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Parameterization and validation of CERES- Rice model in north western Himalayas

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ABSTRACT

A rice crop model CERES-Rice was parameterized and validated in Himachal Pradesh using experimental results. Cultivar specific genotypic coefficients were derived for four varieties during calibration. Validation based on several independent sets of yield data, including different locations, years, nitrogen and irrigation water treatments showed good agreement (R^2=0.7785) between observed and simulated grain yield. The model was used to design management practices of four varieties

Key words : CERES-Rice, crop growth models, parameterization, *Oryza sativa* validation

Rice is one of the most important staple food crops in India and its production has increased tremendously from 20.6 million tonnes (Mt) in 1950-51 to 87.0 Mt in 2003-04 due to increase in area under rice from 30.8 to 44.6 million hectares (M ha) and productivity from 668 to 1804 kg ha^{-1} (Anonymous, 2003). In future, expansion of area under rice is very unlikely due to tremendous increase in population and urbanization. Therefore, increasing demand has to come from increase in productivity per unit area. For achieving this, one of the prime requirements and non monetary inputs is transplanting cultivars at an appropriate time. Simulation models can be used to meaningfully reduce additional experimentation and decision making to increase yield. Varietal character input is incorporated in the model in the form of "genotypic coefficients". For this, detailed data on crop growth, development and yield parameters are required to be generated by conducting field experiments and precise recording of data. An inbuilt programme in the DSSAT called GENCALC, calculates these coefficients. In fact, "genotypic coefficients" input data set for varieties cultivated in Himachal Pradesh are lacking. It was because of unavailability of these coefficients, an attempt has been made in this study to work out the coefficients of four varieties and validate the CERES-Rice model for prediction of yield and use it as a decision support system.

MATERIALS AND METHODS

Field experiment

A field experiment on rice crop was

conducted during 2000 and 2001 *Kharif* seasons (June- October) in Experimental Farm of Department of Agronomy CSK HP Krishi Vishvavidyalaya, Palampur (32°6'N, 76° 3'E 1290.8 m elevation) in north western Himalayas. Soils are alifisols (Typic hapludalf). The soil texture was silty clay loam and acidic in reaction. On an average, bulk density of the 0-60 cm soil layer was 1.30 g cm^{-3} (before rice transplanting). The soil was rich in organic carbon, rated as high in total nitrogen, medium in available phosphorus and potassium in the upper 0-15 cm layer. These values decreased with increase in soil depth.

Field experiment comprised of two dates of transplanting (23 June –D_1 and 8 July- D_2) and four varieties (RP-2421 -V_1, HPR-1064 –V_2, HPR-2027 –V_3 and Naggar Dhan –V_4). These four varieties were transplanted after 26 days of sowing at 20 X 15 cm hill to hill spacing and with two seedlings per hill. The crop was fertilized @ 90: 40: 40 kg ha^{-1} of N: P_2O_5: K_2O, of which one third of nitrogen and whole of phosphorus and potash were applied uniformly as basal dressing and incorporated in the surface soil. Remaining nitrogen was top dressed in two equal splits, 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 different plant parts viz., roots, leaves, stem were recorded at fortnight interval. For these observations, plant samples from an outer row on both sides were 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. Dry weight of each plant part so recorded was converted into kg ha^{-1}. The model simulated and field observed data during the entire crop season were compared.

The simulation study was carried out using CERES-Rice (Godwin *et. al.*, 1992) model. The genotypic coefficients for different varieties of rice worked out and used in the present study have been reported in Table 1. Standard error of treatment means (S.Em) and coefficient of variation (CV) between the observed and simulated values were worked out to assess the performance of model.

Regression equation was also fitted between observed and simulated data and goodness of fit between two types of data was worked out.

The time course data (observed and simulated) on growth parameters like dry matter accumulation in roots, leaves, stem etc., have been plotted in the figures. Closer the observed and simulated curves, better is the performance of the model.

Model validation and application

CERES-rice model was validated for grain productivity (of different rice varieties of which the genotypic coefficients were worked out in this study) only for which reasonably good number of experimental data was available. Data from other experiments conducted on various aspects

Table 1 : Genotypic coefficients for rice varieties using 'GENCALC'

Genotypic coefficients	Varieties			
	RP-2421	HPR-1064	HPR-2027	Naggar Dhan
Juvenile phase coefficient P1(GDD^{0}C)	350	370	400	220
Critical photoperiod (P2O) h	50	50	50	35
Photoperiodism coefficient (P2R)GDD/h	340	229.7	350	300
Grain filling duration coefficient (P5)(GDD^{0}C)	15.0	15	14.5	12
Spikelet number coefficient (G1)	135	135	100	55
Single grain weight (G2)(g)	0.022	0.023	0.022	0.024
Tillering coefficient (G3)	1.50	1.25	1.00	1.20
Temperature tolerance coefficient (G4)	0.69	0.69	0.69	1.00

(weed management, fertilizer application, irrigation management organic farming etc.) were collected. The management of respective experiments was computerized. The reported and simulated data were compared. Coefficient of variation and regression between observed and simulated data were worked out and tested for their statistical significance. After successful validation of the model, it was used for designing agronomic practices. This was achived by systematically altering the various management practices (time of transplanting, amount, time and methods of fertilizer nitrogen application) as input and recording the out put (grain yield after each run). The potential yield was simulated by assuming no nitrogen and water stress (water and nitrogen balance modules turned off).

RESULTS AND DISCUSSION

Growth parameters

The model simulated the dry matter accumulation in different plant parts during the crop season satisfactorily. Fig. 1 reveals that the simulated root dry weight matched closely with observed values for most of the treatments. However, in Naggar Dhan variety (Japonica Type rice) the model consistently underestimated the root dry weight. The model simulated leaf dry weight of all treatments remained close to observed ones during early growth stages, but at later stages the observed leaf dry weight was lower than the simulated values in most of the treatments (Fig. 2). This was due to leaf senescence and decrease in leaf number after flowering of rice under field conditions. But the model did not show any decrease in leaf number. Similar findings were reported by Kumar (2002).

A close look at Fig. 3 clearly shows that simulated and observed stem dry weight matched closely with observed stem dry weight up to flowering stage of the crop. But at later growth stages, the simulated stem weight was lower than observed values. The model simulated an abrupt decrease in stem weight just after flowering

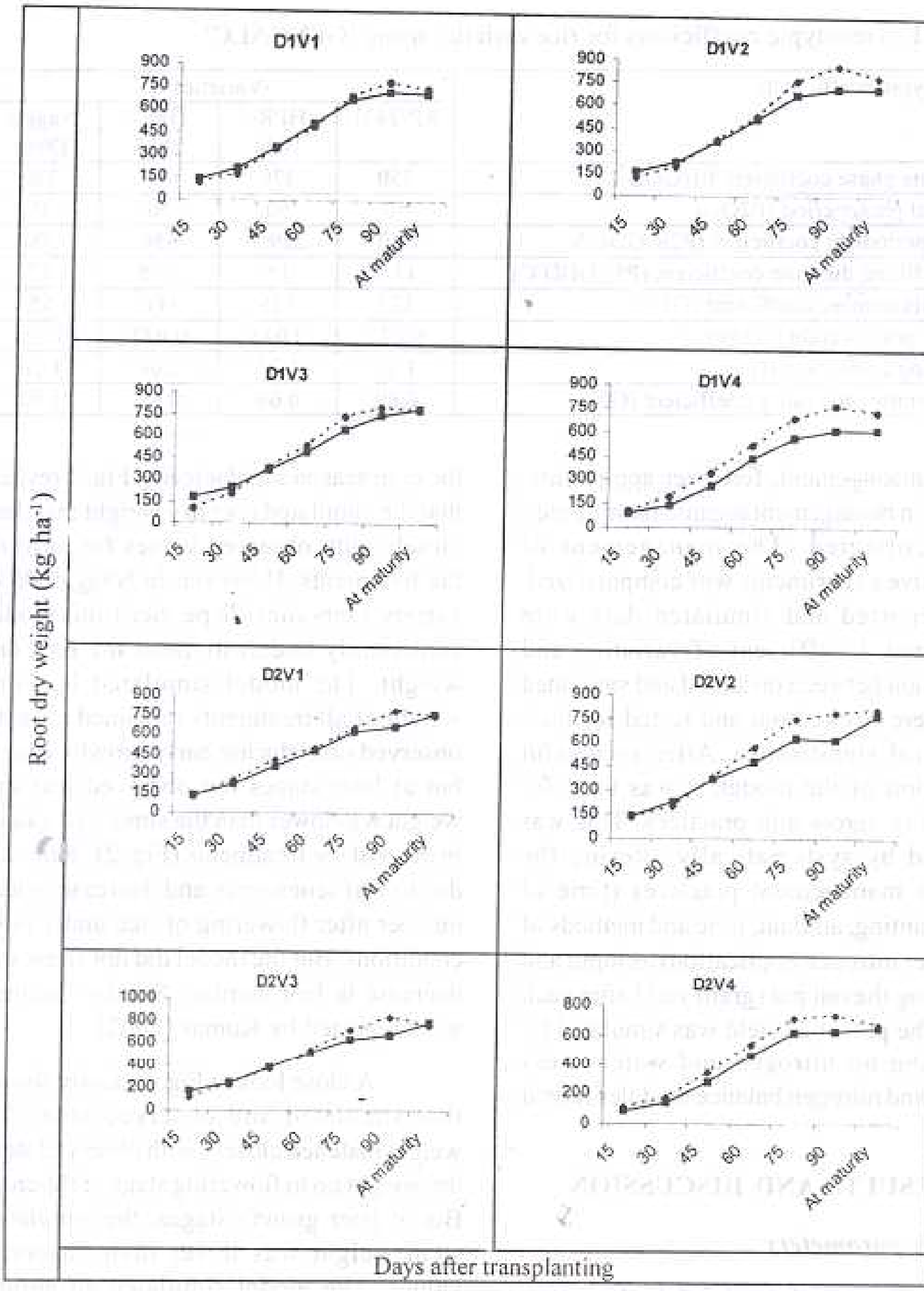

Fig. 1: Observed ----◆---- and simulated —■— root dry weight (kg ha^{-1}) of rice crop

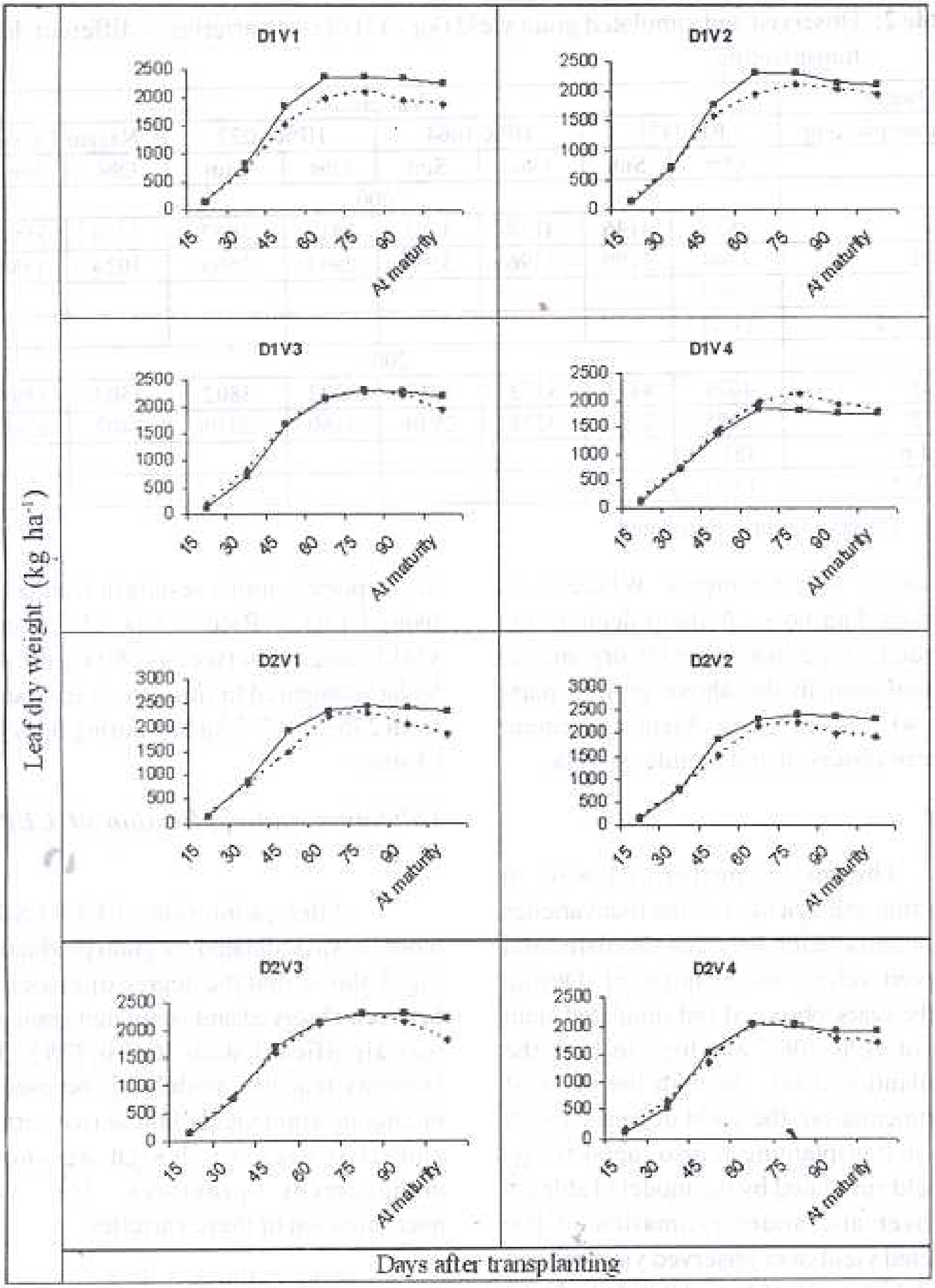

Fig. 2: Observed ····◆···· and simulated —■— leaf dry weight (kg ha^{-1}) of rice crop

Table 2: Observed and simulated grain yield (kg ha^{-1}) of rice varieties in different dates of transplanting

Date of transplanting	Varieties							
	RP-2421		HPR-1064		HPR-2027		Naggar Dhan	
	Obs	Sim	Obs	Sim	Obs	Sim	Obs	Sim
	2000							
D1	3853	4146	4118	4773	3412	3962	3359	3598
D2	3208	3109	3596	3594	2893	2809	3024	3584
SEm	388.1							
CV %	11.31							
	2001							
D1	4078	4434	4372	4717	3302	3802	3507	3592
D2	2995	2362	3298	2949	3160	2879	3402	4269
SEm	481.7							
CV %	13.71							

Obs. : Observed; Sim. : Simulated

in most of the treatments. Whereas, in observed data no such sharp decline was recorded. A perusal of total dry matter accumulation in the above ground parts (Fig. 4) reveals consistent agreement between observed and simulated data.

Yield

The model performed well in predicting grain yield of all the four varieties and the association between simulated and observed values was significant. During both the years, observed and simulated grain yield of HPR-1064 was high in both the transplanting dates. In both the years of experimentation, the yield decreased with delay in transplanting as also supported by the yield simulated by the model (Table 2.) The over and under estimation of the predicted yield over observed yield ranged from 2.42% to 25.48% and 0.05% to 21.13 %, respectively. Saseendran *et al.* (1998ab) also reported similar results in Kerala while using CERES- Rice model. The observed yield ranged between 2893 and 4372 kg ha^{-1} compared to simulated yield ranging from 2362 to 4773 kg ha^{-1} during both years of study.

Validation and application of CERES-Rice

After calibration of CERES-Rice model it was validated for grain productivity. Fig. 5 shows that the degree of association between observed and simulated grain yield was significant with R^2= 0.7785. This suggests that the model can be used for predicting grain yield of these rice varieties and also used to design agronomic management practices for yield maximization of these varieties.

If the calibrated models stand the test of validation with independent data sets, they can be potentially used as tools for

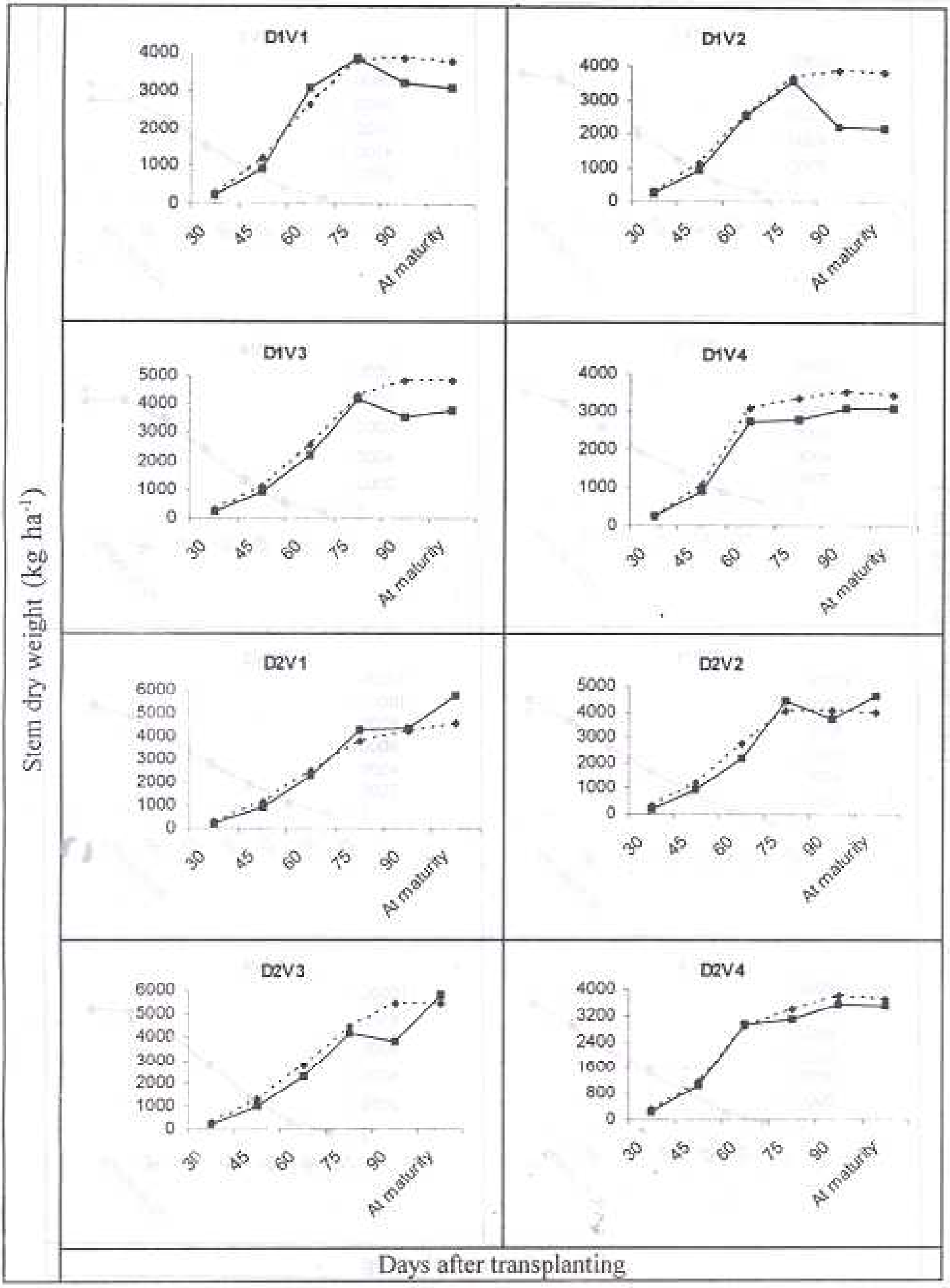

Fig. 3: Observed ----◆---- and simulated —■— stem dry weight (kg ha^{-1}) of rice crop

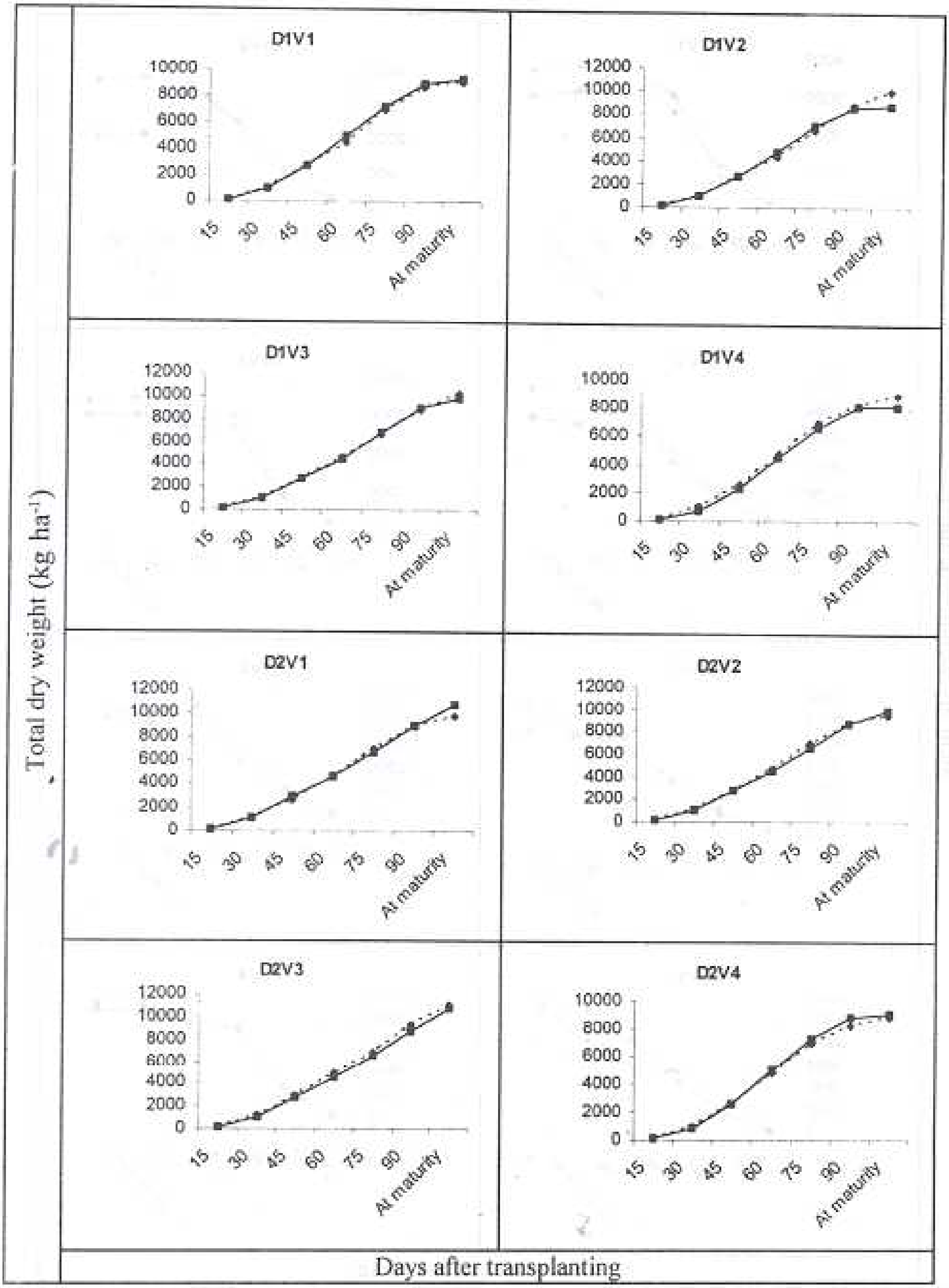

Fig. 4: Observed ····◆···· and simulated —■— total dry weight (kg ha^{-1}) of rice crop

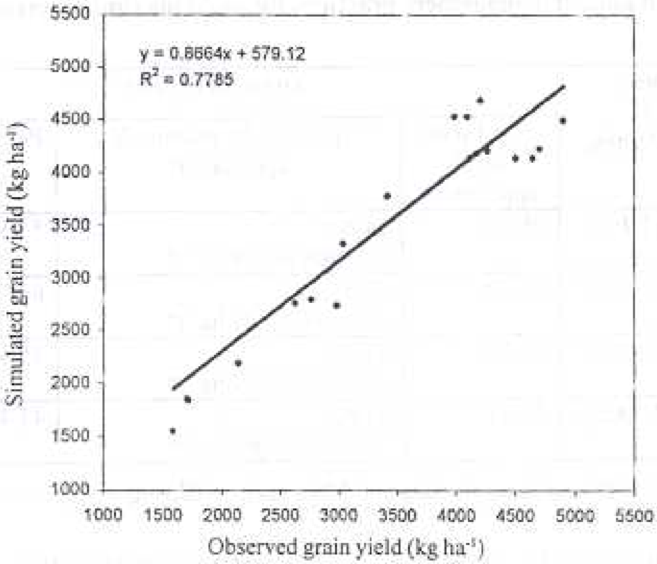

Fig. 5: Validation of CERES-Rice model for grain yield (kg ha^{-1})

operational, tactical, and strategic decision support in on farm crop management (Mathews *et al.*, 2002). CERES-Rice was run under no water stress conditions (water balance module turned off). To work out the optimum time of transplanting of rice varieties, simulation runs were made at weekly interval. from April 1 through July 15 of every year for twenty years making use of long term weather data from 1980-2000 collected at Palampur. Similarly for nitrogen fertilization varying levels were tested with different methods and time of application. From the voluminous simulated yield data generated with different combinations of dates of transplanting, amount and time, method of nitrogen fertilizer applications over the years, the best management practices were identified as reported in Table 3. Perusal of data reveals that the model predicted yield potential of 64-71 q ha^{-1} under no stress conditions for variety HPR-1064 followed by RP-2421 (55-67 q ha^{-1}), HPR-2027 (55-63q ha^{-1}) and Naggar Dhan (43-48 q ha^{-1}) over different years. Grain yield of different varieties leveled off after 105 kg N ha^{-1} for RP-2421 and HPR-2027, 130 kg N ha^{-1} for HPR-1064 and 90 kg N ha^{-1} for Naggar Dhan. In the absence of nitrogen fertilization, yield levels of different varieties ranged between 20-29 q ha^{-1}. Optimum time of transplanting of RP-2421 was worked out to be May 15-June 25 whereas for HPR -1064 and HPR 2027, it was worked out to be second fortnight of May to first fortnight of June. However, Naggar Dhan required early transplanting during May 7- 15 as compared to other varieties. Similarly Hundal and Kaur (1999) and Saseendran *et al.* (1998a,b) also

Table 3 : Simulation guided management practices for yield maximization of different rice varieties

Varieties	Optimum time of transplanting	Grain yield (q ha^{-1})		
		Yield with no N application	Yield with optimum N application	Potential yield
RP-2421	May 15-June 25	25-29	54-60 (45+30+30kgN ha^{-1})*	55-67
HPR-1064	May 20-June 8	27-32	57-63 (50+50+30kgN ha^{-1})*	64-71
HPR-2027	May 18-June 5	23-29	49-57 (45+30+30kgN ha^{-1})*	55-63
Naggar Dhan	May 7 – May 15	20-23	37-42 (30+30+30kgN ha^{-1})*	43-48

*(45+30+30 kg N ha^{-1}) = 45 kg at transplanting and 30 kg each at tillering and panicle initiation stages

used the CERES-Rice model in Indian Punjab and Kerala states, respectively to determine the optimum date of rice transplanting and predicted that the optimum date of rice transplanting was June 15.

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