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Evaluation of CERES-Rice (DSSAT) model for growth, yield and nitrogen uptake of rice varieties in North Western Himalayas

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Abstract

A field experiment was conducted at Palampur for two years during *Kharif* seasons of 1998 and 1999 using four rice varieties *viz.* RP-2421, HPR-927, HPR-957 and Kasturi and two dates of transplanting *viz.* 23 June and 12 July during 1998 and 24 June and 9 July during 1999. CERES- Rice model was used to simulate growth, development and yield. The model correctly simulated the dry matter accumulation in roots, stem, and total above ground biomass but failed to simulate correctly leaf dry weight after 45 days of transplanting in all the varieties. Grain yield of all the varieties except Kasturi was predicted well by the model. Nitrogen uptake in grains was also predicted well by the model but it failed to simulate nitrogen content in grains, straw and total uptake.

Key words: CERES-Rice, simulation, dry matter, yield, nitrogen content and uptake.

Introduction

Agricultural system models have untapped potential to help agricultural research and technology transfer in 21st century (Ahuja *et al.* 2002). These models are based largely on the physiological mechanisms describing these processes and hence, can be used in any part of the world implying zero or at the best only a little alteration in the models for the local conditions. Decision Support System for Agrotechnology Transfer (DSSAT) is one of such crop models which encompass models for several important crops, including CERES-Rice. The software is capable of simulating the effect of different management practices including dates of transplanting, genotypes, responses to irrigation and fertilizer N on almost all the crop growth parameters, yield attributes and yield of different crops along with the soil -water- nitrogen dynamics during and after the crop season. CERES-Rice is a process-based, management-oriented model that can simulate the growth and development of rice as affected by varying levels of water and nitrogen (Ritchie *et al.* 1998). Generation of minimum data set for simulation of the model is prerequisite. In case of Himachal Pradesh, no such model of crop simulation has been used so far. Therefore, the present investigation was carried out to generate such data and simulate the performance of CERES-Rice (DSSAT v3.1) model for growth, yield and nitrogen uptake of rice.

Material and Methods

A field experiment was conducted during *kharif* seasons (July- October) 1998 and 1999 at the Experimental Farm of CSK HP Krishi Vishvavidyalaya, Palampur (32°6'N, 76°3'E, 1290.8 m elevation). The soil texture was silty clay loam and acidic in reaction. The 0-60 cm soil layer had, on an average, bulk density of 1.283 g/ cm^3 (before rice transplanting). The soil was rich in organic carbon, high in total N, medium in available P and K in the upper 0-15 cm layer. These values decreased with increase in soil depth.

Treatments comprised of two dates of transplanting *viz.* 23 June and 12 July during 1998 and 24 June and 9 July during 1999 and four varieties *viz.* RP-2421, HPR-927, HPR-957 and Kasturi. These four varieties were transplanted 26 days after sowing in first date of transplanting and 45 days after in second date of transplanting during 1998, whereas in 1999, 26 days old seedlings were used on both dates of transplanting at 20 × 15 cm hill to hill spacing and with two seedlings per hill. The crop was fertilized @ 90 kg N, 40 kg P_2O_5 and 40 kg K_2O/ha, of which one third of nitrogen and whole of P and K were applied uniformly as basal dressing and incorporated in the surface soil. Remaining N was top dressed in two equal splits each at tillering and panicle initiation stages of crop. The experiment was conducted in

randomized complete block design with four replications. The observations on dry matter accumulation in roots, leaves and stem were recorded at fortnightly interval. For these observations, one outer row on both sides of the plot was used. Four hills from each side were uprooted for dry matter accumulation studies. The uprooted plants were separated into different parts and dried in oven at 70°C till constant weight.

The input data required to run the CERES-Rice model included daily weather data, field capacity, wilting point and initial soil moisture in different layers as well as maximum root depth, crop genetic coefficients and crop management practices such as transplanting dates, plant population, plant row spacing and nitrogen application. Other input files included chemical and physical description of the soil profile with separate information for each horizon, initial organic matter in soil at the beginning of the experiment, initial soil water content, nitrogen concentration and pH for each layer of soil profile. The accuracy of model predictions was estimated by regressing simulated data with observed data (R^2) and by slope of regression line.

Results and Discussion

Dry matter accumulation

Predicted root dry weight matched closely with observed root dry weight for all varieties at all stages of growth which is also supported by higher R^2 values for all varieties (Fig.1). The association between predicted and observed values of root dry weight of all the varieties was also significant as supported by the test of significance for intercept and slope of the regression line. Predicted leaf dry weight also matched closely with observed leaf dry weight during early growth stages up to 45 days after transplanting (DAT) for all the varieties, but at later stages the model overestimated the leaf weight (Fig. 2). This was due to higher number of leaves simulated by the model. The model did not simulate leaf number correctly. The model showed an increase in leaf number up to maturity but in field conditions the leaf number increased up to 75 DAT and decreased thereafter. Salam et al. (2001) also reported similar findings.

Predicted and observed stem dry weight of all the varieties matched closely up to 75 DAT and thereafter the model under - predicted stem dry weight of all the varieties, except HPR-957 (Fig. 3). There was abrupt decline in simulated stem dry weight at 75 DAT but under field conditions no such decrease was noticed. This decline in simulated stem dry weight might be due to translocation of dry matter accumulated in the stems to grains during this period. Mankeb (1993) also reported similar findings. In addition, the model did not permit partitioning of assimilate to stem after heading while the observed results showed continuous increase of stem dry weight after heading. There was good agreement between simulated and observed total dry matter accumulation (above-ground) for all the varieties except HPR-957 in which simulated values were over-estimated at 75 DAT and thereafter (Fig. 4). This was because of over-prediction of simulated leaf (Fig. 2) and stem dry weight (Fig. 3) of HPR-957 as compared to observed values. Goodness of fit (R^2) between predicted and observed values of total dry weight of the varieties was also significant.

Grain yield

The predicted grain yield of rice varieties along with the observed values are presented in Table 1. The predicted values of different rice varieties

Table 1. Observed and predicted grain yield (kg/ha) of rice varieties

Varieties	1998			1999		
	Observed	Predicted	% D	Observed	Predicted	% D
RP-2421	3903	4229	+8	3758	3848	+2
HPR-927	4496	4594	+2	3985	4257	+7
HPR-957	3738	4138	+11	3553	3779	+6
Kasturi	2217	3139	+42	2177	3187	+46

% D -Deviation percentage over the observed values

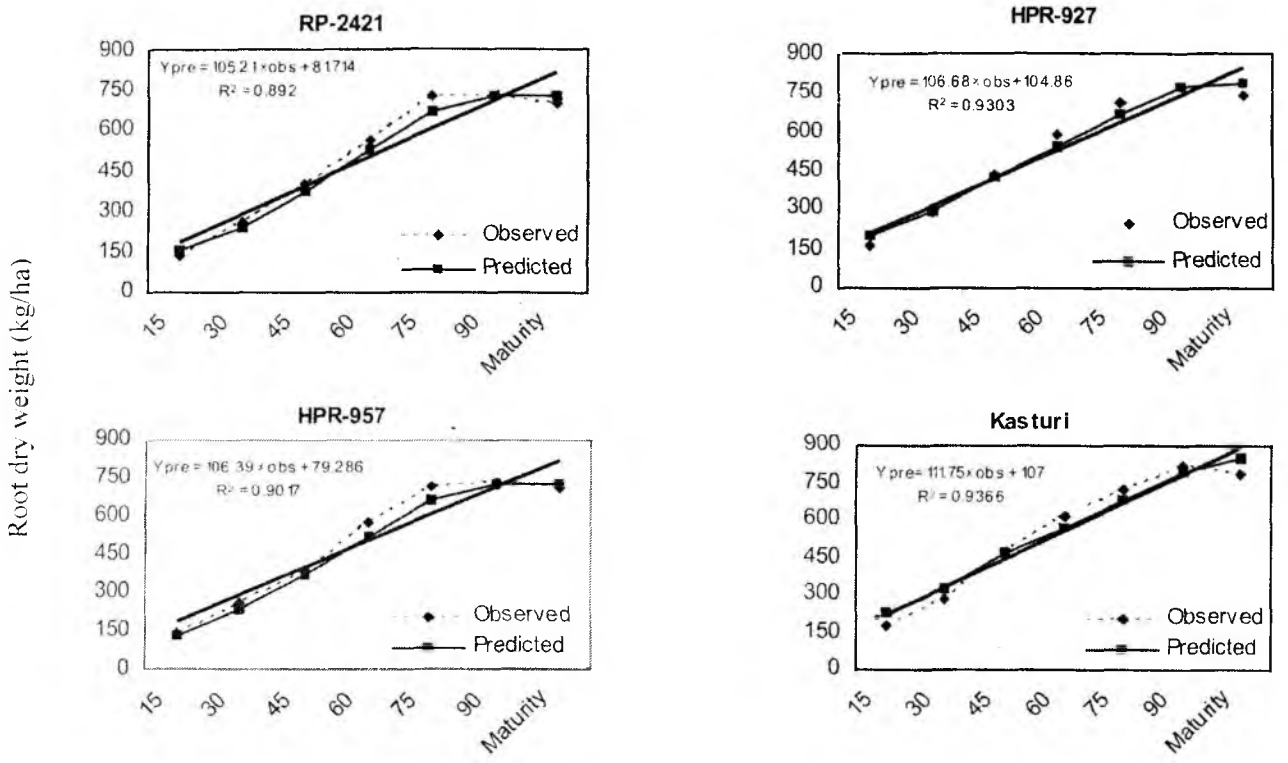


Fig. 1. Comparison of observed and predicted root dry weight (kg/ha) of rice varieties

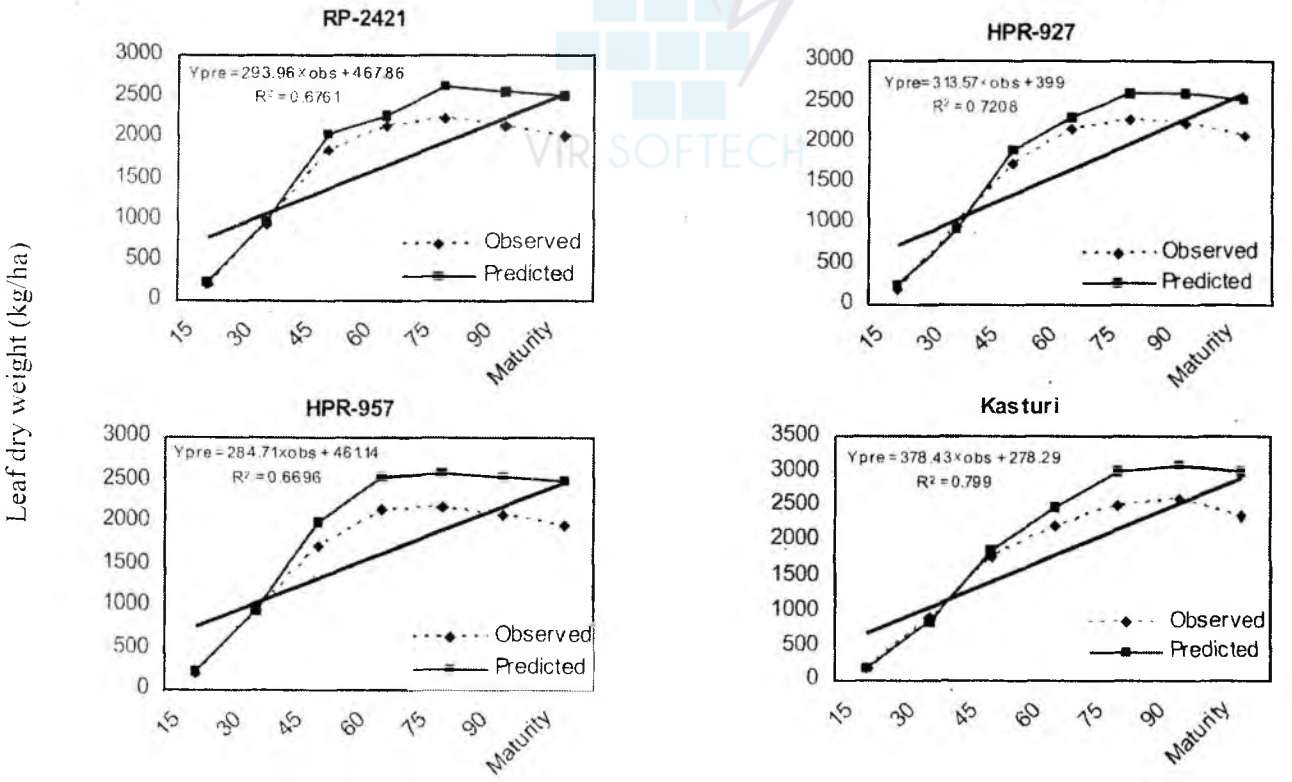


Fig. 2. Comparison of observed and predicted leaf dry weight (kg/ha) of rice varieties

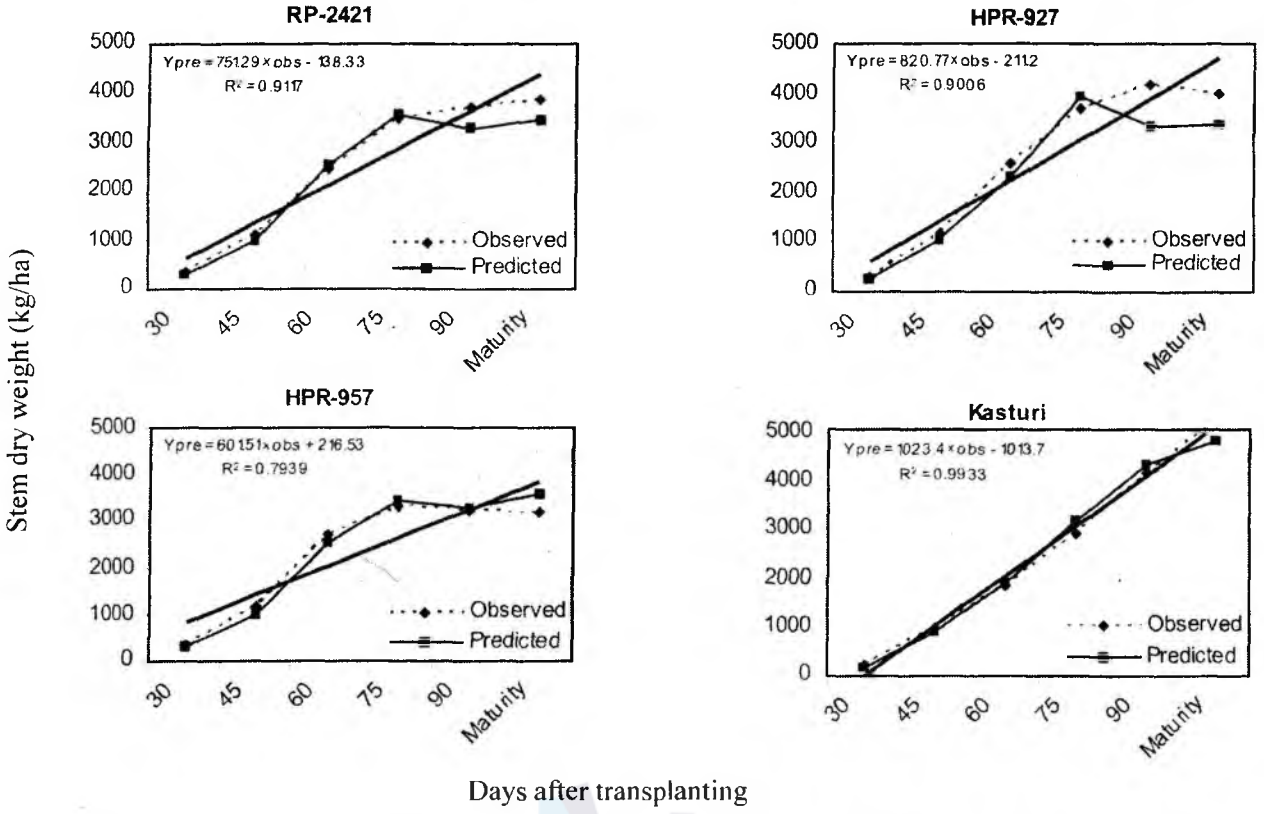


Fig. 3. Comparison of observed and predicted stem dry weight (kg/ha) of rice varieties

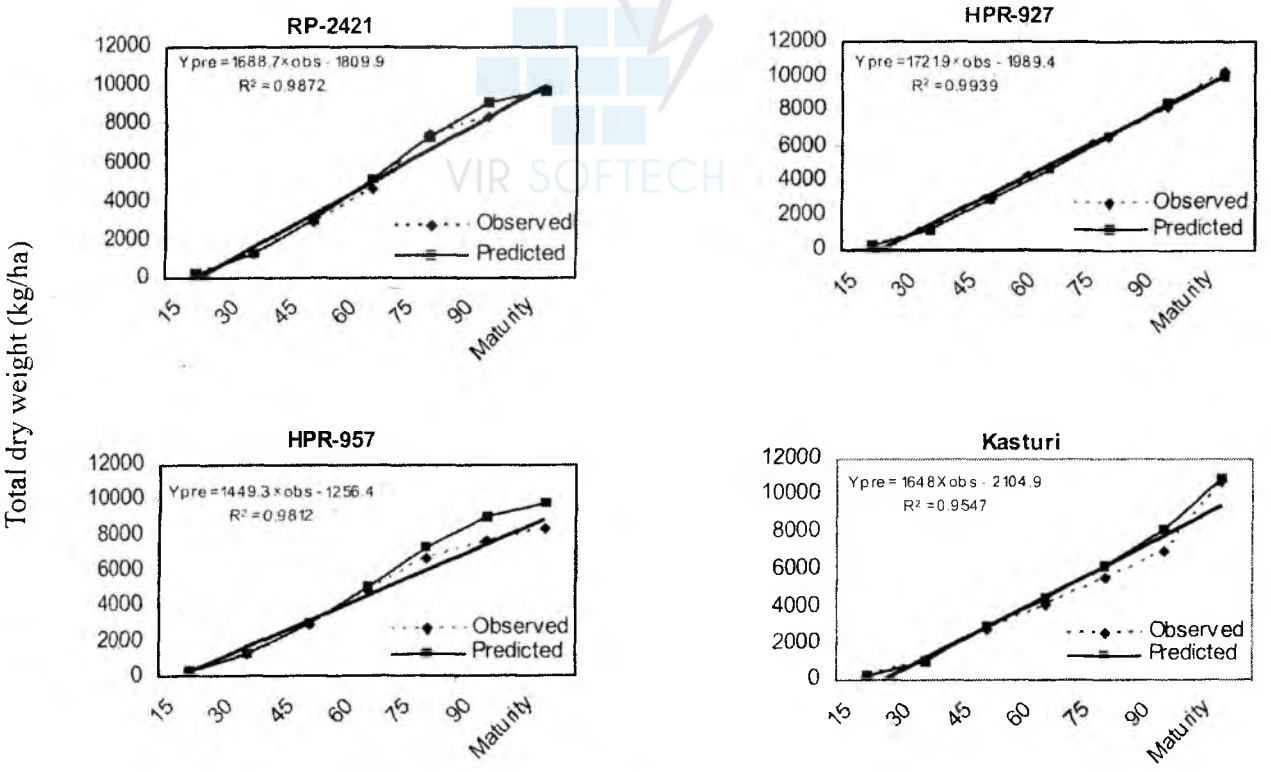


Fig. 4. Comparison of observed and predicted total dry weight (kg/ha) of rice varieties

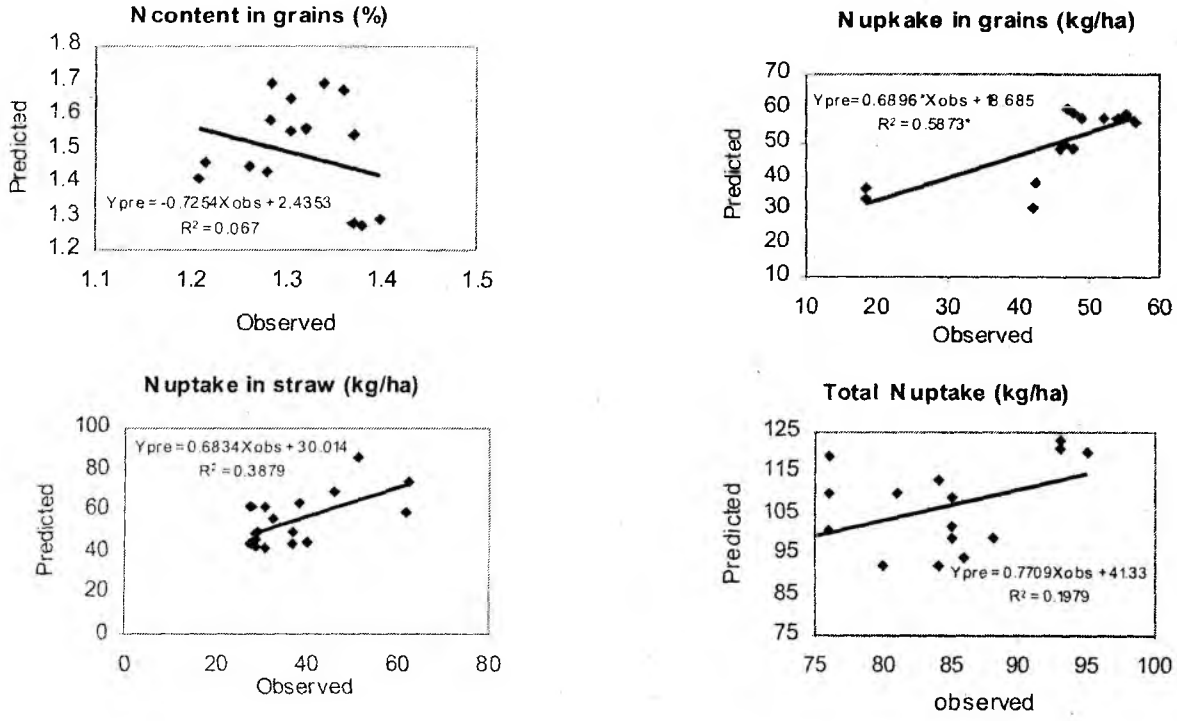


Fig.5. Comparison of observed and predicted N content (%) and N uptake (kg/ha) of rice

were almost equal, except for Kasturi, where the deviation was 42 and 46 percent in both years of study, respectively. This showed that the model failed to simulate grain yield of Kasturi, which may be due to the fact that Kasturi is a photosensitive variety. During both the years, simulated and observed grain yield of HPR-927 was higher than other varieties. The over-estimation of crop yield indicated the potential value of each variety. This model does not take into account losses due to pest, diseases and lodging damage. The model also assumed that spikelets formed would develop into grains that would eventually be harvested. However, field observations showed that there was yield loss due to unfilled spikelets, pests (rat, bird and insect), diseases, lodging and shattering damage. Cheyglinted *et al.* (2001) also reported that the CERES-Rice model predicted slightly higher grain yield than that observed for different varieties.

Nitrogen content and uptake

There were wider differences between observed and simulated values of nitrogen content in grains, uptake in straw and total uptake of rice varieties indicating that the model was unable to predict these parameters. This may be due to the nitrogen dynamics in soil- plant-water system, which the model does not simulate the subroutine describing the real system. Consequently, wider variation between predicted and observed data was obtained. However, the predicted and observed values for uptake of nitrogen in grains were significantly associated as supported by the tests of significance for intercept and slope of regression line. Similarly goodness of fit (R^2= 0.5873) between predicted and observed data was significant (Fig 5) which may be due to close association between predicted and observed grain yield. Timsina *et al.* (2004) also found a reasonably good agreement between observed and simulated N uptake by rice especially for grain N uptake at Delhi.

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