Journal of Agrometeorology 8(2) : 151-160 (Dec. 2006)

Simulating the sowing date and varietal effect on wheat production using CERES-wheat model in north westerm Himalayas

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ABSTRACT

CERES-Wheat model was used to simulate the effect of sowing dates and varieties on wheat production in Himachal Pradesh. The model was calibrated by deriving cultivar specific genotypic coefficient for four wheat varieties. Phenology and grain yield of wheat varieties was simulated fairly well by the model. But the model failed to simulate yield attributing characters, straw yield and harvest index. Validation based on several independent sets of yield data, including different locations, years nitrogen and irrigation water treatments showed good agreement (R^2 =0.8044) between observed and simulated grain yield. After successful validation, the model was used to design agronomic management practices of the four varieties studied.

Key words: Crop models, CERES-Wheat, sowing dates, *Triticum aestivum* L., varieties, validation,.

Wheat is one of the most important staple food crops of India. The interactions among the production factors involve elaborate field experimentation and take long time to refine the agronomic practices. Crop models are capable of expressing these interactions between a range of factors that affect crop performance, including weather, soil properties and management. CERES-Wheat crop model simulates crop growth, development and yield taking into account the effects from weather, genetic characters and soil water, carbon, nitrogen and planting, irrigation and nitrogen fertilizer management. Before using the crop models as a decision support tool with confidence, they have to be calibrated and validated for the varieties and environments of interest. Crop models have been evaluated and used for working out the management practices in India and abroad (Jones *et. al*, 2003; Hundal and Kaur, 1997).

Hence, an attempt was made in this study to evaluate the sowing date and varietal effect on wheat production by using CERES-Wheat model.

MATERIALS AND METHODS

Field experiment

A field experiment on wheat was conducted at Experimental farm of Department of Agronomy, CSK HPKV, Palampur (32^0 6' N, 76^0 3' E, and 1290.8 m elevation) during the winter season (*Rabi*) of 2000-01 and 2001-02 (November-May). The soil texture is silty clay loam and acidic in reaction. On an average, 0-60 cm soil layer had a bulk density of 1.48 g cm^{-3} (before wheat sowing). 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 got decreased with increase in soil depth.

The experiment comprised of three sowing dates (November 30-D_1, December 15-D_2 and December 30-D_3) and four varieties (HPW 89 -V_1, HPW42 -V_2, HPW147 -V_3 and HPW155 -V_4) and experiment was conducted under irrigated condition. A fine seedbed was prepared after a light pre-sown irrigation. The crop was fertilized with 120 kg N, 60 kg $P_2 0_5$ (basal) and $K_2 0$ (basal) ha^{-1} through urea, single super phosphate and muriate of potash. N was applied in two equal splits at sowing and tillering stages. Wheat was seeded at 5 cm depth in 20 cm rows under a seed rate of 125 kg ha^{-1}. The experiment was conducted in randomised complete block design with four replications. The observations on dry matter accumulation (aboveground) were recorded at fortnight interval. For these observations, one outer row on both sides was used for dry matter accumulation studies. The samples so collected were dried in hot air oven at 70°C till constant weight. Dry weight thus recorded was converted into kg ha^{-1}. Simulated and field observed data were compared.

Genetic coefficients

Cultivar specific genotypic coefficients of wheat were derived (Table 1) from the experimental data by using GENCALC. The coefficients calculated were fine tuned to simulate the development stages as well as the growth and yield parameters.

Different statistical tools were used to evaluate the performance of the model in predicting date of flowering/ date of maturity, yield etc. under different treatments. Regression equation was fitted between observed and simulated data of two years on development stages, yield attributes and grain yield and goodness of fit was worked out.

Model validation and application

CERES-wheat model was validated for grain productivity for which data from other experiments conducted on various agronomic aspects (weed management, fertilizer application, irrigation management, organic farming etc.,) were also collected. Actual reported and simulated data on grains yield were compared. CV 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 to simulating agronomic practices. This was achieved by systematically altering the various management options (time of sowing/ amount, time and methods of

Table 1: Genetic coefficients for wheat varieties

Genotypic coefficients	Varieties			
	HPW 89	HPW 42	HPW 147	HPW 155
Vernalisation coefficient (P1V)	0.0	0.0	0.0	0.0
Photoperiodism coefficient (P1D)	5.33	5.40	5.60	4.50
Grain filling duration coefficient (P5)	2.00	-2.00	4.0	7.17
Kernel number coefficient (G1)	9.90	10.00	5.77	6.52
Kernel weight coefficient (G2)	10.00	10.00	5.00	6.0
Spike number coefficient (G3)	4.00	3.20	7.76	7.50
Phyllochron interval (PHINT)	72.00	79.00	70.0	60

fertilizer application) as input and grain yield as the out put. Simulation runs were made over 5 preceding weather years. Thus potential yield ranges have been reported in this paper.

RESULTS AND DISCUSSION

Phenology

Regarding crop phenology simulated by CERES-wheat model, the simulated days to flowering was within -3 to + 13 days and that of maturity was within -1 to +10 days from the observed data. Similarly the goodness of fit between simulated and observed days to flowering (R^2 = 0.9603) and days to maturity (R^2=0.9691) were also significant with low coefficient of variation for pooled data (Figs. 1 & 2). Timsina *et al.*, (1995) and Hundal and Kaur (1997) also reported similar results while validating CERES-wheat for various sowing dates at Pantnagar and Ludhiana, respectively.

Growth parameters

The model gave a little under estimate or over estimate in respect of dry matter in all treatments. The simulated total dry matter accumulation before flowering stage (135-145 DAS) was higher than the observed values (Fig. 3 a & b) in most of the treatments. Porter *et al.* (1993) also reported overprediction of simulated total dry matter by CERES-wheat model.

Yield attributes

The differences between simulated and observed values of yield attributes *viz.*, grains m^{-2} (Fig. 4), grains/spike (Fig. 5) and single grain weight (Fig. 6), were very wide. The association was not significant. This shows that the model failed to simulate yield

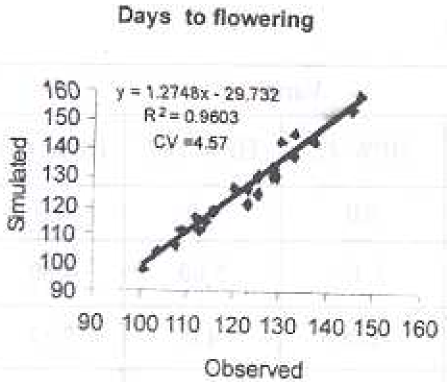

Fig. 1 : Observed and simulated days to flowering (2 years data)

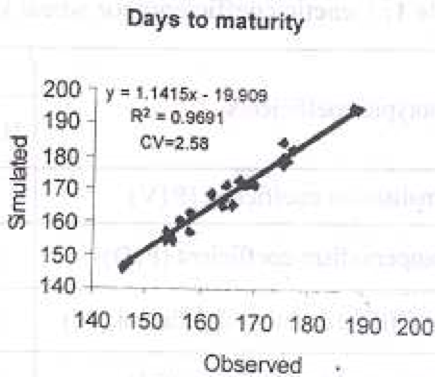

Fig. 2 : Observed and simulated days to maturity (2 years data)

attributes of wheat. The genotypic coefficients of this model need careful fine tuning to represent the Indian cultivars. These findings are in conformity to those of Kumar (2002).

Yield

Inspite of the fact that the CERES-wheat in general, failed to simulate most of the yield contributing characters, its performance in predicting the grain yield of wheat varieties in certain treatments (Table 2) was within acceptable limits. The model could predict the yield with about 71 per cent accuracy (R^2= 0.71). Observed and simulated yield of all the four varieties were the highest for early planting (30th Nov.) and the lowest for late planting (Table 2). Deviation of simulated yield over observed values ranged from -10.6 to +20. 6 per cent in different treatments. Timsina *et al.* (1995) and Heng *et al* (2000) also reported similar findings.

Validation and application of the model

CERES-wheat model was validated for grain productivity (Fig.8) for all the varieties and the association between simulated and observed grain yield was significant (R^2= 0.8044). This shows that model was validated with a fair degree of accuracy under the given set of agronomic management, weather conditions and this can be used to workout management practices for yield maximization in north western Himalayan region.

The simulated results (Table 3) revealed that variety HPW 89 has the maximum yield potential of 64-77 q/ha whereas under resource limiting situation (rainfed, No N application) yield declined to 37-39 q ha^{-1}. Potential yield of HPW 42 was in the range of 55-61 q ha^{-1} under no resource limiting situations. But under resource limiting situation it declined to 24-28 q ha^{-1}. HPW 89 and HPW 42 responded to N application upto 180 kg N ha^{-1} under

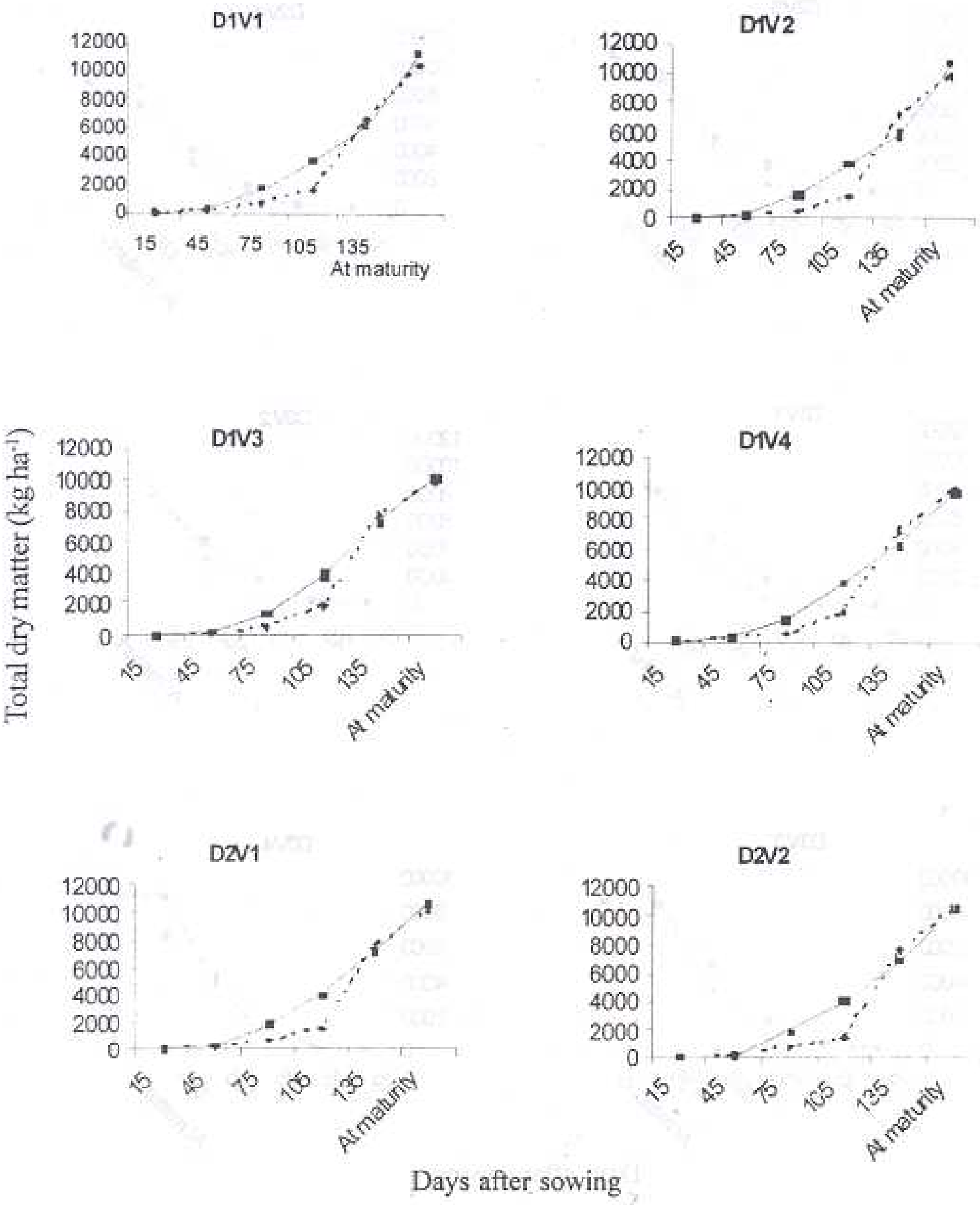

Fig. 3a : Observed ---◆--- and simulated —■— total dry matter (above ground) of wheat varieties in different sowing dates (2 years data)

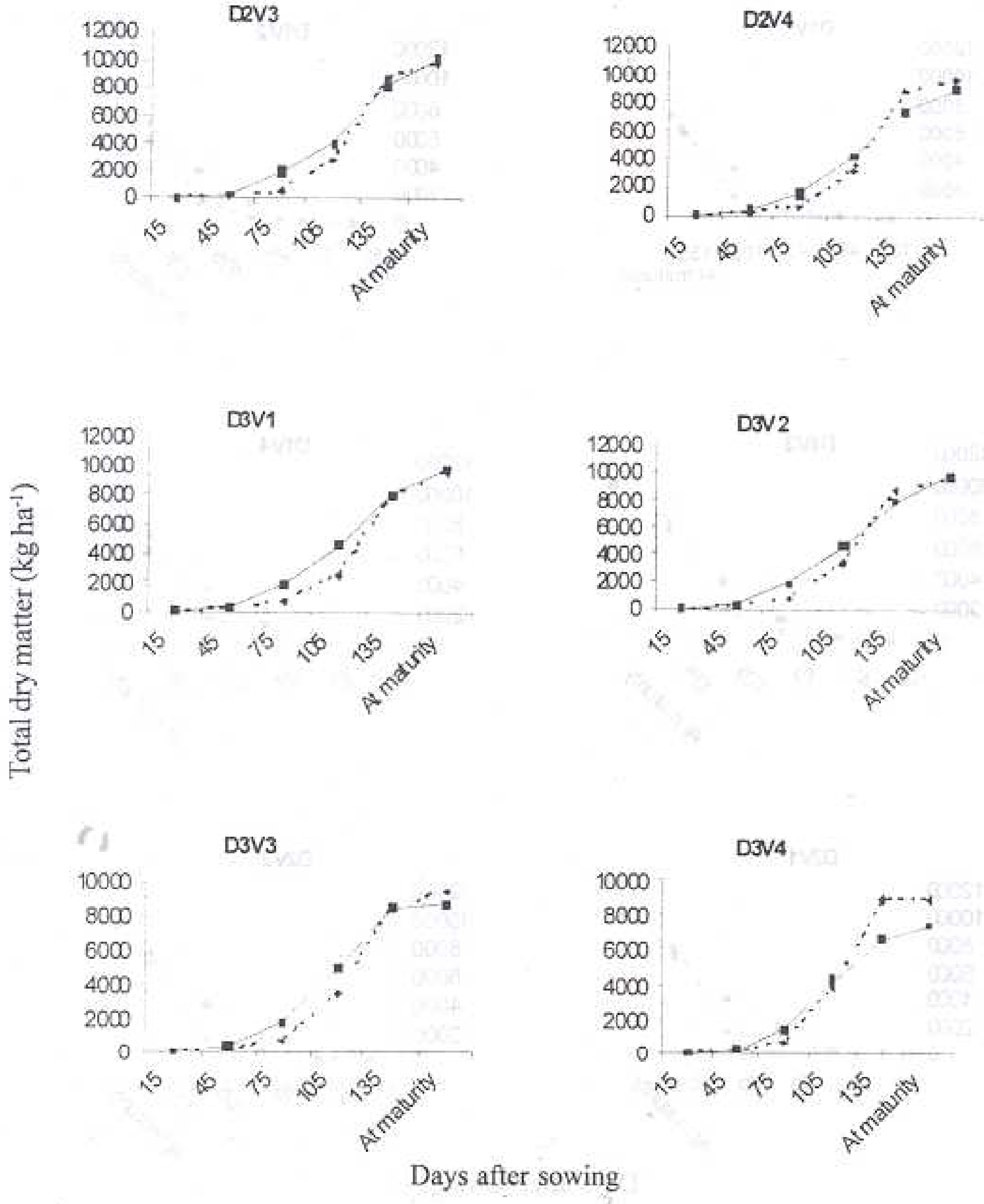

Fig. 3b : Observed ---◆--- and simulated —■— total dry matter (kg ha^{-1}) of wheat varieties in different sowing dates (Pooled data).

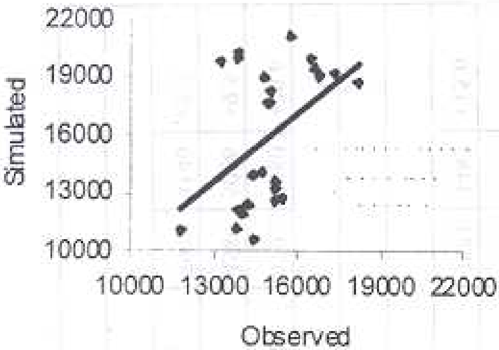

Fig. 4 : Observed and simulated grains m^{-2} of wheat (2 years data)

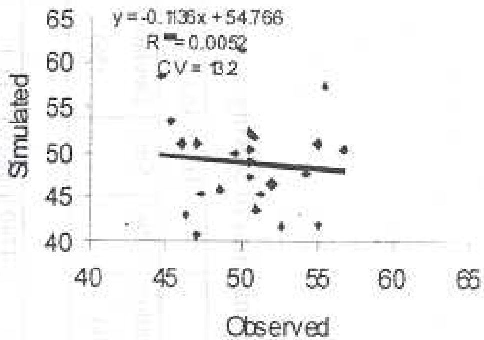

Fig. 5: Observed and simulated grains/ spike of wheat (2 years data)

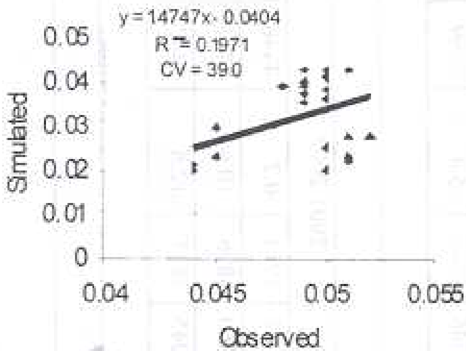

Fig. 6 : Observed and simulated single grain weight of wheat (2 years data)

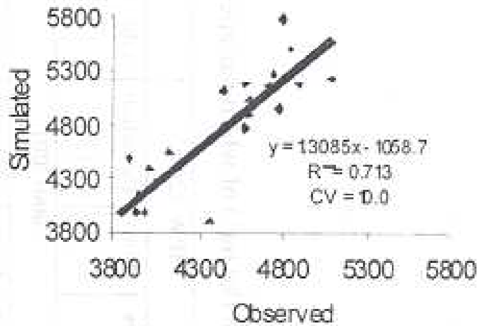

Fig. 7 : Observed and simulated grain yield ($kg\ ha^{-1}$) of wheat (2 years data)

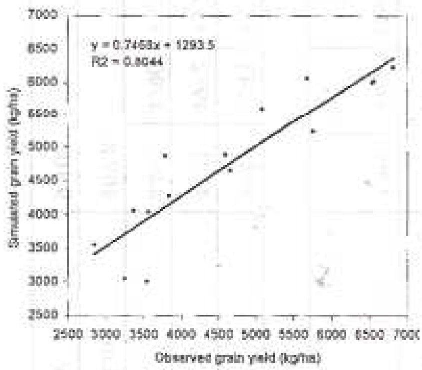

Fig. 8 : Validation of CERES- Wheat model for grain yield

Table 2 : Observed and simulated grain yield (kg ha^{-1}) of wheat varieties under different dates of sowing

Dates of sowing	HPW 89			HPW 42			HPW 147			HPW 155		
	Obs	Sim	Deviation (%)	Obs	Sim	Deviation (%)	Obs	Sim	Deviation (%)	Obs	Sim	Deviation (%)
						2000-2001						
D_1	5086	5243	+3.1	4190	4429	+5.7	4892	5168	+5.6	4740	5267	+11.1
D_2	4771	4952	+3.8	4836	5518	+14.1	4567	4772	+4.5	4568	5179	+13.4
D_3	4457	4790	+7.5	4046	4265	+5.4	3999	4377	+9.4	3881	4485	+15.6
S.Em.	409.8											
CV	9.10											
						2001-2002						
D_1	4581	4888	+6.7	3983	3974	-0.2	4446	5119	+15.1	4792	5780	+20.6
D_2	4120	4555	+10.5	4360	3896	-10.6	4711	5157	+9.5	4589	5026	+9.5
D_3	3929	3982	+1.3	4045	3533	-12.6	3842	3972	+3.4	3939	4140	+5.1
S.Em.	469.0											
CV	10.96											

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

Varieties	Optimum time of sowing	Irrigation management	Grain yield (q ha^{-1})		
			Without N application	Optimum N application	Potential yield
HPW 89	Oct 15- to Oct. 31	Irrigated	43-48	62-66 (90+90 kg N ha^{-1})*	64-77
	Oct.20-Nov.5	Rainfed$	37-39	51-56 (60 + 60 kg N ha^{-1})	51-60
HPW 42	Oct. 20 to Nov. 5	Irrigated	32-34	53-58 (90+90 kg N ha^{-1})	55-61
	Oct. 15 to Oct. 20	Rainfed	24-28	42-48 (60 +60 kg kg N ha^{-1})	52-55
HPW 147	Nov. 10 to Nov. 30	Irrigated	29-35	51-56 (90 +60 kg N ha^{-1})	54-58
	Nov. 20 to Nov. 30	Rainfed	20-26	36-40 (60 + 60 kg N ha^{-1})	37-42
HPW 155	Nov. 25 to Nov. 30	Irrigated	31-34	53-57 (75 + 60 kg N ha^{-1})	55-59
	Nov. 25 to Nov. 30	Rainfed	28-33	38-42 (60+60 kg N ha^{-1})	39-42

$ assuming that initial residual soil moisture content is 0.201 $cm^3 cm^{-3}$
*(90 +90 kg N ha^{-1}): 90 kg at sowing + 90 kg N ha^{-1} at tillering stages.

irrigated condition. Potential yield of HPW 147 was estimated to range between 54-58 q ha^{-1}. Under rainfed situation, optimum dose of N worked out to be 120 kg ha^{-1} with yield ranging between 36-40q ha^{-1}. Whereas under irrigated conditions 150 kg N ha^{-1} was optimum, producing grain yield of 51-56q ha^{-1}. Under water and N limiting conditions the yield of HPW 147 was about 20-26 q ha^{-1}. This variety is suitable for timely sown conditions, therefore, the model predicted 2nd fortnight of November to be the optimum sowing time. Simulation model predicted November 25-30 to be optimum sowing time for HPW-155. Under non resource limiting situation yield potential was estimated to be 55-59 q ha^{-1}. But under rainfed and no N application situation yield was 28-33q ha^{-1}. Like other varieties, response to N under rainfed condition was 120 kg ha^{-1} and 130 kg ha^{-1} under irrigated conditions. Aggarwal *et al*. (2000) also determined potential yield of 7.0 t ha^{-1} for Delhi using CERES-wheat model.

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