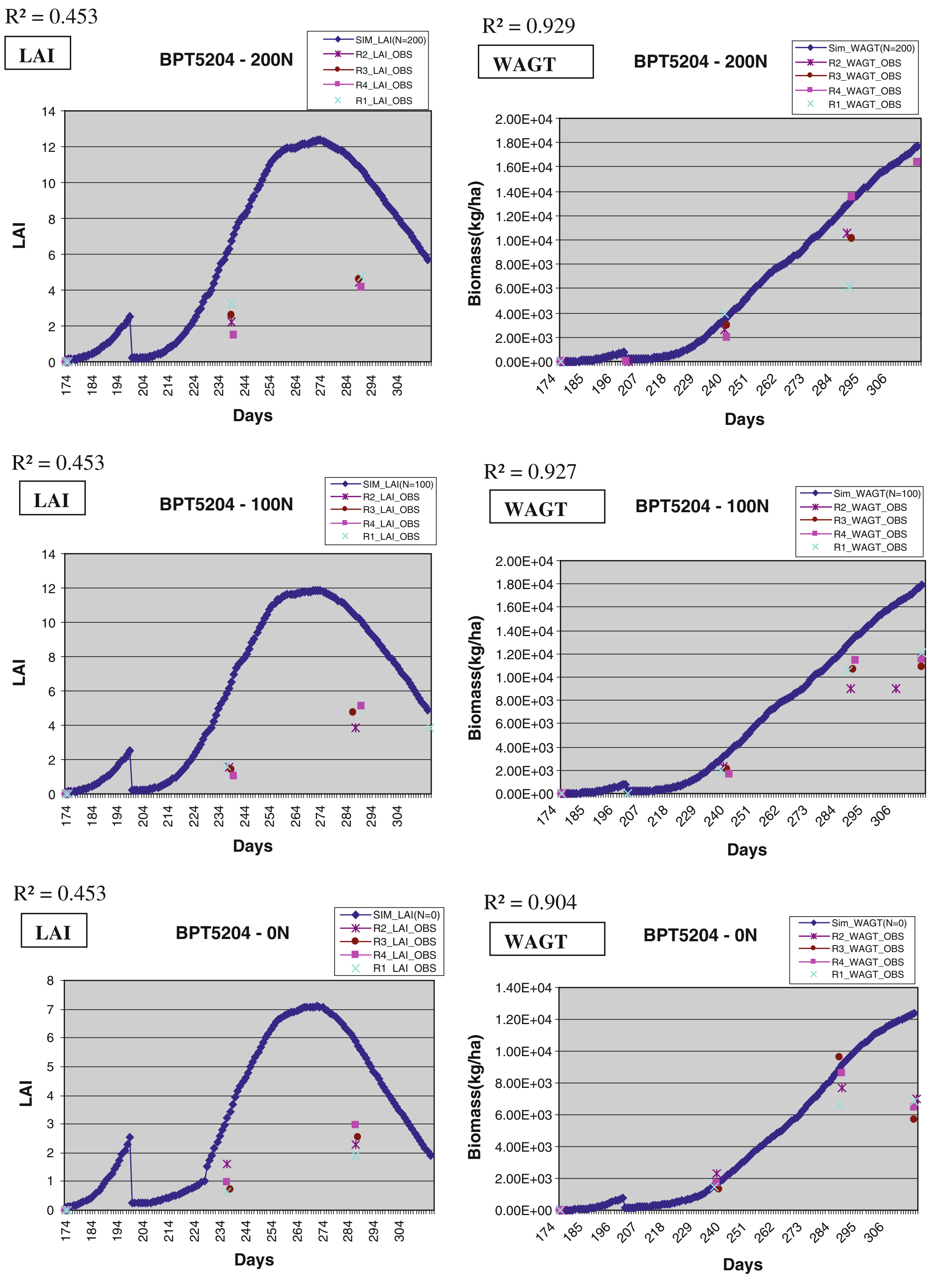
Table 3 Calibrated development rates for Ajaya and BPT 5204 based on field experiments conducted during Kharif 2006 and for Rasi variety during Kharif 2001

Variety	N Level (kg)	DVRJ	DVRI	DVRP	DVRR
Ajaya	0	0.000494	0.000758	0.000657	0.001860
Ajaya	100	0.000494	0.000758	0.000657	0.001860
Ajaya	200	0.000538	0.000758	0.000651	0.001838
BPT 5204	0	0.000400	0.000758	0.000667	0.002103
BPT 5204	100	0.000393	0.000758	0.000669	0.002253
BPT 5204	200	0.000380	0.000758	0.000672	0.002071
Rasi	90	0.000740	0.000758	0.000653	0.001848

Table 2 Date of sowing and duration for different stages of Rasi variety used to validate Oryza under nitrogen and water limited situations

Stages	2001	2002	2003	2004	2005
Sowing	14/06/2001	26/06/2002	19/06/2003	15/7/2004	15/06/2005
Transplanting	25	25	25	25	25
Panicle initiation	59	53	53	59	62
Flowering	89	83	83	93	92
Maturity	119	113	113	118	122


R² = 0.48
LAI
Ajaya - 200N
SIM_LAI(N=200)
R2_LAI_OBS
R3_LAI_OBS
R4_LAI_OBS
R1_LAI_OBS
LAI
Days
R² = 0.922
WAGT
Ajaya - 200N
Sim_WAGT(N=200)
R2_WAGT_OBS
R3_WAGT_OBS
R4_WAGT_OBS
R1_WAGT_OBS
Biomass(kg/ha)
Days
R² = 0.533
LAI
Ajaya - 100N
SIM_LAI(N=100)
R2_LAI_OBS
R3_LAI_OBS
R4_LAI_OBS
R1_LAI_OBS
LAI
Days
R² = 0.919
WAGT
Ajaya - 100N
Sim_WAGT(N=100)
R2_WAGT_OBS
R3_WAGT_OBS
R4_WAGT_OBS
R1_WAGT_OBS
Biomass(kg/ha)
Days
R² = 0.40
LAI
Ajaya - 0N
SIM_LAI(N=0)
R2_LAI_OBS
R3_LAI_OBS
R4_LAI_OBS
R1LAIOBS
LAI
Days
R² = 0.899
WAGT
Ajaya - 0N
Sim_WAGT(N=0)
R2_WAGT_OBS
R3_WAGT_OBS
R4_WAGT_OBS
R1_WAGT_OBS
Biomass(kg/ha)
Days



R² = 0.453
LAI
BPT5204 - 200N
SIM_LAI(N=200)
R2_LAI_OBS
R3_LAI_OBS
R4_LAI_OBS
R1_LAI_OBS
LAI
Days
R² = 0.929
WAGT
BPT5204 - 200N
Sim_WAGT(N=200)
R2_WAGT_OBS
R3_WAGT_OBS
R4_WAGT_OBS
R1_WAGT_OBS
Biomass(kg/ha)
Days
R² = 0.453
LAI
BPT5204 - 100N
SIM_LAI(N=100)
R2_LAI_OBS
R3_LAI_OBS
R4_LAI_OBS
R1_LAI_OBS
LAI
Days
R² = 0.927
WAGT
BPT5204 - 100N
Sim_WAGT(N=100)
R2_WAGT_OBS
R3_WAGT_OBS
R4_WAGT_OBS
R1_WAGT_OBS
Biomass(kg/ha)
Days
R² = 0.453
LAI
BPT5204 - 0N
SIM_LAI(N=0)
R2_LAI_OBS
R3_LAI_OBS
R4_LAI_OBS
R1_LAI_OBS
LAI
Days
R² = 0.904
WAGT
BPT5204 - 0N
Sim_WAGT(N=0)
R2_WAGT_OBS
R3_WAGT_OBS
R4_WAGT_OBS
R1_WAGT_OBS
Biomass(kg/ha)
Days

◀**Fig. 2** Simulated and observed leaf area index (LAI) and weight of above ground dry matter weight(WAGT) values for 4 replications (R1, R2, R3, R4) of BPT 5204 variety under at 3 N levels (200, 100, 0 N) and 20 mm irrigation at 1 day interval (experiment conducted at DRR, Kharif, 2006)

ground dry matter. NOF values are little bit high (0.2–0.5) at 100 kg/ha nitrogen and no applied nitrogen compared to 200 kg/ha nitrogen application. It is clear from NOF values that simulated and observed values are closer at 200 kg/ha nitrogen application than 0 and 100 kg/ha nitrogen application in Ajaya and BPT varieties. D-index (Eq. 1) is ~0.8–0.9 for two varieties at 3 nitrogen application levels. The deviation among observed and simulated values is less than 20 % (Table 6).

Simulation with second data set: model validation over 5 years

The comparison between observed and simulated values of total dry matter weights of Rasi variety over 5 years are presented in Fig. 3. The simulated values lie within the standard error of the corresponding observed values even though there are significant differences in weather conditions during the 5 years (Fig. 3). Simulated total dry matter weight also varied from 12,824 to 14,376 kg and the observed values from 12,280 to 15,600 kg. D index derived for observed and simulated values of dry matter weight of Rasi variety over 5 years is 0.863.

Table 4 Simulated and observed values of weight of rough rice (WRR14-Grain Yield) of Ajaya variety under combined nitrogen and water limited production situation, experiment conducted at DRR, Kharif, 2006

Parameter	Production situations	Amount of N applied (kg/ha)	Simulated values (kg/ha)	Observed values (kg/ha)				
				R1	R2	R3	R4	AVG
Grain Yield at maturity WRR14-(kg/ha)	Nitrogen and water limited	**200**	**8742.0**	**9,000**	7,800	8,100	7,600	8,125
		100	**8527.8**	5,800	5,500	4,400	**7,700**	5,850
		0	**5090.6**	**4,500**	3,900	4,000	3,800	4,050
Biomass at maturity WAGT-(kg)	Nitrogen and water limited	**200**	**17697**	19,030	**18,490**	15,600	13,660	16,695
		100	**17359**	10,990	10,750	9,940	**14,050**	11,433
		0	**11479**	**8,480**	7,310	7,750	7,920	7,865

WAGT weight of above ground dry matter, *WRR14* weight of rough rice

Table 5 Simulated and observed values of weight of rough rice (WRR14-Grain Yield) of BPT5204 variety under combined nitrogen and water limited production, experiment conducted at DRR, Kharif, 2006

Parameter	Production situations	Amount of N applied (kg/ha)	Simulated values (kg/ha)	Observed values (kg/ha)				
				R1	R2	R3	R4	AVG
Grain yield at maturity WRR14-(kg/ha)	Nitrogen and water limited	**200**	**7,900**	**7,900**	**7,900**	6,800	6,000	7,150
		100	**7,210**	**5,800**	4,300	4,800	3,000	4,475
		0	**5,014**	**3,000**	2,700	2,600	3,000	2,825
Biomass at maturity WAGT-(kg)	Nitrogen and water limited	**200**	**18,744**	**18,620**	**18,620**	15,320	16,420	17,245
		100	**17,887**	**12,060**	9,040	10,870	6,290	9,565
		0	**12,389**	6,830	**7,020**	5,710	6,290	6,463

WAGT weight of above ground dry matter, *WRR14* weight of rough rice

Table 6 Evaluation of Oryza2000 under combined nitrogen and water limited production, experiment conducted at DRR, Kharif, 2006

Parameter	Amount of N applied (kg/ha)	Normalized objective function (NOF)		D-index	
Grain yield at maturity WRR14-(kg/ha)		Ajaya	BPT5204	Ajaya	BPT5204
	200	0.10	0.15	0.85	0.87
	100	0.43	0.45	0.83	0.83
	0	0.26	0.50	0.82	0.78
Biomass at maturity WAGT-(kg)	200	0.10	0.17	0.85	0.87
	100	0.34	0.38	0.82	0.82
	0	0.43	0.36	0.79	0.78

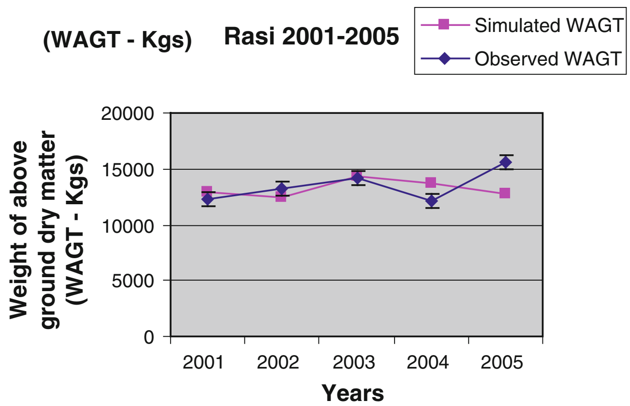


Fig. 3 Simulated and observed total dry matter weights (WAGT) of Rasi variety during 2001–2005, during kharif season under combined nitrogen and water limited situation. *Vertical lines* indicate standard error

Discussion

BPT 5204 (Long) and Ajaya (Medium) and Rasi (Short) varieties were used for evaluating the rice crop growth simulation model Oryza2000 under both nitrogen and water limited situation. Developmental growth rates were derived for each variety. As seen in Table 3, variation in growth rates in the first phase of developmental stage, i.e., DVRJ between the two/three varieties could be due to the initial seed weights, and seed vigour. On the other hand, the second phase is coincided with investment of fertilizer for the development of tillers, leaf area index and enhancement of tiller diameter. In this context, there appears to be not much variation in the developmental rates hence, the values were more consistent. After the completion of the basic vegetative stage, the plant enters into reproductive stage, which is energy consuming process and the genotypes varied in DVRP and is represented by formation of sinks and partitioning followed by seed filling. The efficiency of mobilization of a particular cultivar is thus, related to the developmental rates in DVRR which has been ultimately realized as yield as represented in Table 3.

The model overestimated the Leaf Area Index (LAI) for water and nitrogen limited situation in all observations. It was also reported by Bouman and van Laar (2006) that simulation of LAI by Oryza was relatively poor and that LAI values were generally overestimated by the model, especially at low nitrogen applications. 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).

Model simulations for dry matter (WAGT) were satisfactory for medium and long duration varieties at all N rates and most of the simulated values lie within their corresponding observed values (Figs. 1, 2). Similar results were observed in Vikas and DRRH1 varieties (Sailaja et al. 2009). It was observed from the simulated values of two data sets that even though LAI values were overestimated by the model, at least one observed value (replication—bold values given in Tables 4 and 5) is nearer to simulated values of grain yield and biomass at 0, 100 and 200 N values. In case of Rasi variety in second data set, simulated values of WAGT were close to observed values in all 5 years.

The simulated biomass values of the long and medium duration varieties were in agreement with the observed values at all N rates but agreement was the best at N application rate (200 kg N ha^{-1}) at all growing stages except flowering. This reduction affected the final values of total dry matter and weight of rough rice, indicating requirement of model refinement, particularly after flowering stage, as the growth processes are more complex at grain filling. Another source for model improvement would be the rate of CO_2 assimilation by light saturated leaves, which can vary between 10 and 50 kg CO_2 ha^{-1} leaf h^{-1} for C_3 species and 10–90 kg CO_2 ha^{-1} leaf h^{-1} for C_4 species, depending on N concentration and temperature (Goudriaan 1986; Van Keulen and Seligman 1987). Peng et al. (1995) observed a positive and significant correlation between single leaf net photosynthetic rate and leaf N content per unit leaf area of rice under field conditions. More insights are needed concerning relations between N in leaf and maximum rate of photosynthesis as influenced by genotypes of different duration and morphology.

In case of grain yield at maturity, simulation value of BPT 5204 at 200 N matched exactly with observed values in 2 replications (R1 and R2). At higher N level model performs better for long duration varieties compared to short (Rasi) and medium duration (Ajaya) varieties. Simulation values of biomass of Rasi varied among the 5 years due to variations in weather. Trends shown by crop-simulated yields are usually more reliable than their absolute values because these models are sometimes too sensitive to biological parameters but generally respond well to weather fluctuations (Palanisamy et al. 1993).

Earlier, 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. In this context, model performance was also assessed by statistical analysis (R^2, D-index and NOF). These values also have shown closeness between simulated and observed values for Ajaya and BPT varieties. CERES-Rice and CERES-Wheat model performances were evaluated by using D index and confirmed these models were performing well with D Index ranging from 0.86 to 0.97 (Timsina and Humphreys 2006). R^2 and D-index values (0.9, 0.8–09) have shown relative closeness between observed and simulated values for dry matter weight and grain yield parameters. Model simulation can be further improved if leaf area growth, dry matter partitioning factors, leaf death factors and leaf nitrogen content are calibrated for each development stage and genotype and are being attempted (Dillip et al. 2007).

In conclusion, the results of this validation of two experiments suggest 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 under both nitrogen and water limited situations. Overall, the results show that the crop growth simulation model Oryza2000 can be used effectively to minimize need for years of costly multi location, on station and on farm trials to select rice varieties.

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