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# Simulating the phenology, growth and yield of aromatic rice cultivars using CERES-Rice model under different environments

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## ABSTRACT

Field experiment were conducted during *kharif* seasons of 2007 and 2008 on silty loam soils of Nawagam under middle Gujarat Agroclimatic zone. Four aromatic cultivars of rice were transplanted on three dates to validate the CERES-Rice v.3.5 model. Highly positive significant association was found between simulated and observed days to heading (r = 0.95**). The model overestimated biomass production under estimated test weight and LAI. The performance of the model in simulating grains per square meter was poor. The grain yield was simulated in close agreement with the field observed grain yield.

***Key words :*** Simulation, validation, CERES-Rice model, aromatic rice

Rice (Oryza sativa), one of the three most important food crops in the world, forms the staple diet of 2.7 billion people. India is the largest growing country (8°N to 34°N latitude) of the rice under varying climatic conditions and it accounts for more than 40% of food grain production, providing direct employment to 70% people in rural areas. Being the staple food for more than 65% of the people, national food security hinges on growth and stability of its production (Anon., 2006). The percentage share of export value of Basmati rice in the food grains export earnings was 76.10 per cent during 1993-94. India exported around 581791.0 metric tones of Basmati rice (Anon., 2004).

As crop growth simulation models are useful tools for considering the complex interactions between a range of factors that affect crop performance, including weather, soil properties and crop management. The CERES-Rice model simulates crop growth, development and yield. Hence, the present field experimentation was carried out for selecting suitable aromatic cultivar and appropriate time of transplanting using CERES-Rice models.

## MATERIALS AND METHODS

Field experiments were conducted during *kharif* seasons of 2007 and 2008 at Research farm of Main Rice Research Station, Nawagam, Anand Agricultural University, Anand under middle Gujarat Agroclimatic region. Four different aromatic cultivars $V_1$= Pankhali (P 203), $V_2$= Narmada (Ambica), $V_3$= GR- 104 and $V_4$= Pusa Basmati 1 of rice were transplanted on three different dates, $D_1$: 8th July, $D_2$: 22nd July and $D_3$: 8th August to validate the CERES-Rice v.3.5 model. The farm is located at 22º48'N latitude, 71 º 43' E longitudes and at an altitude of 32.4 m above the mean sea level. The soil of the experimental field was medium black, deep to very deep, poorly drained and salt affected. The textural class of soil was silty loam having 38.1 % sand, 44.1 % silt and 20.8 % clay. The four different genotypes viz,

The different phenological phases of plant development and the observations thereof were recorded by visiting the field frequently from raising of seedlings to harvesting. Leaf area index were calculated by measuring the leaf area with leaf area meter (LI-COR 3100) at various phenophases. To assess the above ground biomass production the leaves, stem, and panicles were separated and initially shade dried. They were then dried in oven at 65°C for 72 hours till a constant weight was obtained and expressed in g $plant^{-1}$. Number of panicles per sq. meter, number of grains per panicle, test weight (1000 grain weight), grain yield and straw yield were recorded and harvest index was calculated for validation of the model

### *Calibration and validation of the CERES -Rice model*

Model calibration or parameterization is the adjustment of parameters so that simulated values compare well with observed values. Eight genetic coefficients (Table 1) that influence the occurrence of growth and stages in the CERES-Rice models for all four genotypes

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**Table 1 :** Genetic coefficients for four genotype of rice

| Genetic Conflict | Description | Genotype of rice | | | |
|---|---|---|---|---|---|
| | | Pankhali (P 203) | Narmada (Ambica) | GR- 104 | Pusa Basmati-1 |
| P1 | Time period (expressed as growing degree days [GDD] in °C above a base temperature of 9°C) from seedling emergence to end of juvenile phase during which the rice plant is not responsive to changes in photoperiod. This period is also referred to as the basic vegetative phase of the plant. | 750.0 | 630.0 | 740.0 | 620.0 |
| P2R | Extent to which phasic development leading to panicle initiation is delayed (expressed as GDD in °C) for each hour increase in photoperiod above P2O. | 60.0 | 90.0 | 75.0 | 65.0 |
| P2O | Critical photoperiod or longest day length (in hours) at which the development occurs at maximum rate. At values higher than P2O the development rate is slowed (depending on P2R), there is delay due to longer day length. | 350.0 | 340.0 | 370.0 | 352.0 |
| P5 | Time period in GDD in °C from beginning of grain-filling (3-4 days after flowering) to physiological maturity with base temperature of 9°C | 11.7 | 11.8 | 11.9 | 11.6 |
| G1 | Potential spikelet number coefficient as estimated from number of spikelets per g of main culm dry weight (less lead blades and sheaths plus spikes at heading. A typical value is 55. | 27.0 | 32.0 | 41.0 | 31.0 |
| G2 | Single dry grain weight (g) under ideal growing conditions. i.e., non limiting light, water, nutrients, and absence of pests and diseases. | 0.0165 | 0.0196 | 0.0226 | 0.023 |
| G3 | Tillering coefficient (scalar value) relative to IR64 cultivars under ideal conditions. A higher tillering cultivar would have coefficient greater than 1. | 1.00 | 1.00 | 1.00 | 1.00 |
| G4 | Temperature tolerance coefficient. Usually 1.0 for cultivars grown in normal environment.G4 for japonica type rice grown in warmer environments would be δ 1.0. Tropical rice grown in cooler environments or season will have G4 $< 1.0$ | 1.00 | 1.00 | 1.00 | 1.00 |

were derived iteratively, by manipulating the relevant coefficients to achieve the best possible match between the simulated and one set of observed field data of first crop year (Table 1).

Validation is the comparison of the results of model simulations with observations from crop that were not used for the calibration. Beyond comparisons, several statistical measures viz, Willm root mean square error (RMSE) described by Willmott (1982) and correlation coefficient (r) and its square, the coefficient of determination ($R^2$), Percent Error (PE) were used to evaluate the association between predicted and observed values using following formulae

**Table 2 :** Test criteria with respect to simulation of days to heading, days to maturity, maximum leaf area index (Max.LAI) and biomass of aromatic rice genotypes

| Parameters | Days to heading | Days to maturity | Max. LAI | Bio-mass | GPSM (no. $m^{-2}$) | Test weight (g) | Grain yield (Kg $ha^{-1}$) | HI |
|---|---|---|---|---|---|---|---|---|
| Observed mean | 96 | 131.88 | 2.86 | 13955 | 14843 | 20.78 | 3535 | 0.252 |
| Observed SD (±) | 3.1 | 4.58 | 0.55 | 1508 | 1864 | 1.31 | 505 | 0.013 |
| Simulated mean | 97.0 | 132 | 2.83 | 14342 | 13667 | 19.97 | 3543 | 0.248 |
| Simulated SD (±) | 3.6 | 4.31 | 0.49 | 1669 | 2038 | 0.79 | 431 | 0.015 |
| r | 0.95** | 0.74** | 0.90** | 0.88** | 0.73* | 0.95** | 0.94** | 0.73** |
| Student 't' | $0.00975^{NS}$ | $0.01525^{NS}$ | $0.68637^{NS}$ | $0.11705^{NS}$ | $0.01713^{NS}$ | $0.029662^{NS}$ | $0.87033^{NS}$ | $0.19887^{NS}$ |
| MAE | 1.33 | 3.75 | 0.18 | 795 | 1363 | 1.06 | 131 | 0.008 |
| MBE | 1.08 | 0.75 | -0.03 | 387 | -1177 | -0.81 | 8 | -0.004 |
| RMSE | 1.58 | 4.28 | 0.23 | 847 | 1822 | 1.35 | 166 | 0.011 |
| PE | 1.65 | 3.25 | 7.99 | 6.0 | 12.3 | 6.50 | 4.7 | 4.33 |
| Index of agreement (D) | 0.99 | 0.98 | 0.98 | 0.99 | 0.98 | 0.95 | 0.99 | 0.97 |

## RESULTS WITH DISCUSSION

***Days to heading and maturity***

The simulated days to heading were (97.0 ± 3.6 d) by the model near to the mean observed days to heading (96.0 ± 3.1 d). Highly positive significant association was observed between simulated and observed days to heading (r = 0.95**). The values of errors as computed in terms of MAE, MBE, RMSE and PE showed that model performed well for simulation of days to heading (Table 2). These results were in good agreement with the finding of Timsina *et al*. (1995) for validation of days to heading using CERES-Rice model. The mean simulated days to maturity (132.63±4.31 d) was nearly matched with the observed mean value (131.88± 4.58 d) (Table 2). The trend of correlation coefficient, 't' test, MAE, RMSE and degree of agreement were observed to be the same as observed for days to heading.

***Maximum LAI***

The observed as well as model simulated LAI was found maximum at the heading stage. The simulated max LAI (2.83) was very close to observed LAI (2.86) with singificant correlation (r=0.90**). The CERES-Rice model slightly underestimated the LAI from emergence to maturity in all four genotypes and dates of transplanting except at few points. The highest LAI was recorded in GR-104 in all the corresponding dates of transplanting than that of others genotypes of aromatic rice.

***Biomass***

The observed mean yields of biomass production of the four genotypes of rice was 13955 ± 1508 kg $ha^{-1}$ while simulated biomass was 14342 ± 1669 kg $ha^{-1}$. Positive significant association was observed between simulated and observed biomass production with correlation coefficient values of 0.88** (Table 2). Non-significant difference was observed between simulated and observed biomass production in terms of paired 't' test. The overall trend of simulated biomass production indicated overestimation by the model except for few treatments but PE remained lower than 9.5.

***Number of grains per square meter***

Simulated grain number per meter square (grains $m^{-2}$) values (13667 ± 2038) were underestimated (MBE= -1177) by the model when compared with the corresponding observed ones 14843 ± 1864. Paired-'t' test between simulated and observed values showed that the differences were non-significant, but the correlation coefficient (r = 0.73*) between observed and simulated values were found significant. The MAE, RMSE and the D between simulated and observed values were 1363, 1822 and 0.98 respectively.

***Test weight***

The association between the observed and corresponding simulated test weight of various cultivars of rice is (Table 2) show that the test weight simulated by the model were lower for the most of the treatments which is supported by the negative values of MBE (–0.81). Similar results have also been reported by Hundal and Kaur (1999).

***Grain yield***

The grain yield (kg $ha^{-1}$) simulated by the model (3543 ± 431) was very close to the observed grain yield (3535 ± 505) and highly positive significant association was calculated between simulated and observed yield (r= 0.94**). The average errors computed as MAE, MBE and RMSE were 131, 8 and 166, respectively (Table 2). The evaluation of the model on an overall basis revealed that the simulation performance of the model in respect of grain yield was found perfect (D=0.99).

***Harvest index (HI)***

Lower errors (MAE and RMSE were 0.008 and 0.011, respectively) and high index of agreement (0.97) revealed that model performed well in simulation of the harvest index of the aromatic rice genotypes. However, the simulated values of HI by the model was slightly lower (MBE= -0.004) when compared with observed values (Table 2). These lower simulated values of HI were due to overestimation of biomass production by the model.

## CONCLUSIONS

It may be concluded from the above findings that that the CERES-Rice model was found good enough research tools to predict the phenological occurrence, grain yield and harvest index of the rice crop inadvance and this can be used to facilitate the farmers to make broad decision on the crop management operations.

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