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Short communication

Evaluation of CERES-Wheat model for different wheat cultivars at Varanasi

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Wheat is a major crop of eastern Uttar Pradesh (UP) grown mainly under irrigated condition (78%) with high inputs during the winter season (DES, 2013). The eastern Uttar Pradesh region extends geographically between latitudes 23–28° N, longitudes 79.5–84 °E. Presently, wheat productivity at farmers field in this region is about 2.1 t ha^{-1}, whereas in state as whole it is about 3.1 t ha^{-1}, and country's average is about 3.2 t ha^{-1}. However, the wheat productivity in the experimental field is about 5-6 t ha^{-1}. Although wheat yield in this region increased significantly over the past five decades with annual variability that has been related to annual variability in maximum and minimum temperature and change in rainfall pattern (Bhatt *et al.,* 2015). Substantial reduction in wheat yield is found across the east UP region when temperature increases during pre flowering stage that affects the delayed completion of the vernalization (Mahdi *et al.,* 2013; Singh *et al.,* 2013). However, there is still substantial scope to increase the productivity of wheat crop in this region to meet at least the national productivity level. In order to identify the constraints limiting productivity at present and opportunities for sustainable increase in future, it is important to analyze the various factors constituting a production environment. Therefore, in this study an attempt has been made to calibrate and validate the wheat crop growth simulation model (CERES-wheat) for different wheat cultivars at Varanasi.

Mechanistic crop growth models are now widely used for yield gap analysis, decision making and planning, strategic and tactical management decisions and climate change studies over India during last decade (Mall and Aggarwal 2002; Baxla *et al.,* 2010; Pal *et al.,* 2014; Mall *et al.,* 2014).

The CERES-wheat model (Hoogenboom *et al.* 2010) requires inputs like weather (daily solar radiation, maximum and minimum temperature and precipitation), soil conditions, plant characteristics and crop management (Hunt *et al.* 2001). For calibration and validation of the model field experiments were conducted at agriculture farm, Institute of Agriculture Sciences, BHU, Varanasi. The data were also collected from the annual reports of the Regional Agricultural Experiment and Demonstration Centre, Varanasi. The data for wheat cultivars HUW234, HUW468 and HUW510 were also collected different reports (DWR, 2009).

Calibration of CERES-wheat model

The genetic coefficients required in the CERES-wheat model for three varieties of wheat crop were estimated by repeated iterations in the model calculations until a close

Table 1: Description of the field experiment for different wheat cultivars

Experimental details	HUW234	HUW468	HUW510
Years of experiment	1999*,2000*,2002*,2003*, 2005**,2006**,2007**, 2008**,2009**,2010**,2011**	2001*,2002*,2006*,2007**, 2008**,2009**,2010**, 2011**	2007*,2008*,2009**,2010**, 2011**
Anthesis days	62-75	63-79	62-76
Maturity days	101-125	100-129	99-115
Grain yield (kg ha^{-1})	4020-5010	3670-5180	4000-5520
Straw yield (kg ha^{-1})	4920-6970	4520-6970	4950-6580
Harvest index	0.405-0.52	0.38-0.5	0.43-0.48

*data used for calibration

** data used for validation

Table 2: Genetic coefficients of the wheat cultivars obtained in calibration experiment.

Code	Parameters	HUW234	HUW468	HUW510
P1V	Relative amount that development is slowed for each day of un-fulfilled vernalization, assuming that 50 days of vernalization is sufficient for all cultivars.	20	22	20
P1D	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)	65	75	65
P5	Degree days above a base of 1ºC from 20 ºC days after anthesis to maturity	750	780	750
G1	Kernel number per unit weight of stem (less leaf blades and sheaths) plus spike at anthesis (g-1)	25	22	24
G2	Kernel filling rate under optimum conditions (mg/day)	42	40	45
G3	Non stressed dry weight of a single stem (excluding leaf blades and sheaths) and spike when elongation ceases	1.0	1.0	1.0
PHINT	A phyllochron is defined herein as the interval of time between leaf tip appearances; in the CERES-Wheat model it is the variable PHINT	99	95	95

*GDD, growing degree days (°C)

match between simulated and observed phenology, growth and yield were obtained developed the genetic coefficient for HUW234, HUW468 and HUW510 wheat cultivars (Table 1). The genetic coefficients determined for three varieties of wheat are presented in Table 2. These coefficients were used in the subsequent validation.

Validation of CERES-wheat model

The validation of model is 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 terms of grain yield and phenology. In recent years various statistical methods have been used for analyzing the model performance like standard deviation, linear regression parameters, coefficient of determination, root mean square error (RMSE), mean biased error (MBE) etc.

The simulated results for days to anthesis and maturity are presented against the measured anthesis and maturity in Fig 1. The observed days to anthesis ranged between 62-79 and simulated days to anthesis between 62-84, observed days to maturity ranged between 99-129 and simulated between 97-126. The result showed that model is able to simulate duration to anthesis and maturity reasonably well for most of treatments. In general, there was a good agreement between the observed and simulated values except some peak and low values. Fig 1 also shows good agreement between simulated and observed values of grain, straw yield and HI for all cultivars for all sowing dates. The result showed that model is able to simulate grain, straw yield and HI for all cultivars reasonably well for most of treatments.

The simulations used in the study assumed that the recommended irrigation and nitrogen applications for optimum yield were followed. These agronomic experiments carried out in the past do not provide full range of crop and soil data needed for crop model evaluation and a few of them lack precision leading to generalization in deriving the genetic coefficients of wheat variety. It is possible that some degree of water stress over different years influenced the field experiments in some cases. The present deviation between simulated and observed results might be attributed partly to error introduced in deriving the genetic coefficient of different varieties of wheat. The precision with which field measurement data used in the simulation studies as stressed by Mall and Aggarwal (2002) and Singh et al. (2010) were not known but usually lies between $\pm$10 to $\pm$15 %.

The calibrated and validated CERES-Wheat model will be useful for further applications and decision-making in Varanasi. It can be used to estimate crop production, water management, to evaluate the effects of climate changes or soil fertility changes and to determine the limiting biophysical factors.

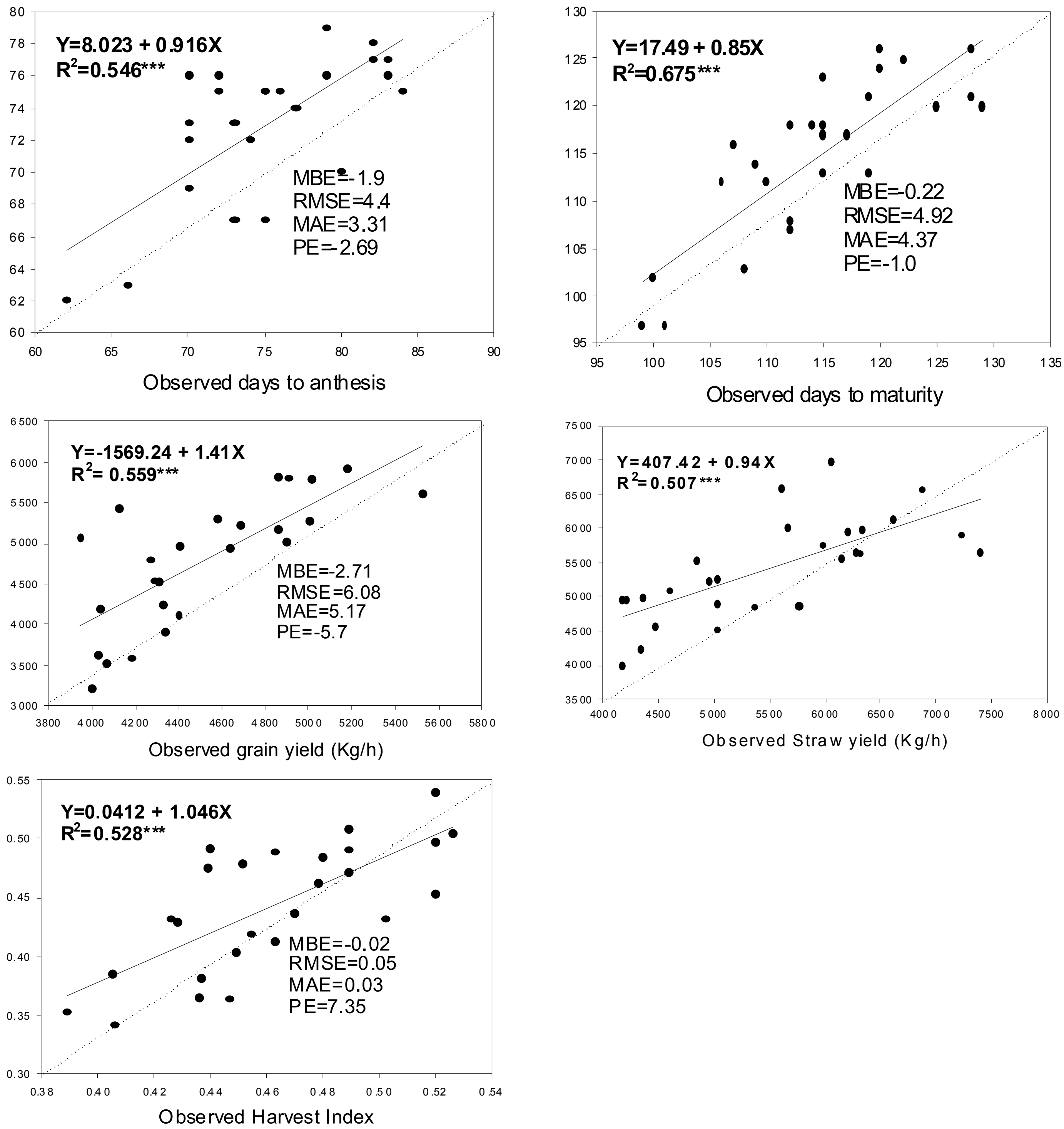

Fig. 1: Comparison of simulated and observed phenology, grain, straw yield and harvest index for all cultivars of wheat. (***Significant at P<0.001)

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