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# Crop weather relationship and studies on the effect of weather fluctuations on rice production in Raipur district

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**Abstract**
The present investigation **"**Crop Weather Relationship and Studies on the effect of weather fluctuations on rice production in Raipur district" was conducted at the Department of Agricultural Meteorology, College of Agriculture, Raipur (Chhattisgarh). The state-level statistics project a strong increasing trend in rice acreage, production and productivity. The rice area, production and productivity are increasing annually by 24,000 ha, 263,000 metric tonnes and 44 kg $ha^{-1}$ respectively. Correlation analysis has been worked out between grain yield and weather variables at various growth stages of rice for MTU-1010 variety. Only P-III (Panicle initiation to heading/emergence) stage was found to have significant results. Rainfall revealed significant negative correlation and maximum temperature, diurnal temperature range and bright sunshine hours revealed significant positive correlation with grain yield. The phenophase-wise thresholds and optimum weather range of individual weather variables responsible for above average (high), average (optimum) and below average (low) yields were analysed for zonal check MTU-1010 variety of rice. Multiple linear regression model was developed to predict the grain yield of rice at P-III stages of crop growth. The model only explained about 21.3% of the variability in the yield by linear functions during panicle initiation to heading/emergence stage. This suggests that other factors not included in the model have a significant impact on the final yield leading to differences between predicted and actual values.

**Keywords:** Fluctuation, temperature, rainfall, rice yield, correlation, regression, relationship

## Introduction
Rice (*Oryza sativa*) is the major food crop in the world. Nearly 40% of the world population consumes rice as the major staple food. The major weather parameters affecting growth and yield include solar radiation, temperature and rainfall. Temperature, solar radiation and rainfall are important weather factors that influence rice yield directly by affecting the physiological processes involved in grain production and indirectly through their effect on diseases and insect-pests (Kenneth and Kriemhild, 2000) [5].

The effect of weather parameters at different stages of crop growth may help in understanding their response in term of final yield (Pandey *et al.* 2015) [7]. Rainfall is an important factor that needs serious attention as Indian agriculture is drastically affected due to inconsistency and distribution of this factor. These components of rainfall are affected due to climate change in rainfed agriculture. Rainfall is a single most important factor for success of crops in the farming areas (Dore, 2005) [2]. Indian agriculture continues to be a gamble of the vagaries of monsoon, rainfall being most critical because nearly 70% of the net sown area is still rain dependent (Kumar *et al.*, 2022) [6].

Temperature is one of the key meteorological factors affecting the growth and yield of crops. Several studies on climate change have indicated an increasing trend in temperature which may significantly affect cropping system and production of livestock (Hingane *et al.*1985) [3]. Global temperature has increased by 0.3-0.6°C since the late 19th century and by 0.2-0.3°C over last 40 years.

## Methodology

Study was conducted at the Department of Agricultural meteorology, College of Agriculture, Raipur, during 2024-25. Analysis of the weather fluctuation and optimum weather range in Raipur district was carried out through standard methods and procedure. This included a correlation, regression and trend analysis of the area, production and productivity of rice crop in the different zones of Chhattisgarh state and in entire Chhattisgarh state over 23 years (2000-01 to 2022-23). The study relied on experimental data and secondary data. Experimental data on rice phenology, grain yield, etc., were collected from the AICRP on Agrometeorology, Department of Agricultural Meteorology, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya Raipur and secondary data from Directorate of Economics and Statistics Department of Agriculture, Cooperation and Farmers Welfare Ministry, Govt. of India and employed linear regression for trend analysis. Weather data was collected from Department of Agricultural Meteorology Indira Gandhi Krishi Vishwavidyalaya, Raipur.

## Results and Discussion

### Trend of Area, Production and productivity of rice crop for different Argo-climatic zones of Chhattisgarh state and the state as a whole (2000-01 to 2022-23)

Trend analysis calculated with respect to area, production and productivity for all agroclimatic zones of Chhattisgarh state for a duration of 23 years (2000-01 to 2022-23). The rice crop (area, production, and productivity) in Chhattisgarh Plains observed highly significant increasing trend in area, production and productivity at 1% level of significance. In Bastar Plateau rice crop was found to have increasing trend in the area and production at 1% level of significance and productivity was found increasing at 5% level of significance. In Northern Hills, rice crop was found to have increasing trend in the area at 5% level of significance and productivity and production was found increasing at 1% level of significance. Chhattisgarh state observed highly significant increasing trend in area, production and productivity at 1% level of significance.

**Table 1:** Trend of area, production and productivity of rice crop for different agroclimatic zone and Chhattisgarh state (2000-01 to 2022-23)

| Agroclimatic zones/state | Area (thousand ha) | | Production (thousand tonnes) | | Productivity (kg ha$^{-1}$) | |
|---|---|---|---|---|---|---|
| | Equation | R2 | Equation | R2 | Equation | R2 |
| Chhattisgarh Plains | y =20.98x+2530.1 | 0.847** | y = 212.89x + 2075.5 | 0.742** | y =62.56x+875.61 | 0.707** |
| Bastar Plateau | y =2.78x+611.89 | 0.735** | y =28.38x+634.15 | 0.366** | y =29.98x+1115.5 | 0.223* |
| Northern Hills | y =0.547x+555.97 | 0.177* | y =21.77x+463.22 | 0.549** | y =39.75x+819.77 | 0.557** |
| Chhattisgarh state | y =24.31x+3698 | 0.837** | y = 263.03x+3172.9 | 0.695** | y =44.08x+936.96 | 0.536** |

S**=1% level of significance, S*=5% level of significance, Degrees of freedom (df) = (n-1)= 22: Critical values of r are: r (1%) =0.515, r (5%) =0.404.

### Fluctuation of weather parameters and its effect on rice yield:

This study investigated the impact of fluctuations in maximum temperature (Tmax), minimum temperature (Tmin), Diurnal temperature range, rainfall and Bright Sunshine Hours (BSS) on rice yield for MTU-1010 variety in transplanted irrigated condition to determine the optimum weather ranges for maximizing rice production in Raipur district over the period from 2001 to 2023 across the three growing environments ($D_1$, $D_2$, and $D_3$). The data showed a fluctuation rice yield ranging from 1157 kg ha$^{-1}$ to 5760 kg ha$^{-1}$.

**Table 2:** Fluctuation of maximum temperature, minimum temperature, diurnal temperature range, rainfall and Bright Sunshine Hours (BSS) on rice yield (2007 to 2023) for MTU 1010 variety

| Year | | Yield (kg ha$^{-1}$) | MAXT(°C) | MINT(°C) | DTR | RF (mm) | SS (hr) |
|---|---|---|---|---|---|---|---|
| 2007 | $D_1$ | 5403 | 30.8 | 24.7 | 6.1 | 1334.4 | 3.4 |
| | $D_2$ | 5181 | 30.7 | 24.3 | 6.5 | 1116.8 | 3.9 |
| | $D_3$ | 4633 | 30.8 | 23.6 | 7.2 | 658.0 | 4.5 |
| 2008 | $D_1$ | 4311 | 31.3 | 24.4 | 6.9 | 735.2 | 3.8 |
| | $D_2$ | 4207 | 31.2 | 24.2 | 7.0 | 587.0 | 4.4 |
| | $D_3$ | 3830 | 31.2 | 23.5 | 7.7 | 559.2 | 4.9 |
| 2009 | $D_1$ | 4116 | 32.2 | 25.6 | 6.6 | 1131.3 | 4.1 |
| | $D_2$ | 4284 | 31.4 | 24.9 | 6.5 | 1130.5 | 4.5 |
| | $D_3$ | 4200 | 31.3 | 24.1 | 7.2 | 990.2 | 5.0 |
| 2010 | $D_1$ | 4789 | 32.1 | 25.4 | 6.6 | 1068.8 | 4.4 |
| | $D_2$ | 4167 | 31.5 | 25.2 | 6.3 | 991.6 | 4.7 |
| | $D_3$ | 3163 | 31.3 | 25.0 | 6.4 | 986.8 | 5.0 |
| 2011 | $D_1$ | 3796 | 31.2 | 24.7 | 6.5 | 1264.5 | 4.0 |
| | $D_2$ | 3339 | 30.9 | 24.5 | 6.4 | 1209.7 | 4.1 |
| | $D_3$ | 3253 | 31.0 | 24.2 | 6.7 | 1183.2 | 4.5 |
| 2012 | $D_1$ | 3339 | 31.0 | 25.0 | 6.1 | 1593.5 | 3.2 |
| | $D_2$ | 3159 | 30.5 | 24.7 | 5.8 | 1500.5 | 3.5 |
| | $D_3$ | 3611 | 30.4 | 24.3 | 6.1 | 1373.5 | 4.0 |
| 2013 | $D_1$ | 3172 | 30.5 | 24.6 | 5.9 | 1365.3 | 3.4 |
| | $D_2$ | 4058 | 30.3 | 24.5 | 5.8 | 1320.7 | 3.3 |
| | $D_3$ | 4020 | 30.3 | 24.2 | 6.1 | 1241.9 | 3.7 |
| 2014 | $D_1$ | 3194 | 32.2 | 24.9 | 7.3 | 1038.6 | 3.8 |
| | $D_2$ | 3805 | 31.9 | 24.7 | 7.1 | 1009.6 | 3.8 |
| | $D_3$ | 3655 | 31.2 | 24.1 | 7.1 | 1029.4 | 4.1 |
| 2015 | $D_1$ | 2372 | 32.9 | 25.5 | 7.4 | 931.8 | 4.3 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | $D_2$ | 4003 | 32.1 | 25.2 | 6.9 | 872.8 | 4.4 |
| | $D_3$ | 4366 | 32.9 | 25.5 | 7.4 | 931.6 | 4.4 |
| 2016 | D1 | 2647 | 32.8 | 25.7 | 7.1 | 1009.4 | 4.1 |
| | D2 | 4873 | 31.4 | 25.2 | 6.2 | 1162.6 | 3.6 |
| | D3 | 3773 | 30.9 | 24.5 | 6.3 | 1086.6 | 3.8 |
| 2017 | D1 | 5280 | 33.3 | 25.6 | 7.6 | 711.8 | 4.1 |
| | D2 | 5760 | 32.3 | 25.3 | 7.0 | 715.8 | 4.0 |
| | D3 | 3990 | 31.9 | 25.0 | 6.8 | 593.0 | 4.1 |
| 2018 | D1 | 3380 | 32.3 | 25.2 | 7.0 | 1114.5 | 3.5 |
| | D2 | 4050 | 31.8 | 25.0 | 6.8 | 1016.3 | 3.7 |
| | D3 | 4340 | 31.3 | 24.4 | 6.8 | 973.0 | 3.6 |
| 2019 | D1 | 1425 | 33.5 | 25.9 | 7.6 | 1040.0 | 4.0 |
| | D2 | 3233 | 32.2 | 25.3 | 6.9 | 1034.6 | 3.9 |
| | D3 | 3498 | 31.2 | 24.8 | 6.4 | 1045.8 | 3.7 |
| 2020 | D1 | 1674 | 32.6 | 25.5 | 7.1 | 1074.3 | 3.7 |
| | D2 | 4199 | 32.1 | 25.5 | 6.6 | 959.7 | 3.4 |
| | D3 | 3827 | 32.1 | 25.3 | 6.8 | 796.5 | 3.9 |
| 2021 | D1 | 3574 | 32.5 | 25.4 | 7.2 | 1047.6 | 3.8 |
| | D2 | 4199 | 32.1 | 25.1 | 7.0 | 900.8 | 3.9 |
| | D3 | 3827 | 32.1 | 24.9 | 7.3 | 817.0 | 4.5 |
| 2022 | D1 | 2482 | 33.4 | 25.4 | 8.0 | 1024.0 | 4.2 |
| | D2 | 3593 | 32.1 | 25.0 | 7.0 | 1033.8 | 3.9 |
| | D3 | 2955 | 31.5 | 24.8 | 6.8 | 1041.4 | 4.1 |
| 2023 | D1 | 1157 | 33.7 | 25.7 | 8.0 | 1565.8 | 4.4 |
| | D2 | 3307 | 32.5 | 25.3 | 7.1 | 1564.6 | 4.1 |
| | D3 | 3223 | 32.1 | 24.9 | 7.2 | 1339.4 | 4.5 |
| r value | | | -0.385** | -0.305* | -0.302* | -0.340* | -0.044 |
| p value | | | 0.0005 | 0.029 | 0.031 | 0.014 | 0.760 |

**: significant at 1% level, *: significant at 5% level

The maximum temperature fluctuated between 30.3 °C to 33.7 °C, while the minimum temperature ranged from 23.5 °C to 25.9 °C. diurnal temperature range fluctuated between 5.8 °C to 8.0 °C. Rainfall during the study period varied significantly with a minimum of 559.2 mm to a maximum of 1593.5 mm. The Bright Sunshine Hours (BSS) fluctuated between 3.2 hr to 5.0 hr. The relationship was analyzed between crop yield and fluctuation in weather parameters (Table 2).

The study revealed that on pooled data analysis, maximum temperature exhibited the strongest negative correlation (-0.385**) with grain yield which is statistically significant at 1% ($p < 0.01$) level of significance and minimum temperature exhibited strong negative correlation (-0.305*) with grain yield which is statistically significant at 5% ($p < 0.05$) level of significance (Table 2). This suggest that increased temperature during the crop growth period tends to reduce yield. High temperature reduces the length of panicle initiation and grain filling and increases respiratory loss. The negative correlation with DTR (-0.302*) indicates that a wider difference between day and night temperatures adversely affects grain yield and p value ($p < 0.05$) indicates it is statistically significant at 5% level of significant. Rainfall exhibited a strong and significant negative correlation (-0.340*) with grain yield and p value ($p < 0.05$) indicates it is statistically significant at 5% level of significance. This is due to the fact that the experiment was grown under transplanted irrigated condition and already water requirement of rice crop was satisfied through irrigation.

**Correlation of weather parameters and rice yield for different growth stages of rice crop for MTU-1010 variety (2007 - 2023)**

Correlation analysis worked out between grain yield and weather variables at various growth stages of rice based on 17 years data (2007-2023) revealed the differential effect of various weather parameters during different growth stages on rice yield. Only P-III (Panicle initiation to heading/emergence) stage was found to have significant results. Rainfall exhibited significant negative correlation with grain yield during the P-III stage (-0.426*) This is due to the fact that the experiment was grown under transplanted irrigated condition and already water requirement of rice crop was satisfied. Maximum temperature exhibited a highly significant positive correlation with grain yield during P-III stage (0.366*). Likewise, similarly Diurnal Temperature Range (DTR) showed highly significant positive correlation with grain yield during P-III stage (0.367*), Bright Sunshine Hour (BSS) exhibited a highly significant positive correlation with grain yield during the P-III stage (0.397*) (Table 3).

**Table 3:** Correlation coefficients between grain yield and weather parameters during different pheno-phases of rice for MTU-1010 variety

| | Stages | Tmax(°C) | Tmin(°C) | DTR (°C) | RF (mm) | BSS (hr) |
|---|---|---|---|---|---|---|
| P-I | Transplanting to maximum tillering | -0.122 | 0.063 | -0.188 | -0.228 | -0.036 |
| P-II | Maximum tillering to panicle initiation | -0.091 | -0.071 | -0.066 | -0.218 | -0.004 |
| P-III | Panicle initiation to heading/ emergence | 0.366* | 0.169 | 0.367* | -0.426* | 0.397* |
| P-IV | Heading/ emergence to 50% flowering | 0.134 | 0.013 | 0.147 | 0.152 | 0.026 |
| P-V | 50% flowering to beginning of grain filling | 0.037 | -0.052 | 0.076 | 0.142 | -0.034 |
| P-VI | Beginning of grain filling to end of grain filling | -0.125 | -0.167 | 0.065 | 0.245 | 0.095 |
| P-VII | End of grain filling to maturity | -0.029 | -0.157 | 0.148 | -0.169 | 0.161 |

*: significant at 5% level

**Threshold weather parameters values significant for higher rice yield under Raipur district for MTU-1010 variety**

The phenophase-wise thresholds of individual weather variables responsible for above average (high), average (optimum) and below average (low) yields were identified for MTU-1010 variety (Table 4). Maximum temperatures threshold worked out for below average yield was 30.4 °C during P-III stage. The diurnal temperature range of 5.5 °C or below, Rainfall of 195.2 mm or more and BSS of 3.0 hours or below in P-III stage are the thresholds for obtaining below average grain yield <2984 kg ha$^{-1}$. Maximum temperature below 31.7 °C during P-III stage caused reduction in grain yield below 4694 kg ha$^{-1}$. During P-III stage, maximum temperature greater than 31.7 °C.The Diurnal Temperature Range (DTR) of above 6.4 °C, rainfall lower than 96.9 mm, sunshine hours greater than 4.6 hrs are favourable threshold weather conditions for attaining above average grain yield >4694 kg ha$^{-1}$. A decrease in maximum temperature from 31.7 °C in P-III stage reduced rice yield from the highest level of > 4694 kg ha$^{-1}$ to the lowest level of < 2984 kg ha$^{-1.}$

**Table 4:** Average threshold values of significant weather parameters during P-III (panicle initiation to heading/emergence) stage of rice for realization of different yield levels for MTU-1010 variety

| Yield levels (kg ha$^{-1}$) | Growth stage | Weather parameters | | | |
|---|---|---|---|---|---|
| | | $T_{max}$ (°C) | DTR (°C) | RF (mm) | BSS hour |
| Below<2984(kg ha$^{-1}$) | P-III | 30.4 | 5.5 | 195.2 | 3.0 |
| Normal 3839(kg ha$^{-1}$) | P-III | 31.0 | 6.1 | 155.5 | 3.9 |
| Above >4694(kg ha$^{-1}$) | P-III | 31.7 | 6.4 | 96.9 | 4.6 |

**Note:** P-III (panicle initiation to heading/emergence stage)

**Optimum weather range significant for higher rice yield under Raipur district for MTU-1010 variety**

The regression equations involving p value < 0.05 being significant at 5% level of significance. To obtain optimum weather range, mean and standard deviation of different parameters at P-III stage was calculated. Subtraction of mean and standard deviation was done for lower value while sum of mean and standard deviation for higher value. For maximum temperature, bright sun shine hour, rainfall and diurnal temperatures range only P-III (panicle initiation to heading/emergence) stage was found to have significant relationship ($p$ < 0.05 * 5% significant level) and other stages were found to have non-significant relationship. optimum range of significant weather parameters for MTU-1010 variety derived during P-III stage of rice for different yield levels (Table 5).

For below-average yield level (< 2984 kg ha$^{-1}$), maximum temperature ($T_{max}$) varied between 28.9 to 32.0 °C, Diurnal Temperature Range (DTR) was 4.1 to 7.0 °C, rainfall (RF) varied between 31.9 to 358.6 mm and Bright Sunshine Hours (BSS) varied from 1.0 to 4.9 hr. For normal yield level (2984 to 4694 kg ha$^{-1}$), maximum temperature ($T_{max}$) varied between 29.8 to 32.2 °C, DTR was 5.2 to 7.1 °C, rainfall was 49.8 to 261.1 mm and BSS was 2.4 to 5.4 hr. for higher or above-average yield level (> 4694 kg ha$^{-1}$), maximum temperature ($T_{max}$) varied between 30.7 to 32.7 °C, DTR varied between 5.8 to 7.0 °C, rainfall varied between 35.4 to 158.4 mm and BSS varied between 3.5 to 5.7 hr.

According to Bal *et al.* (2023) [1] In Raipur (central India), P-III and P-IV stages were the most thermal sensitive stages to Tmax and Tmin, respectively. P-II followed by P-III were identified as most sensitive stages to the availability of BSS. Rainfall had significant impact on grain yield at major growth stages. Unlike other places, relative humidity registered significant impact on all growth stages except P-I stage.

**Table 5:** Optimum range of significant weather parameters during P-III (panicle initiation to heading/emergence) stages of rice for different yield levels of MTU-1010 variety

| Yield levels (kg ha$^{-1}$) | Growth stage | Weather parameters | | | |
|---|---|---|---|---|---|
| | | $T_{max}$ (°C) | DTR (°C) | RF (mm) | BSS hours |
| Below <2984 (kg ha$^{-1}$) | P-III | 28.8-32.1 | 4.0-7.1 | 13.6-440.6 | 1.0-5.5 |
| Normal 2984-4694 (kg ha$^{-1}$) | P-III | 28.5-33.6 | 4.2-8.3 | 7.2-440.6 | 1.0-6.8 |
| Above >4694 (kg ha$^{-1}$) | P-III | 30.1-32.5 | 5.3-7.1 | 26.4-181.0 | 3.1-6.2 |

**Note:** P-III (panicle initiation to heading/emergence stage)

**Development of prediction equation**

Multiple linear regression model was developed to predict the grain yield of rice at different stages of crop growth, with grain yield as the dependent variable and weather parameters occurring at various growth phases as independent variables (Table 6), the model based on weather data during the P-III (panicle initiation to heading/emergence) stage exhibited $R^2$ value of 0.213** The model explains about 21.3% of the variability in the yield only by linear functions during panicle initiation to heading/emergence stage. This suggests that other factors not included in the model have a significant impact on the final yield (e.g., soil nutrients, pest incidence, specific farming practices), leading to differences between predicted and actual values.

**Table 6:** Regression equations for predicting grain yield based on weather parameters during P-III (panicle initiation to heading/emergence) growth stage of the rice crop

| Growth phase | | Regression equations | $R^2$ |
|---|---|---|---|
| P-III | Panicle initiation to heading or emergence | $Y=3532.32-3.8X_1+65.58X_2-2.22X_3+93.23X_4$ | 0.213** |

**Note:** Y= Grain yield of rice (kg ha$^{-1}$), $X_1$ =Maximum temperature(°C), $X_2$ =Diurnal temperature range (°C), $X_3$ = Rainfall (mm), $X_4$ = BSS (hours)

**Conclusion**

The state-level statistics project a strong increasing trend in rice acreage, production and productivity. The rice area, production and productivity are increasing annually by around 24,000 ha, 2,63,000 metric tonnes and 44 kg ha$^{-1}$, respectively. The study highlights the importance of optimum weather parameters,

particularly temperature, rainfall and bright sunshine hours. These parameters are found significant during P-III (panicle initiation to heading/emergence) growth stage of rice for MTU-1010 variety. Understanding the precise weather threshold values and optimum range has been carried out. Development of predictive models also facilitates forecasting of yield outcome based on weather conditions to facilitate strategic planning and decision-making in rice cultivation under Raipur agro-climatic conditions.

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