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Krishna Murari
Department of Agrometeorology, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Dr. GK Das
Department of Agrometeorology, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Jubuli Sahu
Department of Agrometeorology, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Dr. HV Puranik
Department of Agrometeorology, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Predication of grain yield of rice using statistical model in Chhattisgarh plains

Krishna Murari, Dr. GK Das, Jubuli Sahu and Dr. HV Puranik

Abstract
Rice is the chief agricultural product and one of the primary food sources for this reason, it is of pivotal importance for worldwide economy and development. Rice production in the Chhattisgarh is influenced by heat stress due to late sowing for optimization of yield, sowing at the appropriate time to fit the cultivar maturity length. The Statistical model was used to determine to assess the production potential for Raipur districts under varieties Mahamaya. The data analysis by SPSS and MS-Excel, it was found to be the most significant parameter for yield prediction of rice. Maximum temperatures for different decade are found predictors for the final yield in the end. Through SPSS model a simple linear equation has been determined for rice yield prediction in the area. With the help of weekly weather data, we find out correlation coefficient. On the basis of the identified significant weather parameters as independent variables and long term data of grain yield of Mahamaya variety, regression equation has developed. The equation the observed and predicted grain yields and significant results were drawn. The accuracy rate remained generally above 95% in experiment and present analysis of validation of regression model indicates only once in 2016-2017 this remained 96.7% or error is 3.3% during the last 10 years period. The prediction values are very close to the actual values of yield.

Keywords: Rice grain yields, statistical model, SPSS, MS-Excel, yield prediction

Introduction
Rice (*Oryza sativa* L.) is one of the most important food crops of the world, representing the staple food for more than half of the world population (Confalonieri and Bocchi, 2005) [2]. Rice belong to family Poaceae originated from South East Asia, where more than 90 percent of world's rice is produced and consumed (Li and Xu, 2007) [4]. Two countries, China and India, growing more than half of the world total rice production. Out of 24 species of rice only two species *Oryza glaberima* and *Oryza sativa* are cultivated. India is the second largest producer of rice after China having an area of 43.83 million hectare with the production of 104.80 million tonnes (Anonymous, 2014-15) [1]. Chhattisgarh, popularly known as "Rice Bowl of Central India" and occupies an area around 4.82 million hectares with a production of 7.65 Mt. It is grown mostly under rainfed condition. Even in the 32-36% of irrigated area, the productivity of rice in the state is 2050 kg ha-1 (2014-15) that is for below than national productivity 2372kg ha-1.

Statistical models express the relationship between yield and yield component and weather parameters. In these models, relationship is measured using statistical technique. Weather and crops growth relationship is significant at some particular phenological stages. It is the weather which may be used as an input for the purpose of yield prediction in crop modeling, rather than the climate. Prediction of seasonal weather is indeed a hard job but it can be used as input for a crop yield forecast model. After establishing a relation between the seasonal weather pattern and the yield obtained, a better modeling may be carried out. Phenophase of tillering and 50% flowering stage of rice is critical. Later on, the dough (grain filling) stages are the most significant stages in life cycle of rice crop. Favourable temperature conditions and rainfall for rice at tillering, flowering and dough stage give rise to higher number of grains per panicle and let the grain attain its proper size and weight under optimal water supply, consequently good yield may be expected at the end. There are some meteorological as well as agronomic parameters considered significant for growth and development rice crop and ultimately the final yield.

Corresponding Author:
Krishna Murari
Department of Agrometeorology, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Taking all kinds of available meteorological parameters (min/max temperature, rainfall, sunshine hours.), which was analyzed on decadal basis. But surprisingly only a few of them were found playing significant role in affecting final rice yield. Forecasting crop yield at post-harvest period of the crop for the current *kharif* (Rice) seasons was work out. Yield forecast model was also worked out through step-wise regression method using SPSS statistical software. For this purpose, under Raipur condition yield was regressed with significant maximum temperature and rainfall variables (weighted and un-weighted) to get best regression model.

Materials and Methods
Study area and Data base
The present study is confined to Chhattisgarh, Raipur district situated in Eastern India is located 21°16'N Latitude, 81° 36'E Longitude and an altitude of 289.5 m above mean sea level, during *kharif* season of the year 2016. Daily weather data of the study area used in study were collected from the Department of Agricultural Meteorology, Indira Gandhi Krishi Vishwavidyalaya Raipur (Chhattisgarh).

Crop yield forecasting at pre-harvest stage of the crop for the current *kharif* (Rice) seasons. Yield forecast models have been worked out through step-wise regression method using SPSS statistical software. Yield was regressed with 42

variables (weighted and un-weighted) to get best regression model. As weather data is not available for all districts, the available four stations weather data for each weather variable, two indices were worked out.

- Un-weighted weather index = Sum (each weekly weather variable)
- Weighted weather index = Sum (each weekly variable x correlation coefficient between yield and particular week weather variable)

Weather indices denoted as Z; un-weighted indices are 0 and weighted indices are 1. For instance, maximum temperature taken as 1st variable, hence weather index of un-weighted maximum temperature is Z10 and for weighted Z11.In the same way, other indices were worked out for other weather variables (Table-1).

To study the combined effect of weather variables, un-weighted and weighted indices were also computed. For instance, combination of maximum and minimum temperature is obtained by multiplying weekly values of maximum and minimum temperature. After getting best regression models, it was validated against observed yield and percent deviation was calculated.

Table 1: Notations for un-weighted and weighted indices

S. No	Weather variable	Un-weighted index	Weighted index
1	Tmax	Z10	Z11
2	Tmin	Z20	Z21
3	Rainfall	Z30	Z31
4	RH-I	Z40	Z41
5	RH-II	Z50	Z51
6	SSH	Z60	Z61
7	Tmax & Tmin	Z120	Z121
8	Tmax & Rainfall	Z130	Z131
9	Tmax & RH-I	Z140	Z141
10	Tmax & RH-II	Z150	Z151
11	Tmax & SSH	Z160	Z161
12	Tmin & Rainfall	Z230	Z231
13	Tmin & RH-I	Z240	Z241
14	Tmin & RH-II	Z250	Z251
15	Tmin & SSH	Z260	Z261
16	Rainfall & RH-I	Z340	Z341
17	Rainfall & RH-II	Z350	Z351
18	Rainfall & SSH	Z360	Z361
19	RH-I & RH-II	Z450	Z451
20	RH-I & SSH	Z460	Z461
21	RH-II & SSH	Z560	Z561

Linear Regression
Linear regression estimates the coefficients of the linear equation, involving one or more independent variables, which best predicts the value of the dependent variable. The model's output is shown here in which the following abbreviations are used:

Tmax = Mean maximum temperature
Tmin = Mean minimum temperature
Rain = Rainfall in millimetres
SSH = Total sunshine hours

The value for R^2(correlation coefficient) shows how strong is the correlation held between a predictor or independent variable and the dependent variable. The sign of 'r' indicates the slope of the regression line.

Regression equation
After analysis a simple linear equation has been developed, which may be a useful tool for yield prediction of rice crop in the region.

$$Y = a + (b1) (x1) + (b2) (x2)$$

Where-

Y	=	Predicted population
A	=	Intercept
b1, b2, b3, b4	=	Regression coefficient
X1, x2, x3, x4	=	Dependent variables

Formula of Deviation % -
Deviation % = Actual yield - Predicted yield /Actual yield*100

Results and Discussion
Rice yield forecast for Raipur condition was worked out at post-harvest stages for kharif season 2016. The weekly weather data *viz.*, maximum temperature, minimum temperature and rainfall for the period 22-46 standard meteorological weeks were used to get weighted and un-weighted indices for regression analysis. The regression equation along with predicted yield and per cent deviation for different years is presented in table -2 and fig.-1
Regression equation for Predicted yield:

$$Y = 13480.97 + (2.153)(Z561) + (-0.522)(Z140)$$
$$R^2 = 0.90**$$

(Significant at 1% level)

Where

Y	=	Predicted yield
Z561	=	Weighted weather index (RH-II & SSH)
Z140	=	Un-weighted weather index (Tmax & RH-I)

After data analysis by SPSS and MS-Excel, it was found to be the most significant parameter for yield prediction of rice. Maximum temperatures for different decade are found predictors for the final yield in the end. Through SPSS model a simple linear equation has been determined for rice yield prediction in the area. It can be seen from Table-2 and Figure-1that prediction values are very close to the actual values of yield.
The accuracy rate remained generally above 95% in experiment and present analysis of validation of regression model indicates only once in 2016-2017 this remained 96.7% or error is 3.3% during the last 10 years period.

Table 2: Actual and Predicted grain yield for rice crop based on variety Mahamaya at Raipur condition

Years	Actual Yield	Predicted Yield	Error %
2007-2008	4174.3	4116.9	1.4
2008-2009	4465.7	4534.0	-1.5
2009-2010	4444.3	4461.8	-0.4
2010-2011	4744.7	4418.6	6.9
2011-2012	3658.7	3730.4	-2.0
2012-2013	5399.0	5371.5	0.5
2013-2014	4579.0	4689.3	-2.4
2014-2015	4470.8	4585.3	-2.6
Validated yield (kg/ha)			
2015-2016	3819.3	4055.5	-6.2
2016-2017	3913.2	3783.6	3.3
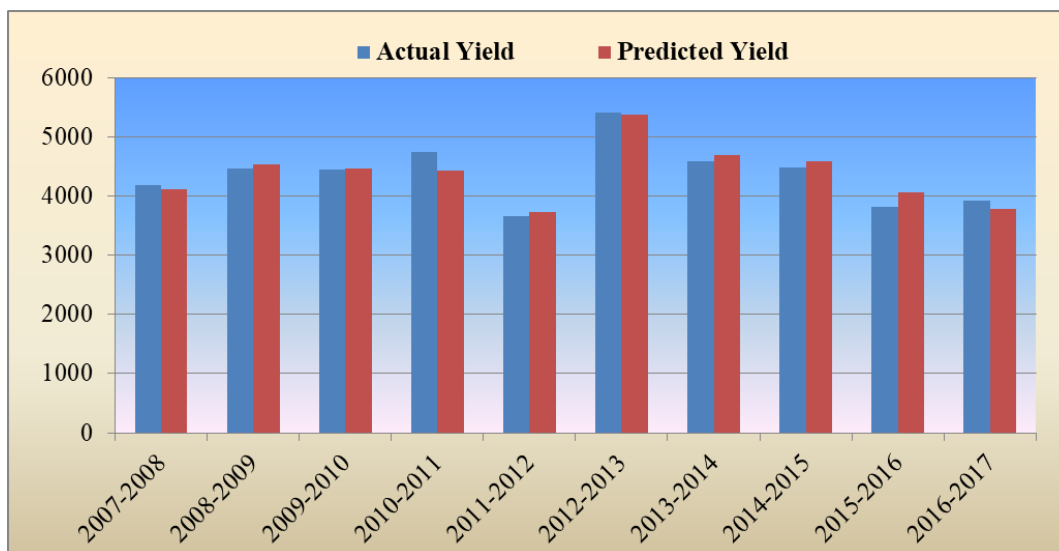
Fig 1: Actual and predicted grain yield (kg ha^{-1}) for rice crops through statistical models based on variety Mahamaya at Raipur condition for the period 2007-2016.

Conclusions
For rice yield forecast, statistical model showed 96.7 percent accuracy with 3.3 percent error in pre harvest stage. After data analysis by SPSS and MS-Excel, it was found to be the most significant parameter for yield prediction of rice. Maximum temperatures for different decade are found predictors for the final yield in the end. Through SPSS model a simple linear equation has been determined for rice yield prediction in the area. It can be seen from Table 2 and Figure 1 that prediction values are very close to the actual values of yield. The accuracy rate remained generally above 95% in experiment and present analysis of validation of regression model indicates only once in 2016-2017 this remained 96.7% or error is 3.3% during the last 10 years period.

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