ISSN: 2394-1391

*Original Article*

Indian Journal of Biology
Volume 10 Number 1/January - June 2023
DOI: http://dx.doi.org/10.21088/ijb.2394.1391.10123.2

# Sensitivity Analysis of Yield Parameters to Elevated Temperatures in DSSAT V4.7.5 Simulation Model For CV. Swarna of Rice Over Khordha Region of Odisha

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**How to cite this article:**
Chinmaya Kumar Sahu, Naveen Kumar Bini et. al./Sensitivity Analysis of Yield Parameters to Elevated Temperatures in DSSAT V4.7.5 Simulation Model For CV. Swarna of Rice Over Khordha Region of Odisha/Indian J Biol 2022; 10(1): 17–23.

**Abstract**

The study was conducted in Khordha district of Odisha during kharif season of 2014-2019, to see the effect of climate change especially of temperature onyield, LAI and yield attributes of swarna rice variety. Mainly changes in maximum and average temperature i.e (0.5 – 4.0°C) and (0.5 – 3.0°C) respectively through weather modification window of DSSAT CERES Rice cropsimulation model were tried for the anthesis stage (60-90 DAP) of the crop. The experiment was laid out as a split plot design and replicated three times. The results showed that the yield was decreasing with respect to increasing in temperature after threshold limit. The interaction of maximum & average temperature with grain yield was significant only for 1st date of sowing andthe rest 2nd & 3rd date of sowing showed non significant. The leaf area index (LAI) interactionwith maximum and average temperature did not show significant for only 2nd date of sowing but in case of 1st and 3rd date of sowing it showe dsignificant. Like wise, the interaction of physiological maturity days with average temperature showed significant for all three date of sowing, though the comparision between maximum temperature and physiological maturity days showed decreasing order but there was no significant relation. The other two yield attributes like number of panicles/$m^2$ and harvest index also showed decreasing order while interaction with maximum & average temperature but there was not significant.

**Keywords:** Dssatceres-Ricemodel; Climate change; Swarna; Yield; Yield Attributes; Sowing Date; Tempearture; Anthesis.

## Introduction

Rice as a cereal grain, it is most widely consumed staple food for a large part of the world's human population, especially in Asia. Odisha is one of the premier Rice producing state in India. Odisha produces about 4.47% of rice in India. Although about 2/3rd of total cropped area of Odisha is devoted to rice, and the total production is about 7.6 quintals/hectare. The Khordha district of Orissa comes under the North-Eastern ghats, has the geographical area of 2888 sqkm, where the Rice is cultivated under the area of 136.8 Ha with the production of 110.3 tonnes and yield of 806Kg/hectare. Khordha district contributes to 2.79% of total Rice area in Odisha. Swarna is the Mid early & medium maturity duration, which yields better under low nitrogen levels, possess seed dormancy and it is the highly stable variety.

The Decision Support System for Agrotechnology Transfer (DSSAT) is a set of computer programs for simulating agricultural

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**Received date:** 26.11.2022

**Accepted date:** 28.12.2022

crop growth. The DSSAT software package comprises crop simulation models for over 42 crops. DSSAT models simulate growth, development, and yield of crops as a function of soil plant atmosphere management dynamics. The crop models require daily weather data, soil surface and profile information, detailed crop management and crop genetic information as input. DSSAT and its crop simulation models have been used for many applications ranging from on farm and precision management to regional assessments of impact of climate variability and climate change.

The optimum temperature for rice cultivation is between 25°C and 35°C. Any further increase in mean temperatures during sensitive stages may reduce rice yields drastically. In tropical regions, the temperature increase due to the climate change is probably near or above the optimum temperature range for the physiological activities of rice (Baker et al. 1992). Intemperate Regions, rice growth is impressed by limited period that favours its growth (Reyes et al. 2003). 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). High temperatures would induce sterility and lead to low harvest index and grain yield.

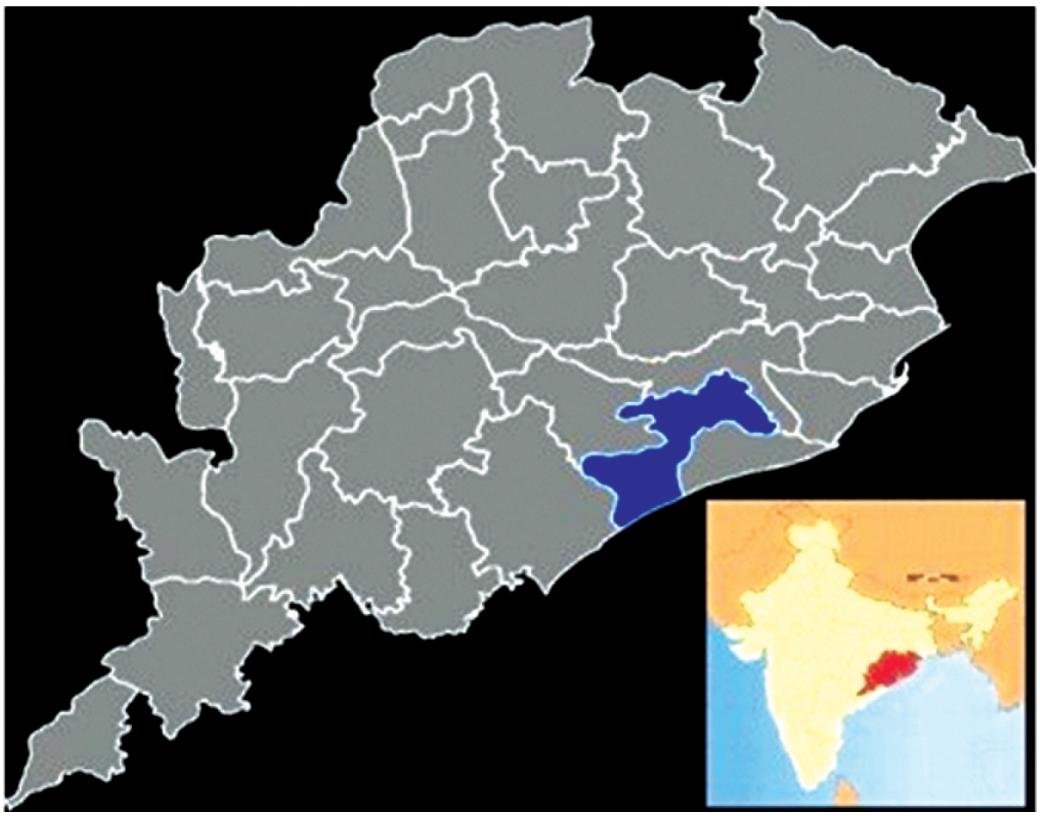

**Fig. 1:** Study area

## Materials and Methods

Study Area: Khordha district of Odisha is selected as study area. Khordha is located at 20.18°N and 85.62°E, and the latitude and longitude of the district is 20. 1662379 and 85.6919708 respectively. It has an average elevation of 75m (246 ft). Area of the district is 28888 square kilometres (1115 square miles). It has the average temperatures of 41.4°C (Max) and 9.5°C (Min). and mean annual rainfall of 1443mm. The soils of Khordha district are classified under the Alfisols, Inceptisols, and Entisols. The amount of land suitable for rice cropping was 195,731 ha against the currently cultivated land of 122, 183.38 ha. Therefore, there was a possibility of more amount of land that could be available for rice cultivation in Khordha district.

### *Ceres-Rice Model*

CERES is a process based, dynamic and mechanistic model which can simulate the growth and development of cereal crops under varying weather, soil and management levels. The various processes simulated by this model are phenological development of the crop; growth of leaves, stems and roots; biomass accumulation and partitioning among leaves, stem, panicle, grains and roots; soil water balance and water use by the crop; and soil nitrogen transformations and up take by the crop. 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, pearlmillet etc.

The weather data, soil data, and crop management data of about 6 years (2014-2019) and some required data of study area has been collected from the reports, websites, IMD and also by referring the research paper. 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. Layer wise soil data (0 – 80 cm) for Khordha district was taken from IMD, New Delhi. It includes so many soil parameters soil type, soil classification, slope

**Table 1:** General Information provided for Soil file in DSSAT.

| Soil Classification | Alfisols |
|---|---|
| Color | Red |
| Runoff potential | Moderately low |
| Fertilit yfactor | 1 |
| Slope | 1 |
| Runoff curveno | 84 |
| Soil texture | Clayloam |
| Drain age type | Surface furrows |

percentage, runoff curve number, pH, bulk density, clay & sand percentage etc.

**Crop management data:** Crop management data which is required for DSSAT input from 2014-2019 taken from IMD. The data was used first calibration and then validation of the model. It consists of all the data from starting of field operation to harvest in gover rice crop in Khordha region. Planting Date of The Rice Crop For 1 St DOS, 2nd dos and 3 dos is 18 june, 18 july and 18 august respectively to study the climatic effect on crop.

Swarna is the Mid-early & medium maturity duration, semi-dwarfrice variety with the crop duration of 145-150 DAS which yields 4.5-5.5 t/ha under low nitrogen levels, possess seed dormancy and it is the highly stable variety.

### *Genetic Coefficient*

These coefficients are crucial because they strongly influence the simulation of growth and development of the crop. The CERES-Rice model uses eight genetic coefficients viz., P1, P2O, P2R, P5, G1, G2, G3 and G4. The eight coefficients for the cultivar swarna are collected from IMD, New Delhi. The genetic coefficients for the cv. swarna are shown in Table 2 below as follows:

**Table 2:** Genetic Coefficient 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 |

## Methodology

Area as khordha district of odisha and swarna rice variety which is very popular in that region was taken. The average simulated yield and its parameters is taken as control and it is compare with the effect of maximum temperature and average temperature on the yield and its parameters for the year of 2014-2019.

**Environmental modification:** It is the part of DSSAT crop simulation model which help to modify or change the weather parameters as per requirements of the study. With the help of environmental modification solar radiation, maximum temperature, minimum temperature, rainfall, $CO_2$ concentration and humidity we can change on different time period or date. For the present study to see the effect of temperature on crop, there is increase in the maximum temperature from 0.5 - 4.0°C and average temperature from 0.5 –3.0°C during anthesis period (60-90 DAP) in the crop simulation model.

**Significance test:** The Pearson correlation is the most widely used correlation statistic and linear regression analysis is used to measure the degree of the relationship between linearly related variables which is widely used in climate research, will be employed in this study to find out significance

level of 0.05 and 0.01 (indicates 5% and 1% risk respectively) trends with the help of IBMSPSS statistics package.

## Result and Discussion

Rice crop is more sensitive to temperature at anthesis period. So, to see the temperature effect on crop yield and its parameters, we did an analysis of grain yield, leaf area index at maturity, harvest index, maturity days and panicle number at three date of sowing which is listed below intable. The comparision between yield and temperature shows that the yield is decreasing with respect to increasing in temperature after certain limit. Similar results were obtained by Ray M. et al. (2018), which have reported that Increase in maximum and minimum temperatures beyond optimum temperatures forrice production led to a decrease in yield and minimum temperature changes had more profound negative impacts as compared to maximum temperature changes. The study revealed that increase in both maximum and minimum temperatures affects the grain yield. Similarly in Bangladesh, the impact of climate change on high yield rice varieties was studied by Karim et al. (1994), using the CERES rice model and several scenarios and sensitivity analysis. It was found that high temperatures reduced rice yields in all seasons in mostarid locations. But when we make regression analysis for the yield of three date of sowing with maximum and average temperature, only first date of sowing shows significance effect. Similar results have been reported by D. Rajalakshmi et al. (2015), that the maximum and minimum temperatures are projected to increase, while all other parameters indicated no consistent trend at the end of the century. The yield of rice is projected to decrease for both control and $CO_2$ enriched conditions. Likewise there also found significance between maximum temperature, average temperature and leaf area index (LAI) for first and third date of sowing. In the case of physiological maturity days with temperature it is found that the increase in maximum and average temperature results in decreasing the physiological maturity of the crop. By the regression analysis it is found that, there is only significance between average temperature with maturity days for three date of sowing. Number of panicles and harvest index also shows decreasing or draw it increases temperature. Though the set woparameters are showing decreasing trend line but there is no such significance seen. Similarly Wheeler et al. (2000), studies have also shown that even a few days of temperature above threshold value, if coincident with anthesis, can significantly reduce yield & yield attributes, through affecting subsequent reproductive processes.

**Table 3:** Model output of maximum temperature with yield, leaf area index, number of panicle, days to physiological maturity and harvest index for different date of sowing of cv. Swarna.

| Temp. (°C) | Yield(kg/ha) | | | Leaf Area Index | | | Number of Panicle (no./m²) | | | Days to Physiological Maturity (DAP) | | | Harvest Index(%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D1 | D2 | D3 | D1 | D2 | D3 | D1 | D2 | D3 | D1 | D2 | D3 | D1 | D2 | D3 |
| Ctrl | 3250.6 | 2907.1 | 3063.5 | 2.88 | 3.1 | 3.21 | 1055 | 1056 | 1056 | 96 | 94 | 98 | 39.6 | 34.8 | 30.5 |
| Tmax+0.5 | 3205.8 | 2917.6 | 3085.5 | 2.86 | 3.1 | 3.26 | 1059 | 1056 | 1054 | 96 | 94 | 97 | 39.7 | 35.0 | 31.0 |
| Tmax+1.0 | 3225.1 | 2929.3 | 3104.5 | 2.83 | 3.1 | 3.18 | 1060 | 1056 | 1053 | 95 | 94 | 98 | 40.2 | 35.1 | 30.9 |
| Tmax+1.5 | 3237.8 | 2878.3 | 3119.8 | 2.83 | 3.1 | 3.25 | 1059 | 1057 | 1056 | 95 | 93 | 95 | 40.5 | 34.5 | 32.5 |
| Tmax+2.0 | 3203.6 | 2893.3 | 3152 | 2.83 | 3.1 | 3.2 | 1058 | 1057 | 1054 | 95 | 93 | 98 | 40.3 | 34.8 | 31.2 |
| Tmax+2.5 | 3142.5 | 2992.5 | 3060.8 | 2.78 | 3.08 | 3.25 | 1056 | 1058 | 1054 | 95 | 93 | 97 | 39.4 | 36.0 | 30.8 |
| Tmax+3.0 | 3123.8 | 2990 | 3092.5 | 2.78 | 3.08 | 3.26 | 1056 | 1059 | 1061 | 95 | 93 | 97 | 39.4 | 36 | 31 |
| Tmax+3.5 | 3095.6 | 2924.6 | 3221.3 | 2.76 | 3.06 | 3.23 | 1056 | 1060 | 1053 | 95 | 93 | 98 | 39.2 | 36.1 | 31.7 |
| Tmax+4.0 | 3058.1 | 2932.1 | 3122.3 | 2.76 | 3.06 | 3.21 | 1055 | 1060 | 1055 | 95 | 93 | 94 | 38.9 | 36.4 | 32.5 |

(Tmax= Maximum temperature in°C)

**Table 4:** Model output of average temperature with yield, leaf area index, number of panicle, days to physiological maturity and harvest index for different date of sowing of cv. Swarna.

| Temp. | Yield (kg/ha) | | | Leaf Area Index | | | Number of Panicle (no./m$^2$) | | | Days to Physiological Maturity (DAP) | | | Harvest Index (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D1 | D2 | D3 | D1 | D2 | D3 | D1 | D2 | D3 | D1 | D2 | D3 | D1 | D2 | D3 |
| Ctrl | 3250.6 | 2907.1 | 3063.5 | 2.88 | 3.1 | 3.21 | 1055 | 1056 | 1056 | 96 | 94 | 98 | 39.6 | 34.8 | 30.5 |
| Tavg+0.5 | 3127.8 | 2912.1 | 3110.1 | 2.8 | 3.1 | 3.18 | 1057 | 1057 | 1053 | 95 | 93 | 98 | 38.9 | 34.8 | 31 |
| Tavg+1.0 | 3133.5 | 2853.6 | 3197.6 | 2.76 | 3.08 | 3.23 | 1056 | 1060 | 1053 | 95 | 93 | 98 | 39.3 | 34.6 | 31.6 |
| Tavg+1.5 | 3055.3 | 2844.5 | 3051.1 | 2.75 | 3 | 3.23 | 1056 | 1057 | 1057 | 95 | 92 | 94 | 38.9 | 35.7 | 31.8 |
| Tavg+2.0 | 3000.8 | 2790.1 | 2947.8 | 2.63 | 2.95 | 3.25 | 1059 | 1060 | 1057 | 94 | 92 | 93 | 39.3 | 35.6 | 32.1 |
| Tavg+2.5 | 3038 | 2821.8 | 2950.5 | 2.65 | 3.05 | 3.26 | 1058 | 1061 | 1059 | 94 | 92 | 92 | 39.9 | 35.9 | 32.1 |
| Tavg+3.0 | 3012.1 | 2781 | 2949.8 | 2.65 | 3.05 | 3.26 | 1057 | 1060 | 1059 | 94 | 91 | 92 | 39.8 | 35.8 | 32.4 |

(Tavg = Average Temperature In°C)

## *Summary and conclusion*

Temperature effect on yield and yield parameters has been analysed for 3 date of sowing of Swarna variety of Rice over Khordha district of Odisha. The analyses showed that the yield increases upto certain points and then tends to decrease with temperature and when the regression analyses was done with SPSS, the significance for 1st date of sowing has been shown, though the yield for rest 2$^{nd}$ and 3$^{rd}$ date of sowing is in decreasing trend but there was no significance. By Analyzing the data of Leaf area index with changing weather for anthesis stage of crop using SPSS software for significance test, the results are presented in the table 5 showed that the 1$^{st}$ and 3$^{rd}$ date of sowing were significant. The physiological Maturity Days was also analysed and the relation between the average temperature and Maturity Days of all 1$^{st}$, 2$^{nd}$, and 3$^{rd}$ date of sowing was shown significance. The other yield attributes like number of panicles (per m$^2$) & harvest index (%) was also in decreasing trend with increasing temperature but the reisno such significance seen. The table 5 listed below shows the levels of significance, regression coefficient and regression equation for three date of sowing of swarnarice variety. Therefore to improve rice production with cv. swarna, always the optimum planting date should be used, proper understanding of the prevailing weather conditions and regular monitoring is necessary.

**Table 5:** Regression analysis of maximum temperature, average temperature withgrain yield, leaf area index and physiological maturity.

| Temp | Grain yield | | | Leaf area index | | | Physiological maturity | | |
|---|---|---|---|---|---|---|---|---|---|
| | D1 | D2 | D3 | D1 | D2 | D3 | D1 | D2 | D3 |
| Tmax | R = 0.311Sig = 0.022* Y = - 40.988x 4495.595 | NS | NS | R = 0.335Sig = 0.013* Y = -0.031x 3.816 | NS | R = 0.277Sig = 0.042* Y = 0.024x + 2.515 | NS | NS | NS |
| Tavg | R = 0.419 Sig = 0.006** Y = -70.988x + 5188.499 | NS | NS | R = 0.406 Sig = 0.008** Y = -0.079x + 5.082 | NS | R = 0.346Sig = 0.025* Y = 0.031x + 2.438 | R = -0.484 Sig = 0.001** Y = -0.552x + 111.460 | R = -0.338Sig = 0.028* Y = -0.507x + 107.479 | R = -0.587 Sig = 0.00** Y = -1.834x + 142.520 |

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

## Acknowledgements

Iam thankful to Dr. K.K. Singh, Head, Agromet, Dr. A.K. Baxla and Mrs. Mehnaj Tharranum of IMD for their support, guidance and Dr. Biswarup Mehera, Dr. Shweta Gautam of SHUATS, Prayagraj for their immense support.

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