The Pharma Innovation Journal 2023; 12(4): 2255-2258

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(4): 2255-2258

www.thepharmajournal.com
Received: 13-02-2023
Accepted: 16-03-2023

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Impacts of weather parameters on wheat yield in Chhattisgarh plain region

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Abstract
Studies on "Impacts of weather parameters on wheat yield in Chhattisgarh plain region" was performed in the consider District of C.G. Plain Zone. The effect of three climatic parameters: minimum temperature, maximum temperature and rainfall on crop productivity. Five models such as Linear, Quadratic, Cubic, Compound, Exponential were determined. The Selection criterions are R^2, MAE and RMSR. It was documented that the quadratic model was best fitted model for wheat crop with respect to rainfall, minimum temperature and maximum temperature. When the entire District was considered as a whole i.e., C.G. Plain Region, wheat crop was found minimum temperature had a highly significant effect with yield. These models help farmers in Chhattisgarh to take decisions about their chances for the future and potential course of action. Creating a precise, accurate, and best-fit model for the future forecasting was a very difficult assignment for the researchers. Hopefully, this study's innovative methodology can clear the air and lead to new directions in forecasting.

Keywords: Weather parameters, wheat yield, MAE, RMSR

1. Introduction
The overall changes in different activities related to temperature, rainfall, humidity etc., which together form weather, are called climatic condition. With accordance to change in geographical condition, the climate condition also changes. The climate affects many phenomena and agriculture is depending upon it. Chhattisgarh is a state located in central part of India. 80% of population is engaged in agriculture. 43% of entire arable land is under cultivation. Average rainfall in the state is around 1200 mm confined in the southwest monsoon season i.e., 15 June to September. The precipitation in the state has irregular temporal and spatial distribution. Because of these variations in rainfall, the output of the state's agriculture is affected. The irrigated area in the state is only 16% of the total cultivable area.4.3 million ha location may be irrigated if we nicely harness the floor water towards the trusting irrigation ability of 1.38 million ha.

Wheat (*Triticum aestivum*) is a grass, widely cultivated for its seed, a cereal grain that is a worldwide staple food, belonging to Gramineae family in India. It is a major crop during Rabi season. World's most widely cultured crop occupying 22% cultivated areas (Joshi, 2008). India is second largest producer of wheat in the world after China with about 12% share in total world wheat production. The production level of wheat in India had a quantum jump from 6.46 million tonne from an area of 9.75 million ha in 1950-51 to more than 95.84 million tones from an area of about 30.47 million hectares during 2013-14 (Joshi 2007). In 2020, the total global production of wheat was 760 million tons. China, India, and Russia are the three largest individual wheat producers in the world, accounting for about 41% of the world's total wheat production. Wheat is grown in India over an area of about304.73 lakh ha, with a production of958.49 lakh tones. In Chhattisgarh for wheat crops growing area is 102.8 ha and where production 130.0 million tonne and productivity 1304 kg/ha during the year 2013- 14. Due to the extreme weather variability seen in recent years, huge changes in wheat productivity have been reported. Wheat production is significantly influenced by climatic changes, with climate change and global warming scenarios having a negative impact on wheat output in various parts of the world. Crop productivity should be maintained at a higher level in India to fulfill the future food demands of a rising population. Wheat is a long-day plant that is also thermo-sensitive and photo-insensitive, making it sensitive to temperature, which has an impact on wheat output in India. The onset and end of favorable temperature regimes limit the beginning and end of the wheat crop season, which ultimately influences wheat quality and output.

Moisture and radiation are basic meteorological characteristics that have an impact on agriculture when weather parameters are examined (Reddy, 2016).

2. Methods and Materials

2.1 Study area: District level seasonally weather data over a span of 20 years data period i.e.2000- 2019 for Rainfall, minimum temperature, maximum temperature of 9 district namely; Bilaspur, Dhamtari, Durg, Janjgir, Kawardha, Korba, Mahasamund, Raipur and Rajnandgaon will be collected from various secondary sources for wheat crop (meteorological observatory of Department of Agricultural Meteorology, COA, and Raipur, C.G.).

Yield data of wheat (*Triticum aestivum* L.) crop that are mainly grown in Rabi season will be taken. The yearly data on area, production and yield under wheat crop for the period of 19 years (2000-01to 2018-2019) has been collected from (Department of Agriculture , Chhattisgarh).Yield data will be procured from the published booklets and official website Directorate of Agriculture C.G. and Directorate of Economics & Statistics - Ministry of Agriculture.

2.2 Descriptive Statistics

Descriptive statistics, show, and summarize the basic feature of a dataset found in a given study, presented in a summary that describes the data sample and its measurements. In this study we used mean, standard deviation, maximum, minimum, skewness and kurtosis.

2.3 Growth model

Different regression model such as linear, quadratic, cubic, compound and exponential are fitted for wheat crop with respect to crop yield with different weather parameters of Chhattisgarh plain region.

Table 1: Different Regression model used for developing the best fit model

Model Name	Equation	Eq. No.	Description
Linear	$Y = b_0 + b_1x_1 + e$	(1)	Y and x_1's is yield and weather parameters respectively. b_0 and b_1's are constants to be estimated and e is the residual term.
Quadratic	$Y = b_0 + b_1x_1 + b_2x_1^2 + e$	(2)	Y and x_1's is yield and weather parameters respectively. b_0 , $b_1$and b_2 are constants to be estimated and e is the residual term.
Cubic	$Y = b_0 + b_1x_1 + b_2x_1^2 + b_3x_1^3 + e$	(3)	Y and x_1's is yield and weather parameters respectively. $b_0, b_1, \ldots b_i$are constants to be estimated and e is the residual term.
Compound	$Y = b_0\, x_1^{b_1} + e$ or $\ln(Y) = \ln(b_0) + b_1 \ln(x)$	(4)	Y and x_1's is yield and weather parameters respectively. b_0 and $b_1$are constants to be estimated and ln is Natural Log and e is the residual term
Exponential	$Y = b_0 * \exp^{(b_1x)} * e$	(5)	Y and x_i's is yield and weather parameters respectively. b_0 and $b_1$areconstantsto be estimated, and e is the residual term

2.4 Criteria of Model Selection

2.4.1 Coefficient of determination (R^2)

Coefficient of determination (R^2) for the models shows the closeness of the estimates to the actual value. The potential range of values of this R^2 is well defined with end points corresponding to perfect fit and complete lack of fit, such as $0<R^2<1$, where $R^2 = 1$ corresponds to perfect fit and $R^2 \geq 0$ for any reasonable model specification. Kvalseth (1985) the modified R^2 given as:

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(\hat{y}_i - \bar{y})^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2}$$

Where, $y_i$is the value of the i^{th} observation of y?

$\hat{y}_i$Predicted value of the i^{th} observation of y

$\bar{y}$ Mean value of y value

2.4.2 Root Mean Square Error (RMSE)

The RMSE is defined as the standard deviation of the residuals (prediction errors). Residuals are a measure of how far from the regression line data points are.

$$\text{RMSE} = \sqrt{\frac{\sum(y_i - \hat{y}_i)^2}{n}}$$

Where,

y_i = Actual value for the i^{th} observation

$\hat{y}_i$= predicted value for the i^{th} observation

n = Total no. of observation

2.4.3 Mean Absolute Error (MAE)

The MAE is defined as the arithmetic mean of the positive magnitudes of all the absolute error. Mean absolute error represents the difference between the original and predicted values extracted by averaged the absolute difference over the data set Kotz*et.al.* (2006).

$$\text{MAE} = \frac{\sum|y_i - \hat{y}|}{n}$$

Where $y_i$is the value of the i^{th} observation of y_i

$\hat{y}_i$estimated value of they_i, n is the number of observations

2.5 Correlation

The association among weather parameters and yield components will study with the help of correlation coefficient.

$$r_{xy} = \frac{\text{Cov}(X, Y)}{\sigma_x \cdot \sigma_y}$$

Where,

r_{xy} is the correlation coefficient between yield and weather parameters and

σ_x is a Standard deviation of weather parameter &σ_y Standard deviation of yield.

2.6 Trend

A trend is a pattern found in time series datasets; it is used to de describe if the data is showing an upward r downward movement for part, or all of, the time series. Trend may be

classified into two types:
1 Linear Trend
2 Curvy-Linear Trend or Non-Linear Trend

If one plots the trend values for the time series on a graph paper and if it gives a straight line then it is called a linear trend i.e., in linear trend the rate of change is constant where as in non-linear trend there is varying rate of change.

2.7 Method of Moving average
It consists in measurement of trend by smoothing out the fluctuations of the data by means of a moving average. Moving average of extent (or period) m is a series of successive averages (arithmetic means) of m terms at a time, starting with 1st, 2nd, 3rd term etc. Thus, the first average is the mean of the 1st, m terms; the 2nd is the mean of the m terms from 2nd to (m+1)th term, the third is the mean of the m term from 3rd to (m+2)th term, and so on
It is one of the most popular methods for calculating Long Term Trend. In this method we calculate the Moving Average for certain years.

3. Results and Discussion
3.1 Descriptive statistics for the wheat yield data in C.G. plain region during 2000-2019.
Here, analysis of descriptive statistics of C.G. plain has been carried out to study the basic characteristics of wheat yield data set along with data set of climatic parameters.

Table 2: Descriptive statistics for wheat data along with data set of weather parameters for C.G. plain region

Statistics	Wheat			
	Rainfall (mm)	Max temp (°C)	Min temp (°C)	Productivity (Tonnes/ha)
Mean	0.66	30.49	15.19	1.25
Std.dev	0.48	0.67	0.51	0.28
Maximum	2.22	31.75	16.49	1.76
Minimum	0.13	29.32	14.30	0.84
Skewness	2.08	0.30	0.95	0.22
Kurtosis	6.02	-0.22	1.81	-1.33

However, these descriptive statistics do not provide any evidence of relationship between productivity and changing climate. To build the quantitative justification for weather change during the growing season for wheat crop separately, therefore regression models was taken for three major weather variables such as rainfall, maximum temperature and minimum temperature.

3.2 Model selection using different statistical criteria for predicting wheat yield.
Model selection is a crucial task for predicting crop yield using climatic parameters as independent variables. Here, five different models: linear, Quadratic, cubic, compound and exponential were used to find the best fit model. In these statistical models, coefficient of determination (R^2), Root Mean Square Error **(**RMSE) and Mean Absolute Error (MAE) were determined as the criteria for judging the goodness of fit of the model. The smaller the value of RMSE, and MAE, the better is the model whereas greater the R^2 better is the model.

Table 3: Different statistical models with their R^2, MAE & RMSE for wheat yield with rainfall

District/model		Linear	Quadratic	Cubic	Compound	Exponential
C.G. plain	**R^2**	**0.02**	**0.13**	**0.02**	**0.01**	**0.01**
	MAE	0.29	0.28	0.30	0.29	0.27
	RMSE	0.36	0.34	0.38	0.35	0.37

Table 4: Different statistical models with their R^2, MAE & RMSE for wheat yield with maximum temperature

District/model		Linear	Quadratic	Cubic	Compound	Exponential
C.G. plain	R^2	0.02	0.20	0.20	0.01	0.01
	MAE	0.32	0.21	0.36	0.36	0.34
	RMSE	0.37	0.25	0.45	0.45	0.44

Table 5: Different statistical models with their R^2, MAE & RMSE for wheat yield with minimum temperature

District/model		Linear	Quadratic	Cubic	Compound	Exponential
C.G. plain	R^2	0.03	0.05	0.05	0.04	0.04
	MAE	0.34	0.24	0.34	0.34	0.35
	RMSE	0.43	0.26	0.45	0.45	0.44

Table 3, 4, 5 was depicting R^2, MAS and RMSE of different models fitted for data set of C.G. plain for wheat yield with rainfall, maximum temperature and minimum temperature. Here, highest R^2 was observed in case of Quadratic model for C.G. plain. At least one of MAS and RMSE was minimum was observed in Quadratic model. Hence, among all five models explored for C.G. plain. Quadratic model was best fit for wheat crop with rainfall, maximum temperature and minimum temperature.

3.3 Impacts of weather parameters on crop yield in Chhattisgarh Plain Region.
In this section we have presented the effect of weather parameters on crop productivity by using quadratic model. Here, moving average method has been used to smooth out the crop productivity trend by averaging three preceding values given in the time series data set.

Table 6: Different Variable used in model for weather effect of Wheat in Chhattisgarh Plain Region

Climatic parameters	Coefficient			t-value	p-value	R^2
	b_0	b_1	b_2			
Rainfall	-0.370(0.185)	0.389(0.193)	0.286(0.143)	-0.619	0.545	0.025
Max temp	0.209(0.104)	0.227*(0.113)	0.391(0.195)	1.872	0.051	0.189
Min temp	-0.404(0.202)	0.421(0.210)	0.548**(0.27)	-1.877	0.003	0.190

**Significant at 5% level, *significant at 10% level

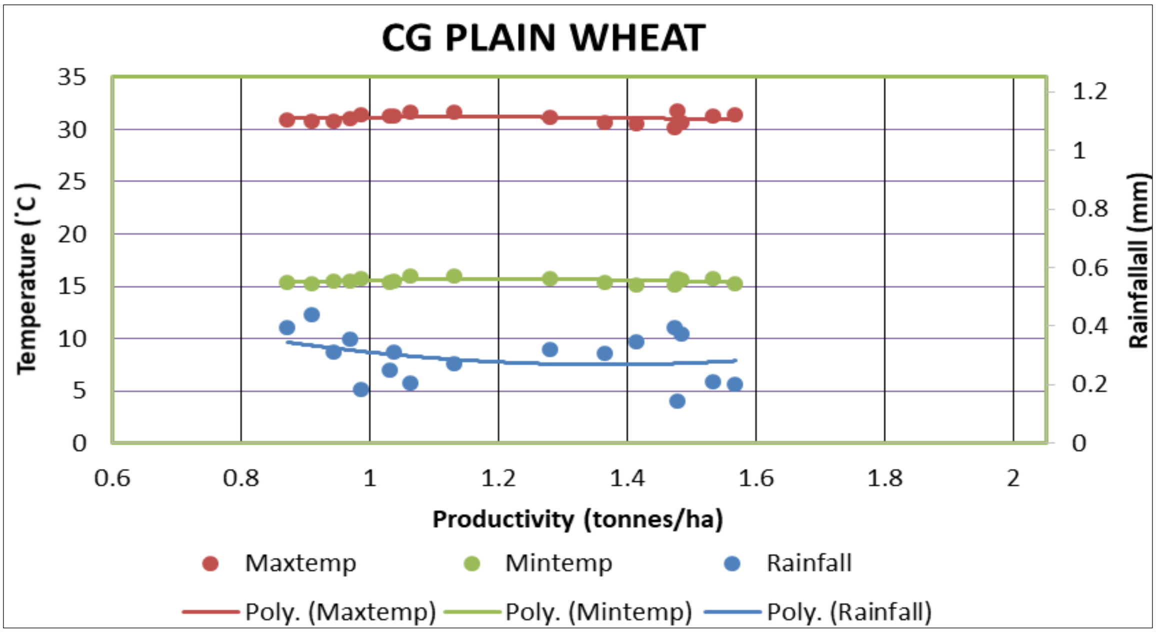

Fig 1: Weather variables v/s wheat productivity in Chhattisgarh Plain Region

3.4 Impacts of weather parameters on Wheat yield in Chhattisgarh Plain Region

Table 6 shows different variables in fitting the model as a result explains the effect of three climatic variables on the wheat yield for C.G. plain region. These indicate that the overall yield was statistically significant and implied that the climate variables were able to explain some of the variation in wheat production. p-values revealed that these two climate variables are highly significant. Both minimum temperature and maximum temperature was statistically significant at 1% and 5% level; thus, this result implies a highly significant contribution of minimum temperature to the wheat yield

Fig 1 depicts the fitted curve for the model. It shows that along with increasing minimum temperature, productivity is also increasing.

4. Conclusion

The objective of this study was to estimate the relationship between wheat yield and weather variables using average moving data. The present study implies that descriptive statistics do not provide any evidence of changing weather. To build the quantitative justification for weather change during the growing season for Wheat crops separately, therefore regression model was selected. On the basis of the highest R-square value and the lowest MAE and RMSE value with respect to rainfall, maximum temperature & minimum temperature, it was discovered that the quadratic model was the best fitted model for Wheat yield. In C.G. Plain Region, wheat (*Rabi*) was found highly Significant for minimum temperature which means that as minimum temperature increases yield and rainfall was found non-significant effect for wheat yield.

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