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Response of CERES-wheat and CROPGRO-urd model (DSSAT model v 4.5) for tarai region of Uttarakhand

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सार – इस शोध पत्र में उत्तराखंड के तराई वाले क्षेत्र में सिरस–गेहूँ और क्रॉपग्रो–उड़द मॉडल संस्करण पर अध्ययन किया गया है। वर्ष 2007 और 2008 में रबी और खरीफ फसल के मौसम में गोविन्द बल्लभ पंत कृषि एवं प्रौद्योगिकी विश्वविद्यालय पंतनगर, उत्तराखंड के एन. ई. बोरलाग फसल अनुसंधान केन्द्र में खेतों में प्रयोग किए गए। इस अध्ययन में सिरस गेहूँ और क्रॉपग्रो–उड़द मॉडलों के वी 4.5 संस्करण का उपयोग किया गया है। गेहूँ और उड़द की फसलों के अशांकन के समय कल्टीवर स्पेसिफिक जिनोटाइपिक गुणांक प्राप्त किए गए हैं। इस मॉडल का सत्यापन नाइट्रोजन की अलग–अलग मात्रा एवं सिंचाई के स्तरों के साथ–साथ फसल की वृद्धि और उपज के आँकड़ों के कई स्वतंत्र सेटों के आधार पर किया गया है। सभी प्राचलों के लिए किया गया टी टेस्ट महत्वपूर्ण नही पाए गए हैं (संगणित टी के मान सारणीकृत टी के मान से अन्य मानों के स्तर से 5 प्रतिशत कम हैं) इससे प्रेक्षित मानों ओर अनुमानित मानों में बहुत कम अंतर होने का पता चला है। इस मॉडल के माध्यम से फसल की फिनोलोजी, विकास और उपज की भविष्यवाणी के संतोषजनक परिणाम प्राप्त हुए हैं। अतः इस क्षेत्र में इस प्रकार के मॉडल का उपयोग गेहूँ तथा उड़द की फसल के विकास और उपज की भविष्यवाणी देने के लिए किया जा सकता है।

ABSTRACT. The study aimed response of CERES-wheat and CROPGRO-urd model for tarai region of Uttarakhand. Field experiments were conducted at N. E. Borlaug, Crop Research Centre, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand during rabi and kharif seasons 2007 and 2008. CERES-wheat and CROPGRO-urd models version v 4.5 were used in this study. Cultivar specific genotypic coefficients were derived for wheat and urd during calibration. Model validation based on several independent sets of growth and yield data, including different nitrogen and irrigation levels. For all parameters *t*-test was found non-significant (‘*t*’ calculated values were smaller than *t* tabulated values at 5% level of significance), indicating that there were least differences between observed and predicted values. The result obtained with the model demonstrated satisfactorily prediction of phenology, growth and yield and thus it can be used for the prediction of wheat and urd growth as well as yield in this region.

Key words – CERES model, CROPGRO model, Wheat, Urd.

1. Introduction

The Decision Support System for Agrotechnology Transfer (DSSAT) has been in use for more than 15years in over 100 countries worldwide. Crop models were successfully applied to assess the sowing dates and varietal effect on wheat using CERES-wheat model (Sharma and Kumar, 2006), the trends of national wheat yields with changes of weather (Supit, 1997), the pre harvest forecast of wheat yields in different regions using minimal data sets of weather variables (Nain *et al*., 2002), impact assessment of climate change on wheat yield (Pandey *et al*., 2007) and the forecasts of wheat yields for the central Indo-Gangetic Plains in India using historical weather data (Nain *et al*., 2004). An attempt was made in this study to evaluate different growth and yield effects on wheat and urd production by using CERES-wheat and CROPGRO-urd model.

2. Materials and methods

Pantnagar is situated at Tarai belt, foothills of the Shivalic range of Himalayas at 29°1' N, latitude, 79.28° E longitude and at an altitude of 215.00 m above the mean sea level. The climate of Pantnagar is temperate with severe cold winter and hot summer. Generally, the monsoon sets around the third week of June and lasts upto September end. Regarding spatial variability annual rainfall varies between 1300-1500 mm and distributed over 55 to 60 rainy days.

The CERES-Wheat model (Godwin *et al*., 1990; Ritchie and Otter, 1985) is a simulation model, which describes daily phenological development and growth in response to environmental factors (soils, weather and management). CROPGRO version v 4.5 was used for urd in this study. The main time step in CROPGRO is one

TABLE 1

Genetic coefficients of wheat cultivars used in the CERES-wheat version 4.5 model

Code	Gen.	Parameters
VAR#	IN0701	Identification code or number for a specific cultivar
VAR. NAME	UP-2565	Name of cultivar
P1V	38	Relative amount that development is slowed for each day of un-fulfilled vernalization, assuming that 50 days of vernalization is sufficient for all cultivars
P1D	36	Relative amount that development is slowed when plants are grown in one hour photoperiod shorter than the optimum (which is considered to be 20 hours)
P5	750	Degree days above a base of 1ºC from 20 ºC days after anthesis to maturity
G1	30	Kernel number per unit weight of stem (less leaf blades and sheaths) plus spike at anthesis (g^{-1})
G2	20	Kernel filling rate under optimum conditions (mg/day)
G3	1.3	Non stressed dry weight of a single stem (excluding leaf blades and sheaths) and spike when elongation ceases
PHINT	80.0	In determining the vegetative development of wheat, it is necessary to define a term related to leaf appearance, the phyllochron. A phyllochron is defined herein as the interval of time between leaf tip appearances; in the CERES-Wheat model it is the variable PHINT

TABLE 2

Genetic coefficients of urd cultivars used in the CROPGRO-urd version 4.5 model

Code	Gen.	Parameters
ECO#	Pant urd- 31	Code for the ecotype to which this cultivar belongs
CSDL	11.17	Critical Sho Critical Short Day Length below which reproductive development
PPSEN	0.04	Slope of the slope of the relative response of development to photoperiod with time (positive for short-day short day plants (1/hour)
EM-FL	33.0	Time between plant emergence and flower appearance (R1)
FL-SH	2.0	Time between first flower and first pod (R3) (photothermal days)
FL-SD	11.0	Time between first flower and first seed (R5) (photothermal days)
SD-PM	28.5	Time between first seed (R5) and physiological maturity (R7) (photothermal days)
FL-LF	7.0	Time between first flower (R1) and end of leaf expansion (photothermal days)
LFMAX	1.0	Maximum Maximum leaf photosynthesis rate at 30 ºC, 350 vpm CO_2, and high light (mg $CO_2/m^2/s$)
SLAVR	295	Specific leaf area of cultivar under standard growth conditions (cm^2/g)
SIZLF	133	Maximum size of full leaf (three leaflets) (cm^2)
XFRT	1.0	Maximum fraction of daily growth that is partitioned to seed + shell
WTPSD	0.55	Maximum weight per seed (g)
SFDUR	11.0	Seed filling duration for pod cohort at standard growth conditions (photothermal days)
SDPDV	3.5	Average seed per pod under standard growing conditions (#/pod)
PODUR	3.5	Time required for cultivar to reach final pod load under optimal conditions (photothermal days)
THRSH	78	The maximum ratio of [seed/(seed + shell)] at maturity (Threshing percentage).
SDPRO	0.235	Fraction protein in seeds [g(protein)/g(seed)]
SDLIP	0.030	Fraction oil in seeds [g(oil)/g(seed)]

day, corresponding to the daily weather information, but it computes canopy photosynthesis in hourly time steps using leaf-level photosynthesis parameters and hedge-row light interception calculations (Boote *et al.*, 1998). After calibrating and validating for a specific environment, the model can be used to assess alternative management choices.

3. Data used

The data base included all relevant information including the different management practices adopted, location specific soil and weather conditions obtained from field experiment conducted during Kharif and Rabi seasons of 2007 and 2008 at N. E. Borlaug Crop Research Centre, G. B. Pant University of Agriculture and Technology Pantnagar, Uttrakhand. In the present study replicated data were used in the model calibration and validation process. Urd (*Vigna mungo* L. Hepper) variety Pant Urd-31 and Wheat (*Triticum aestivum* L.) UP-2565 were used in this study. The wheat crop was fertilized at the rate of 100 and 150 kg ha^{-1} N levels, 60 kg ha^{-1} P_2O_5, 40 kg ha^{-1} K_2O of which one third of nitrogen and whole phosphorus and potash were applied uniformly as basal dressing and incorporated in surface soil. Remaining doses of nitrogen levels was top dressed in tow equal splits at CRI and vegetative stage of wheat crop. For wheat crop two irrigation levels were also provided (full and deficient). Under full irrigation, irrigations were applied as per requirements and under deficient irrigation, only three irrigations were given, *i.e.*, CRI, vegetative and milking stage. Similarly, urd crop was fertilized at the rate of 20:40:20 of N: P_2O_5: K_2O of which one third nitrogen and full dose of phosphorus and potash were applied homogeneously as basal dressing and remaining dose of nitrogen were top dressed at 25 days interval.

4. Results and discussion

4.1. *Calibration and derivation of genetic coefficients*

The genetic coefficients required in the CERES and CROPGRO model version 4.5 were estimated by varietal character input as incorporated in the model in the form of "genetic coefficients". An inbuilt programme in DSSAT called GENCALC, calculates genetic coefficients. The genetic coefficients determined in CERES and CROPGRO model using identical management and other conditions were used in the subsequent validation and application (Tables 1 & 2).

4.2. *Wheat crop*

4.2.1. *Emergence (DAS)*

Days to emergence [Fig. 1(a)] ranged between 7 to 8 days and 4 to 5 days for observed and simulated data respectively. The seeds germinated within 8 days after sowing. The observed emergence dates were found almost similar in both years. The RMSE for 2007 and 2008 varied 33.0% and 44.0% respectively. The RMSE of the first year (2007) is less as compared with the values of 2008 because the values of year 2007 have been used in the calibration process and the second year (2008) values used for validation of model.

4.2.2. *Anthesis (DAS)*

The days to anthesis ranged between 93 to 96 and 93 to 97 for observed and simulated data, respectively. The 2007 showed close prediction over observed values (RMSE = 1.97%) followed by 2008 (RMSE = 2.04% and R^2 = 0.32). Mitchell (1996) has also reported a close agreement between observed and predicted anthesis date. Singh *et al*. (1982) found a positive relationship between grain yield and days taken to flowering, whereas a highly negative correlation was found between grain yield and days taken to flowering by Jain and Aulakh (1971). The 2008 *t*-test result was non significant. Among the nitrogen levels and irrigation levels, the 100 kg N level and the full irrigation was found to have maximum closeness of simulated values over observed data followed by 150 kg N and deficient irrigations in both years [Fig. 1(b)]. These findings are in conformity with Stapper *et al*. (1989) and Nain and Kersebaum (2007).

4.2.3. *Maturity (DAS)*

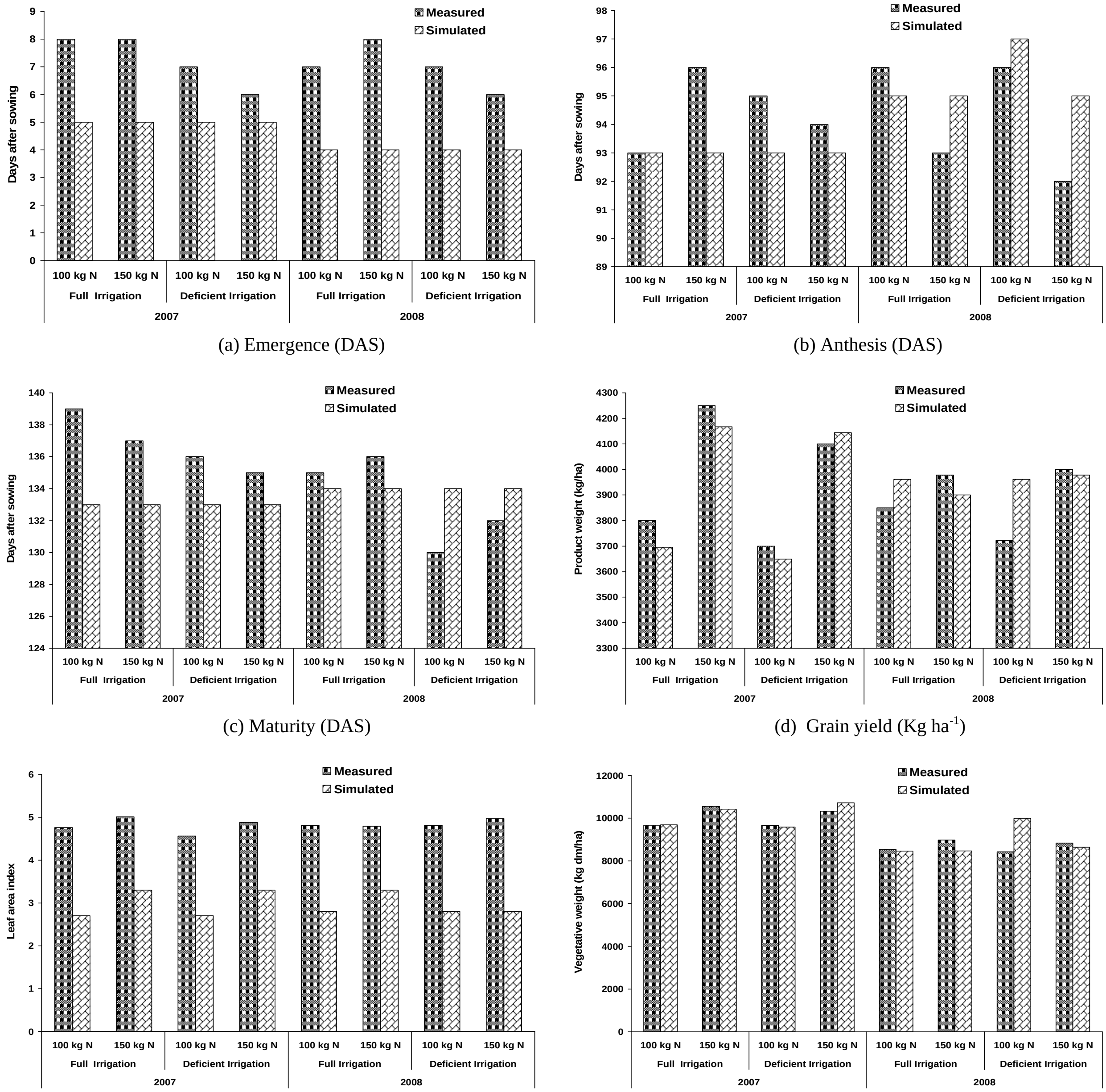
The model provided good estimate for crop maturity. The observed values of all treatments ranged from 130 to 139 whereas corresponding simulated values for maturity (DAS) ranged from 133 to 134 [Fig. 1(c)]. The values of RMSE for 2007 and 2008 are 2.94% and 1.87% respectively.

4.2.4. *Grain yield (Kg ha^{-1})*

The simulation of grain yield was good in relation to observed values [Fig. 1(d)] Simulated grain yield kg ha^{-1} for wheat at different nitrogen and irrigation levels form 2007 and 2008, were found to have close predictions in 2007 (RMSE = 1.89, R^2 = 0.94) followed by 2008 (RMSE = 5.99, R^2 = 0.75). Similar results were reported by Hundal and Kaur (1997), Tripathi *et al*. (1999), Nain *et al*. (2002) and Tatar and Yazgan (2001). The 150 kg nitrogen level and full irrigation found reliable simulated values as compared to other treatments. The '*t*' test result showed that the data of 2007 was significant and data is non significant for the data of 2008. The results showed that model is able to simulate grain yield reasonably well for treatments.

4.2.5. *Maximum leaf area index (LAI)*

Comparing the predicted and observed LAI [Fig. 1(e)] and their respective RMSE, the predictions were not satisfactory. The RMSE and R^2 values for the



(a) Emergence (DAS)

(b) Anthesis (DAS)

(c) Maturity (DAS)

(d) Grain yield (Kg ha^{-1})

(e) Maximum leaf area index

(f) Biomass (kg ha^{-1})

Figs. 1(a-f). Effect of measured and simulated values at different nitrogen and irrigation levels of CERES-wheat model

year 2007 and 2008 are 37.70% and 0.74, and 35.7% and 0.19, respectively. Observed LAI ranged between 4.76 and 5.01, as compared with 2.7 to 3.3 simulated, respectively. Aggrawal (2002), Kaur *et al*. (2007). reported a similar tendency of the model. The test of significance result showed that 2007 and 2008 data were non significant [t = 2.38 and 0.68, respectively at 5% level of significance for 2 d.f.]. Among the nitrogen levels and Irrigation levels, the 150 kg N level and the full irrigations were found to be closer to simulated values followed by 150 kg N and deficient irrigations in both years.

4.2.6. *Biomass (kg ha^{-1})*

Model provided good estimate of Biomass (kg ha^{-1}) compared with measured values. It is apparent that in 2007 both the nitrogen level and irrigation levels [Fig. 1(f)] have close prediction over observed value

TABLE 3

Comparison of measured and simulated values of Urd for growth and yield parameters during 2007 and 2008 of CROPGRO-urd model

Parameter	2007			2008		
	Measured	Simulated	% Difference	Measured	Simulated	% Difference
Anthesis (DAS)	40	41	-2.43	41	43	-4.65
First pod day (DAS)	43	44	-2.27	44	45	-2.22
Physiological maturity (DAS)	76	78	-2.63	77	76	1.31
Grain yield kg ha^{-1}	1878	1948	-3.72	1584	1577	0.44
Maximum leaf area index	6.78	5.25	22.5	6.98	6.41	8.16
Harvest maturity (DAS)	82	87	-6.09	88	86	2.27

DAS = Days after sowing

(RMSE = 1.65%, R^2 = 0.88). It is also evident from the data in 2008 that the model prediction was not good as compared with 2007 data (RMSE = 9.50%, R^2 = 0.45). The *t*-values for 2007 and 2008 were 4.01 and 1.28 respectively. Ouda *et al*. (2005) reported a similar trend in biological yield, which decreased by 5.77%. The test of significance showed that the data were non significant in both the years at 5% level of significance for 2 d.f.

4.3. *Urd crop*

4.3.1. *Anthesis (DAS)*

Results show that the days to anthesis fluctuated between 40 to 41 and 42 to 43 for observed and simulated values, respectively (Table 3). These results are in the close agreement with the findings of Kumar *et al*. (2008).

4.3.2. *First pod day (DAS)*

Days to first pod day (DAS) ranged between 43 to 44 days and 44 to 45 days (Table 3) for observed and simulated data, respectively as also reported by the Robertson *et al*. (2002). The Difference % for 2007 and 2008 varied -2.27% and -2.22% respectively.

4.3.3. *Physiological maturity (DAS)*

The days to physiological maturity (DAS) around 76 to 78 showed close agreement (Table 3).

4.3.4. *Grain yield (kg ha^{-1})*

The yield (kg ha^{-1}) varied between 1584 to 1878 and 1577 to 1984 for observed and simulated data, respectively (Table 3). Simulated yield (kg ha^{-1}) for wheat found to have close predictions in 2008 (Difference = 0.44%) followed by 2007 (Difference = -3.72%). Robertson *et al*. (2002) reported that the CROPGRO model simulated legume grain yield reasonably well.

4.3.5. *Maximum leaf area index*

The predictability of Maximum leaf area was comparatively poor as evident from high value of difference as leaf area index was under predicted as shown in Table 3. Observed LAI varied between 6.41 to 6.98 as compared with 5.25 to 6.41 simulated LAI for both years as also seen for wheat. The difference values for the year 2007 and 2008 are 22.5 and 8.16 % respectively.

4.3.6. *Harvest maturity (DAS)*

The overall values of percentage difference between the predicted and measured values for harvest maturity (DAS) (Table 3) indicated that the model slightly over predicted the Harvest maturity (DAS) in 2007 and under predicted in 2008. It is noticeable in 2008 model found to have close prediction over observed value (Difference = 2.27) and in 2007 (Difference % = -6.09).

5. Conclusions

In nutshell, CERES and CROPGRO models were able to simulate the phenological events and grain yield. The model provides insights about the response mechanism to different nitrogen and irrigation managements. *t* - test was found non-significant for all parameters ('*t*' calculated values were smaller than '*t*' tabulated values at 5% level of significance), indicating that there were least differences between observed and predicted values. In the future calibrated and validated CERES-wheat and CROPGRO-urd model may be used as a management tool to determine an optimum planting date or cultivar choice, taking into account the variability of weather and the associated yield loss risks. It may also be used to predict crop performance in regions where the crop has not been grown before, by predicting probabilities of grain yield levels for a given soil type and rainfall distribution.

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