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Effect of increased temperature sensitivity study on yield for cv. Swarna of rice over Khordha region

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Abstract
In order to determine the impact of climate change, namely the temperature, on the production of the swarna rice variety, the study was carried out in the Khordha district of Odisha between 2014 and 2019. DSSAT CERES-Rice crop simulation model's weather modification window was mostly used to experiment with temperature adjustments for the crop's anthesis stage (60-90 DAP), specifically variations in maximum and average temperatures of (0.5 - 4.0 °C) and (0.5 - 3.0 °C), respectively. The experiment was performed three times and set up as a split plot design. The findings demonstrated that when temperature increased over the threshold limit, the yield decreased. Only the first planting date exhibited a significant interaction between the highest and average temperature with grain yield and the other two dates of sowing showed no significant interaction.

Keywords: Swarna, CERES-Rice model, climate change, yield, temperature

1. Introduction
The most common cereal grain used by the majority of people in the globe, particularly in Asia, is rice. One of the top states in India for the production of rice is Odisha. Around 4.47% of India's rice is produced in Odisha. Although though rice makes up nearly 2/3 of Odisha's total planted land and accounts for 7.6 quintals per hectare of production. Rice is grown over an area of 136.8 Ha with a yield of 806 Kg/hectare in the Khordha district of Orissa, which is part of the North-Eastern Ghats and has a geographical area of 2888 sq km. In Odisha, the Khordha district makes up 2.79% of the total rice area. Swarna is a mid-early and medium maturity duration cultivar that is very stable, produces well under low nitrogen levels, and has dormancy in the seeds.

The Decision Support System for Agrotechnology Transfer (DSSAT) is a collection of software tools for modelling the growth of agricultural crops. Around 42 different crop simulation models are included in the DSSAT software suite. Crop growth, development, and yield are simulated using DSSAT models as a result of soil-plant-atmosphere-management dynamics. Daily meteorological data, information on the surface and profile of the soil, precise crop management, and crop genetic data are all inputs needed by the crop models. Many applications, ranging from on-farm and precision management to regional analyses of the influence of climatic variability and climate change, have made use of DSSAT and its crop simulation models.

Rice should be grown at a temperature of between 25 and 35 °C. Any additional rise in mean temperatures during vulnerable times may significantly lower rice yieldsThe temperature increase brought on by climate change in tropical areas is likely close to or over the range of temperatures where rice can function physiologically (Baker *et al*. 1992) [2]. In temperate regions, rice growth is impressed by limited period that favours its growth (Reyes *et al.*, 2003) [9]. Increasing trend of daily maximum temperature may decrease the rice spikelet fertility, which affects for reduction of the yield while the increasing trend of atmospheric CO_2 concentration could increase the rice yield (Dharmarathna *et al.*, 2012) [4]. High temperatures might cause infertility and lower grain yields and harvest indices.

2. Materials and Methods
2.1 Study Area
Odisha's Khordha district has been chosen as the research region. Khordha is situated at 20.180N and 85.620E; the district's latitude and longitude are respectively 20.1662379 and

85.6919708. It is typically 75 metres above sea level (246ft). The district covers an area of 28888 square kilometres (1115 square miles). Its maximum and minimum average temperatures are 41.40 °C and 9.50 °C, respectively, with a mean annual rainfall of 1443mm. Alfisols soil category was used to describe the soils of the Khordha district. 195,731 hectares of land might be used for growing rice, compared to the 122,183.38 ha that is now under cultivation. As a result, there was a chance that Khordha district may have additional land accessible for rice farming.

2.2 Ceres-rice Model

The growth and development of cereal crops under various weather, soil, and management conditions may be simulated by the process-based, dynamic, and mechanistic CERES model. The various processes that this model simulates include the crop's phenological development, the growth of its leaves, stems, and roots, the accumulation and distribution of biomass among those components—leaves, stems, panicles, grains, and roots as well as the soil's water balance and the crop's use of it. It also models the crop's uptake of soil nitrogen. This model is running under the DSSAT include the CERES (Crop Estimation through Resource and Environment Synthesis) for model cereal such as, rice, wheat, maize, sorghum, pearl millet etc.

The meteorological data, soil data, crop management data, and some other necessary study area data have been gathered from reports, websites, IMD, and research papers during a period of around 6 years (2014-2019). Required weather parameters like maximum temperature, minimum temperature, rainfall and solar radiation data taken from NASA POWER website (https://power.larc.nasa.gov/data-access-viewer/) from the year 2014-2019. We obtained the Khordha district's layer-by-layer soil data (0–80 cm) from IMD in New Delhi. It contains a wide range of soil characteristics, including soil type, soil classification, slope %, runoff curve number, pH, bulk density, clay and sand percentage, etc.

Table 1(a): General Information provided for Soil file in DSSAT

Soil classification	Alfisols
Color	Red
Runoff potential	Moderately low
Fertility factor	1
Slope	1
Runoff curve no	84
Soil texture	clay loam
Drainage type	surface furrows

2.3 Crop management data:

Data on crop management needed for DSSAT input from 2014 to 2019 was obtained from IMD. The model was calibrated using the data before being validated. It includes every piece of information from the beginning of field work through the harvesting of the whole rice crop in the Khordha area. The rice crop will be planted on June 18, July 18, and August 18 for the first, second, and third growing seasons, respectively, to evaluate the impact of the weather on the crop.

Table 1(b): Crop Management Data used in DSSAT.

Particulars	Swarna 1st DOS	Swarna 2nd dos	Swarna 3RD DOS
Planting date	17/06/2014	17/07/2014	17/08/2014
Planting method	Transplants	Transplants	Transplants
Plant population at seedling	110	108	111
Plant population at emergence	105	104	105
Row spacing	20	20	20
Plants per hill	3	2	3

Swarna is a semi-dwarf rice variety that is mid-early and medium in maturity and has a crop length of 145–150 DAS. It yields 4.5–5.5 t/ha at low nitrogen levels, has dormant seeds, and is a highly reliable variety.

2.4 Genetic coefficient

These factors are essential because they have a significant impact on how the crop's growth and development are simulated. The CERES-Rice model employs eight genetic coefficients, namely P1, P2O, P2R, P5, G1, G2, G3, and G4. The eight coefficients for the swarna cultivar were gathered from IMD in New Delhi. The genetic coefficients for the cv. swarna are shown in Table 1(c) below as follows:

Table 1(c): Genetic coefficients of swarna rice variety

VARIETY	P1	P2R	P5	P2O	G1	G2	G3	G4
Swarna	740	115	330.0	11.0	68	0.0213	1	1

2.5 Methodology

The swarna rice variety, which is particularly popular in the khordha district of Odisha was taken. In order to compare the impact of the maximum temperature and average temperature on the yield and its parameters for the years 2014 to 2019, the average simulated yield and its parameters are used as the control.

Environmental modification: It is a component of the DSSAT crop simulation model that aids in modifying or altering the meteorological parameters in accordance with the needs of the research. We may modify on different time period or date with the aid of environmental modification such as solar radiation, maximum temperature, lowest temperature, rainfall, CO_2 concentration, and humidity. The crop simulation model has increased the maximum temperature during the anthesis phase (60-90 DAP) from 0.5 - 4.0 ºC and the average temperature from 0.5 – 3.0ºC in order to see how temperature affects crops in the current study.

Significance test: The most popular correlation statistic is the Pearson correlation, and this study will use the IBM SPSS statistics package to find trends with significance levels of 0.05 and 0.01 (indicating 5% and 1% risk, respectively). Linear regression analysis, which is frequently used in climate research to measure the degree of relationship between linearly related variables, will also be used in this study.

3. Results and Discussion

Around the time of anthesis, rice crops are more temperaturesensitive. We thus conducted an examination of grain yield at three dates of planting, which is mentioned below in the table, in order to see the impact of temperature on crop output. When yield and temperature are compared, it becomes evident that, beyond a certain point, the yield is declining as the temperature rises. Similar results were obtained by Ray M. *et al.*, (2018) [8], which have reported that Increase in maximum and minimum temperatures beyond optimum temperatures for rice production led to a decrease in yield and minimum temperature changes had more profound negative impacts as compared to maximum temperature changes.

According to the study, a rise in both the maximum and lowest temperature has an impact on grain output. Similarly in Bangladesh, the impact of climate change on high yield rice varieties was studied by Karim *et al.*, (1994) [6], using the CERES rice model and several scenarios and sensitivity analysis. In the majority of dry regions, it was discovered that high temperatures decreased rice yields in all seasons. Yet only the first date of sowing exhibits relevance when we do regression analysis for the yield of three sowing dates with maximum and average temperatures. Similar results have been reported by D. Rajalakshmi *et al.*, (2015) [3], that the maximum and minimum temperatures are projected to increase, while all other parameters indicated no consistent trend at the end of the century. Under both the CO_2 enhanced and control settings, a decline in rice output is anticipated. Similarly Wheeler *et al.*, (2000) [12], studies have also shown that even a few days of temperatures over a threshold can drastically lower yield and yield characteristics by interfering with later reproductive processes if they occur during anthesis.

Table 1(d): Model output of maximum temperature with yield for different date of sowing of cv. Swarna

Temperature (°C)	D1		D2		D3	
	Yield (kg/ha)	Percent change %	Yield (kg/ha)	Percent change %	Yield (kg/ha)	Percent change %
Ctrl	3250.6		2907.1		3063.5	
Tmax+0.5	3205.8	-1.38	2917.6	0.36	3085.5	0.72
Tmax+1.0	3225.1	-0.78	2929.3	0.76	3104.5	1.34
Tmax+1.5	3237.8	-0.39	2878.3	-0.99	3119.8	1.84
Tmax+2.0	3203.6	-1.45	2893.3	-0.47	3152	2.89
Tmax+2.5	3142.5	-3.33	2992.5	2.94	3060.8	-0.09
Tmax+3.0	3123.8	-3.90	2990	2.85	3092.5	0.95
Tmax+3.5	3095.6	-4.77	2924.6	0.60	3221.3	5.15
Tmax+4.0	3058.1	-5.92	2932.1	0.86	3122.3	1.92

(Tmax = Maximum temperature in ^{o}C)

Table 1(e): Model output of average temperature with yield different date of sowing of cv. Swarna

Temperature (°C)	D1		D2		D3	
	Yield (kg/ha)	Percent change %	Yield (kg/ha)	Percent change %	Yield (kg/ha)	Percent change %
Ctrl	3250.6		2907.1		3063.5	
Tavg+0.5	3127.8	-3.78	2912.1	0.17	3110.1	1.52
Tavg+1.0	3133.5	-3.60	2853.6	-1.84	3197.6	4.38
Tavg+1.5	3055.3	-6.01	2844.5	-2.15	3051.1	-0.40
Tavg+2.0	3000.8	-7.68	2790.1	-4.02	2947.8	-3.78
Tavg+2.5	3038	-6.54	2821.8	-2.93	2950.5	-3.69
Tavg+3.0	3012.1	-7.34	2781	-4.34	2949.8	-3.71

(Tavg = Average temperature in °C)

Table 1(f): Regression analysis of maximum temperature & average temperature with grain yield

Temperature	Grain yield		
	D1	D2	D3
Tmax	R = 0.311 Sig = 0.022* Y= -40.988x +4495.595	NS	NS
Tavg	R = 0.419 Sig = 0.006** Y= -70.988x + 5188.499	NS	NS

(Tmax = Maximum temperatue, Tavg = Average temperature, R= Coefficient of correlation, * = 5% level of significance & ** = 1% level of significance, NS = Non-significant)

4. Summary and Conclusion

Three dates when the Swarna variety of rice was sown in the Khordha district of Odisha, the impact of temperature on yield has been examined. The results of the analyses indicated that the yield rises to a certain point and then tends to fall with temperature. When regression analyses were conducted using SPSS, the significance for the first date of sowing was revealed, even though the yield for the remaining dates of sowing the second and third was in a trend of falling yield but there was no significance. For three dates of sowing of the swarna rice variety, the degrees of significance, regression coefficient, and regression equation are displayed in the table 1(f) below. Consequently, to increase rice output with cv. Swarna, it is essential to select the best planting date, have a thorough awareness of the current weather and need for regular surveillance.

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