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Field calibration and evaluation of crop simulation model, InfoCrop to estimate wheat yields

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ABSTRACT

Different statistical test criteria were applied to validate the performance of the InfoCrop- a dynamic crop simulation model in estimation of wheat yields. The model was calibrated and validated with the data sets generated respectively during *rabi* 2000 and 2001, through the field experiment laid out in strip plot design with three replications on loamy sand soils of Agronomy Farm, B A college of Agriculture, Anand Agricultural University, Gujarat, India. The main treatments were three dates of sowing with an interval of two weeks from I[st] Nov to 30[th] Nov and with three to six irrigations in sub plots., The model explained more than 92 per cent of variation in pooled yield. Under Anand environment, the model has best applicability for 15[th] Nov sowing with not less than five or six irrigations. However, there is scope for improvement of the models in accounting for the yield loss due to lodging.

Key words: Simulations, InfoCrop, calibration, validation, wheat

Globally, wheat production was on decline for the last five years and in 2001, the production was only 1550 million tons (m t). Similarly, the situation in India was in no way different. Wheat production decreased by 7 m t reduced during the year 2000 – 2001 as compared with that in the previous year (75.5 m t, Ministry of Agriculture, 2001). In this context, the use of crop yield simulation models come handy as they provide advance estimation of yields.

MATERIALS AND METHODS

In the present investigation, InfoCrop model (Aggarwal, 2004) was used to calibrate and evaluate it for Gujarat conditions in order to predict wheat growth and yield. Its general structure is based on a large number of earlier models: MACROS (Penning de Vries *et al.*, 1989), WTGROWS (Aggarwal *et al.*,1994), ORYZA1 (Kropff *et al.*, 1994) and SUCROS (Laar *et al.*, 1997) .

It simulates daily dry matter production as a function of irradiance, maximum and minimum temperatures, water, nitrogen and biotic stresses (pests). The crop growth process that can be simulated are: phenology, photosynthesis, respiration, leaf area growth, assimilate

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Table 1: Genotypic characteristics of GW – 496 used in InfoCrop

Genetic coefficients	Unit	Value
Thermal time for		
-Germination	degree days	80
-Seedling emergence to anthesis	degree days	925
-Anthesis to maturity	degree days	600
Specific leaf area of variety	fraction	0.003
Potential rate of growth	fraction	0.008
Correction factor for grain number	number	32000
Potential rooting depth growth rate	mm d^{-1}	30
Maximum number of grains per hectare	number ha^{-1}	250000000
Potential weight of a grain	mg $grain^{-1}$	48

partitioning, source-sink balance, nutrient uptake and partitioning, transpiration.

Data used

The experiment was carried out for two years (2000-01 to 2001-02) at the farm of BA College of Agriculture, Anand Agricultural University, Anand , Gujarat state (latitude - 22.35 °, Longitude-72.55 ° and 45.1 m amsl). The daily weather data used were solar radiation (KJ m^{-2}), maximum temperature (°C), vapour pressure (KPa), wind speed (ms^{-1}), rainfall (mm) and relative humidity (%). The thickness and bulk density of soil were 1.2 m and 1.35 g cm^{-3} respectively. The composition of sand content was 80.2 % with the organic carbon content of 0.38 % and p^H of the soil was 7.9. The volumetric water content parameters were taken as initial (37 %), field capacity (24 %) and wilting point (7 %)

The wheat variety GW-496 was sown on 3 dates (D_1, 1st Nov, D_2- 15th Nov and D_3 - 30 th Nov) in both the years with seed rate of 125 kg ha^{-1} and sowing depth of 4 cm. The irrigation treatment was comprised of 3, 4, 5 & 6 irrigations given at - I_1 - CRI, BT, and ML, I_2 - CRI, TL, FL and DS, I_3 - CRI, TL, BT, FL and ML and I_4 - CRI, TL, BT, FL, ML and DS (Table 2). The crop was fertilized with 120 N kg ha^{-1}.

The model was calibrated and validated with the data sets generated, respectively during *rabi* 2000 and 2001, through the field experiment laid out in strip plot design with three replications on loamy sand soils. The wheat variety used was GW-496 during both the years of study (Table 1).

The final grain and straw yield of the two year data and also the data of the pooled over the seasons were subjected to statistical analyses (ANOVA) to ascertain the best treatment combination resulting in high yields. After the ANOVA, comparisons were made between the

Table 2: Effect of dates of sowing and irrigation levels on grain yield (kg ha^{-1}) and dry matter (above the ground, kg ha^{-1}) in wheat

Treatments	Pooled (2000 and 2001)	
Irrigation Levels (I)	grain yield	dry matter
I_1- CRI, BT, ML	3467	8174
I_2- CRI, TL, FL, DS	4214	9530
I_3- CRI, TL, BT, FL, ML	4920	10339
I_4- CRI, TL, BT, FL, ML, DS	5152	10819
S.Em ±	118	199
CD at 5 %	257	613
CV %	11.27	8.67

CRI - Crown Root Initiation
BT - Booting
ML - Milking
TL - Tillering
FL - Flowering
DS - Dough Stage

simulated yield (Y) by the model and observed (X) results with regression analysis of the form Y = a + bX.

Mean absolute error (MAE) and Mean bias error (MBE) and Root mean square error (RMSE) were the Difference measures estimated along with Index of agreement (D). In addition, error per cent was calculated in the different treatments under study.

RESULTS AND DISCUSSION

Yield

The grain yields of either the years of the study, or the pooled data over the years did not show any significant differences among dates of sowing. However, the second date of sowing was consistent in yield performance and mainly attributable to favourable low mean daily temperatures encountered by the crop during 50-90 DAS period (anthesis to dough stage) . Several authors have observed that wheat crop requires periods of cold spells during booting to heading and soft dough phases (Wardlow, 1970; Spirtz, 1974; Fisher and Maller,1976 and Shekh, 1985). This treatment, namely, that of the second date of sowing was followed in succession by third and the first date of sowing in respect of the level of performance. The yield data in respect of different irrigation treatments showed significant differences. Three irrigations (I_1) gave significantly the lowest grain yield (3467 kg ha^{-1}, Table 2) when compared with that for any other irrigation

Table 3: Test criteria in evaluation of InfoCrop with respect to grain yield (kg ha^{-1}) and dry matter (above the ground, kg ha^{-1}) in wheat

Parameter	2000		2001		Pooled	
	Yield	Dry matter	Yield	Dry matter	Yield	Dry matter
OMDM*	4608	10392	4268	9040	4438	9716
S Do	620	1136	855	1094	751	1291
SMDM*	4298	9691	4170	8740	4233	9215
S Ds	918	1814	1095	1708	990	1790
R	0.96**	0.93**	0.97**	0.95**	0.98**	0.95**
MAE	386	967	294	711	340	631
MBE	-311	-701	-98	-300	-205	-399
RMSE	463	1072	321	758	398	791
% of observed RMSE	10.04	10.32	7.52	8.38	8.96	8.14
Index of agreement (D)	0.89	0.85	0.97	0.91	0.94	0.99

** $P < 0.01$
OMDM* - Observed Mean Dry Matter (kg ha^{-1})
SMDM* - Simulated Mean Dry Matter (kg ha^{-1})
S D - Standard Deviation
S Do - Standard Deviation (observed)
S Ds - Standard Deviation (simulated)

treatment.

Simulated pooled grain yields by InfoCrop ranged from 2201to 5701 kg ha^{-1} (Fig.1), respectively under the treatments of D_1I_1 (lowest) and D_2I_4 (highest).. While, measured grain yield values varied from 2678 (D_1I_1) to 5642 kg ha^{-1} (D_2I_4) under the same treatments.

The correlation coefficient (r) between measured and simulated yields was 0.96 and 0.97 respectively in 2000 and 2001 (Table 3). The pooled simulated results explained 92 per cent of variation in the yield. Root mean square error (RMSE) of 398 kg ha^{-1} amounted to 8.96 per cent of observed yield in case of pooled data.

The MAE in case of yields estimated during 2000 was 386 kg ha^{-1}, while it was lower in 2001 (294 kg ha^{-1}). On the other hand the magnitude of underestimation in terms of error bias, (MBE) was -311 and –98 in 2000 and 2001, respectively. The index of agreement (D) of the pooled data over the years was tending towards to one (0.94) indicating better performance of InfoCrop. The model simulated error per cent was as high as 2.44 (D_3I_3) to a low of -19.64 (D_3I_1) (Table 4) for *rabi* 2000 season. The error per cent was relatively low in case of the second date of sowing when compared with that for other dates during both the years of study.

The error per cent decreased with increase in irrigation levels. The error per cent was more when the number of irrigations were less [three (I_1) and four (I_2)] than those for more number of irrigations

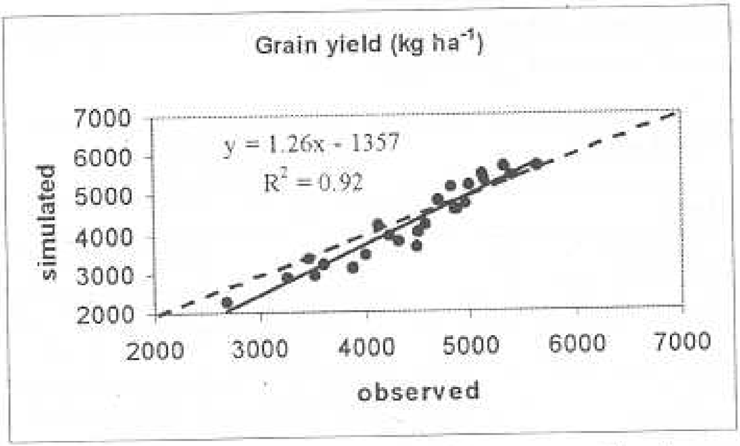

Fig. 1: Comparison of model simulated yield with that observed in wheat, pooled 2000 and 2001

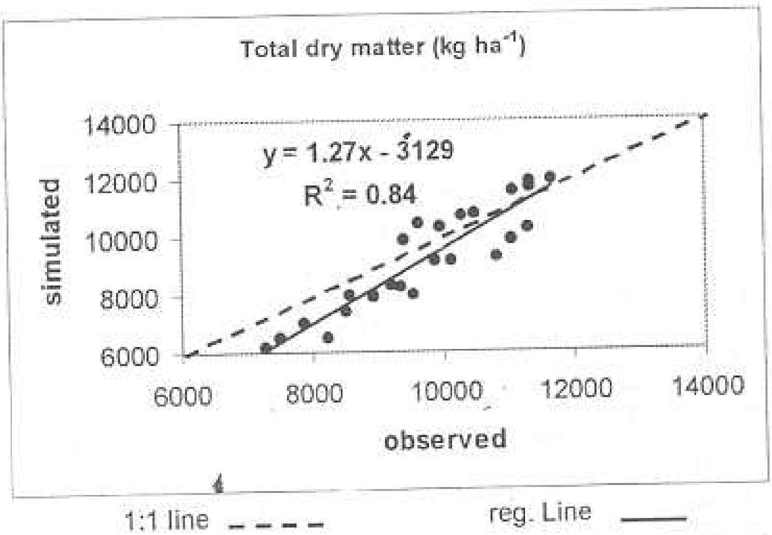

Fig. 2: Comparison of models simulated dry matter with that observed in wheat, pooled 2000 and 2001

[five (I_3) and six (I_4)]. The poor agreement between observed and simulated yields in case of the treatments with less number of irrigations was attributable to reduced model response under sub-optimal conditions of moisture and crossed the limit of $\pm$15 per cent of error. Poor response of the model to sub-optimal conditions also

Table 4: Error per cent by InfoCrop simulated grain yield from observed in wheat during *rabi season of* 2000 and 2001

Treatments	Error per cent * Irrigation levels			
Year 2000				
Dates of sowing	I_1	I_2	I_3	I_4
D_1-1st Nov	-15.85	-11.64	-5.29	-4.86
D_2-15th Nov	-12.92	-11.12	0.98	1.05
D_3-30th Nov	-19.64	-18.82	2.44	4.32
Year 2001				
D_1-1st Nov	-17.81	-16.24	-8.38	-5.33
D_2-15th Nov	-5.96	5.21	2.02	4.54
D_3-30th Nov	-6.05	-5.88	5.93	6.54

* Error per cent =[(Simulated – Observed)/ Observed)]*100

Table 5 : Error per cent in InfoCrop simulated total dry matter from observed in wheat during *rabi season of* 2000 and 2001

Treatments	Error per cent * Irrigation levels			
Year 2000				
Dates of sowing	I_1	I_2	I_3	I_4
D_1-1st Nov	-20.81	-15.88	-14.17	-8.98
D_2-15th Nov	-11.79	-10.67	4.63	2.48
D_3-30th Nov	-11.32	-9.34	4.18	2.81
Year 2001				
D_1-1st Nov	-14.95	-12.53	9.80	-6.82
D_2-15th Nov	-10.44	5.03	3.92	2.94
D_3-30th Nov	-12.94	-6.45	8.91	4.22

* Error per cent =[(Simulated – Observed)/ Observed)]*100

has been reported by Sehgal (2000).

But, the exception of higher degree of overestimation in I_4 in comparison with that in I_3 in the second and third dates of sowing was due to lack of better definition of functional relation to account for lodging of the crop caused by high speed winds over a moisture laden field. This result pointed to a scope for further improvement of the model. Robortson *et al.* (2001) opined similarly, in case of pigeon pea simulated model, where reproducing the yield could not capture the effect of water logging, a site specific problem at ICRISAT.

Total dry matter

The statistical analysis of the data of the individual years and also the data of pooled over two years revealed significant differences among irrigation levels but not among the dates and their interactions with irrigation levels.

Three irrigations (I_1) at Crown Root Initiation (CRI), Booting (BT) and Flowering (FL) recorded significantly low total dry matter as compared with that recorded at any other irrigation level. Pooled data revealed 14, 21 and 24 per cent decrease in dry matter yield with respect to (I_1) when compared with that for I_2, I_3 and I_4, respectively (Table 1).

The observed dry matter (pooled) was 9716 ± 1291 kg ha^{-1}, whereas that simulated by InfoCrop was 9215 ± 1790 kg ha^{-1}(Table 2). The simulated results explained 84 per cent of variance (Fig.2) The RMSE was higher in 2000 (1072 kg ha^{-1}), which constituted 10.32 per cent of the observed mean. The corresponding RMSE value simulated in 2001 was 758 kg ha^{-1} and constituted 8.38 per cent of the observed mean dry matter. Other difference measure calculated for evaluating the model viz., mean average error (MAE) was also higher in 2000 as compared to that in 2001. Higher proportion (-300 kg ha^{-1}) of MBE in 2001 as compared with that in 2000 (-701 kg ha^{-1}) indicated more underestimation in the former year than in the latter. In the year 2000, the estimated error per cent was higher than ±15% and lower in contrast to the error estimates of 2001 where it was within ± 15 per cent (Table 5).

Leaf area index

The magnitude of error was more during 2001 than that during 2000. Irrespective of the date of sowing three irrigations (I_1), showed underestimation of LAI and the magnitude of error decreased with increased number of irrigations. The treatments, which exhibited the best fit were those involving five and six irrigations in case of the second and third date of sowing where the overestimation was not more than five per cent in 2000 (Table 6), and it ranged between 2.17 (D_3I_4) and 7.89 (D_2I_2) in 2001.

CONCLUSION

InfoCrop model has proved to be valuable tool for predicting wheat growth and yield at higher irrigation levels. However, increasing the functional ability of the model to respond to lodging or lower number of irrigations may further enhance

Table 6 : Error per cent in InfoCrop simulated LAI from observed in wheat

Year 2000				
	I_1	I_2	I_3	I_4
D_1	-22.6	-16.7	-14.3	6.7
D_2	-18.4	-12.2	2.2	2.1
D_3	-21.2	-18.9	4.8	2.2
2001				
D_1	-24.00	-19.35	-10.53	-4.65
D_2	-12.90	7.89	4.65	2.17
D_3	-10.71	-8.57	6.98	2.17

its utility.

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