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TESTING OF INFOCROP MODEL FOR GROWTH AND YIELD PREDICTION OF WHEAT CULTIVARS IN CENTRAL IRRIGATED PLAINS OF PUNJAB STATE

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ABSTRACT

Field experiments were conducted during *rabi* 2006-07, 2007-08 and 2009-10 to generate field data for evaluating the response of three *wheat* cultivars, viz PBW 343, PBW 502, and PBW 550 under variable environmental conditions created by three dates of sowing (D_1–1st week of October; D_2–3rd week of October; D_3–2nd week of November). The INFOCROP model was validated by comparing the model simulated and actual field data on phenological events (anthesis date and physiological maturity date), growth (maximum LAI) and yield (grain yield) for wheat cultivars. The model gave overestimation as well as underestimation of these events. The anthesis and physiological maturity dates were simulated between -15 to +4 days and -13 to +14 days, respectively of the actual observed dates for wheat cultivars. The maximum LAI was and grain yield were simulated between -23 to +39 % and -17 to +17 % of the actual observed data for wheat cultivars under different environments. However, the model gave very low grain yield for wheat cultivars sown in December month, thereby indicating that the partitioning of dry matter between grain and straw under late sown conditions needs further scrutiny. The results of this study reveal that the calibrated INFOCROP model can be used for the prediction of wheat growth and yield in the Punjab. Also a well validated model when linked with GIS and remote sensing can be used for yield forecasting at regional level.

INTRODUCTION

Wheat (*Triticum species*) is a crop of global significance. It is grown in diversified environments. It is a staple food of millions of people. Approximately one-sixth of the total arable land in the world is cultivated with wheat crop. Whereas paddy is mainly cultivated in Asia, wheat is grown in all the continents of the world. It supplies about 20 per cent of the food calories for the world's growing population. Global wheat production touched 622.2 million tones in 2007-08. India is the second largest producer of wheat after China. Wheat has a distinct place among the food grain crops. Carbohydrate and protein are two main constituents of wheat. On average wheat contains 11-12% protein.

Dynamic simulation modeling of crop growth aims at the simulation of day-to-day assimilation of photosynthetic material based primarily on the exchange of energy and mass among the various growth processes taking place in a plant. These dynamic models not only help in understanding the climate-crop interaction and the processes that contribute to the growth and yield of crops but also assist in evaluating the potentials of various soil and crop management options (Hoogenboom *et al*, 1997) and form an important component in systems approach research.

INFOCROP, a generic crop model, simulates the effects of weather, soils, agronomic management (planting, nitrogen, residues and irrigation) and major pests on crop growth, yield **(**Aggarwal *et al*., 2006a), soil carbon, nitrogen and water, and greenhouse gas emissions. The model considers different crop development and growth processes influencing the yield. Total crop growth period in the model is divided into three phases viz. sowing to seedling emergence, seedling emergence to anthesis and the storage organ filling phases. The model requires genetic coefficients like thermal time for phenological stages, potential grain weight, specific leaf area, maximum relative growth rate and maximum RUE of the crop varieties. The outputs are based on the source-sink balance of the crop in relation to its environment. This model has been used to simulate growth and yield attributes of various crops such as potato (by Singh *et al*., 2005), wheat and rice (Aggarwal *et al*., 2006), rice (Ebrayi *et al*., 2007) and coconut (Kumar et al., 2008) by various scientists throughout India .

MATERIALS AND METHODS

Site description:

The soil, crop and weather data used in the study were collected from research farm of Punjab Agricultural University at Ludhiana (30^0 54′ N, 75^0 48′ E, 247 m above mean sea level). The area receives 700 mm of annual rainfall, about 80% of which occurs from June to September. This area is representative of the central irrigated plains of the Indian Punjab and is characterized by a sub-tropical, semi-arid climate. The average maximum temperature and minimum temperature during *rabi* season are 24.4 ^oC and 9.5 ^oC, respectively at Ludhiana. The monthly mean meteorological data for the three experimental years are shown in table 1.

Data description:

Field experiments were conducted during *rabi,* 2006-07, 2007-08 and 2009-10 to compare phenology, growth and yield of three wheat cultivars, viz PBW 343, PBW 502, and PBW 550 under three dates of sowing (D_1–1st week of October; D_2–3rd week of October; D_3–2nd week of November). The crop was sown with a row – row spacing of 22.5 cm. Wheat crop for each date of sowing was sown following pre-sowing "*rauni*" irrigation. Subsequently, irrigation was applied as per recommendations. Fertilizer were applied @125Kg N / ha, 62 Kg P_2O_5 / ha, and 30 kg MOP / ha as per recommendations. At the time of sowing, one half of nitrogen and all P_2O_5 were applied as a basal dose. The remaining half dose of nitrogen was given at the time of first irrigation, i.e. at CRI stage of wheat crop.

Table 1: Mean monthly meteorological data during three wheat crop seasons at Ludhiana

Months	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)	Maximum Relative Humidity (%)	Minimum Relative Humidity (%)	Sunshine hour (Hrs)	Evaporation (mm)
***Rabi* 2006-07**							
October	32.0	18.5	6.8	89	46	7.4	113.7
November	26.4	12.8	14.0	94	45	5.8	59.6
December	20.1	7.2	8.7	95	54	6.1	44.2
January	19.5	4.2	10.0	97	48	7.3	53.0
February	20.4	10.1	84.7	96	64	5.5	47.1
March	26.1	12.4	41.3	91	44	9.1	110.3

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***Rabi* 2007-08**							
October	32.5	15.2	0.0	91	33	8.9	115.7
November	27.5	11.2	1.3	93	34	4.5	65.1
December	19.9	5.7	17.7	97	52	6.4	46.0
January	16.9	4.5	16.3	93	48	6.1	53.2
February	20.2	6.4	3.2	95	49	6.9	68.4
March	30.4	14.0	0.0	90	39	9.1	131.9
***Rabi* 2009-10**							
October	31.8	16.4	26.2	91	44	8.7	101.8
November	25.1	10.6	5.1	93	41	4.7	52.3
December	21.2	6.8	0.0	96	46	5.5	42.5
January	15.7	6.6	18.4	99	74	2.8	26.5
February	22.5	9.0	25.0	94	50	7.3	71.4
March	31.0	14.8	1.0	92	38	9.4	132.8

Input data for INFOCROP model :

The daily weather data needed to run the INFOCROP model, i.e., minimum and maximum air temperature (^oC), solar radiation (k $Jm^{-2}d^{-1}$), vapour pressure (k Pa), wind speed (ms^{-1}) and rainfall (mm) were collected at the Agromet observatory of the Punjab Agricultural University, Ludhiana. The layer-wise soil profile data used in the model was generated from the actual soil profile data of experimental field. The INFOCROP model requires crop management data such as date of sowing, depth of sowing, seed rate, row-row spacing, , amount and time of irrigation, amount and time of fertilizer application was collected from the field experiments conducted during the three consecutive crop years.

The "INFOCROP" model was calibrated for three *wheat* cultivars, viz PBW 343, PBW 502, and PBW 550 for three dates of sowing (D_1–1st week of October; D_2–3rd week of October; D_3–2nd week of November) using the actual crop data for the crop year 2007-08. Since the true values of the local cultivars used in the study are not known, the procedure for determining genetic coefficients initially involves running the model with values, derived elsewhere and then re-running the model using a range of values for each coefficient until a satisfactory level of agreement between simulated and observed values is reached. Finally,

those values of the coefficients which most realistically simulated the growth and yield of wheat crop were selected.

RESULTS AND DISCUSSION

Crop phenology :

The phenological events, i.e., anthesis date and physiological maturity date simulated by INFOCROP model and those actually observed in the field for wheat cultivars are given in Fig 1 and 2, respectively. The perusal of the data revealed that the crop phenological stages were both underestimated as well as overestimated by the model for the three wheat cultivars under different environments. The INFOCROP model predicted the days to anthesis date within –12 to +4 days and physiological maturity within –4 to +5 of the observed dates for wheat cv PBW 343. For wheat cv PBW 502 the model predicted the anthesis date within –11 to -4 days and physiological maturity within –8 to +14 days of the observed dates. The anthesis date was predicted within -17 to 8 days and physiological maturity date within –5 to +5 days of the observed dates for wheat cv PBW 550.

Crop growth and yield:

The "INFOCROP" model simulated crop growth and yield attributes such as maximum LAI, 1000-seed weight, seed yield and biomass yield for the three *wheat* cultivars in close agreement with field observations under different sowing dates.

Maximum LAI ranged from 3.5 to 6.7 for cv PBW 343, 3.3 to 5.6 for cv PBW 502 and 3.9 to 6.4 for cv PBW 550 under different growing environments (Fig 3). Modeled results gave both underestimation and over estimation of maximum LAI. Out of 9 set of environments for PBW 343, the model underestimated maximum LAI by 12% in 1 data set; whereas the model overestimated maximum LAI by more than 30% in 4 data sets, between 10-20% in 1 data set, and between 0-10percent in 3 data sets as compared to field observed maximum LAI. In case of cv PBW 502, out of 6 set of environments, the model underestimated maximum LAI by more than 20% in 1 data sets and the model overestimated maximum LAI above 20% in 3 data sets and between 0-10 percent in 2 data sets as compared

to field observed maximum LAI. Out of 9 set of environments for PBW 550, the model underestimated maximum leaf area index less than 10% in 2 data sets; whereas the model overestimated maximum leaf area index more than 30% in 3 data sets, between 10-30% in 3 data sets, and between 0-10% in 1 data set as compared to field observed maximum LAI.

Grain yield ranged from 2934 to 5300 kg/ha for PBW 343, 4016 to 5490 kg/ha for PBW 502 and 2260 to 5660 kg/ha for PBW 550 (Fig 4). The grain yield was both underestimated as well as overestimated by the model for the three cultivars of wheat under different environments. Out of 9 set of environments for PBW 343, the model underestimated grain yield more than 30% in 3 data sets, between 10-30% in 3 data sets and between 0-10% in 2 data sets; whereas the model overestimated grain yield by 30% in 1 data set as compared to field observed grain yield. In case of for PBW 502 out of 6 set of environments, the model underestimated grain yield more than 10% in 1 data set and between 0-5% in 3 data sets; whereas the model overestimated grain yield more than 10% in 2 data sets as compared to field observed grain yield. Out of 9 set of environments for PBW 550, the model underestimated grain yield more than 20% in 3 data sets and between 0-10percent in 2 data sets; whereas the model overestimated grain yield more than 30% in 1 data set and between 0-10percent in 3 data sets as compared to field observed grain yield.

Biomass yield ranged from 8570 to 12970 kg/ha for PBW 343, 8480 to 12383 kg/ha for PBW 502 and 8370 to 12740 kg/ha for PBW 550 (Fig 5). The biomass yield was both underestimated as well as overestimated by the model for the three cultivars of wheat under different environments. Out of 9 set of environments for PBW 343, the model underestimated biomass yield more than 30% in 3 data sets, between 10-30% in 1 data set and between 0-10percent in 1 data set; whereas the model overestimated biomass yield less than 10% in 4 data sets as compared to field observed biomass yield. In case of for PBW 502 out of 6 set of environments, the model underestimated biomass yield more than 30% in 1 data set and between 0-10% in 1 data sets; whereas the model overestimated biomass yield more than 10% in 1 data set, between 0-10% in 3 data sets as compared to field observed biomass yield. Out of 9 set of environments for PBW 550, the model underestimated biomass yield more than 20% in 4 data sets and between 0-10percent in 1 data set; whereas the model

overestimated biomass yield less than 10% in 4 data sets as compared to field observed biomass yield.

Evaluation of Infocrop model as Agronomic tool:

Table 2 : Effect of different date of sowing on simulated grain yield of different wheat cultivars by using INFOCROP model .

	Estimated yield (kg/ha)		
Date of sowing	**PBW 343**	**PBW 502**	**PBW 550**
20th October	3717.9	3631.3	3782.5
30th October	4842.9	4391.0	4651.1
10th November	5220.7	5301.8	5266.8
20th November	5411.4	5192.1	5190.5
30th November	5263.4	5008.4	4866.6
10th December	4553.8	4285.2	4287.5

The perusal data revealed that the maximum simulated grain yield for cv. PBW 343 obtained under 20th November (Date of sowing) whereas PBW 502 and PBW 550 obtained for 10th November sown wheat crop. So delay in sowing of PBW 343 upto 20th November and earlier sowing during 10th November of other two cultivars will give higher grain yield.

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Fig. 1 Comparison of observed and simulated days to anthesis of wheat cultivars under different environments using the INFOCROP model (Rabi 2006-07, 2007-08 and 2009-2010)

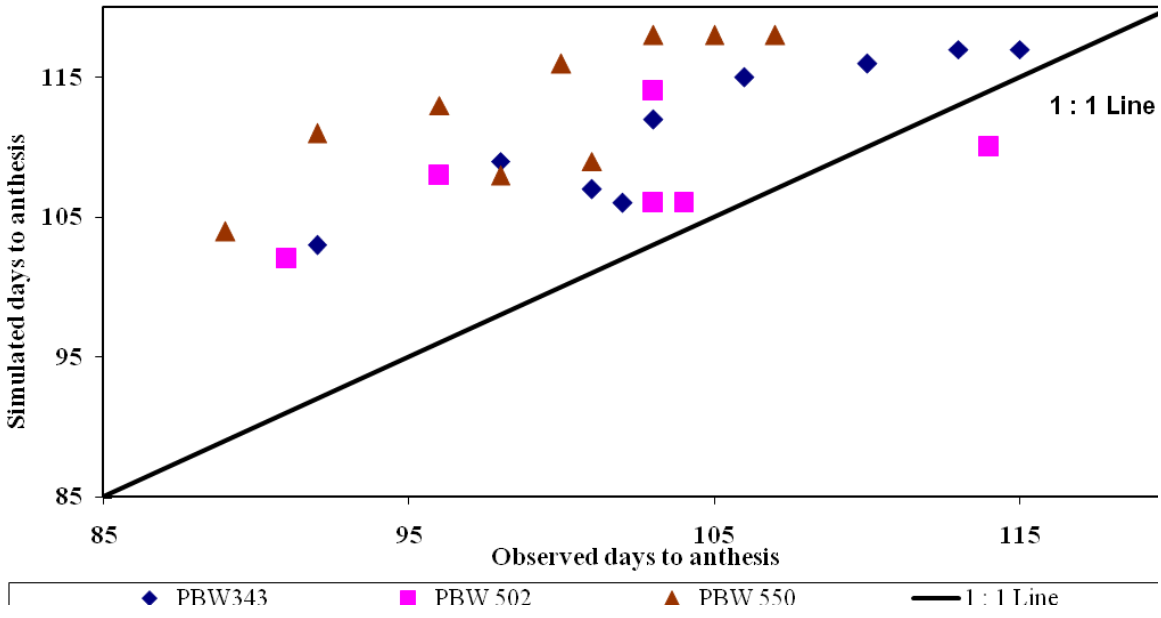

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Fig. 2 Comparison of observed and simulated days to physiological maturity of wheat cultivars under different environments using the INFOCROP model (Rabi 2006-07, 2007-08 and 2009-2010)

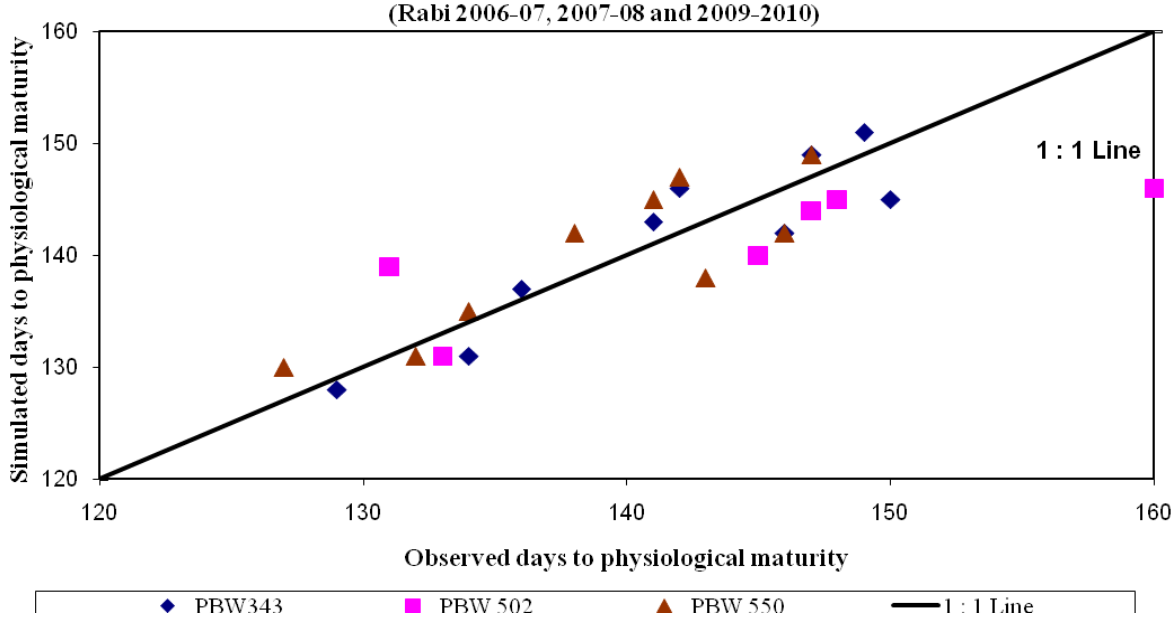

Fig. 3 Comparison of observed and simulated maximum Leaf Area Index (LAI) of wheat cultivars under different environments using the INFOCROP model (Rabi 2006-07, 2007-08 and 2009-2010)

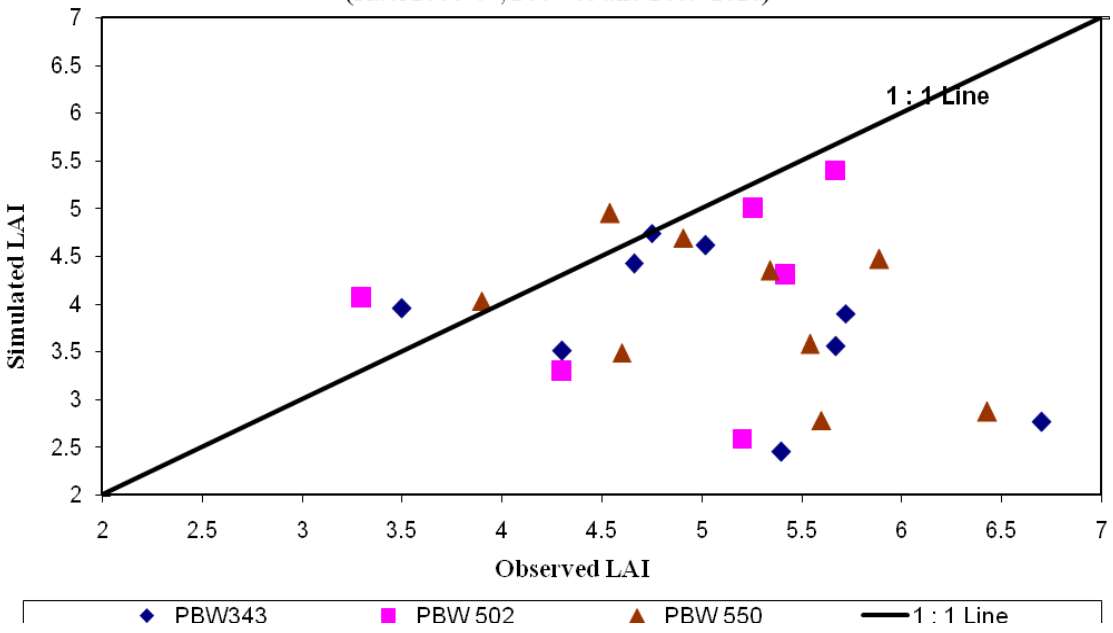

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Fig. 4 Comparison of observed and simulated grain yield of wheat cultivars under different environments using the INFOCROP model (Rabi 2006-07, 2007-08 and 2009-2010)

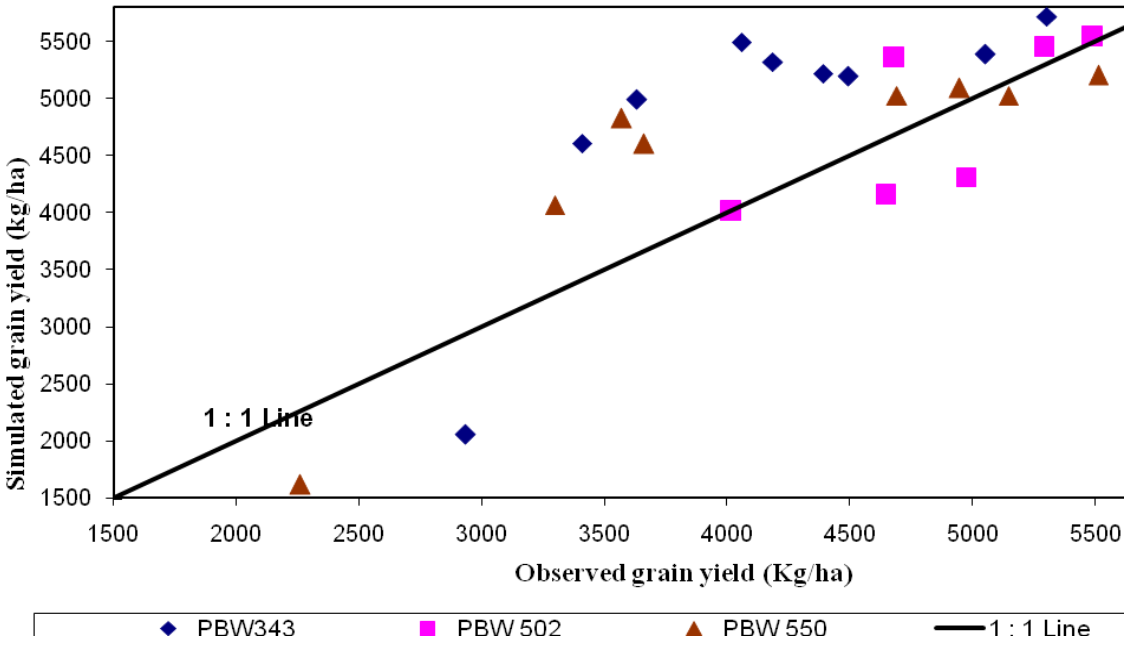

Fig. 5 Comparison of observed and simulated biomass yield of wheat cultivars under different environments using the INFOCROP model (Rabi 2006-07, 2007-08 and 2009-2010)