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Multivariate statistical wheat yield prediction model for Bilaspur district of Chhattisgarh

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Abstract
Weather plays an important role in yield forecasting of agricultural crop. Weather affects crop growth at different phenological phases and is therefore, responsible for variation in yields from year-to-year and place-to-place. An attempt has been made in this paper to study the effect of vital weather parameters on wheat yield on basis of 15 years (2000-2015) weather data and wheat production and to develop a different type of multivariate statistical model for yield forecast of this region. Different types of models have been developed using SPSS software. Model 5 has the highest R^2 value 0.97, which describes the 97% variability in wheat yield due to weather parameters.

Keywords: Wheat, weather variables, quantified, correlation, coefficient estimated and multivariate statistical equations

1. Introduction
In India, wheat covered about 30.72 mha during 2016- 17 crop season and accounts for about 36 per cent of the country's total food grains production as per the data estimated by Directorate of Economics and Statistics (DES), Ministry of Agriculture and Farmers Welfare, India. During 2016-17, a record wheat production of 98.38mt with an average national productivity of 3172 kg/ha has been achieved. A crop-weather model is a simplified representation of the complex relationships between weather and climate and crop performance by using established mathematical or statistical techniques (Baier, R., and Fey, K.1979) [2]. An important role has been played by the statistical analysis on food security (Ray *et.al.*2012). Various types of statistical models have been used for the analysis of yield time series. Linear regression has been used in many studies (Lin *et al*, 2012 and Ladha *et al*, 2003) [7, 5, 6]. Many studies have also shown bi-linear, tri-linear, quadratic, and other type of regression models (Brisson *et al*, 2010 and Ray *et al*., 2012) [3, 9]. There is a need to predict the yield of wheat and other crops in-order to know whether there is stagnation or decreasing or increasing trend in crop productivity in the changing climatic scenarios. Pre-harvest crop yield forecast is required for storage, pricing, marketing, import, export etc. Models based on weather parameters can provide reliable forecast of crop yield in advance of harvest and also forewarning of pests and diseases attack so that suitable plant protection measures could be taken up timely to protect the crops (Agrawal and Mehta, 2007) [1]. The temperature, solar radiation and rainfall are some important parameters of weather which have direct effect of them on physiological processes of wheat crop. The aim of the present study was to develop a more complete understanding of the weather factors that regulate crop.

2. Materials and Methods
2.1 Study area: Bilaspur is located in Chhattisgarh (22° 33' N to 21°14'N Latitude and 82° 6' to 81° 38'E Longitude.) The average temperature in Bilaspur is 26.8 °C. Average precipitation is around 1259 mm (Rice zone) of the state. The weekly maximum and minimum temperature were recorded as 38.1 and 20.5 °C respectively.

2.2 Yield Data: The area, production and productivity of wheat for 15 years yearly production (q) and area (ha) under wheat crop in Bilashpur district for the period 2000-2015 were collected from the Statistical Abstract of CHHATTISGARH (Stats, 2014-15). For each year, the total production of the district was divided by the total acreage to calculate the wheat productivity.

2.3 Weather Data: Weekly data of maximum and minimum temperatures, relative humidity, rainfall, sunshine hours and number of rainy days for the period 2000-2015 were collected from the agro meteorological observatory located in the IGKV Raipur Chhattisgarh.

2.4 SPSS Model: SPSS (Statistical Product and Service Solutions) was used to compute Pearson's correlations between observed yield and weather parameters, and with combinations of weather parameters. Sum of weather parameter and sum product of different weather parameter and correlation coefficient has been derived. Multiple regressions between dependent variable (yield) and independent variables (time, sum and sum products for different weather parameters) were carried out. Regression equation was written using the regression formula

2.5 Statistical Model Development

Spatio temporal variability in wheat crop productivity and climatic variables has been studied in this study using different statistical procedure. The statistical models were developed for yield production of wheat for Bilaspur district using SPSS software.Multiple linear regressions equations have been developed between the dependent variable (yield) and independent variables (weather parameters). The goal of multiple linear regressions (MLR) is to model the relationship between the explanatory and response variables. The model for MLR, given n observations, is:

$$Y_i = B_0 + B_1X_{i1} + B_2X_{i2} + ... + B_pX_{ip} + E$$

Where i = 1,2,..., n

Y = Dependent Variable, X= Independent Variables, B_1, B_2...... are regression coefficient.

In order to find out the relationship between weather variables and wheat yield correlation analysis was carried. Correlation studies between yields of crop with the various weather parameters were carried out with the help of methodology described by Gomez and Gomez (1984) [4].

3. Results

3.1 Relationship between weather variable and wheat yield

The results revolted that there was a significant positive and negative relationship between the weather variables and wheat yield of Bilaspur district. (Table. 1) depicts the important weather variables having strong positive and negative relationship between weekly weather variables and wheat yield of crop season. For CRI and milking stage it is visible from the (Table 2.) that there is a strong positive relationship between yield and minimum temperature, while negative relationship in booting stage. In case of rainfall there is a positive relationship of yield during initial stage i.e CRI, while negative correlation has been found in milking and maturity stage. This implies that wheat crop requires water essentially in its germination and seed filling stage. The results are in accordance with the study conducted by Jayabhai *et al* (2014) on impact of weather variability on growth and yield of soyabean under different geometry.

3.2 Development of Multivariate Statistical wheat Yield Model

In this study the yield prediction model has been developed for wheat crop. The multivariate statistical model for wheat has been developed 5 models. Model 1 has shown the R^2 value (0.53) with the variable i.e. maximum temperature of 11st week. Model 2 has shown the R^2 value (0.72) with the variables i.e. maximum temperature of 11st week & Average bright sun shine hours of 06th after sowing. Model 3 has shown the R^2 value (0.89) with the variables i.e. maximum temperature of 11st week, Average bright sun shine hours of 06th & Average rainfall of 07 th week after sowing. Model 4 has shown the R^2 value (0.94) with the variables maximum temperature of 11st week, Average bright sun shine hours of 06th, Average rainfall of 07 th week after sowing, and average minimum relative humidity of 3rd week of sowing. Model 5 has the highest R^2value (0.97), which describes the 97% variability in wheat yield due to weather parameters. with the variables maximum temperature of 11st week, Average bright sun shine hours of 06th, Average rainfall of 07 th week after sowing, average minimum relative humidity of 03rd week of sowing and maximum relative humidity of 03rd week of sowing. This may be due to more weather factors involved in the Model 5, instead of any other models. From Fig. 1 it has been seen that the RMSE of estimated (3.05%) and predicted (7.0%) years are under acceptable limits. (Table no. 3).

(Fig 1) depicted that wheat crop it is also found that the RMSE value for observed wheat yield during the estimation period (2000-2013) of model 1, model 2, model 3, model 4 and model 5 were 12.32%, 9.49%, 6.05%, 4.28%, and 3.05%, respectively and (2013-14 & -2015) predicted wheat yield by model 1 was 14.42, model 2 was 9.06%, model 3 was 8.28%, model 4 was 10.46% and model 5 was 7.00%.

Rajavel *el al.* 2018 [8] has also conducted a study to develop regression model in different districts of Chhattisgarh. The models used to forecast district level yield of rice in Chhattisgarh in mid-season of 2014 and 2015. The forecasted yield obtained has been validated with actual yield of corresponding year to find the accuracy of developed model. The accuracy of forecast model is less than10% in 6 districts in 2014 and 4 districts in 2015.

Table 1: Generalized growth stages of wheat

Phenophases	Growth stages	DAS	SMW
P1	Crown root	1-21	48-50
P2	Booting	21-42	51-01
P3	Flowering to milking	43-63	02-05
P4	Dough development stage	64-76	06-09

Table 2: Bilaspur district average wheat yield with statistical analysis

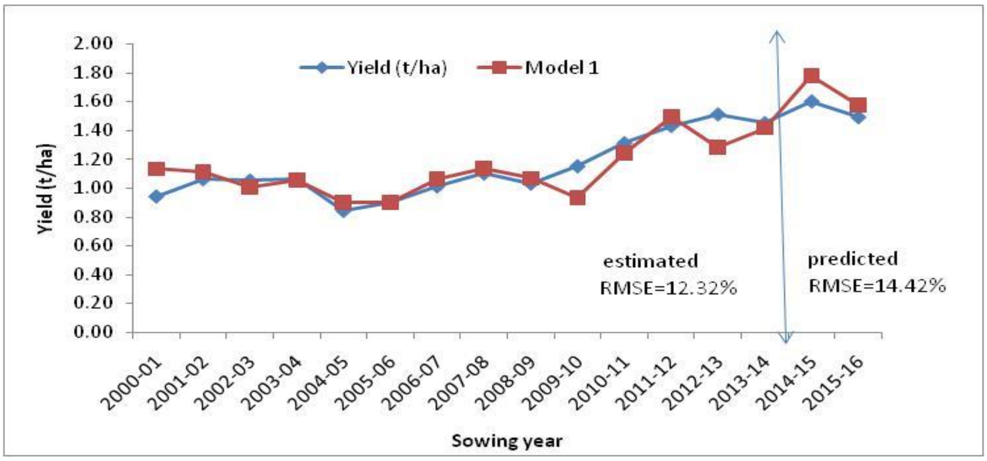
Growth Stage	Sm W	T. Max	T. Min	Rainfall	Rh.	BSS
Crown Root (P1)	48	0.269*	0.105	-0.165	0.063	-0.613**
	49	0.038	0.084	0.477**	-0.050	-0.482**
	50	0.169	0.605**	0.514**	0.370**	-0.427**
Booting (P2)	51	-0.256*	-0.389**	0.025	-0.130	-0.282*
	52	0.297*	-0.135	-0.135	-0.002	-0.193
	01	0.475**	0.091	0.403**	0.145	-0.567**
Milking (P3)	02	-0.292*	0.080	0.318*	0.064	0.099
	03	-0.122	0.149	-0.396**	0.029	-0.492**
	04	0.098	0.480**	-0.279*	0.322*	-0.574**
	05	0.028	-0.032	-0.355**	-0.032	-0.337*
Dough development to Maturity (P4)	06	0.731**	0.168	-0.196	-0.110	-0.271*
	07	-0.331*	0.212	-0.095	0.007	-0.436**
	08	-0.280*	-0.293*	0.140	0.121	-0.456**
	09	-0.127	-0.128	0.436**	0.225	-0.376**

Note: *Significance of r ≥ 0.250 at 5%, **Significance of r ≥ 0.340 at 1%.

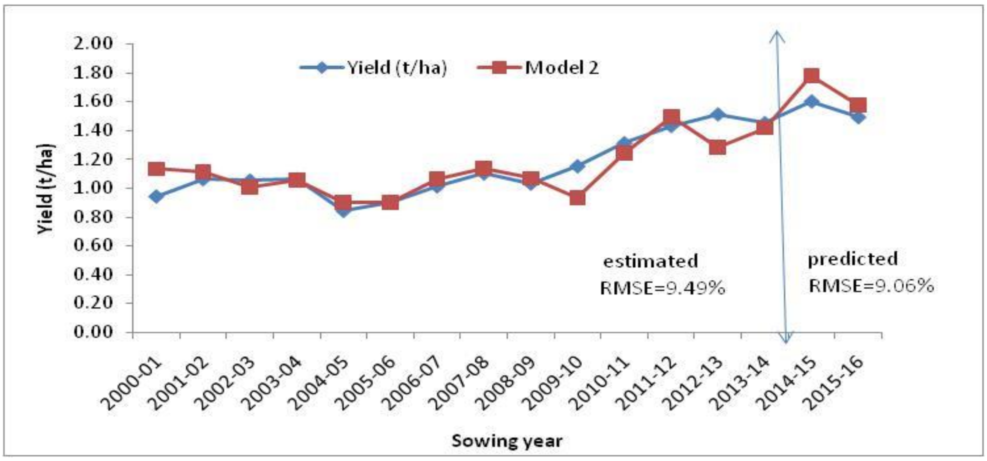
Table 3: Correlation coefficient between weather parameter and grain yield of Wheat at different phenological phases

S. No.	Model	R^2
1.	$Y=-4.638+0.17*(X_1)$	.534
2.	$Y=-2.722+0.15*(X_1)*1-0.156*(X_2)$	.724
3.	$Y=-2.984+0.158*(X_1)-0.162*(X_2)+0.148*(X_3)$	.890
4.	$Y=-2.283+0.128*(X_1)-0.155*(X_2)+0.102*(X_3)+0.007*(X_4)$	.944
5.	$Y=-0.663+0.103*(X_1)-0.1*(X_2)+0.089*(X_3)+0.015*(X_4)-0.017*(X_5)$	.971

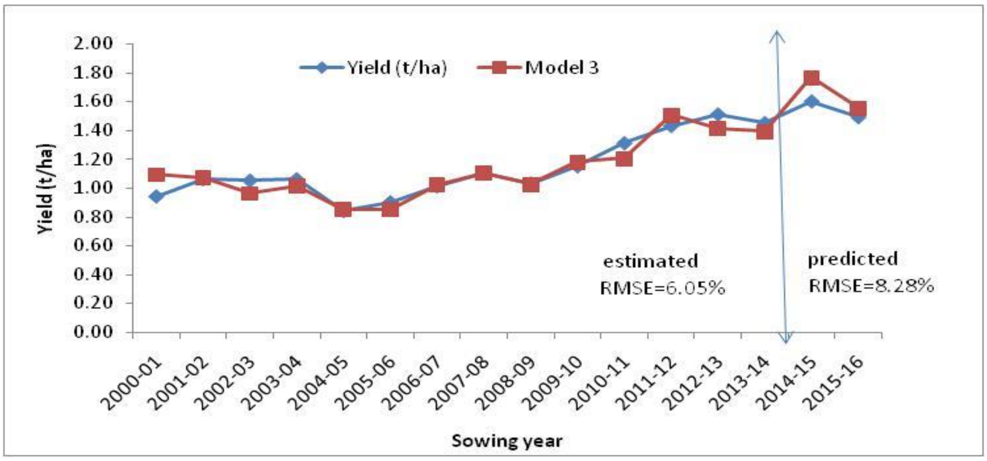
Where, Y=Wheat yield (t/ha). X_1= average maximum temperature of 11[th] week after sowing, X_2=Average bright sun shine hours of 06[th] after sowing, X_3=Average rainfall of 07[th] week after sowing, X_4= Average minimum relative humidity of 03[th] week of sowing, X_5= Average maximum relative humidity of 03[th] week of sowing.



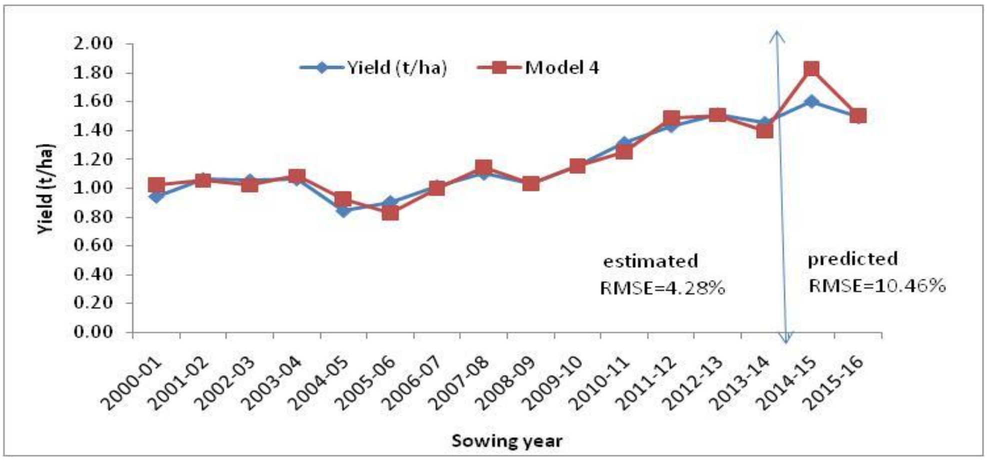
Model (1)



Model (2)



Model (3)



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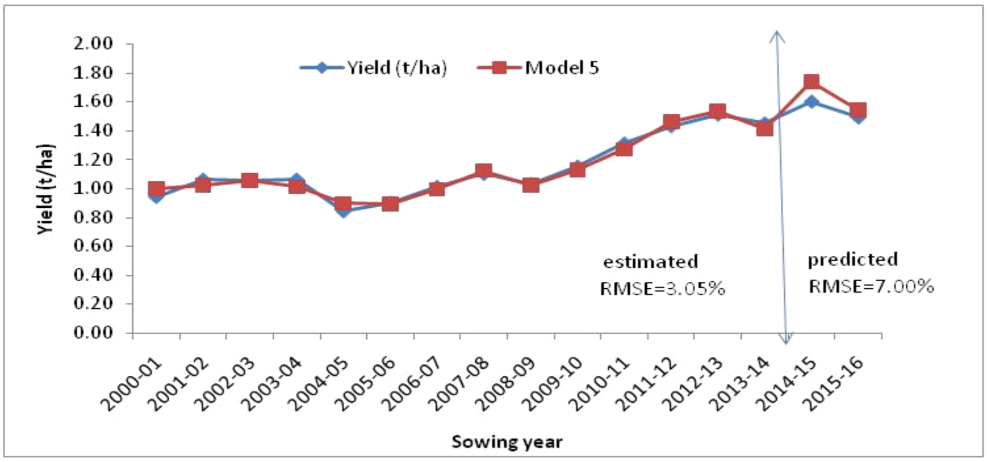

Model (5)

Fig 1: Comparison between observed and predicted Wheat yield for Bilaspur using Multivariate -meteorological yield model. (1, 2, 3, 4 & 5).

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