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Short Communication

Pre-harvest wheat yield prediction using CERES-wheat model for Ludhiana district, Punjab, India

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Wheat (*Triticum aestivum* L.) is a major cereal crop of India after rice (Ranjan *et al.,* 2012).Ludhiana is one of the major wheat producing districts and contributes 12 per cent to total wheat produced by Punjab (Kaur *et al.,* 2007). Weather factors such as temperature, rainfall and solar radiation are important to wheat production. Importance of change in temperature in wheat growing areas of India has been highlighted by Sandhu *et al.,*(2016). Crop simulation models are useful tools to predict the growth, development and yield of a crop integrating soil, crop and climate information. It has potential applications in yield forecasting. Timely and accurate crop yield forecasting is immensely important,which can facilitate crop production management system starting from the farmers at production level to policy makers at district, state and national levels. Multiple regression models have been used to predict the yield of wheat and rice in Punjab (Bal *et al*., 2004; Mallick *et al*., 2007). Crop simulation model WOFOST have been integrated with GPS and remote sensing data for spatial wheat yield prediction (Chaudhari *et al*., 2010). Keeping all the above in view, the present study was planned to predict the wheat yield of Ludhiana district using crop simulation CERES-wheat model.

Sixteen years (2000-01 to 2015-16) weather data and wheat yield data of Ludhiana district was used in this study. Weather data was obtained from the Agrometeorological observatory, Punjab Agricultural University, Ludhiana and yield data was obtained from the Statistical Abstracts of Punjab, India.Since model simulates yield for a particular location it was integrated over the district taking into account the time of sowing under different varieties as well as area covered and due weightage was given. The model was calibrated for three wheat cultivars-HD 2967 sown on 25th October, PBW 621 sown on 15th November and PBW 550 sown on 05th December categorized as early, timely and late sown cultivars.The agronomic practices were followed as recommended by Punjab Agricultural University, Ludhiana. In Punjab, generally 15 per cent farmers go for early sowing, 75 per cent for timely sowing and 10 per cent for late sowing correspondingly varieties PBW 621, HD 2967 and PBW 550 were selected for the study.The yield of three wheat cultivars was simulated using CERES wheat model. The weighted average yield from three wheat cultivars according to the area they occupied was calculated for the Ludhiana district each year.Hence,varieties HD 2967, PBW 621 and PBW 550 were given 75, 15 and 10 per cent weightage for calculation of weightage average yield. This weighted yield was correlated with the actual yield and an equation was developed using 11 years (2000-01 to 2010-11) data and validation of that equation was done for the next five year period (2011-12 to 2015-16). The genetic coefficient derived for three varieties are presented in Table 1.

The yield prediction was provided before harvest (March 20th) of the wheat crop. The actual weather data for the simulation study was used till 19 March and normal (long term average) for the remaining period.

The results were statistical analysed using four statistical procedures like NRMSE (normalized root mean square error), MBE (mean bias error), per cent deviation and R^2 (coefficient of determination) as given in Sandhu *et al*. (2018).

The total weighted yield for the three wheat cultivars was calculated and comparison was made with the actual yield of Ludhiana district (Fig.1). The weighted yield was higher than the actual yield in all the years.The R^2 between weighted and actual yield was highly significant (R^2 = 0.82**), which means that the CERES-wheat model was capturing the yearly variation in wheat productivity due to variation in weather with good level of confidence. The standard deviations of weighted and actual yield were 335 and 416 kg ha^{-1}, respectively. The mean of eleven year weighted and actual yield were 5571 and 5121 kg ha^{-1},

Table 1: Genetic coefficients of three wheat varieties used in CERES-wheat model

Coefficients/varieties : Expansion	HD 2967	PBW 621	PBW 550
P1V: Vernalization sensitive coefficient (%/d of unfulfilled vernalization)	26	30	30
P1D: Photoperiod sensitive coefficient(%reduction/h near threshold)	55	55	55
P5: Thermal onset from the period of linear fill to maturity (°C d)	500	515	515
G1: Kernel number per unit stem +spike weight at anthesis (#/g)	19	16	20
G2: Potential kernel growth (mg/(kernel d))	29	44	44
G3: Tiller death coefficient (g)	1.6	3.2	3.2
PHINT: Thermal time between the appearance of leaf tips (°C d)	60	110	100

Table 2: Comparison of predicted and actual wheat yield

Year	Actual yield (kg ha^{-1})		Predicted yield (kg ha^{-1})	% deviation
2011-12	5676		5463	-3.75
2012-13	5295		5046	-4.70
2013-14	5113		4906	-4.05
2014-15	4650		4142	-10.92
2015-16	4670		4489	-3.88
Mean	5081		4809	-5.35
Standard deviation	435		510	
NRMSE (%)		5.80		
MBE		-271		
R^2		0.945		

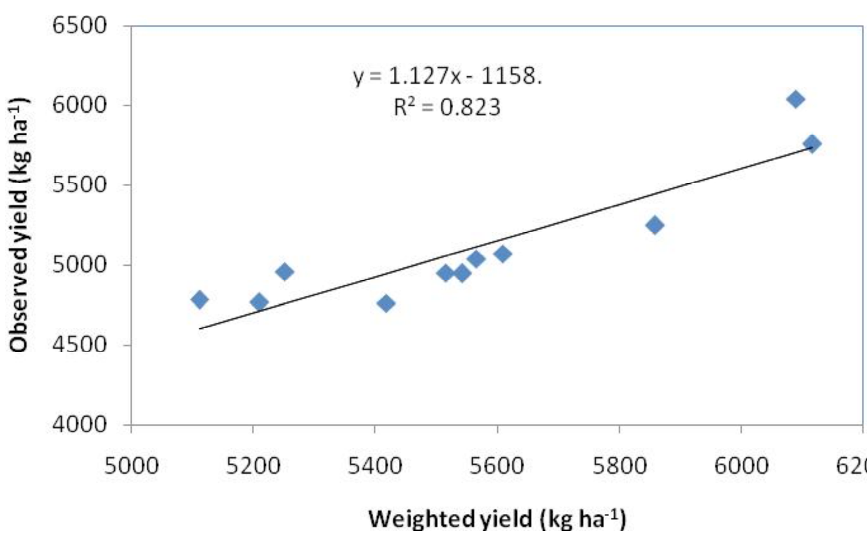

Fig. 1: Comparison of weighted and actual wheat yield during 2000-01 to 2010-11

respectively. The reason for higher weighted yield is that it was derived from simulated yield by CERES-wheat model which was calibrated with the yield of experiments conducted at research stations. Yield in research plots are generally higher than yield at farmers' field. Therefore, a regression equation was derived (Fig. 1) by comparing both weighted and actual district yield from these eleven years data(2000-01 to 2010-11). The pre harvest yield prediction (Table 2) was done by using the weighted yield as one variable in the developed equation for the next five year period from 2011-12 to 2015-16.

The predicted yield was compared with the actual yield(Table 2), which revealed under-estimation by the model.The predicted yield varied from 4142 to 5463 kg ha^{-1}, with the mean yield of 4809 kg ha^{-1}. The per cent deviation of predicted yield from the actual yield was between -3.7 to -10.9. This shows a very good agreement between the predicted and actual yield. The value of NRMSE was 5.80 per cent and Jamieson *et al*., (1991) proposed that if the NRMSE is less than 10 the prediction is considered excellent. The MBE showed underestimation by -271.38 kg ha^{-1} in pre harvest wheat yield prediction done on March 20^{th}.The average per cent deviation of the predicted wheat yield was -5.35 per cent.The coefficient of determination (R^2) between predicted and actual yield was very high (0.945). The high R^2 value signifies that the approach followed in the present study is capable of capturing variation in wheat yield quite satisfactorily.

The results showed that by using the methodology the pre-harvest wheat yield forecast can be done with a good level of confidence.

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