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Development of multivariate statistical Pigeon pea yield prediction model for Raipur district Chhattisgarh

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Abstract
The changing climatic conditions have a major impact on rain fed crops including pulses. An attempt has been made in this paper to study the effect of vital weather parameters on Pigeon pea yield and to develop a multivariate statistical model for yield forecast of Raipur district Chhattisgarh. On basis of 15 years (2000-2015) weather and Pigeon pea production 3 types of models have been developed using SPSS software. Result revealed that model 3 has the highest R^2 value 0.88, which describes the 88% variability in Pigeon pea yield due to weather parameters i.e. rainfall of 6th week after sowing, maximum temperature of 5th week after sowing and rainfall of 11th week after sowing. This may be due to more weather factors involved in the Model 3, instead of any other models.

Keywords: Pigeon pea, multivariate statistical model, sowing, weather parameters

1. Introduction
The changing climatic conditions have a major impact on rain fed crops including pulses (Basu *et al.*, 2009) [2]. Pulses are a wonderful gift of nature as they nourish mankind with highly nutritive food and keep the soil alive and productive. Pigeon pea (*Cajanus cajan* (L.) Millsp) is commonly known as red gram an important legume component in the dry-land agriculture, mainly because of its ability to produce large biomass and protein-rich leguminous seeds (Jat and Ahlawat 2010) [5]. Legumes are very important both ecologically and agriculturally because they are responsible for a substantial part of the global flux of nitrogen from atmospheric nitrogen to fixed form (Patriarca *et al*., 2002) [7]. It is mainly grown in the rainy season (June –Nov). Pigeon peas are drought resistant crop, so it can be grown in areas where annual average rainfall is less than 650 mm. Moisture stress is one of the major constraints in productivity of pigeon-pea. More than 50 % loss in the yield of pigeon-pea has been recorded due to drought (Sharma *et al*., 2016) [9]. Pigeon-pea and chickpea are major pulses, which contribute about 60% of total pulse production Pulses are reported to be particularly sensitive to heat stress at the bloom stage; only a few days exposure of high temperature (30- 35°C) can cause heavy yield losses through flower drop or pod damage (Siddique *et al*., 1999) [10]. It is a tropical grain legume mainly grown in India and ranks second in area and production (3.81 M ha area with production 3.02 MT, Anonymous 2014) [1]. This study has been undertaken to examine the impact of change in weather variables, viz. temperature and rainfall on yield of Pigeon pea. The relationship between crop yield and weather parameters is generally carried out with help of multiple regression models. Considering the importance of legumes this study was carried out to forecast the district level yield forecast of Pigeon pea.

2. Materials and Methods
2.1 Study area
Chhattisgarh state, situated in eastern India, is located between the latitudes of 17° 46' N -24° 5' N and longitudes of 80° 15' E- 84° 20' E. The climate of Chhattisgarh is tropical. It is hot and humid because of its proximity to the Tropic of Cancer and its dependence on the monsoons for rains. Raipur is situated between 22° 33' N to 21°14'N Latitude and 82° 6' to 81° 38'E Longitude. The average annual temperature in Raipur is 26.8 °C. Precipitation here averages 1276 mm.

2.2 Crops Yield Data: Yearly production (q) and area (ha) under Pigeon pea crop in Raipur district for the period 2000-2015 were collected from the (Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare).

2.3 Weather Data: Weekly data of maximum & minimum Temperatures (°C), Relative Humidity (%), Sunshine Hours (hours/day) and Rainfall (mm) number of rainy days for the period 2000-2015 were collected from the agro meteorological observatory located in I.G.K.V. Raipur Chhattisgarh.

2.4 Development of Statistical Model

The statistical models have been developed for predicting the Pigeon pea yield in the given environmental conditions. The models were developed based on the weekly weather data of crop season and Pigeon pea yield. SPSS (Statistical Product and Service Solutions) software was used to develop the statistical model between observed yield and weather parameters. 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 rice 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 pigeon pea yield

The result revealed that there was a significant positive and negative relationship between the weather variables and Pigeon pea yield. The value of correlation coefficients is significant at 1% and 5% level of significance. Positive correlation between Pigeon pea yield and rainfall during flowering & Podding stage. During its flowering phase & Podding stage there is strongly negative correlation with maximum temperature and negative correlation with bright sunshine hours. While during Podding stage in Pigeon pea there is significantly positive relationship between Pigeon pea yield and minimum temperature & relative humidity (Table no 2).

Kandiannan *et al.* 2002 [6] also explained the relationship of crop with weather and developed a model for turmeric yield forecasting for Coimbatore district, Tamil Nadu, India

3.2 Development of multivariate statistical pigeon pea yield model

In this study the yield prediction model has been developed for pigeon pea crop. The multivariate statistical model for pigeon pea has been developed 3 models. Model 1 has shown the R^2 value (0.54) with the variable i.e. rainfall of 6th week after sowing, Model 2 has shown the R^2 value (0.73) with the variables i.e. rainfall of 6th week after sowing and maximum temperature of 5th week after sowing and Model 3 has the highest R^2 value 0.88, which describes the 88% variability in pigeon pea yield due to weather parameters i.e. rainfall of 6th week after sowing, maximum temperature of 5th week and rainfall of 11th week after sowing. This may be due to more weather factors involved in the Model 4, instead of any other models. (Table no.3).

Fig.1 Depicted that the RMSE values for observed pigeon pea yield during the estimation period (2000-2013) of model 1, 2 and 3 were 10.76%, 8.09% and 5.38%, respectively and for predicted rice yield during the period (2014-2015) of model 1, 2 and 3 were 33.20%, 32.59% and 32.8%, respectively.

Rajavel *et al.* 2018 [8] has 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 Pigeon Pea

Phenophases	Growth stages	DAS	SMW
P1	Vegetative stage	1-28	27-30
P2	Flowering stage	29-70	31-36
P3	Podding stage	71-98	37-40

Where, P1= Vegetative stage, P2= Flowering stage, P3= Podding stage

Table 2: Correlation coefficient between weather parameter and grain yield of Pigeon pea at different phenological phases

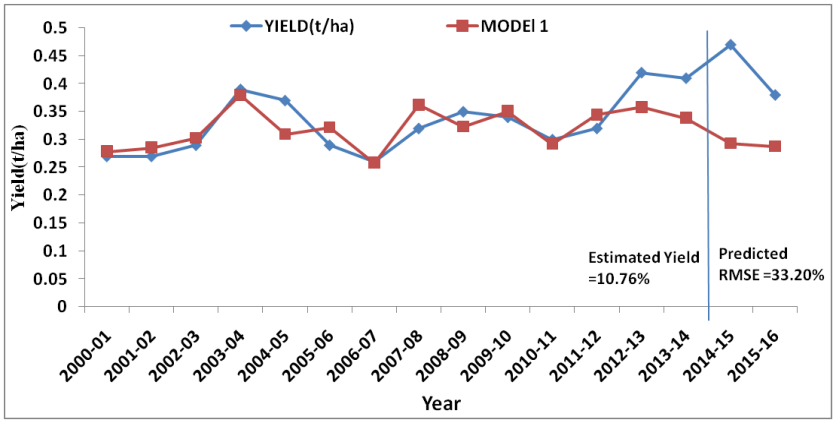
Stage	SMW	Tmax.	Tmini.	RF	RH	BSS
P1	27	-0.235*	-0.315*	0.205	0.377*	0.113
	28	0.112	-0.108	0.279*	0.088	0.337*
	29	0.322*	0.359*	0.218	-0.021	0.241
	30	-0.353*	-0.093	0.002	0.313*	-0.451*
P2	31	-0.538**	-0.422*	0.540**	0.391*	-0.334*
	32	-0.220	0.099	0.738**	0.401*	-0.443*
	33	0.274*	0.162	-0.155	-0.116	0.149
	34	-0.232	-0.197	0.306*	0.062	-0.124
	35	-0.043	0.122	0.338*	0.285*	-0.037
P3	36	-0.201	-0.029	-0.076	0.146	-0.335*
	37	-0.252*	0.380*	-0.250*	-0.019	-0.075
	38	-0.244	0.009	0.439*	0.526**	-0.463*
	39	-0.080	0.536**	0.220	0.243	-0.254*
	40	-0.511**	0.234	0.268*	0.281*	-0.272*

*Significance of $r \geq 0.250$ at 5%, **Significance of $r \geq 0.340$ at 1%.
Where, P1= Vegetative stage, P2= Flowering stage, P3= Podding stage

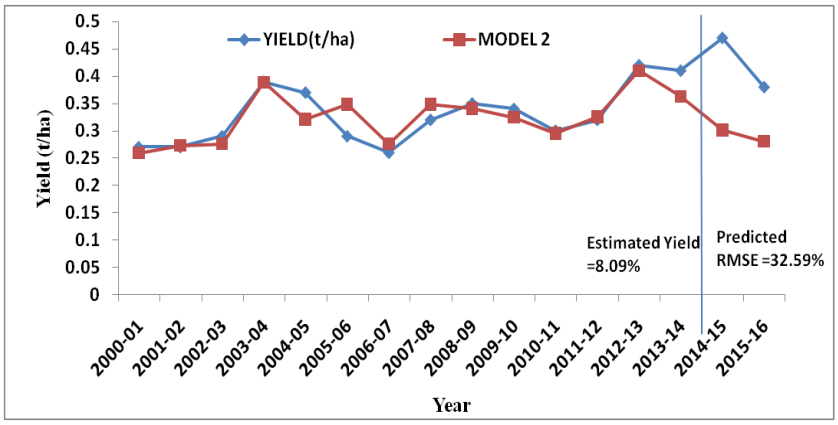
Table 3: Multivariate Statistical models for Pigeon pea yield

S. No.	Model	R^2
1	Y =0.251+0.001*(X1)	0.544
2	Y=0.587+0.001*(X1)-0.011*(X2)	0.734
3	Y =0.726+0.001*(X1)-0.015*(X2)-0.00036*(X3)	0.887

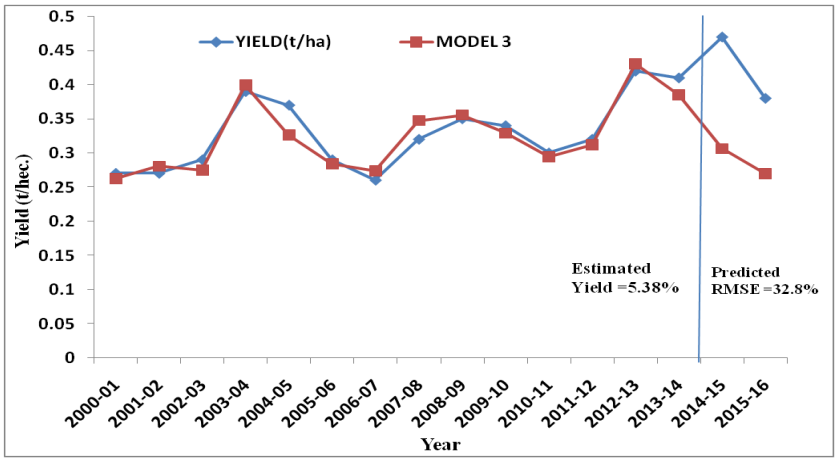
Where, Y=rice yield (t/hc). X1=rainfall of 6th week after sowing, X2=maximum temperature of 5th after sowing, X3=rainfall of 11th week after sowing.



Model 1



Model 2



Model 3

Fig 1: Comparison between observed and predicted yield for Raipur using multivariate -meteorological yield model (1, 2 & 3)

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