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Developing regression model to forecast the rice yield at Raipur condition

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Abstract
The present investigation entitled "Developing regression model to forecast the rice yield at Raipur condition." was carried out during kharif seasons of 2015-16 at Research and Instructional Farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur to examine to validate the results of crop weather relationship of different rice varieties grown under different growing environments. The treatment combinations of three sowing dates (01 June, 15 June, and 30 June) and three varieties Swarna(National check), Mahamaya, MTU-1010 were laid out in a Factorial randomized block design with three replications with one treatment of underdose in Swarna variety 100:60:40. The linear correlation analysis with SPSS-model has been found at tillering stages negative relationship significant at 5% level for maximum and minimum temperature. In 50% flowering stages maximum temperature significant at 1% level and rainfall were significant correlated at 5% level. and dough stages are strongly negative correlated (1% level) to rainfall.

Keywords: SPSS-model, phenological stages, grain rice yield, crop weather relationships

Introduction
Rice is an integral part of creation myth and remains today as leading crop and most preferred food (Huke and Huke, 1997). In some countries of Asia, namely Bangladesh, Combodia, Laos, Myanmar, Srilanka and Vietnam, 90 percent of the people are rice consumers, whereas, in other countries like Indonesia, Japan, Korea, Taiwan and Thailand the percentage of rice consumers are 70-80 percent (De Datta, 1981). Rice in Chhattisgarh occupies an area of around 3610.47 thousand hectares with the production of 5.48 MT and productivity of 1517 kg per hectare (Anonymous, 2010). Chhattisgarh popularly known as "Rice Bowl" of India. In Chhattisgarh rice is mainly grown under rainfed conditions, which is about 50.52% of geographic area of Chhattisgarh plain and 28.62% of Bastar plateau and 20.86% of Nothern hill zone. Weather is one of the most important factors influencing crop growth. It may influence production directly through affecting the growth structural characteristics of crop such as plant population, number of tillers, leaf area etc. and indirectly through its effect on incidence of pests and diseases. The effect of weather parameters at different stages of growth of crop may help in understanding their response in term of final yield and also provide a forecast of crop yields in advance before the harvest. The extent of weather influence on crop yields depends not only on magnitude of weather parameters, but also on their frequency distribution. Therefore, the knowledge of the frequency distribution of weather parameters is also essential while developing the pre-harvest model. Weather is widely recognized as an important determinant of the level and variability of crop yield. For explaning this relationship between weather and crop yield it has been a common practice to use annual rainfall (and sometimes seasonal rainfall) as a measure of weather condition. However, the use of rainfall alone leads to a specification bias in the model because rainfall is only one component of the wider phenomenon of weather. Therefore, while considering the effect of weather on yield we must consider in addition to rainfall, the distribution of rainfall, maximam and minimum temperature, humidity and such other things over different months/weeks days of the year. These weather variables affect the crop differently during different stages of its growth. Thus weather needs to be recognised as a multidimensional phenomenon. Moreover, for perennial crops, weather conditions throughout the crop year have a direct and indirect influences on crop. 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 1979). The effects of meteorological factors on crop production and yield can be assessed in two different ways (van Keulen 1987). First, location or periods with different weather conditions can be compared and second, `sensitivity analysis' in which, one individual factor is changed in a

systematic way and the effect on final result is analysed. Once the detailed knowledge has been acquired of how, and at what growth stages, climatic factors influence the yield, it is possible to derive complex variates that give appropriate weight to the different factors for correlation with yield in naturally varying climates, and use them to predict yield from meteorological records (Watson 1963).

Description of Study Area

Raipur is the district headquarters. Only one block of Raipur district of Chhattisgarh is semi-critical as per report published by CGWB, NCCR, Raipur. Also most of the data including meteorological, hydrological and hydro-geological are available hence Raipur district was chosen for the present study. This district is the part of the middle agro climatic zone known as Chhattisgarh plains. Location of the study area is shown in Fig. 1. The brief description including location and salient features of this district is given below.

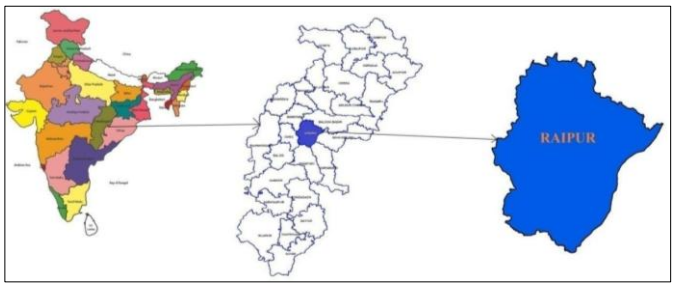

Fig 1: Location of the study area in India and Chhattisgarh

Materials and Methods

The present experiment "Developing regression model to forecast the rice yield at Raipur condition.." was conducted during the Kharif season of 2015.SPSS is a data analyzing software through which different types of data may be analyzed on statistical basis, like in MS-Excel. In this study, the yield prediction of Rice on meteorological basis was the main intention; therefore this model is utilized to find out the yield predictors. The approach was to investigate which of the meteorological parameters are the prominent contributors towards the final rice yield. For this purpose the decadal based agromet data of last 15 years for kharif months i.e. June to November (which has shown significant correlation with Rice yield) fed as input for the model. The yield data (Kg/ha) treated as dependant variable

Multiple Correlations by "SPSS" Model

SPSS is a data analyzing software through which different types of data may be analyzed on statistical basis, like in MS-Excel. In this study, the yield prediction of Rice on meteorological basis was the main intention; therefore this model is utilized to find out the yield predictors. The approach was to investigate which of the meteorological parameters are the prominent contributors towards the final rice yield. For this purpose the decadal based agromet data of last 15 years for kharif months *i.e.* June to November (which has shown significant correlation with Rice yield) fed as input for the model. The yield data (Kg/ha) treated as dependant variable and the method employed is linear regression.

1. 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 dependant. The sign of 'r' indicates the slope of the regression line.

2. 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

Results and Discussion

Linear Regression Models

Linear regression models have been developed for rice yield using maximum temperature, minimum temperature, rainfall and sunshine at different phenological stages of Mahamaya variety

The Table 1 showed that to identify the most sensitive stages to different weather parameters in linear regression, phenological stages influencing yield of rice crop variety Mahamaya linear regression models between the yield over three dates of sowing (growing environments) and ten years of experimentation an phenological wiese avaerage of maximum temperature, minimum Tempertaure, rainfall and sunshine were regressed.

Maximum temperature

The significant stages are found to be seedling, tillering, 50% flowering and maturity. Based on 't' statistics, 50% flowering stage is found to be the most sensitive stage and any deviation above the optimum value will finally result in grain yield reduction. Other sensitive phenological stage found to be in order are tillering, maturity and seedling. The negative influence of maximum temperature on tillering stage was found to be less significant however it increased in 50% flowering stage and again becoming less in milking stage as shown by t values.

In linear regression, maximum temperature seems to be influencing at seedling, tillering, 50% flowering and maturity stages. Linear regression models of yield with weather parameters (Maximum temperature, minimum temperature, rainfall, sunshine separately) during all the phenological satges significantly (<0.05) and adversely influenced the grain yield of Mahamaya variety of rice. The maximum temperature did not influence rice grain yield at panicle initiation, booting stage, panicle emergence, milk and dough stages which shows that maximum temperature seems to varying within optimum level limits. The negative adverse effect of maximum temperature on rice yield associated with t statistics was highest during 50% flowering stage followed by tillering, maturity and seedling stages.

Minimum temperature

This is one of the interesting result which has come out that minimum temperature under Raipur condition is not a constraint for rice production (Mahamaya variety) and minimum temperature only at tillering stage is found to be affecting the rice production. It means that minimum temperature has varied within cardinal limits and found to be optimum for rice production. One interesting result has been

found that minimum temperature at tillering stage has been found to be affecting the final grain yield. One logical point is that minimum temperature in Kharif season did not touch the cardinal points and limits and varied within optimum and favouarble range in all the stages of crop growth. However due to its variation outside optimum values ranges in tillering stage, relationship has been established with grain yield.

Rainfall

As the crop is grown under transplanted irrigated condition, rainfall might not shown the results which might have been obtained under rainfed condition. However, there are some significant correlations found out in rainfall parameter which might have been developed due to varying conditions.

When the role of rainfall in linear regression analysis (var. Mahamaya) was studied, it was found that rainfall at 50% flowering stage and milking stage is positively and significantly contributing for rice grain yield. This is followed by tillering stage in the same positive way. Rice being a high water requirennt crop, therefore rainfall at this stage will help to meet its its water requirement of evapotranspiration losses and also requiring impounding condition because of Hydrophytic nature. However rainfall at dough (grain filling) stage is not much required as it will result in reduced grain yield, the possible explanation for this is that the experiment is under assured irrigated condition and this stage is seed hardening stage of rice crop. Therefore, it can be said that there is much significance of rainfall in Mahamaya rice variety and 50% flowering has been identified as the most critical stage of rainfall with absolute 't' value of 2.59 (P<0.05) and rainfall had positive effect on grain yield.

Sunshine

Seedling and 50% flowering are crucial phenophases identified however 't' statistics has been found to negative. As regards to sunshine hours where only two stages are negatively significant at seedling stage and 50% flowering stages. Rest of all stage are not at all significant at 5% level.

Differences were observed in the responses (both negative and positive) of Mahamaya variety to Kharif rice variety Mahamaya *viz.* maximum temp., min temp., rainfall and sunshine during different phenological stages. As regards to rainfall parameter, the highest significant effect of rainfall was observed during 50% flowering stage. Therefore because of its sensitivity to maximum temperature and rainfall, 50% flowering and tillering stages are identified as critical stages regarding thermal and moisture stress. Milking stage has been found to be as third most critical stage as it is affected by rainfall quantity and distribution. The yield and all weather parameters conditions pooled over cultivars also showed the tillering stage and 50% flowering stages to be the most sensitive phenological stages for both maximum temperature and rainfall with absolute t values 0.21 (P<0.05) and 2.59 (P<0.05) respectively, closely followed Y milking stage in maximum temperature.

Overall it can be said that tillering phenophase is very crucial in rice crop as value of three meteorological parameters (Maximum temperature, minimum temperature and rainfall) is going to finally affect the yield. While max. Temp. And min. temp. Are going to cause reduction in the grain yield and rainfall is going to positively affect the crop growth which ultimately reflected in grain yield. Another sensitive phenological stage found is 50% flowering where maximum temperature above cardinal value will negatively reflect in grain yield and rainfall will be positively contributing for grain yield.

As regards to the sun shine hours where only two stages are negatively significant at seedling stages and 50% flowering and rest of all stages are not significant at 5% level. Differences were observed in the responses (both negative and positive) of mahamaya variety to field rice maximum, minimum temperature and rainfall during different phonological stages.

Yield prediction

Weather and crop's 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. Favorable 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 allience 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 rice crop and ultimately the final yield. Taking all such kinds of available meteorological parameters whether they were observed directly (min/max temperature, rainfall, sunshine hours.), analysis was made 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. Yield forecast models have been 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.

For each weather variable, two indices were worked out.

1. Un-weighted weather index = Sum (each weekly weather variable)
2. 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 2) to study the combined effect of weather variables, un-weighted and weighted indices were also computed. For instance, combination of maximum temperature & minimum temperature, maximum temperature & rainfall, minimum temperature and rainfall is obtained by multiplying weekly values. After getting best regression models, it was validated against observed yield data for the year 2015 and percent deviation was calculated. Rice yield forecast for Raipur condition was worked out at post-harvest stages for *kharif* season 2015-16. 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 4.15.

Regression equation for Predicted yield
$Y = 9178.32 + (78.3)\ (z11)\ R^2 = 0.90$

Where
z11 = Weighted weather index (Tmax)
Y = Predicted yield

Significant Crop growth stages wise regression equation for Predict yield

$Y = 7227.70 + (-89.20)\ (X_1)$	**$R^2 = 0.08$**
$Y = 3825.75 + (22.50)\ (X_2)$	$R^2 = 0.007$
$Y = 9996.78 + (-220.32)\ (X_3)$	$R^2 = 0.074$
$Y = 4595.13 + (-1.05)\ (X_4)$	$R^2 = 0.014$
$Y = 4427.80 + (6.47)\ (X_5)$	$R^2 = 0.037$
$Y = 10634.98 + (-61.16)\ (X_1) + (39.07)\ (X_2) + (-216.04)\ (X_3) + (-1.74)(X_4) + (6.11)(X_5)$	R2 = 0.20

Where
X_1 = Tmax (Tillering stage) X_2 = Tmax (50% flowering stage) X_3 = Tmin (Tillering stage)
X_4 = Rainfall (50% flowering stage) X_5 = Rainfall Dough stage Y = Predicted yield

Table 1: Linear regression models for grain yield for Mahamaya variety

weather parameter	Statistics	Seedling	tillering	panicle initiation	Booting stage	Panicle emergence	50% Flowering	Milking	Dough	maturity
Max-T	Intercept	6923.185	13245.69	6910.39	6266.289	5986.124	13157.535	6269.039	3929.071	9617.193
	Linear	-74.791	-287.195	-78.548	-57.14	-47.013	-273.208	-55.34	18.322	-163.368
	t- value	-1.024	-2.537	-0.458	-0.6	-0.394	-3.023	-0.492	0.156	-1.537
	Pr> |t|	< 0.05	<0.05	NS	NS	NS	<0.05	NS	NS	<0.05
	Adj. R2	0.002	0.158	-0.028	-0.023	-0.03	0.219	-0.027	-0.035	0.045
	Pr > F	< 0.05	<0.05	NS	NS	NS	<0.05	NS	NS	<0.05
Min-T	Intercept	8413.601	19017.02	3799.721	8634.274	4911.363	4437.237	4360.867	4181.727	4602.684
	Linear	-155.081	-582.509	28.567	-167.413	-16.37	2.969	6.374	14.74	-4.651
	t- value	-0.613	-2.292	0.094	-0.734	-0.091	0.024	0.102	0.289	-0.08
	Pr> |t|	NS	<0.05	NS	NS	NS	NS	NS	NS	NS
	Adj. R2	-0.022	0.128	-0.035	-0.016	-0.035	-0.036	-0.035	-0.033	-0.035
	Pr > F	NS	<0.05	NS	NS	NS	NS	NS	NS	NS
RF	Intercept	4583.154	4155.01	4561.173	4438	4618.719	4282.079	4436.441	4680.086	4423.053
	Linear	-0.249	1.244	-0.209	1.048	-2.353	5.317	3.268	-7.506	5.922
	t- value	-0.355	1.127	-0.207	-0.511	-1.106	2.596	1.17	-2.78	0.884
	Pr> |t|	NS	<0.05	NS	NS	NS	<0.05	<0.05	<0.05	<0.01
	Adj. R2	-0.031	0.009	-0.034	-0.026	0.008	0.165	0.013	0.188	-0.008
	Pr > F	NS	<0.05	NS	NS	NS	<0.05	<0.05	<0.05	<0.01
SSH	Intercept	5034.295	4613.806	4437.549	4525.682	4304.025	5299.681	4483.54	4318.732	5807.605
	Linear	-159.604	-32.45	18.931	-3.241	37.897	-127.446	3.478	26.928	-175.611
	t- value	-1.062	-0.369	0.144	-0.113	0.608	-1.96	0.102	0.366	1.698
	Pr> |t|	<0.05	NS	NS	NS	NS	<0.05	NS	NS	NS
	Adj. R2	0.004	-0.031	-0.033	-0.035	-0.022	0.089	-0.035	-0.031	0.061
	Pr > F	<0.05	NS	NS	NS	NS	<0.05	NS	NS	NS

Table 2: 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	Tmax & Tmin	Z120	Z121
5	Tmax & Rainfall	Z130	Z131
6	Tmin & Rainfall	Z230	Z231

Conclusion

In seedling stages negative correlation of all four parameters such as maximum, minimum temperature, rainfall and sunshine hours but there is no significant relationship of all parameters. In tillering stages negative relationship significant at 5% level for maximum and minimum temperature has been obtained but rainfall and sunshine hours having positive relationship has been obtained but not significant. During Panicle initiation stage negative relationship of maximum temperature and rainfall has been found but minimum temperature and sunshine are found to have positive relationship but to be are insufficient significant relationship has been found as. In 50% flowering stages maximum temperature and rainfall were significant correlated. It dough stages rainfall is negatively correlated. The highest significant effect of rainfall was observed during 50% flowering. Rainfall at crucial phases of tillering, 50% floweing, milking and maturity stages is helping to meet the crop water requirement which includes maintaining soil moisture status and evapo-transpirational losses. Higher sunshine values at panicle emergence, dough and physiological maturity stages will contribute for higher grain yield production while more values of sunshine during Seedling, tillering, and 50% flowering stage can adversely affect normal functioning. Rice yield forecast for Raipur condition was worked out at post-harvest stages. 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.

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