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Evaluation of DSSAT-CERES model for irrigation scheduling of wheat crop in Varanasi region of Uttar Pradesh

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ABSTRACT

The DSSAT-CERES-Wheat model (V-4.6) was calibrated and validated using field experiment data (2008-2014) collected on phenology, yield and yield attributes of four cultivars (HUW 234, Kundan, HUW 510 and PBW 373) of wheat for Varanasi. The simulated yields were very close to observed grain yield as evident from R^2 of 0.96 with nRMSE (4.92%) and D-index (0.99). The simulated phenological events and yield attributes of wheat cultivars were also in good agreement. Therefore, the model was used for evaluation of irrigation scheduling in wheat crop. The results revealed that the model performance was good under three, four and five irrigation scheduling while poor performance was observed under two and one irrigation treatments.

Key words: Evaluation, DSSAT-CERES model, wheat, irrigation scheduling,Varanasi.

Wheat (*Triticumaestivum* L.) is the second most important food grain crop of India and is associated with the food security of the country.In Uttar Pradesh, it ranks first in respect of crop coverage area (9.67 million ha) and production (33.66 million tons) however the average productivity is less (3.41 tons $ha.^{-1}$) (Anonymous, 2013-14). The eastern Uttar Pradesh share about 34% acreage and 32% production of wheat in Uttar Pradesh (Singh *et al.,* 2014). The wheat production is highly variable due to climatic variability. There is a great challenge for sustainable wheat production in the country.

Crop simulation models are valuable tools for evaluating potential effects of environmental, biological and management factors on crop growth and developments. These tools are handy and provide practical means for scheduling irrigations. In the past, these model has been successfully utilized in irrigation planning for crop (Behera and Panda, 2009), optimization of irrigation water use (Fortes *et al.,* 2005; Bulatewicz *et al.,* 2009), comparison of various scenarios and strategies (Rinaldi, 2004; Rinaldi *et al.,* 2007), spatial water requirement of rice crop (Kandiyal *et al.,* 2015) and many more. For eastern Uttar Pradesh regions studies have been concentrated on the effect of climate change on phenology, grain yield (Yadav *et al.,* 2015) and yield gap, potential yield (Aggrawal *et al.,* 2000), yield forecasting (Nain *et al.,* 2004) etc. The present study is aimed at the evaluation of DSSAT-CERES-Wheat model for irrigation scheduling on wheat crop.

MATTERIALS AND METHODS

A field experiment was conducted on four cultivars wheat (HUW 234, Kundan, HUW-510 and PBW 373) under FASAL (Forecasting of Agricultural output using Space, Agrometeorology and Land based observation) project at the Agricultural Research Farm of Institute of Agricultural Sciences, BHU, Varanasi during 2011-14. The data were also collected from the field experiments conducted at Agricultural Research Farm, BHU, Varanasi during 2008-12 for calibration and validation of CERES-Wheat model (Table 1).

The genetic coefficients required in the CERES wheat model for four cultivars of wheat were estimated by repeated iterations in the model calculations until a close match between simulated and observed phenology, growth and yield were obtained. The genetic coefficient determined for all cultivars of wheat crop used for simulation of irrigation scheduling are presented in Table 2.

The validation of model was done using data, which was not used for calibration. The capability of the model to predict was tested by judging the performance of crops in

Table 1: Description of experiment of different wheat cultivars

Experimental details	HUW 234	KUNDAN	HUW 510	PBW 373
Years of experiment	2008*, 2009*, 2010*, 2011*, 2012*, 2013**, 2014**	2011*, 2012*, 2013**, 2014**	2008*, 2009*, 2010*, 2011*, 2012*, 2013**, 2014**	2010*, 2011*, 2012*, 2013**, 2014**
Emergence	3-6	5-7	4-6	5-7
Anthesis days	74-83	78-82	70-77	76-82
Maturity days	102-118	107-115	102-112	107-115
Grain yield (kg ha^{-1})	2597-3938	2542-4977	2681-4769	2694-4977
Straw yield (kg ha^{-1})	3629-7200	3467-7189	3807-7216	3666-7189
Harvest Index (%)	33-45	32-43	35-44	34-43

*Data used for calibration

**Data used for validation

Table 2: Genetic coefficients of the wheat cultivars.

Code	Parameters	HUW 234	KUNDAN	HUW 510	PBW 373
P1V	Days at optimum vernalizing temperature required to complete vernalization.	20	20	20	20
P1D	Percentage reduction in development rate in a photoperiod 10 hour shorter than the threshold relative to that at the threshold.	80	70	75	65
P5	Grain filling (excluding lag) phase duration (°C.d)	750	695	700	690
G1	Kernel number per unit canopy weight at anthesis (#/g)	25	24	26	22
G2	Standard kernel size under optimum conditions (mg)	40	36	38	38
G3	Standard, non-stressed dry weight (total, including grain) of a single tiller at maturity (g)	1.1	1	1.3	1.2
PHINT	Interval between successive leaf tip appearances (°C. d)	95	90	90	95

Table 3: Irrigation scheduling details of wheat crop.

Irrigation scheduling	Amount of irrigation (mm)	Number of irrigation	Total (mm) water applied
I_1: Crown root initiation (21 DAS)	50	1	50
I_2: CRI + Booting (75 DAS)	50	2	100
I_3:CRI + Tillering (45 DAS) + Booting	50	3	150
I_4: CRI + Tillering + Booting + Milking (100 DAS)	50	4	200
I_5: CRI + Tillering + Jointing (65 DAS) + Flowering (85 DAS) + Milking (100 DAS)	50	5	250

terms of grain yield and phenology. The model performance was tested using statistical parameters viz. standard deviation, linear regression parameters, coefficient of determination, root mean square error (RMSE), normalized root mean square error (nRMSE) and D-index etc.

Also, a field experiment was conducted on irrigation scheduling (irrigation applied at $I_{1;}$ Crown root initiation, $I_{2;}$ CRI + Booting, $I_{3;}$ CRI + Tillering + Booting, $I_{4;}$ CRI + Tillering + Booting + Milking and $I_{5;}$ CRI + Tillering + Jointing + Flowering + Milking) with four wheat cultivars (V_1; HUW 234, V_2; Kundan V_3; HUW510 and V_4; PBW 373) during 2013-14 and 2014-15 (Table 3). Calibrated and

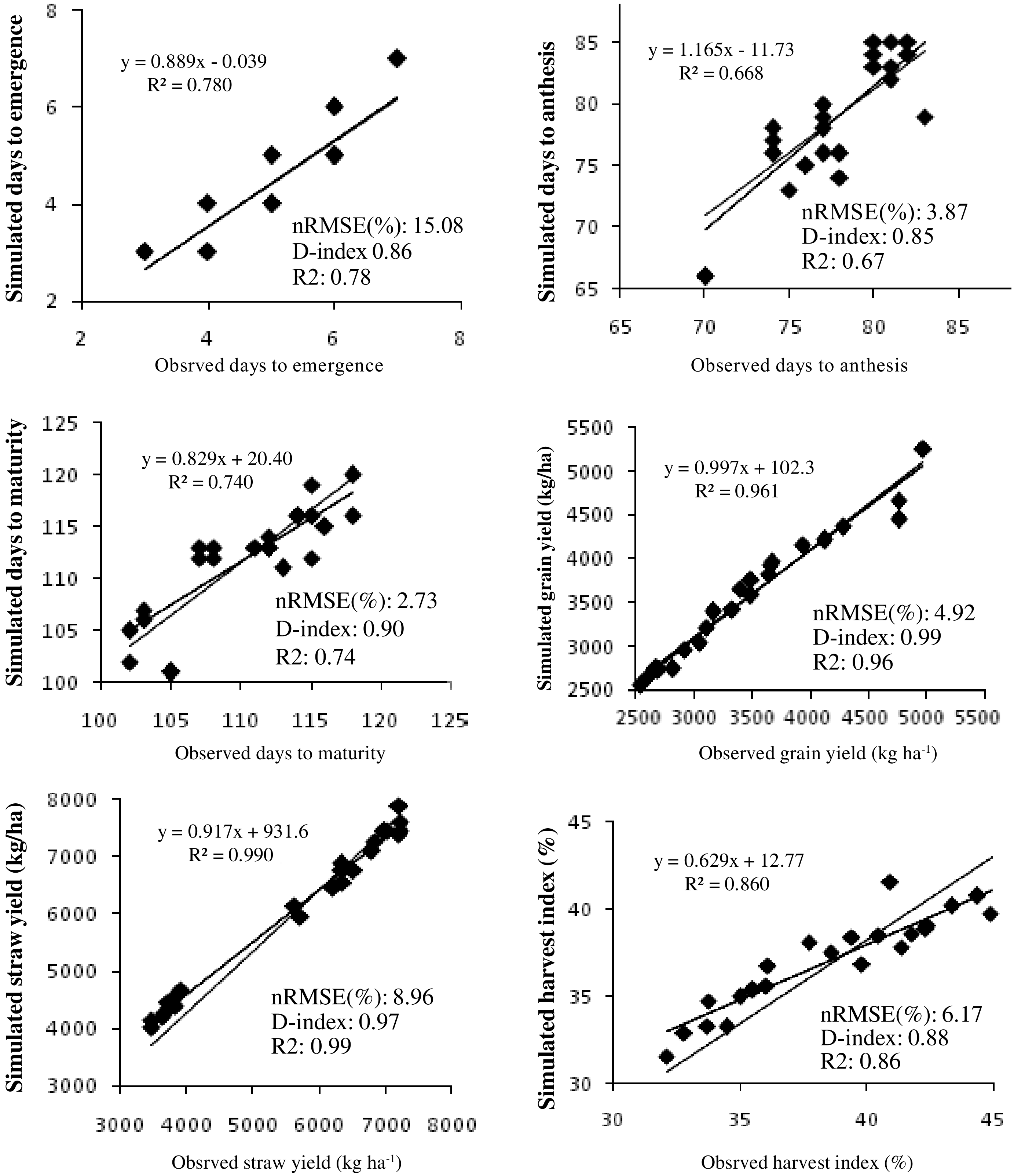

Fig 1: Comparison of simulated and observed phenology and yieldfor all cultivars of wheat.

validated model was used for simulation of effect of irrigation scheduling on grain and straw yield of wheat crop.

RESULTS AND DISCUSSION

The observed and simulated phenological events like

Table 4: Evaluation of DSSAT-CERES model for different irrigation scheduling and different cultivars of wheat.

Treatments	Grain yield (kg ha^{-1})						Straw yield (kg ha^{-1})					
	SIM	OBS	RMSE	nRMSE (%)	D-index	R^2	SIM	OBS	RMSE	nRMSE (%^{1})	D-index	R^2
Irrigation												
I_1	2118	2363	263	11.11	0.63	0.84	3348	3184	200	6.34	0.59	0.84
I_2	2436	2568	171	6.66	0.73	0.66	3673	3384	301	8.88	0.40	0.52
I_3	2655	2643	60	2.28	0.98	0.94	3848	3450	349	9.92	0.52	0.73
I_4	2714	2723	62	2.27	0.98	0.91	4154	3662	506	13.82	0.34	0.66
I_5	2830	2790	57	2.02	0.98	0.94	4335	3733	607	16.25	0.36	0.90
SEm±	——	66.9	——	——	——	——	——	89.4	——	——	——	——
CD (p =0.05)	——	148.3	——	——	——	——	——	198.2	——	——	——	——
Cultivars												
V_1	2868	2606	174	6.11	0.89	0.88	3912	3507	439	12.53	0.64	0.95
V_2	2520	2413	85	3.40	0.91	0.86	3713	3372	394	11.70	0.47	0.81
V_3	2664	2691	151	5.66	0.92	0.96	4033	3599	470	13.05	0.67	0.97
V_4	2484	2577	73	3.06	0.97	0.91	3828	3523	348	9.86	0.73	0.96
SEm±	——	42.0	——	——	——	——	——	55.6	——	——	——	——
CD(p =0.05)	——	82.5	——	——	——	——	——	109.2	——	——	——	——

days to emergence, anthesis and maturity, and yields are presented in Fig 1. The model performance parameters viz. nRMSE, D-index and R^2 show the correctness of the model and values are also given on the figures. The results show that model is able to simulate days to emergence, anthesis and maturity reasonably well for most of treatments. In general, there was a good agreement between the observed and simulated values. Fig 1 also shows good agreement between simulated and observed values of grain yield, straw yield and harvest index for all cultivars for all sowing dates. The result show that model is able to simulate grain yield, straw yield and harvest index for all cultivars reasonably well for most of treatments.

Effect of irrigation scheduling on grain and straw yield

Model evaluation was performed for simulation of grain yield treated with irrigation schedule at different stages of wheat (Table 4). Simulated grain yield increased with increasing irrigation levels. The lowest grain yield (2118 kg ha^{-1}) was recoded with one irrigation and maximum grain yield (2830kg ha^{-1}) with five irrigations. Model performance parameters viz. RMSE (263 to 171 kg ha^{-1}), nRMSE (11.11 to 6.66%), D-index (0.63 to 0.73) and R^2(0.84 to 0.66) were less in one and two irrigation scheduling, in comparison to three, four and five irrigation treatments, RMSE (60 to 57 kg ha^{-1}), nRMSE (2.28 to 2.02%), D-index (0.98) and R^2(0.91 to 0.94).Model performance parameters were better under three, four and five irrigation treatments (optimum condition of irrigation water) in comparison to treatments having two and one irrigation (stress condition of irrigation water). Performance of all four cultivars were good as nRMSE less than 7 and D-index more than 0.89 for grain yield.

The lowest straw yield (3348 kg ha^{-1}) was recoded with one irrigation and maximum straw yield (4335kg ha^{-1}) with five irrigations (Table 4). Model evaluation indices viz. RMSE varied from 200 to 607 kg ha^{-1}, nRMSE from 6.36 to 6.25 per cent, D-Index from 0.34 to 0.59 and R^2varied from 0.52 to 0.90 under different irrigation treatments. Cultivar; PBW 373 has lowest error and better performance in comparison other cultivars *i.e.* HUW 234, Kundan and HUW 510 regarding grain and straw yield (Table 4). The result show that increasing of irrigation number in wheat crop increased the RMSE and *n*RMSE between simulated and observed straw yield and decreased the D-index value. Therefore, it is required to improve the CERES-wheat model for irrigation scheduling in wheat crop in case of straw yield. However, performance for grain yield were good under three to five (optimum condition) irrigation treatments, while poor performance was recorded with one and two irrigation treatments.

CONCLUSIONS

DSSAT-CERES-Wheat model (V 4.6) calibrated and validated for wheat cultivars in Varanasi region suggested that model performance was good under optimum condition of irrigation water while poor performance was observed under stress condition of irrigation water. Therefore, it is required to improve the model for good performance in stress condition of wheat crop.

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