

**SIMULATION AND CALIBRATION OF DSSAT MODEL FOR
RICE CROP AT RAIPUR WEATHER CONDITION**

M.Sc. (Ag.) Thesis

by

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**DEPARTMENT OF AGROMETEOROLOGY
COLLEGE OF AGRICULTURE
INDIRA GANDHI KRISHI VISHWAVIDYALAY
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**SIMULATION AND CALIBRATION OF DSSAT MODEL FOR
RICE CROP AT RAIPUR WEATHER CONDITION**

Thesis

Submitted to the

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by

MUKESH PRADHAN

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FOR THE DEGREE OF**

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in

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CERTIFICATE – I

This is to certify that the thesis entitled “**Simulation and Calibration of DSSAT model for rice crop at Raipur weather condition**” submitted in partial fulfilment of the requirements for the degree of **Master of Science in Agriculture** of the Indira Gandhi Krishi Vishwavidyalaya, Raipur, is a record of the bonafide research work carried out by **Mukesh Pradhan** under my/our guidance and supervision. The subject of the thesis has been approved by the Student’s Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma or certificate course. All the assistance and help received during the course of the investigations have been duly acknowledged.


23/9/24

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Chairman

Date: 23/9/24

THESIS APPROVED BY THE STUDENT’S ADVISORY COMMITTEE

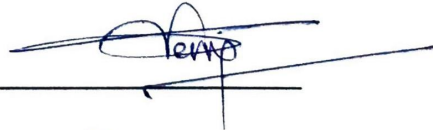
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CERTIFICATE – II

This is to certify that the thesis entitled “**Simulation and Calibration of DSSAT model for rice crop at Raipur weather condition**” submitted by **Mukesh Pradhan** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur, in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture** in the **Department of Agrometeorology** has been approved by the external evaluator and Student’s Advisory Committee after oral examination, under the chairmanship of head of the Department/Dean (in case of out campii).

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MUKESH PRADHAN

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LIST OF ABBREVIATIONS/SYMBOLS

%	percent
/	per
mm	Millimeter
cm	Centimetre
kg	kilogram
°C	degree Celsius
°F	degree Fahrenheit
ha	Hectare
q	Quintal
Fig	Figure
g	Gram
&	And
@	at the rate
i.e.	that is
<i>viz.</i>	Namely
.	
Obs.	Observed
Sim.	Simulated
WTH	Weather file
FILEX	Experimental file

THESIS ABSTRACT

- a) Title of the Thesis : “Simulation and Calibration of DSSAT model
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- b) Full Name of the student : Mukesh Pradhan
- c) Major Subject : Agrometeorology
- d) Name and Address of the
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Department of Agrometeorology,
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- e) Degree to be awarded : M.Sc. (Ag.) Agrometeorology



Signature of the Student



Signature of the Major Advisor

Date: 23/9/21



Signature of Head of the Department

ABSTRACT

The present study was conducted at Department of Agrometeorology, IGKV, Raipur to assess the simulation and calibration of DSSAT model for rice crop at Raipur weather condition. Three varieties i.e. MTU-1010, Rajeswari and CG Sugandhit Bhog with 3 dates of transplanting (1st July, 15th July and 30th July) consisting 9 treatments repeated three times in Randomized Block Design. The historical field crop data of year 2017 and 2018 was used for calibration and its validation was made from field crop data of the year 2019. The Genetic coefficients of variety MTU1010 is P1=541, P2O=246, P2R=146, P5=12, G1=49, G2=0.250, G3=1 and G4= 1, for Rajeswari P1=522, P2O=447, P2R=142, P5=11.7, G1=55, G2=0.257, G3=1 and G4= 1 and for CG Sugandhit Bhog P1=741, P2O=320, P2R=148, P5=11.4,

G1=51,G2= 0.250,G3=1 and G4= 1. It was found that model calibrated for Variety MTU1010 and the value of R^2 , RMSE & D-index for panicle initiation was found 0.75 & 0.89, 1.33 & 2.16 and 0.86 & 0.77 in the year 2017 and 2018 respectively. Similarly, the value for anthesis was 0.84 & 0.98, 1.29 & 2.70 and 0.89 & 0.65 in 2017 and 2018 respectively. At maturity the value of R^2 was 0.85 in both the year i.e. 2017 and 2018, while RMSE value was 2.16 & 4.08 and D-index value 0.75 & 0.54 in 2017 and 2018 respectively. For grain yield, R^2 value was 0.18 & 0.09, RMSE value was 204.0 to 398.7 and D-index value was 0.22 & 0.19 in the year 2017 and 2018 respectively.

In variety Rajeswari the value of R^2 , RMSE & D -index for Panicle initiation was found 0.95 & 0.93, 3.37 & 0.82 and 0.68 & 0.90 in the year 2017 and 2018, respectively. Similarly, the value of anthesis was 0.88 & 1, 3.11 & 6.0 and 0.67 & 0.39 in 2017 & 2018 respectively. At maturity the value of R^2 was 0.95 & 0.62, RMSE was 2.16 & 5.80 and D-index was 0.88 & 0.47 in the year 2017 and 2018 respectively. For grain yield, R^2 value was 0.76 to 0.01, RMSE value was 249.1 & 375.9 and D-index value was 0.34 and 0.29 in the year 2017 & 2018 respectively.

In variety CG Sugandhit Bhog the value of R^2 , RMSE & D-index for panicle initiation was found 1.0 & 0.48, 1.0 & 1.82 and 0.96 & 0.72 in the year 2017 & 2018 respectively. Similarly, at anthesis value of R^2 was of 0.99 in both the year 2017 & 2018 while RMSE value was 5.35 & 7.68, D-index value was 0.58 & 0.26 in 2017 and 2018 respectively. For maturity R^2 value was 0.43 & 0.71, RMSE value was 4.66 & 3.11 and D-index value was 0.48 & 0.46 in 2017 & 2018 respectively. For grain yield, R^2 value was 0.74 & 1.0, RMSE value was 295.4 & 333.6 and D-index was 0.49 & 0.77 in the year 2017 & 2018 respectively.

To validate CERES-Rice model, the crop data of year 2019 was used for different phenophases. In cv. MTU1010, the R^2 value, RMSE value & D-index value with respect to panicle initiation was 0.99, 3.16 & 0.66 respectively. For anthesis the value was 0.99, 3.16 & 0.71, for maturity the value was 0.42, 2.08 and 0.60 and for grain yield was 0.09, 303.7 and 0.34 respectively.

In cv. Rajeswari the R^2 value, RMSE value & D-index value calculated for panicle initiation was 0.99, 1.41 & 0.81. For anthesis it was 0.64, 2.58 and 0.70, for maturity it was 0.95, 3.78 and 0.53 and for grain yield was 0.94, 214.4 and 0.87 respectively.

In cv. CG Sugandhit Bhog the R^2 value, RMSE value & D-index value calculated for panicle initiation were 0.83, 2.11 and 0.69. For anthesis it was 1.0, 5.20 and 0.55, for maturity was 0.82, 3.37 and 0.13 and for grain yield it was 0.38, 538.9 and 0.36 respectively. The predicted days to panicle initiation, anthesis and physiological maturity and yield were found in reasonable agreement with the observed value. The percent error between simulated and observed for all the parameters were found below $\pm 10\%$ except in case of CG Sugandhit Bhog during validation it was overestimated but within the acceptable limit. The early and late transplanting dates resulted in lower yields as compared to optimum transplanting date of 15th July.

Based on simulation for production potential of three varieties under three date of transplanting in Raipur districts of Chhattisgarh, it was observed that the duration from anthesis and maturity periods varied considerably in all the varieties under different transplanting dates. Duration from transplanting to maturity was more in 1st date of transplanting as compared to delayed transplanting. Highest yield 4392 kg /ha was recorded in CG Sugandhit Bhog at Raipur district under D2 (15th July) and lowest 2667 kg/ha was observed in MTU1010 under third date of transplanting in Raipur district.

Result of sensitivity analysis indicates that cv. MTU1010 transplanted on 2nd date responded well with decrease of minimum temperature by 0.5°C & produced 8.5 percent more rice yield over base yield. Decreased of only minimum temperature by 0.5°C the cv. Rajeswari transplanted on 2nd date responded well & gave increased grain yield of rise by 4.0 percent over base yield. The cv. CG Sugandhit Bhog transplanted on 3rd date responded well with increased of maximum and minimum temperature by 1°C & produced 7.7 percent more rice yield over base yield in Chhattisgarh plain zone.

Key words: Rice, Simulation model, Yield, Calibration, Validation

शोध ग्रंथ सारांश


- (अ) शोध का शीर्षक : “रायपुर मौसम की स्थिति में धान की फसल के लिए DSSAT मॉडल का अनुकरण एवं अंशांकन”
- (ब) विद्यार्थी का पूरा नाम : मुकेश प्रधान
- (स) प्रमुख विषय : कृषि मौसम विज्ञान
- (द) प्रमुख सलाहकार का नाम व पता : डॉ. जी.के. दास, (प्रोफेसर और प्रमुख) कृषि मौसम विज्ञान विभाग, कृषि महाविद्यालय, रायपुर. (छ.ग.)
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23/9/21

मुख्य सलाहकार के हस्ताक्षर


छात्र के हस्ताक्षर

दिनांक : 23/9/21


विभाग प्रमुख के हस्ताक्षर

सारांश

वर्तमान अध्ययन “रायपुर मौसम की स्थिति में धान की फसल के लिए DSSAT मॉडल का अनुकरण एवं अंशांकन” कृषि मौसम विज्ञान विभाग, इंदिरा गांधी कृषि विश्वविद्यालय, रायपुर (छत्तीसगढ़) में वर्ष 2019–20 में किया गया। यह परीक्षण 3 किस्मों (एम.टी.यू.- 1010, राजेश्वरी और सी. जी. सुगंधित भोग) व रोपाई की 3 तारीखों (1 जूलाई, 15 जूलाई और 30 जूलाई) के साथ आर.बी.डी. (रैंडमाइज्ड ब्लॉक डिजाइन) में तीन बार दोहराया गया था। वर्ष 2017 और 2018 के ऐतिहासिक फसल क्षेत्र आंकड़ा का उपयोग अंशांकन के लिए किया गया था। प्रमाणीकरण वर्ष 2019 में लिए गए आंकड़ों के आधार पर किया गया। एम.टी.यू.-1010 के लिए अनुवांशिक गुणांक $P1 = 541$, $P2O = 246$, $P2R = 146$, $P5 = 12$, $G1 = 49$, $G2 = 0.250$, $G3 = 1$ और $G4 = 1$, राजेश्वरी के लिए $P1 = 522$, $P2O = 447$, $P2R = 142$, $P5 = 11.7$, $G1 = 55$, $G2 = 0.257$, $G3 = 1$ और $G4 = 1$, सी.जी. सुगंधित भोग के लिए $P1 = 741$, $P2O = 320$, $P2R = 148$, $P5 = 11.4$, $G1 = 51$, $G2 = 0.250$, $G3 = 1$ और $G4 = 1$ निर्धारित किया गया। एम.टी.यू.-1010 के लिए

मॉडल का अंशांकन R^2 , RMSE और D– index के आधार पर किया गया । पुष्पगुच्छ अवस्था में वर्ष 2017 और 2018 में R^2 , RMSE और D– index का मान क्रमशः 0.75 & 0.89, 1.33 & 2.16 और 0.86 & 0.77 पाया गया। इसी तरह वर्ष 2017 और 2018 में परागोद्भव अवस्था के लिए मान क्रमशः 0.84 & 0.98, 1.29 & 2.70 और 0.89 & 0.65 था। परिपक्वता अवस्था पर R^2 का मान वर्ष 2017 और 2018 दोनों में 0.85 था जबकि RMSE मान क्रमशः 2.16 & 4.08 और D– index का मान 0.75 और 0.54 वर्ष 2017 व 2018 में पाया गया। अनाज की पैदावार के लिए R^2 का मान 0.09 & 0.18, RMSE का मान 204.0 & 398.7 और D– index का मान 0.22 और 0.19 वर्ष 2017 व 2018 में दर्ज किया गया।

राजेश्वरी किस्म कि पुष्पगुच्छ अवस्था में R^2 , RMSE और D– index वर्ष 2017 और 2018 में 0.95 & 0.93, 3.37 & 0.82 और 0.68 & 0.90 पाया गया। इसी तरह वर्ष 2017 और 2018 में परागोद्भव अवस्था के लिए मान क्रमशः 0.88 & 1, 3.11 & 6.0 और 0.67 & 0.39 था। परिपक्वता अवस्था पर R^2 का मान 0.95 & 0.62 RMSE मान 2.16 & 5.80 और D– index का मान 0.88 और 0.47 क्रमशः वर्ष 2017 व 2018 को दर्ज किया गया। अनाज की पैदावार के लिए R^2 का मान 0.01 & 0.76, RMSE का मान 249.1 & 375.9 और D– index का मान 0.34 और 0.29 वर्ष 2017 व 2018 में पाया गया।

सी.जी. सुगंधित भोग किस्म कि पुष्पगुच्छ अवस्था में R^2 , RMSE और D – index वर्ष 2017 और 2018 में क्रमशः 1 & 0.48, 1 & 1.82 और 0.96 & 0.72 पाई गई। इसी तरह परागोद्भव अवस्था पर R^2 का मान 0.85 वर्ष 2017 और 2018 में था जबकि RMSE मान क्रमशः 5.35 & 7.68 और D–index का मान 0.58 और 0.26 दर्ज किया गया। परिपक्वता अवस्था पर R^2 का मान 0.43 & 0.09 RMSE मान 4.66 & 3.11 और D– index का मान 0.48 और 0.46 क्रमशः वर्ष 2017 व 2018 में पाया गया। अनाज की पैदावार के लिए R^2 का मान 0.74 & 1, RMSE का मान 295.4 & 333.6 और D– index का मान 0.49 और 0.77 वर्ष 2017 व 2018 में देखा गया।

CERES धान मॉडल को प्रमाणित करने के लिए वर्ष 2019 के फसल आंकड़ा का उपयोग विभिन्न घटना प्रावस्था के लिए किया गया था। एम.टी.यू-1010 किस्म में R^2 का मान 0.99, RMSE मान 3.16 और D– index का मान 0.66 पुष्पगुच्छ के संबंध में पाया गया। परागोद्भव अवस्था के लिए मूल्य 0.99, 3.16 और 0.71 परिपक्वता के लिए मूल्य 0.42, 2.08 और 0.60 और अनाज की पैदावार के लिए क्रमशः 0.09, 303.7 और 0.34 पाया गया।

राजेश्वरी किस्म में पुष्पगुच्छ अवस्था में R^2 का मान 0.99, RMSE का मान 1.41 और D – index का मान 0.81 दर्ज किया गया। परागोद्भव के लिए यह 0.64, 2.58 और 0.70 पाया गया। परिपक्वता के लिए 0.95, 3.78 और 0.58 और अनाज की पैदावार के लिए क्रमशः 0.94, 214.7 और 0.87 पाया गया।

इसी तरह सी.जी. सुगंधित भोग किस्म में पुष्पगुच्छ अवस्था में R^2 का मान 0.83, RMSE का मान 2.11 और D – index का मान 0.69 पाया गया। परागोद्भव अवस्था के लिए यह 1, 5.20 और 0.55 दर्ज किया गया। परिपक्वता के लिए क्रमशः 0.82, 3.37 और 0.13 और अनाज की पैदावार के लिए क्रमशः 0.38, 538.9 और 0.36 पाया गया। अनुरूपण और अवलोकन के बीच उचित समझौते में भविष्यवाणी पुष्पगुच्छ अवस्था, परागोद्भव अवस्था, शारीरिक परिपक्वता दिन और उपज पाए गए। सभी मापदण्डों के लिए अनुमान और अनुरूपता के बीच त्रुटि प्रतिशत 10% के नीचे पाई गई जबकि स्वीकार्य सीमा के भीतर सीजी सुगंधित भोग के मामलों में सत्यापन के दौरान अधिक पाया गया था। रायपुर में धान की रोपाई के लिए उपर्युक्त दिनांक 15 जूलाई पाया गया क्योंकि 15 जूलाई की रोपाई पर सबसे अधिक उत्पादन प्राप्त हुआ है। 15 जूलाई से जल्दी (1 जूलाई) व देर (30 जूलाई) से रोपाई करने पर इसकी उत्पादकता कम दर्ज की गई।

संवेदनशीलता विश्लेषण का परिणाम यह इंगित करता है कि छत्तीसगढ़ की मैदानी क्षेत्र में न्यूनतम तापमान में 0.5 डिग्री सेल्सियस कम होने पर एम.टी.यू-1010 की 15 जूलाई की तारीख में रोपाई होने पर 8.5 प्रतिशत की वृद्धि पाई गई। केवल न्यूनतम में तापमान में 0.5 डिग्री सेल्सियस कम होने पर राजेश्वरी की 15 जूलाई की तारीख में रोपाई होने पर 4.0 प्रतिशत की वृद्धि दर्ज की गई। अधिकतम और न्यूनतम तापमान में 1 डिग्री सेल्सियस बढ़ने पर सीजी सुगंधित भोग किस्म की 30 जूलाई की तारीख में रोपाई होने पर उपज में 7.7 प्रतिशत की वृद्धि पाई गई।

मुख्य बिन्दु :- धान, उपज, अनुकरण, अंशाकन

CHEPTER-I

INTRODUCTION

Rice is one of the most important food grains produced and consumed all over the world. Similarly, Two thirds of the world's population is living in Asia where rice is the prime source of daily food. More than 70 per cent of the rural households depend on agriculture and allied sectors which provide employment to over 60% of the population. The world's total rice area is 167.2 M ha and production is about 769.6 MT with the productivity of 4.6 t ha⁻¹. Among rice growing countries, India has the largest area and is second in production next to China, where it is grown in an area of 43.7 M ha annually with a production and productivity of 168 MT and 3.8 t ha⁻¹ respectively (FAOSTAT, 2017) and it accounts for 45% of food grain production in the country.

In India rice is grown in 43.86 million ha, area with the production level of 104.80 million tons and the productivity is about 2390 kg/ha (Anon 2015). This crop is the backbone of livelihood for millions of rural household and play vital role in the country food security. Agriculture is an important part of the Indian economy, accounting for roughly 17% of the total GDP.

Chhattisgarh, popularly known as “Rice Bowl of Central India” and the state has about 3.7 million ha under the rice cultivation out of which 70 % is under rainfed condition, covering both upland and shallow lowland. The average productivity of rice in the state is 20.5 q /ha (Anon 2017). The major area of the state belongs to Dry sub-humid climate. The southwest monsoon is the main source of rainfall in the state during kharif-season. The state's average annual rainfall is around 1188 mm and irrigation facility is only about 36% of cropped area during kharif that too protective in nature.

Rice crops are better suited to a wider range of climatic conditions than any other single crop of cereal. As such, from lowlands, floodplains, and deltas to hills and mountains, cultivated lands exist. Rice is vulnerable to change in weather and its cultivation continues to be a risky enterprise under unfavorable environment, despite of advances made in rice production technologies. Rice production is affected by sets of various environmental parameters, including genetic

characteristics of crop, soil properties, weather conditions and cultivation practices. The quantity and quality of rice cultivar is mainly dependent upon micro climate of the area conditions such as soil types, Rainfall, solar radiation and temperature etc.

Rainfall, temperature and radiation play a major role in deciding crop growth, development and yield levels among the various weather elements. As mentioned by the Intergovernmental Panel on Climate Change (IPCC, 2007), crop yields have declined in many Asian countries, due to rising temperatures and extreme weather events. Climate change and global warming are high likelihood that pose a major problem to agriculture as well as to global food security. Changes in solar radiation, temperature and precipitation would affect the change in crop yields and, thus, the agricultural economy.

Crop models which share a common input and output data format have been developed and embedded in a software package called Decision Support System for Agrotechnology Transfer (DSSAT) by the IBSNAT group. The DSSAT itself is a shell that allows the user to organize and manipulate crop, soil and weather data and to run crop models in various ways and analyze their outputs. The models running under DSSAT include the CERES models for rice, maize, wheat, sorghum, pearl millet and barely; the CROPGRO models for bean, peanut, soybean etc. The CERES-Rice model is a process– oriented crop growth simulation model that simulates soil water balance and nitrogen balance on daily incremental basis during the crop life cycle. The model simulates the transformation of seeds, water and fertilizers into grain and straw through the use of land, energy (solar, chemical and biological) and management practices, subject to environmental factors such as solar radiation, maximum/minimum temperature, precipitation, day length variation, soil properties and soil water conditions. Phenological stages are simulated in the model using the concept of thermal time or degree days and photoperiod as defined as by the genetic characteristics of the crop.

The crop model provides a regional reasonable estimate of potential yield where historical climate data are available. Potential yield is defined as the yield of a cultivar when it grown in ideal environment to which it is adopted maximum level of prediction. Quantifying the yield potential of rice for a region is a key to

understand the yield gap and identify the important constraints to achieve optimum yield.

The crop model is a crucial asset for incorporating knowledge of the bio-physical process governing the plant soil, atmosphere system, and extrapolating research findings to other locations or sites where long sequences of the daily weather data crop model can be used to assess the production uncertainties associated with any of these management scenarios. Thus, the model can be used both spatially and temporally to validate findings of the study. It is very important that best management practices, yield forecasts, incidences of pests and diseases, acceptable varieties and best sowing dates are recommended for optimum crop production under unpredictable climatic conditions.

Calibration of genetic coefficient under DSSAT Model of any particular crop cultivar needs detailed field component with desired treatments. Simulated and actual crop parameters are method by tuning the genetic coefficient which is known as calibration of the model. The genetic coefficient is used for yield and yield attributing simulation of the corresponding crop and cultivar once the calibration has been done.

Validation of model, its simplest forms is a comparison between simulated and observed value. Test criteria have been operated into two groups called summary measures difference measure. Summary measure includes the mean of observed and predicted value the standard deviation of observation and the prediction. The summary measure describes the quality of simulation while the difference measure by to locate and quantify the errors. It includes the mean absolute error (MAE), mean bias error (MBA) and root mean square error (RMSE) (Patil and Patel, 2017).

In this research, the ability of the CERES rice crop simulation model to simulate practically the variations in productivity and identify the critical phenological stages and establish optimum plant weather interactions for improved rice production has been attempted using weather data from Raipur weather. It useful for study of climate change and know the impact on cultivar MTU1010, Rajeswari and CG Sugandhit Bhog in Raipur.

In this context, the present investigation entitled “**Simulation and Calibration of DSSAT model for rice crop at Raipur weather condition**” was carried out with the following objectives.

- i. To find out the Genetic coefficient of different rice varieties at Raipur weather condition.
- ii. To calibrate and validate the model for different varieties of rice at Raipur weather condition.
- iii. To find out the optimum date of sowing of different varieties of rice crop based on output of model.

CHAPTER- II

REVIEW OF LITERATURE

The review of literature related to present investigation entitled “**Simulation and Calibration of DSSAT model for rice crop at Raipur weather condition**” have been presented in this chapter. Here the outcome of work conducted at state, national & international level has been summarized in brief. The review of literature have been categorized under the following sub heads-

- 2.1 Crop simulation model
- 2.2 Calibration and Validation of model
- 2.3 Determine optimum sowing time

2.1 Crop simulation model

Rana et al. (2018) reported that calibration and validation CERES -rice and CERES-wheat models to estimate rice and wheat yield. To get the best match between cultivar specific simulated parameters and field observed data, the length of each phenological stage, the initial and maximum canopy covers as well as the crop development were adjusted until the agreement between both the values comes within 5%. The important aspect of crop physiology Leaf Area Index (LAI) was also derived spatially in this study using remote sensing data besides simulated LAI. CERES-rice model simulated rice yield within the range of -3.4% to 7.0% during validation stage. The physiological maturity pertains to higher percentage error while simulated days to anthesis were in close agreement with the observed values. In case of wheat, CERES-wheat model slightly underestimated the tested parameters except days to anthesis and yield for selected cultivar under two sowing environments. Comparative analysis between MODIS LAI and simulated LAI values indicated that from both the sources in third polynomial order followed the pattern but with marked underestimation. The difference could be attributed to scale mismatch, various stages of crop and inherent limitation of MODIS data in estimating LAI.

Satpute et al. (2018) conducted experiment during Kharif season of 2012 and 2013 to validate of the CERES 4.5v model for rice at different dates of transplanting and different varieties. The simulation modelling was subsequently

validated against observed data from field experiment. The model suggested that, in 10th July transplanting in cv. IET-6223, IET-14461, MTU-1010, G.B.-1; the simulated days to panicle initiation were in good conformity with observed values. The results revealed for that under 09th August (D5) transplanting the comparison with observed with simulated for anthesis was similar in all cultivars. The model was fitted well up to the date of anthesis in respect of MTU1010. It was observed that in cv. G.B.-1, observed value were less than simulated value at different dates of transplanting (1.43 % to 4.62 %). In cv. MTU-1075 was very close prediction between observed and simulated value (0.00 % to - 3.57 %). Model overestimated the anthesis (DAT) value.

Singh *et al.* (2017) field experiment was conducted during *Kharif* 2013 to generate the ground truth data of rice crop at Agro meteorological Research Farm of N.D.U.A&T, of Kumarganj, Faizabad (U.P.) evaluation the DSSAT model for genotypes under different weather conditions. Higher change (10.8%) from base yield was recorded with decrease of minimum temperature by 3 °C over normal temperature while, higher yield recorded 13.6% over with decrease in maximum temperature by 3 °C over normal. The yield attributing characters closely simulated to observed values under timely (5 July) transplanting of rice crop, suggested that the simulated yield were well within the accepted limits, therefore the model can be used for predicting rice yield and phenological events.

Kumar *et al.* (2017a) CERES-Rice model was calibrated and validated at Faizabad. The increase in sunshine duration and solar radiation resulted increase in the yield of rice vice versa, while increase in maximum and minimum temperatures resulted decrease in the yield of rice. Among the sowing dates, the impact of sunshine duration under early transplanted rice (30th June) rice gave higher yield than late transplanted rice (30th July). Result shows that with increase in sunshine duration there is increase in yield under all the dates of transplanted rice and vice versa. The rice yield increased upto 6.3-6.7% with increase in sunshine duration of 1.0 h under 30th June to 15th July transplanted rice and decreased upto 30-35% with decrease in sunshine duration.

Vyankatrao (2017) observed that climate change will significantly affect the agricultural sector in developing countries, leading to serious consequences related to food production and food security, with bigger impacts on small farmers and the poor. Most of the available studies indicates that there will be big threat in Agriculture & allied sectors in developing countries. India is one of the world's largest rice producer's countries, accounting for 20% of all world rice production. So, it is important to know that how climate change is going to affect rice production in India. Series of extremely are going on the commonly to assess the impact of climate change in India by using different models. Food security of growing population in the commonly is a challenging how is changing climatic scenario.

Palanisami (2017) reported that climate change will reduce the overall rice yield by 3 to 5% under medium emission scenario and 3.5 to 10% under high emission scenario in india. As rice area will increase only marginally (0.4%) in the future, it was also found that as compared to current rice production of 107 m.t in India, future rice production due to climate change with medium emission is projected to be 104 m.t during mid-century (2021-2050) and 101 m.t. during end century (2071- 2100). With high emission scenario, rice production during mid and end century will be 103 m.t and 96 m.t respectively. Among the rice producing regions, southern and eastern regions offer more scope to increase rice production in future. Whereas the production will stable in other region. Due to climate change one side yield will reduce and other side thus will be variability in rice production on way critical situation in future. Several adaptation strategies such as direct seeding of rice, modified system of rice intensification (MSRI), supplemental irrigation, alternate wetting and drying, improved management practices etc has been recommended Pradhan Mantri Fasal Bima Yojana (PMFBY) has also implemented to increase rice yield, to address the variability (risk) in rice production.

Mohammadi *et al.* (2015) assessed the impacts of future climatic change on irrigated rice yield using the CERES-Rice model in the Southern Coast of Caspian Sea under three climate change scenarios of Sra1b, Sra2 and Srb1. Required data for this research includes the meteorological, soil and crop

management data. Soil and product management data provided from field experiment was conducted from 2008 to 2009 at the Rice Research Institute in Rasht. Validating of Global Climate Models show that ECHAM5 climate model has the highest correlation with the lowest error to simulate the future temperature and precipitation. They used ECHAM5 climate model coupled with a crop growth model for simulating of the effects of climate change on rice production. The results of prediction of climate change scenarios show that minimum and maximum temperature will be ascending order and precipitation will be decreasing order in the Rasht station. Results of simulated yield and biomass of the rice crop base on scenarios of Sra1b, Sra2 and Srb1 show decrease yield and biomass decrease with increasing of mean temperature and decreasing of precipitation.

Verma *et al.* (2014) worked on DSSAT model v4.5 to find out states of rice yield in the future. They reported that the early and late sowing dates gave lower yield as compared to optimum sowing dates. The reduction on the yield of rice in early sowing (1st week of July) dates and late sowing (last week of July) may probably be attributed due to the increasing temperature in the future. The weighted yield was observed more than actual yield in central Chhattisgarh.

Vilayvong *et al.* (2014) worked on crop simulation model CERES rice model which was evaluated with data sets from the TDK8 and TDK11 cultivars in farmers' fields in the Vientiane plain in 2012. The model evaluation results showed strong agreement between simulated and observed data for days to harvest with a difference within four days. The model provided acceptable accuracy for grain yields with normalized root mean square error values ranging between 1 and 16 %. The results from the model application indicated that TDK8 and TDK11 produced similar yields. Transplanting TDK8 with two plant densities produced similar yields. The highest yield for both cultivars was achieved on the transplanting date of 15 Jan. N-fertilizer application at 60 and 120 kg N ha⁻¹ was able to increase yield for TDK8 by 50 and 87 %, respectively, and for TDK11 by 54 and 70 %, respectively. Rice transplanted on 15 Jan with 5 seedlings hill⁻¹ and N-fertilizer at 120 kg N ha⁻¹ had the highest average yield for both cultivars with 6,460 and

6,351 kg ha⁻¹ for TDK8 and TDK11, respectively. The CSM-CERES-Rice model is an alternative tool in determining crop management practices for rice production

Geethalaksmi *et al.* (2011) analyzed the effect of climate change on crop yield for baseline year data 2000 and daily weather data for 2020, 2050 and 2080. The concentrations of carbon dioxide used in the model for the base line, 2020, 2050 and 2080 runs were 376, 414, 522 and 682 ppm respectively as expected in the IPCC (2001) report. Replicated rice production shows that usually rice production revealed declining phase in Tamil Nadu by 8.7, 23.6 and 42.2 % from the production level of the year 2000 to 2020, 2050 and 2080 respectively. The results of the projected climate change over the Cauvery basin of Tamil Nadu for A1B scenario using PRECIS and RegCM3 regional climate models showed an increasing trend for maximum temperature, minimum temperature and rainfall. The results revealed that the increase in maximum temperature in PRECIS was 3.7°C and in RegCM3 it was 3.1°C. The increase in minimum temperature in PRECIS was 4.2°C and in RegCM3 it was 3.7°C during the same period. The increase in minimum temperatures is higher than that in maximum temperatures in both models.

Basak *et al.* (2010) used DSSAT model to find out the yield of the boro rice varieties in changing climate change. The yield of BR3 and BR14 boro varieties for the years 2008, 2030, 2050 and 2070 were simulated for 12 locations (districts) of Bangladesh. The model predicted significant reduction in yield of both boro rice varieties due to climate change. The prediction of average yield reductions was in between 20% and 50% during 2050 and 2070, respectively. Increases in daily maximum and minimum temperatures was main reason in yield. Increases in incoming solar radiation and atmospheric carbon-di-oxide concentration were found to increase rice yield up to some extent, but their effect is not significant compared to the negative effects of temperature. Variations in rainfall pattern over the growing period have also been found to affect rice yield and water requirement. Increasing temperatures and solar radiation were found to reduce the duration of physiological maturity of the rice varieties. Model results also suggest that in addition to reducing yield, climate change may also make rice yield more

vulnerable to transplanting date. DSSAT modeling system could be a useful tool for assessing possible impacts of climate change and management practices on different rice varieties and other crops.

Timsina *et al.* (1998) validated CERES-Rice model using two rice cultivars, three N regimes, two soil moisture regimes and two dates of transplanting. Close correspondence between simulated and observed number of days to anthesis and maturity with root mean square error of 4.3 and 2.3 days respectively, across cultivars. Simulated grain yields, were over or under estimated relative to observed yields.

2.2 Calibration and Validation of model

Sanadya and Singh (2019) was calibrated and validated on DSSAT model for rice (var. NDR – 359, NDR – 97 and SARJU – 52) using experimental data of 6 years (2012 – 2018) recorded of Research Farm, College of Forestry, SHUATS. The yield attributes as simulated by models were compared with the observed data. The result revealed that average error percentage of rice yield as simulated by DSSAT model for var. NDR – 359, NDR – 97 and SARJU – 52 were 2.36, 4.84 and 3.23 respectively.

Murari *et al.* (2018) assessed the production potential through the DSSAT model of Rice varieties (Swarna, Mahamaya and MTU-1010) and three dates of sowing D1(01June2016), D2 (15June2016) and D3 (30 June2016) under Chhattisgarh plain condition in Raipur district. it observed that Swarna recorded highest grain yield (51.6-57.8 qha-1) followed by Mahamaya (39.1-47.9 qha-1) and MTU-1010 (35.6-41.7 qha-1) under all three dates of sowing. Second date of sowing (51.6-57.8) found suitable period for Raipur due to favourable weather condition.

Ray *et al* (2018) estimated rice yield with the help of DSSAT crop simulation model in Keonjhar District of odisha. This study was conducted to identify the yield and growth changes of the popular rice variety (Swarna) cultivated in Keonjhar district in kharif season. The model was validated using rice growth and development data recorded during 2015. Crop management data were

obtained from an experiment which was conducted in Keonjhar. A good match was obtained between observed and simulated grain yield with a RMSE of 0.817 t/ha and a normalized RMSE (RMSEn) of 14.943%. An index of agreement for grain yield closer to 1 (0.869) also revealed that the model performed well in predicting the yield. The regression analysis gave a coefficient of determination (R^2) value of 0.778. In general, the results from the model validation indicate that CERES rice version 4.6 was able to predict growth and development for Swarna variety in a good manner.

Tabasum *et al.* (2018) carried out the field experiment at Research station Anantnag (Kudwani) Sher-e- Kashmir University of Agricultural Sciences and Technology, during 2011 and 2012. CERES-Rice (ver.4.5.) was used to calibrate and validate the data from field experiment comprises of four cultivars (Jhelum, Shalimar rice-1, SKAU-341 and SKAU-382) and three sowing dates (25 May, 10 and 25 June). Model performance was satisfactory with regard to phenological parameters (days to anthesis and maturity), grain yield, top weight at maturity and N-uptake. The per cent variation in simulated duration to anthesis over observed value ranged from -6.5 to 1.9 days. Duration of maturity also varied between transplanting dates and varieties under both simulated and observed values. The percent variation in simulated duration to maturity over observed value ranged from -7.3 to 2.8 days. The observed values of grain yield of all treatments during both the years ranged from 3241 to 8931 kg ha⁻¹, as compared to simulated data ranging from 3058 to 9221 kg ha⁻¹ respectively.

Shukla *et al.* (2018) conducted field experiment during Kharif 2016 to generate the ground truth data of rice crop at Agrometeorological Research Farm of N.D.U.A&T, of Kumarganj, Faizabad. The historical field crop data of year 2014 and 2015 were used for calibration and its validation was made from field crop data of the year 2016. Result reveals that crop growth simulation model was Model simulated the days taken to Panicle Initiation, Anthesis, Physiological Maturity, and Yield. Lowest error % was recorded in timely Transplanting crop of rice (5th July) with Swarna variety (D2V3) and error % increased with delay in Transplanting. DSSAT crop growth simulation model in rice crop depicted well the variation in yield due to varying crop growth environment. The simulated grain

yield and phenological events were overestimated to observed values in timely transplanting suggested that the simulated yield were well within the accepted limits, therefore the model can be used to predict for predicting rice yield and phenological events in eastern U.P area.

Choudhury *et al.* (2018) was evaluate the DSSAT (v4.6) crop model in Bangladesh for wheat production. Genetic co-efficient of four wheat cultivars (BARI Gom-25, 26, 27 & 28) were determined through DSSAT model. Experimental data on irrigation and nitrogen effect on wheat production was used for model calibration and date of sowing effect for model validation. Model evaluation results showed closer estimation of crop growth duration, grain and biomass yields. Percent error difference in grain yield of wheat varieties (BARI Gom- 25, 26, 27 and 28) between simulated and observed values were 10.98%, 8.70%, 10.79% and 8.94%, respectively. Relationship between simulated and observed grain yields, and simulated and observed crop duration both at calibration and validation process are strong having higher R² value. The model has been successfully calibrated and validated for wheat growing in Bangladesh environment and can now it can be taken for further applications in natural resources management and climate change impact studies.

Kumar *et al.* (2017b) calibrated and validated the DSSAT model (v4.5) for late sown wheat in western zone of Haryana. The DSSAT model was calibrated with the field experimental data of *rabi* 2010-11 having 3 levels of irrigation (one irrigation at crown root initiation [CRI], two level of irrigations at CRI and heading and four level of irrigations at CRI, late tillering, heading and milking) with 5 nitrogen levels (0, 50, 100, 150 and 200 kg N/ha) and validated with data of experiment *rabi* 2011-12 conducted at Hisar. The model performance was evaluated using average error (Bias), root mean square error (RMSE), normalized root mean square error (nRMSE), index of agreement (d-stat) and coefficient of determination (r²), and it was observed that DSSAT model was able to predict the growth parameters (maximum leaf area index and total effective tillers), yields (grain, straw and biomass) and harvest index with reasonably good accuracy (error % less than ± 15).

Maniruzzaman *et al.* (2017) calibrated and validated CERES Rice model for major rice varieties growing in the dry season. Yield performances for BRRI dhan 28, BRRI dhan 29 and BRRI dhan 58 were tested at Gazipur, Rangpur, Rajshahi, Barisal, Comilla and Habiganj districts of Bangladesh under recommended agronomic management practices, respectively result revealed that the prediction errors in calibration for average grain yield, biomass and growth durations. During calibration, the prediction errors for average grain yield, biomass and growth duration varied from 3.46 to 4.80%, 10.20 to 15.39% and 0.92 to 2.25%, respectively indicates satisfactory level of model performances of model. The changes in simulated results compared to observe values varied from -1.82 to 9.12% for grain yield, 5.38% to 18.82% for biomass production and -4.67 to 4.87% for growth duration depending on tested varieties.

Sar and Mahdi (2017) revealed that the model underestimated the yields of the cultivar and overestimated rest of the parameters. The average error percent of pod yield, anthesis and maturity for cv. Rajendra Mahsuri-1 as simulated by DSSAT model were 1.46, 1.94 and 1.62 respectively. Simulated growth and development (anthesis, physiological maturity and grain yield) were close to observed and measured parameters for all the years of study.

Ahmed *et al.* (2017) conducted field experiment using DSSAT model for commonly cultivated maize cultivars in Bangladesh. The present study was undertaken to firstly calibrate DSSAT model for popular four hybrid maize cultivars (BARI Hybrid Maize-7, BARI Hybrid Maize-9, Pioneer 30B07 and NK-40). The performance of the model was satisfactory and within the significant limits. After calibration, the model was tested for its performance through validation procedure by using second season data. The model performed satisfactorily through phenology, biomass, leaf area index (LAI) and grain yield. Phenology, as estimated through days to flower initiation and maturity, was in good agreement, although simulated results were slightly over predicted as compared to observed values but within the statistical significance limit (p value = 0.05). The periodic LAI and biomass were simulated satisfactorily when compared with observed values at specific growth stages of the crop. The final

yield values (10.12 to 10.59 t·ha⁻¹) were in close agreement with the observed values (10.16 to 10.94 t·ha⁻¹), as the percentage error was within tolerable limit (0.39% to 6.81%). The model has been successfully calibrated and validated for Gazipur environment and now can be used for climate change impact studies for similar environments in Bangladesh.

Patil and Patel (2017) was calibrated and validated the DSSAT CROPGRO model using field experimental data of two consecutive *rabi* seasons 2014-15 and 2015-16 at Anand, Gujarat. The genetic coefficients for cultivar GG-1 of chickpea were estimated. Higher R²(0.97) was obtained between measured and simulated value for days to anthesis, with percent error (PE) 8.08 % and D-index 0.91. The PE between measured and observed for all the parameters were found below ±10 % error. The model could be used to predict the seed yield accurately under different management conditions. Hence, the CROPGRO model can be used to simulate the phenology and yield of chickpea.

Singh et al. (2017) conducted experiment during kharif 2015 and 2016 at Agro met Research Farm of NDUAT faizabad to predict yield of rice crop in Eastern U.P. using simulation Model. The genetic coefficients were determined by the Decision Support System for Agro Technology Transfer (DSSAT) model using the identical management and other conditions as in the field experiment for three varieties of rice (Sarooj-52, NDR-359 and Swarna). These determined coefficients were used in the subsequent in calibration on validation and other applications. Results reveal that observed value of grain yield of rice transplanted in July 5th was higher over simulated value, due to higher number of days taken to anthesis and physiological maturity over simulated value. Due to delay in transplanting, the grain yield of rice decreased in accordance with observed value too. This shows the better sensitivity of DSSAT model.

Singh et al. (2016) conducted field experiments using DSSAT vs. 4.5 which was calibrated for genetic coefficients of rice CERES-rice model during the kharif season at Jorhat, Kalyani, Ranchi and Bhagalpur, the results of which were used to estimate the gap in rice yield. The trend of potential yield was found to be positive and with a rate of change of 26, 36.9, 57.6 and 3.7 kg ha⁻¹ year⁻¹ at

Jorhat, Kalyani, Ranchi and Bhagalpur districts respectively. Delayed sowing in these districts resulted in a decrease in rice yield to the tune of 35.3, 1.9, 48.6 and 17.1 kg ha⁻¹ day⁻¹ respectively. Finding reveals that DSSAT crop simulation model is an effective tool for decision support system. Estimation of yield gap based on the past crop data and subsequent adjustment of appropriate sowing window may help to obtain the potential yields.

Ibarra et al. (2014) studied impact of climate change and validating models that help to project possible scenarios for selection of varieties. This study seeks to validate and calibrate the DSSAT model as a tool that facilitates the characterization of the behavior of new varieties in the face of new scenarios generated by climate change. The determination of genetic coefficients of three bread wheat (*Triticum aestivum* L.) varieties was considered in the methodology; this was done with the database of the historical records of the Instituto de Investigaciones Agropecuarias (INIA) Wheat Breeding Program for the 2000 to 2011 period. Once the adjustment level of the model was dealt with, it was feasible to obtain genetic coefficients of three spring wheat varieties (Pandora-INIA, Kipa-INIA, and Millán-INIA); days from planting to anthesis variable exhibited RMSE values fluctuating between 3.5 and 9.7 depending on the variety. For total duration of days to maturity, 'Millán-INIA' exhibited a very good adjustment (RMSE = 0.25) as compared to 'Pandora-INIA' (RMSE = 1.35) and 'Kipa-INIA' (12.22). Furthermore, the coefficient of determination of the genetic coefficients indicates that the varieties have minimum vernalization requirements; these are similar to the photoperiod between 'Pandora-INIA' and 'Millán-INIA' and lower in the case of 'Kipa-INIA'. Thermal requirements for grain filling, biomass production, and plant height did not exhibit any important differences among varieties. Finally, the methodology allowed calibrating the DSSAT model and achieving a good predictive level of yields for the three varieties. The plant development parameters must be studied in greater detail because of the low association between simulated and observed values.

Verma et al. (2014) predicted the future yield of rice in plane region of Chhattisgarh using DSSAT v 4.5 model. DSSAT v 4.5 model which was calibrated

and validated for locally popular medium duration rice varieties karma masuri of kharif season (2011 & 2012). The result showed that the early and late sowing dates gave lower yield as compared to sowing on optimum dates. The decrease in the yield of rice in early sowing (1st week of July) dates and late sowing (last week of July) may probably be attributed due to the increasing temperature in the future. The weighted yield was observed more than actual yield in central Chhattisgarh.

Parmar *et al.* (2013) was calibrated and validated the DSSAT model for *kharif* groundnut (cv. GG-2 and GG-20) using past experimental data (2007 to 2009) of Dry Farming Research station, J.A.U., Targhadia, Rajkot, Gujarat with two dates of sowing (D1: Onset of monsoon 1st July; D2: After 15 days of D1 15th July). The yield and yield attributes, phenological stages, harvest index, shelling percentage as simulated by model were compared with the observed data. The results revealed that the model underestimated the LAI and haulm yield for both the cultivars and overestimated rest of the parameters. The average error percent of pod yield for cv. GG-2 as simulated by DSSAT model was 2.2 % and for cv. GG-20 it was 1.6 %.

Shamim *et al.* (2012) conducted field experiment during *kharif* seasons of 2007 and 2008 on silty loam soils of Nawagam under middle Gujarat Agroclimatic zone. Four aromatic cultivars of rice were transplanted on three dates to validate the CERES-Rice v.3.5 model. Highly positive significant association was found between simulated and observed days to heading ($r = 0.95^{**}$). The model overestimated biomass production under estimated test weight and LAI. The performance of the model in simulating grains per square meter was poor. The grain yield simulated was in close agreement with the field observed grain yield.

Dass *et al.* (2012) worked on studied CERES-Rice model which was applied to the data recorded in two years (2008 and 2009) with two rice varieties ('Pant Dhan 4' and 'Hybrid 6444') cultivated with system of rice intensification (SRI). The overall gap between predicted and observed yield was 5% for 'Pant Dhan 4' and 11.4 % for 'Hybrid 6444'. Hence, the model can be used for predicting maturity and yield of these rice varieties grown with SRI method.

Xiong *et al.* (2008) assessed the impacts climate change and their adaptation to Crop simulation models in relation to agricultural production. This study examines the performance of CERES-Rice model at the regional scale across China using a cross calibration process based on limited experiment data, agroecological zones (AEZ) and 50km×50km grid scale geographical database. Model performance is evaluated using rice yields from experimental sites at the plot scale, and/or observed yield data at the county scale. Results suggest: the CERES-Rice model was able to simulate the site-specific rice production with good performance in most of region China, with a root mean square error (RMSE) = 991 kg ha⁻¹ and a relative RMSE= 14.9% for yield across China. The cross calibration process, in which AEZ-scale parameter values were derived, gave a relative bigger bias to yield estimation, with a RMSE= 1485 kg ha⁻¹ and a relative RMSE= 22.5%, but achieved a reasonable agreement with observed maturity day and yield at spatial scale. The bias rose further if this cross calibrated model was used to simulate the real farmer rice yields at a regional scale, with a RMSE= 2191 kg ha⁻¹ and relative RMSE= 34% across China. The pattern of yield variation was captured spatially by the model in most of the rice planting areas, but not temporally.

Nain and Kersebaum (2007) calibrated and validated the CERES model to simulate the averaged conditions for wheat and barley. The model was calibrated to with data of two plots worked during the years 1993–1994 for winter wheat and reworked during 1994–1995 for winter barely. The performance of the calibrated model was verified on an independent data set (one plot of 1993–1994 and three plots of 1997–1998 for winter wheat and one plots of 1994–1995 for winter barley) and the data set, which was not used for the calibration such as water and nitrogen dynamics in soil. The results showed that the model could very well simulate the crop variables such as crop phenology, above- and below-ground biomass and grain yield (The root mean square error (RMSE) was below 20% and the coefficient of determination (R²) value more than 0.85, which was significant at 90% probability level). The performance of the model for simulating water dynamics in different soil layers was also good with RMSE less than 20% and a correlation coefficient more than 0.69 ($t \geq 48.10$; $p < 0.001$). However, the model

showed limited accuracy in simulating nitrogen dynamics (nitrate and ammonium). The model performance for simulating nitrate content was satisfactory to some extent as the model could at least capture the trends of nitrate dynamics in different soil layers (correlation coefficient more than 0.61, which is significant on 99% probability level, $t \geq 4.41$; $p < 0.001$), but the ability of the model to simulate ammonium dynamics in soil is poor (RMSE more than 20% and correlation coefficient less than 0.23).

Rai and Kushwaha (2005) worked on CERES-Rice model which was validated to predict the development and yield attributes of upland rice cv. Pant Dhan-4 under transplanted condition with three dates sowing during Kharif seasons. The results showed that simulated and observed values of days taken to panicle initiation and 50 % flowering were predicted well ($r = 0.717$ and 0.945 , respectively), but days taken to maturity were overestimated during both the years. There were high correlations between observed and simulated values of yield attributes including number of panicles m⁻² ($r = 0.972$), number of grain panicles-1 ($r = 0.660$) and 1000 grain weight ($r = 0.983$), and yield ($r = 0.935$). The results indicated that CERES-Rice model can be considered as good tool for prediction of development, yield attributes and yield of upland rice.

2.3 Determine optimum sowing time

Jha et al. (2020) reported that studied the ten years (2006–2015) of field experimental data were collected from the CIMMYT and BISA , Pusa, Bihar research farm to obtained the impact of water stress crop production, and best management strategies to improve the rice yield, followed by the calibration (2006–2010) and validation (2011–2015) from the collected field experimental data. The genetic coefficients were developed for the rice variety, Rajendra Mahsuri. The normalized root-mean-square error (RMSEn) and d-index values were obtained 2.73% and 0.62, respectively, for prediction of yield with the model performance efficiency (ME) of 75% in the range of 5 years of validation studies. Optimum transplanting date was found in the the month of June to harvest maximum yield of Rajendra Mahsuri rice.

Sandhu *et al.* (2019) reported that the CERES-wheat model was used to analyze the effects of climate change on optimum sowing window of wheat. The simulation results suggested that climate change has caused a shift in optimum sowing window of wheat. The optimum period of sowing window for which crop duration 2006-15 was 22-28 October in north eastern Punjab, 24-30 October in central Punjab and 21-27 October in south western Punjab. The rate of decrease in productivity with delay in sowing from the optimum sowing window by each day was lowest for north eastern Punjab ($36.09 \text{ kg ha}^{-1}\text{day}^{-1}$) and highest for south western Punjab ($70 \text{ kg ha}^{-1}\text{day}^{-1}$).

Santos *et al.* (2017) studied CERES-Pearl Millet from the DSSAT model suite for its ability to simulate growth, development, and forage accumulation of pearl millet at three Brazilian semi-arid locations, and to use the model to study the impact of different sowing dates on forage productivity of pearl millet. Four pearl millet cultivars were grown during rainy season 2011. The genetic coefficients of the four pearl millet cultivars were calibrated for the model, and the model performance was evaluated with experimental data. The model was run for 14 sowing dates using long-term historical weather data from three locations, to determine the optimum sowing window. Results showed that performance of the model was satisfactory as indicated by accurate simulation of crop phenology and forage accumulation against measured data. The optimum sowing window varied from location to location locations depending on rainfall patterns, although result showing the same trend for cultivars within the location. The best sowing windows recorded were from 15 April to 15 May for the Bom Conselho location; 12 April to 02 May for Nossa Senhora da Gloria; and 17 April to 25 May for Sao Bento do Una. The model can be used as a tool to find out the suitable sowing date to harvest food forage yield of pearl millets in Brazilian semi-arid condition.

Andarzian *et al.* (2014) conducted a field experiment in south Khuzestan. The genetic coefficients of cultivar Chamran were calibrated for the CSM-CERES-Wheat model and crop model performance was evaluated with experimental data. Wheat cultivar Chamran was shown on different dates, ranging from 5 November to 9 January during five years of field experiments that were conducted in the

Khuzestan province, Iran, under full and deficit irrigation conditions. The model was run for eight sowing dates starting on 25 October and repeated every ten days until 5 January using long-term historical weather data from the Ahvaz, Behbahan, Dezful and Izeh locations. The seasonal analysis program of DSSAT was used to determine the optimum sowing window for different locations as well. Evaluation with the experimental data showed that performance of the model was reasonable as indicated by fairly accurate simulation of crop phenology, biomass accumulation and grain yield against measured data. The normalized RMSE were 3%, 2%, 11.8%, and 3.4% for anthesis date, maturity date, grain yield and biomass, respectively. Optimum sowing window was different among locations. It was opened and closed on 5 November and 5 December for Ahvaz; 5 November and 15 December for Behbahan and Dezful and 1 November and 15 December for Izeh, respectively. CERES-Wheat model could be used as a tool to evaluate the effect of sowing date on wheat performance in Khuzestan conditions.

Jibrin *et al.* (2012) conducted a study to test the ability of a model to predict maize yields under varying planting dates. Data on two open-pollinated maize cultivars (TSB-SR and TZE-COMP4) sown on different dates (June 29th, July 13th, July 21st and July 28th) in 2006 and 2007 at Azir and Damboa in the Sudan Savanna of Nigeria were used to run the model. Experimental data from Azir in 2006 was used to calibrate the model, while the data for 2007 at Azir 2006 and 2007 at Damboa were used to validation the model. The model predicted days to anthesis at Damboa as reasonably well in both the years ie. 2006 and 2007 (d-index >0.8), while at Azir, the prediction of days to anthesis was very poor in the year 2007. The match between predicted and observed grain yield were very good in the year 2007 at both locations. The root mean square error (RMSE) values for grain yield in 2007 were 431.5 and 226.5 kg ha⁻¹ at Azir, and 799.5 and 611.5 kg ha⁻¹ at Damboa for TZB SR and TZE COMP4, respectively, while the d-index values were all greater than 0.94. Generally, the model predicted decrease in grain yield with delay in planting date except for TZB-SR at Azir in year 2006 where planting on July 13th gave higher yield than planting on June 29th. The grain yield values from the simulations suggested late June to early July was the optimum planting window for both varieties at both the place ie. Azir and Damboa.

CHAPTER- III

MATERIALS AND METHODS

The present study, on “**Simulation and Calibration of DSSAT model for rice crop at Raipur weather condition**” was carried out at the Department of Agricultural Meteorology, College of Agriculture, Raipur. The standard procedure and methodology applied during work of study are given below

3.1 Description of the study area

Chhattisgarh is the state of east-central India situated between latitudes $17^{\circ}46'N$ and $24^{\circ}06'N$ and longitudes $80^{\circ}15'E$ and $84^{\circ}20'E$. It is bounded to the north and northeast by the Indian states of Uttar Pradesh and Jharkhand, to the east by Odisha, to the south by Telangana, and Andhra Pradesh to the west by Madhya Pradesh and Maharashtra. Chhattisgarh extending over 137.90 lakh hectares of geographical area. Geographical location of Raipur $21^{\circ}14' N$ Latitude and $81^{\circ}39'E$ Longitude and mean sea level of 298 m. Area, Production and Productivity of rice in Raipur district 158.86 ha, 329.78 MT and 2102 kg./ha. respectively.

3.2 Data for the study

3.2.1 Weather data

The daily maximum and minimum temperatures, rainfall and solar radiation are the meteorological data required by the DSSAT model. The observed daily weather data of Raipur was obtained/collected from Department of Agrometeorology, College of Agriculture, Raipur for the period of 2017 to 2019.

3.2.2 Soil data

Soils data required by DSSAT model are the number of soil layers that differ in their characteristics, soil texture, and volumetric water content at saturation, field capacity, permanent wilting point and saturated hydraulic conductivity. The soil data was collected from Department of Agrometeorology, IGKV, Raipur.

3.3. Model description

Decision Support System for Agro-technology Transfer (DSSAT) is developed by J.W. Jones, using CERES-Rice model by International Benchmark Systems Network for Agrotechnology Transfer (IBSNAT). The model encompasses process-based computer models that predict growth, development and yield as a function of local weather and soil conditions, crop management scenarios and genetic information. It comprises crop simulation models for over 42 crops and database for which (e.g. CERES, CROPGROW, SUBSTOR etc.) soil, experimental conditions, measurement and genotypes information are obtained. The CERES-Rice model is a process-oriented crop growth simulation model that simulates soil water balance and nitrogen balance on daily incremental basis during the crop life cycle. The model simulates the transformation of seeds, water and fertilizers into grain and straw through the use of land, energy (solar, chemical and biological) and management practices, subject to environmental factors such as solar radiation, maximum/minimum temperature, precipitation, day length variation, soil properties and soil water conditions. Phenological stages are simulated in the model using the concept of thermal time or degree days and photoperiod as defined as by the genetic characteristics of the crop.

3.3.1 Inputs data required for CERES-Rice model

Input files for CERES-Rice model requires a weather file, a soil data file, an experimental details file and a genotype data file.

3.3.1.1 Weather data file (WTH.)

The weather data file contains a daily weather data of maximum temperature, minimum temperature, rainfall and total solar radiation for the entire crop duration. Daily weather data (*viz.*, maximum and minimum temperature, rainfall and bright sunshine hours) of the year 2017 to 2019 has been collected from the Department of Agrometeorology, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G).

3.3.1.2 Preparation of weather files for simulation model

Weather data were arranged in a specific format of the model and save the file on extension of WTH Data.

3.3.2 Soil Data

3.3.2.1 Soil data file (FILES)

The soil data related to the experimental site were used to develop the soil file for the study area. It involves soil texture, soil classification, soil family CSC scheme, soil depth (cm), color (wet), albino (fraction), evaporation limit (cm), flow rate (fraction day), run-off curve number, mineralization factor (0 to 1 scale), photosynthesis factor (0 to 1) scale, buffer determination process pH, nitrogen, phosphorus, and potassium determination process. The model also needs horizon wise information such as, horizon amount, horizon thickness (cm), field potential (fraction), crop point (fraction), air-dry level (fraction), reduced drained limit (cm³ cm⁻³), organic carbon (percent), water & buffer pH, root development factor C mol (kg⁻¹), cation exchange capacity (0.0 to 1.0).

3.3.3 Crop Data

Crop data for the year 2017, 2018 and 2019 was collected from Department of Agro meteorology, College of Agriculture , IGKV, Raipur which includes information of planting and emergence, plant population at seeding and at emergence, planting method, planting distribution, row spacing, row direction, planting depth, planting material, transplant age, plants per hill, dates of simulation beginning etc Table:3.1. Crop data (Crop coefficient values, phenological stages, rooting depth, yield and yield attributes etc.) and crop management data (such as amount of irrigation, irrigation method, fertilizer and harvesting, planting information) were collected from the Department of Agrometeorology, Raipur and published literatures. Three rice varieties i.e. MTU1010, Rajeswari and CG Sugandhit Bhog are most commonly grown in study area.

Table: 3.1 List of input required by CERES-Rice model

Parameter			
Variety	MTU1010, Rajeswari and CG Sugandhit Bhog		
Date of sowing	1 st June	15 th June	30 th June
Date of Transplanting	1 st July	15 th July	30 th July
Planting method	Transplanted	Transplanted	Transplanted
Spacing	20cm ×10cm	20cm ×10cm	20cm ×10cm
Irrigation amount	75 mm each irrigation	75 mm each irrigation	75 mm each irrigation
Irrigation	As and when required	As and when required	As and when required
Irrigation method	flooding	flooding	flooding
Date of Fertilizer	Basal:1 July Top dressing: 31 July 31 August	Basal: 15 July Top dressing: 15 August 15 September	Basal: 30 July Top dressing: 30 August 30 September
Amount of Fertilizer	100:60:40 kg/ha	100:60:40 kg/ha	100:60:40kg/ha
Type of Fertilizer (N,P and K)	Urea, SSP and MOP	Urea, SSP and MOP	Urea, SSP and MOP
Fertilizer application method	Broadcasting	Broadcasting	Broadcasting

3.3.4 Cultivars data file (FILEX)

This file contains the cultivars specific co-efficient, a specific number recognizes the cultivars. Eight genetic coefficients are needed for describing the performance of particular genotype under various aspects: **P1, P2R, P5, P2O, G1, G2, G3 and G4** and these coefficients are as described below.

3.3.5 Experimental data files (FILEX)

This file documents the input (observed field data on hypothetical one) to the model for every experiment to be simulated. The details of the experiment condition viz., field characteristics, field descriptions, weather station name and Soil analysis data set of soil properties used for the simulation on nutrient status. Dynamically, based on field nutrient sampling, initial soil water and inorganic conditions for water and nitrogen in the profile and also used for root residue carried over from previous crop and N symbiosis initial condition, planting detail, dates of planting, population emergence date, seedling depth row spacing, direction etc.

Consideration, Date of irrigation, thresholds and rice flooding water depth, fertilizer management (date, type and amount of fertilizer application), organic residue application, tillage application, environmental modification, adjustment factor for weather parameter as used in climate change and constant environmental studies, harvest management and simulation controls are options for model component and output option are taken into consideration.

3.3.6. Running the crop model

The model was run for all the cultivars once all the desired files were carefully created. For each model run, output files of each variety were created.

3.4 Genetic coefficients of rice

“RICER047.CUL” is a file containing genetic coefficients of rice varieties, composed of development or phasic coefficients (P coefficients) and growth coefficients (G coefficients). The P coefficients allow the model to predict events during development such as Panicle initiation, anthesis and maturity. Table 3.2 presents the description of the P and G coefficients. The components of P allow the model to predict maturation rates because temperature drives the physical development of rice. However, the temperature effect is modified by day length if it is photoperiod sensitive variety. Temperature is then converted into heat units or degree-days which is computed and accumulated on daily basis.

Table: 3.2 Description of 8 genetic coefficients of rice crop.

Name (Genetic parameter)	Description
Juvenile phase coefficient (P1)	Time period (expressed as growing degree days [GDD] in °C above a base temperature of 9°C) from seedling emergence during which the rice plant is not responsive to changes in photoperiod. This period is also referred to as the basic vegetative phase of the plant.
Critical photoperiod (P2O)	Critical photoperiod or the longest day length (in hours) at which the development occurs at a maximum rate. At values higher than P2O developmental rate is slowed, hence there is delay due to longer day lengths.
Photoperiodism coefficient (P2R)	Extent to which phasic development leading to panicle initiation is delayed (expressed as GDD in °C) for each hour increase in photoperiod above P2O.
Grain filling duration coefficient (P5)	Time period in GDD (°C) from beginning of grain filling (3 to 4 days after flowering) to physiological maturity with a base temperature of 9°C.
Spikelet number coefficient (G1)	Potential spikelet number coefficient as estimated from the number of spikelets per g of main culm dry weight (less leaf blades and sheaths plus spikes) at anthesis. A typical value is 55.
Single grain weight (G2)	Single grain weight (g) under ideal growing conditions, i.e. nonlimiting light, water, nutrients, and absence of pests and diseases.
Tillering coefficient (G3)	Tillering coefficient (scaler value) relative to IR64 cultivar under ideal conditions. A higher tillering cultivar would have coefficient greater than 1.0.
Temperature tolerance coefficient (G4)	Temperature tolerance coefficient. Usually 1.0 for varieties grown in normal environments. G4 for japonica type rice growing in a warmer environment would be 1.0 or greater. Likewise, the G4 value for indica type rice in very cool environments or season would be less than 1.0.

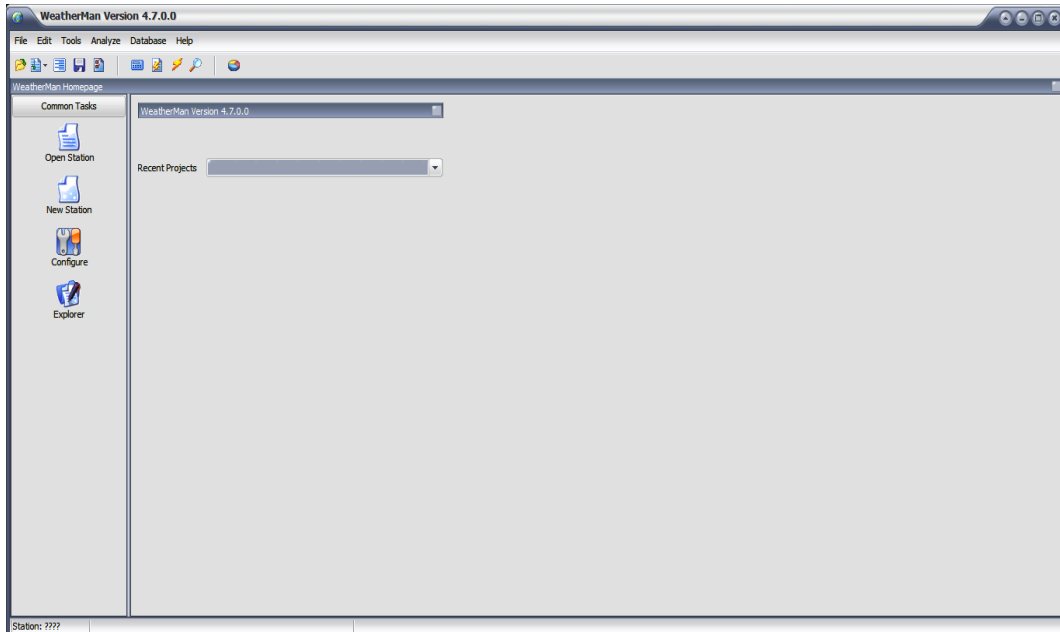


Fig: 3.1 Weather Man file for creating weather data in DSSAT model

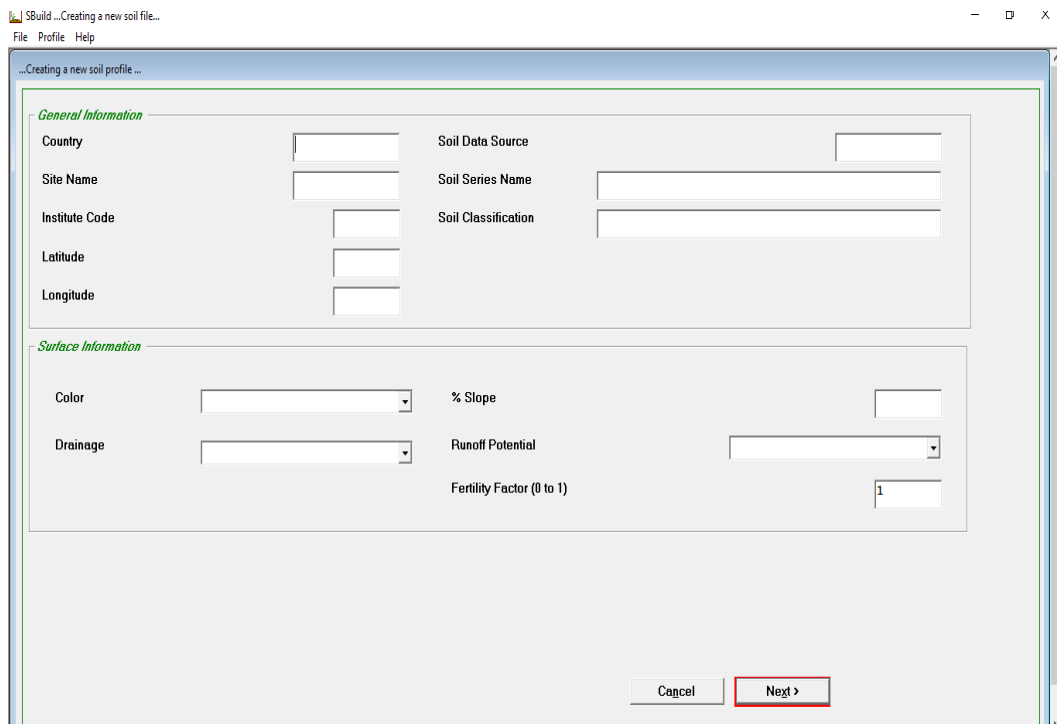


Fig: 3.2 S Build file for creating soil data in DSSAT model

XBuild v 4.7.0

File Environment Management Treatments Simulation Options Refresh Help

General Information- C:\DSSAT47\RICE\IGMU1701.RIX(Experimental)

File Type: Experimental

Experiment Name: IGMU1701

Experiment Identifier (file name)

Institute Code: IG

Site Code: MU

Year: 2017

Experiment Number: 1


Crop: Rice

General Information

People: MUKESH

Address: Department of Agrometeorology raipur

Site: Raipur



Plot

Plot Information

Gross Plot Area per rep, m2: 46.2

Rows per Plot: 26

Plot Length, m: 7.7

Plots Relative to Drains, degrees: 90

Plot Spacing, cm: 20

Plot Layout:

Harvest Information

Harvest Area, m-2: 40

Harvest Row Number: 26

Harvest Row Length, m: 7.7

Harvest Method: manual

Additional Information

Fig: 3.3 X Build for creating crop management data in DSSAT model

3.5 Calibration of CERES Rice model

Model calibration or parameterization is the adjustment of parameters so that simulated values compare well with observed values. The genetic coefficients that influence the occurrence of developmental stages in the CERES model were derived by manipulating the relevant coefficients to achieve the best possible match between the simulated and observed number of days to the phenological events. These include initially determining the values of the coefficients of phenology and then the values of the coefficients describing growth and grain development. Minimum crop performance data set are required viz., dates of emergence, anthesis, beginning of grain filling, maturity duration, grain yield, above ground biomass, grain density and weight for calibrating the genetic coefficient.

3.6 Validation of the model

Model validation, in its simplest form is a comparison between simulated and observed values. Test criteria have been separated into two groups, called summary measures and difference measures. Summary measures include the mean of observed (\bar{O}) and predicted values (P), the standard deviation of observations (S_o) and the predictions (S_p). The summary measures describe the quality of simulation while, the difference measures try to locate and quantify the errors. The latter include the mean absolute error (MAE), mean bias error (MBE) and root mean square error (RMSE). They were calculated according to (Loague and Green, 1991) as following and were based on the terms ($P_i - O_i$):

$$RMSE = \left[\sum_{i=1}^n (P_i - O_i)^2 / n \right]^{0.5}$$

MAE and RMSE indicate the magnitude of the average error, but provide no information on the relative size of the average difference between (P) and (O). The statistic MBE describes the direction of error bias. The value of MBE is related to the magnitude of the values under investigation. A negative MBE indicates that the predictions are smaller in values than those of the corresponding

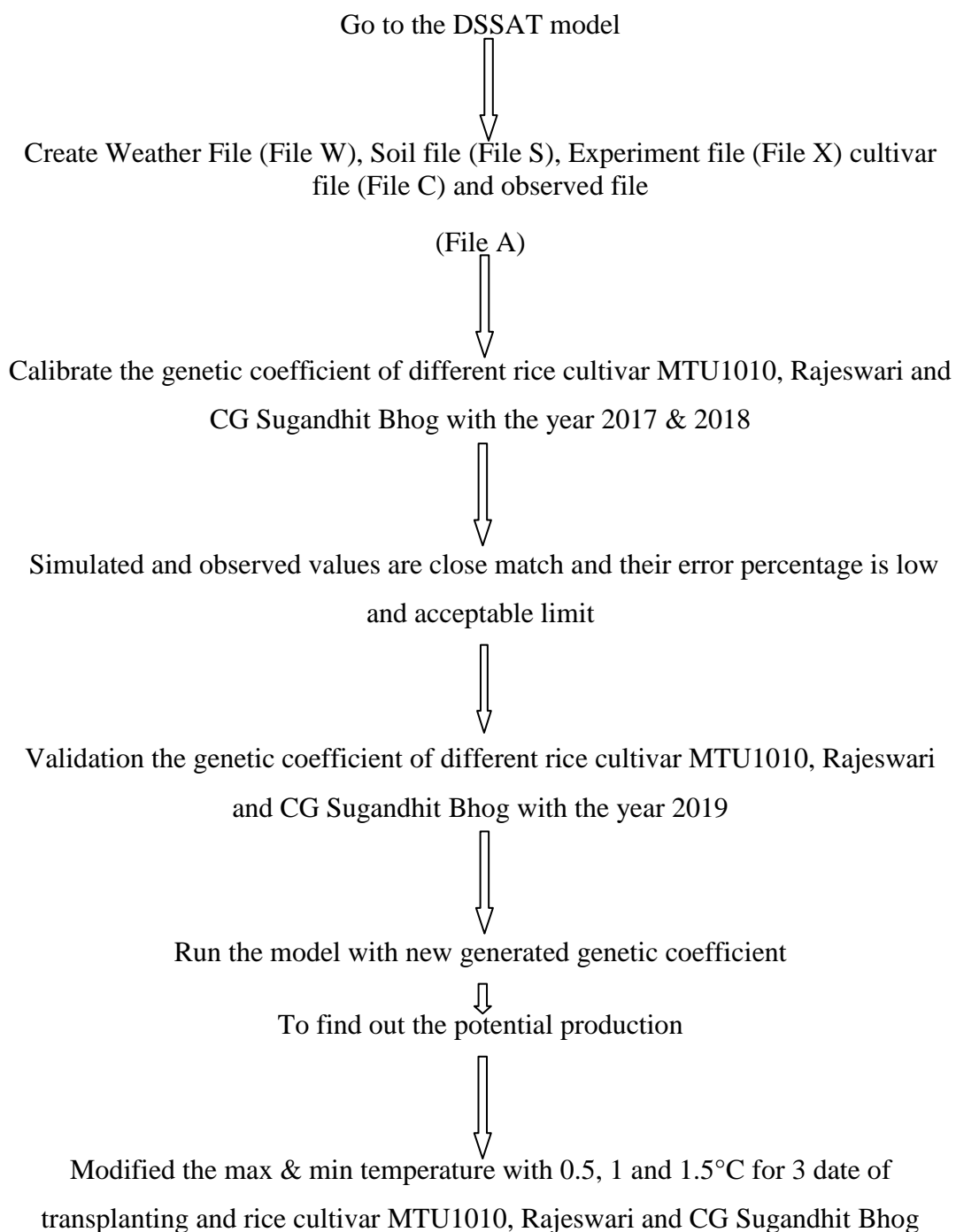
observations. Test criteria have been separated into two groups, called summary measures and difference measures. Summary measures include the mean of observed values (O) and predicted values (P), the standard deviation of observations (S_o) and the predictions (S_p), the slope (b) and intercept (a) of the least square regression ($P_i = a + b + O_i$). Willmott *et al.* (1985) calculated an index of agreement (D) as follows:

$$D = 1 - \left[\sum_{i=1}^n (P_i - O_i)^2 / \sum_{i=1}^n (|P_i| + |O_i|)^2 \right]$$

$0 \leq (D) \leq 1$ where,

$$P_i = P_i - P \text{ and } O_i = O_i - O.$$

Flow chart



CHAPTER-IV

RESULTS AND DISCUSSION

The result of present investigation entitled “**Simulation and Calibration of DSSAT model for rice crop at Raipur weather condition**” has been presented in this chapter. Crop simulation model is a good tool to analyze the crop-weather relationship, to evaluate the performance of crop cultivars in different sets of agro climatic conditions, to evaluate the performance of crop in untraditional regions, and to analyze nutrients and management practices of particular varieties of crop. If we want to apply the model in any specific region, the calibration and validation of the model are prerequisite. The genetic coefficients were developed for CERES-rice model and performance of model was evaluated on the independent agro climatic data set of Raipur districts. In order to know the prospects of rice production in Chhattisgarh, Production potentials of different rice cultivars were also simulated. The results of study is divided into five segments and discussed in the light of cause and relation effect as per need.

4.1 Genetic coefficient of different rice cultivars.

4.2 Calibration and validation of rice cultivars at Raipur weather condition.

4.3 Determining optimum sowing date of rice crop.

4.4 Assessment of Production Potential of different rice varieties through DSSAT Model for Raipur District.

4.5 Sensitivity analysis of rice cultivars for CERES-Rice model for Raipur District.

4.1 Genetic coefficient of rice cultivars

4.1.1 Calibration of genetic coefficient

Genetic coefficients of rice “RICER047.CUL” is a file containing genetic coefficients of rice varieties, composed of development or phasic coefficients (P coefficients) and growth coefficients (G coefficients). The P coefficients enable the model to predict the development events such as panicle initiation, flowering and maturity. The definition of P and G coefficients are presented in Table 4.1. The P components permit the model to predict maturity rate because the phenological development of rice is driven by temperature. However, the temperature effect is

modified by day length if it is sensitive varieties. Temperature is then converted into heat units or growing degree-days which is computed and accumulated on daily basis. The P1 and P5 coefficients are defined as the duration of the vegetative and grain filling stages, respectively. The P1 coefficient varies greatly among different types of variety. The maturity days of a particular variety depends upon the value of P1 and P5 coefficients. The P2O is a critical photoperiod or the longest day length at which the development occurs at a maximum rate. The development rates slow down when day length is greater than P2O. The panicle initiation is delayed for each hour increase in photoperiod above P2O.

The growth coefficients as defined in Table 4.1 represent the potential value for a particular variety. Grain size (G2) is a genetic coefficient that varies with varieties, which achieved under ideal condition and it is the most stable character of a particular variety. Grain yield is the product of grain size (G2) and grain number (G1). Grain number depends upon the number of panicle numbers in turn depends on numbers of effective tillers (G3).

Table: 4.1 Genetic coefficients different parameters for MTU-1010, Rajeshwari and CG Sugandhit Bhog.

Variety	P1	P2O	P2R	P5	G1	G2	G3	G4
MTU-1010	548	246	146	12	49	0.250	1	1
Rajeshwari	522	447	142	11.7	55	0.257	1	1
CG Sugandhit Bhog	741	320	148	11.4	51	0.265	1	1

The outcome of study indicates that the P1 and P5 coefficients for cv.MTU 1010, Rajeshwari & CG Sugandhit Bhog were 548, 522, 741 and 12, 11.7, 11.4 respectively. The P1 coefficient varies greatly among different types of variety. The P1 coefficient of CG Sugandhit bhog was 741 i.e. greater than MTU 1010 (522) and Rajeshwari (548). The maturity days of a particular variety depends upon the value of P1 and P5 coefficients. The highest coefficient of P5 of cv. MTU 1010 was 12 i.e. more then cv. Rajeswari (11.7) and CG Sugandhit Bhog (11.4). Genetic coefficients P2O of MTU1010, Rajeswari & CG Sugandhit Bhog were 246, 447 & 320 respectively. P2O coefficient value of Rajeswari was 447 which was more than CG Sugandhit Bhog and MTU-1010. Genetic coefficients P2R for

MTU1010, Rajeswari & CG Sugandhit Bhog were 146, 142 & 148 respectively. P2R coefficient value of CG Sugandhit Bhog is 148 is more than Rajeswari and MTU-1010. Genetic coefficients G1 of MTU1010, Rajeswari & CG Sugandhit Bhog wear 49, 55 & 51 respectively. Similarly Genetic coefficients G2 for MTU1010, Rajeswari & CG Sugandhit Bhog were 0.250, 0.257 & 0.265 respectively. The genetic coefficients G3 & G4 of all varieties were also 1. Because all variety were grow in normal environments. Our finding are in close confirm it with the findings of Maniruzzaman *et al.* 2017 who also reported that variation in value of genetic coefficient parameter were similar to our result.

4.2 Calibration and validation of rice cultivars at Raipur weather condition.

4.2.1 Phenological development

In order to get accurate simulation of crop growth and yield of rice crop varieties, the accurate simulation of phasic development of the crop is crucial. Thus, evaluation of the phasic development is the most important and the first step in any study aimed to assess the performance of a simulation crop model. The genetic coefficients calibrated during 2017 and 2018 using DSSAT v. 4.7 for the rice varieties, MTU-1010, Rajeswari and CG Sugandhit bhog and the validation of CERES rice model was done in the year 2019 with all destined parameter for three rice varieties. The results obtained from the field observation showed that, phenological observation for all the varieties with respect to different planting dates were found different. There was reasonably a good agreement between observed and simulated phenology for MTU-1010, Rajeswari and CG Sugandhit bhog.

4.2.1.1 Days to panicle initiation

The data observed and simulated outcome for days taken to panicle initiation at different dates of transplanting of three rice genotypes are presented in Table-4.2 and depicted in Fig.-4.1

The observed and simulated value of days required for panicle initiation in variety MTU-1010 was in the range of -4.9 to 5.6 % with different dates of sowing

in the year 2017, where in the RMSE value was 1.33, R^2 value was 0.75 and D-index value was 0.86. In the year 2018 the error percent ranges between -7.0 to 5.7 with RMSE value of 2.16, R^2 value of 0.89 and D-index value of 0.77. When the model was validated in the year 2019 the error percent was in the range of -11.4 to -2.7 with RMSE, R^2 & D-index value of 3.16, 0.99 and 0.66, respectively indicates that simulation outcome is under acceptable limit.

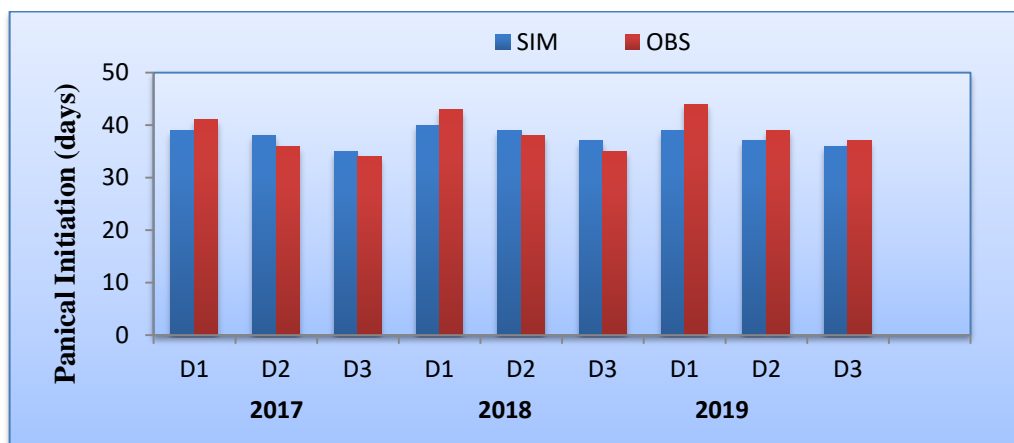
When the data of Rajeswari were recorded for days taken to panicle initiation and compared with simulated value, it was observed that the error percent was in the range of -9.5 to -7.0 with the RMSE value of 3.37, R^2 value of 0.95 and D-index value of 0.68 in the year 2017. While during 2018 our result were in the error of -2.4 to 2.7% with RMSE value of 0.82, R^2 value of 0.93 and D-index value of 0.90. When the error percent of days taken for panicle initiation in variety Rajeswari was validated during 2019 the result was in the range of -4.8 to -2.6 in different date with RMSE value of 1.41, R^2 value of 0.99 and D-index value of 0.81. In nutshell it indicates that it can be said that our results are in the range of acceptable limits.

The error percent of days taken for panicle initiation in CG Sugandhit Bhog variety was in the range of 1.9 to 2.2 percent during 2017 with RMSE value 1.0, R^2 value 1.0 and D-index value 0.96. The range of error percent was in between 0.0 to 6.0 during 2018 with RMSE, R^2 and D-index value of 1.8, 0.48 and 0.72 respectively with three date of transplanting. While during validation it was in the range of 2.0 to 6.3 percent in D1 and D2 respectively. Which indicates that on observed and simulated results are in the acceptable limit.

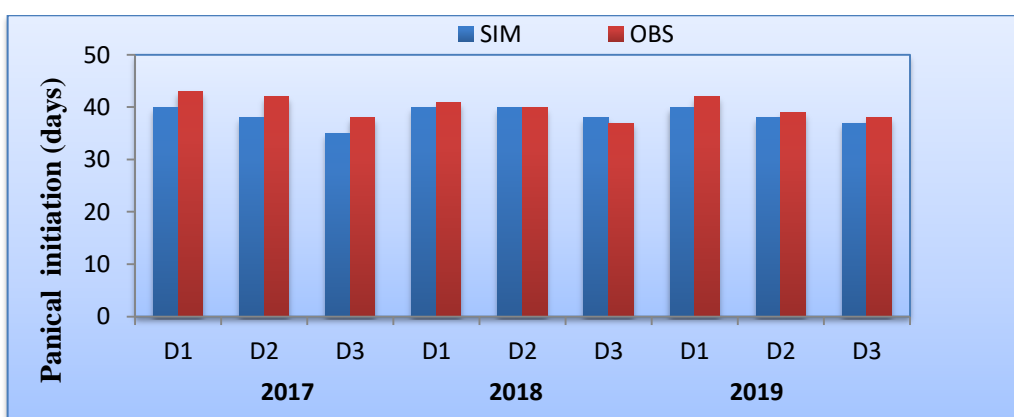
The result indicates that the model is able to predict panicle initiation of the crop cultivar MTU-1010, Rajeswari and CG Sugandhit Bhog for different date of transplanting with in under acceptable limit. It also suggested that the coefficients can be satisfactorily utilized for evaluation of growth and phenology of the all three varieties of rice in Chhattisgarh plain agro climatic condition.

Table: 4.2 Comparison of simulated and observed days required for panicle initiation for different rice cultivars i.e. MTU-1010, Rajeswari and CG Sugandhit Bhog under different growing environment.

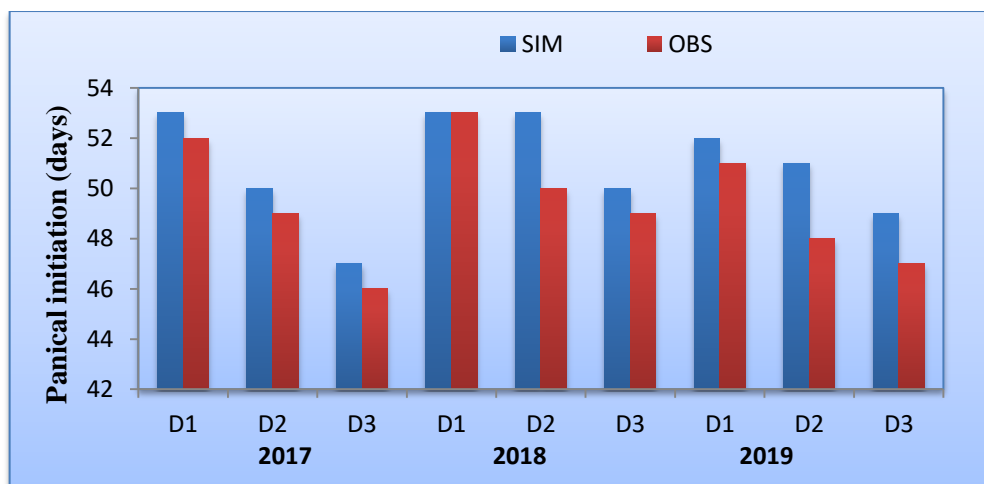
Date of transplanting Year 2017	Cultivars								
	MTU-1010			Rajeswari			CG Sugandhit bhog		
	Obs.	Sim.	Error %	Obs.	Sim.	Error %	Obs.	Sim.	Error %
D1	41	39	-4.9	43	40	-7.0	52	53	1.9
D2	36	38	5.6	42	38	-9.5	49	50	2.0
D3	34	35	2.9	38	35	-7.9	46	47	2.2
R ²	0.75			0.95			1.00		
RMSE	1.33			3.37			1.00		
D- index	0.86			0.68			0.96		
Year 2018									
D1	43	40	-7.0	41	40	-2.4	53	53	0.0
D2	38	39	2.6	40	40	0.0	50	53	6.0
D3	35	37	5.7	37	38	2.7	49	50	2.0
R ²	0.89			0.93			0.48		
RMSE	2.16			0.82			1.82		
D- index	0.77			0.90			0.72		
Year 2019									
D1	44	39	-11.4	42	40	-4.8	51	52	2.0
D2	39	37	-5.1	39	38	-2.7	48	51	6.3
D3	37	36	-2.7	38	37	-2.6	47	49	4.3
R ²	0.99			0.99			0.83		
RMSE	3.16			1.41			2.11		
D- index	0.66			0.81			0.69		



(a)



(b)



(c)

Fig: 4.1 Comparison of simulated and observed days required for panicle initiation for different rice cultivars i.e. (a) MTU-1010 (b) Rajeswari (c) CG Sugandhit Bhog under different growing environment.

4.2.1.2 Days to anthesis

The observed and simulated value on days taken to anthesis recorded at different dates of transplanting of rice genotypes are presented in table-4.3 and depicted in fig.-4.2

The error percent of days taken for anthesis in MTU-1010 variety was in the range of 0.0 to 2.9 percent during 2017 with RMSE value 1.29, R^2 value 0.84 and D-index value 0.89. During 2018 it was in the range of 3.0 to 4.3 with RMSE, R^2 and D-index value 2.70, 0.98 and 0.65 respectively with three date of transplanting. During validation it was in range of 2.9 % with D1 and 6.3 with D3. Which indicates that on observed and simulated results are in acceptable limit.

The error percent of observed and simulated value of days required for anthesis in variety Rajeswari was in the range of 2.9 to 4.8 % with different date of transplanting in the year 2017, where in the RMSE value was 3.11, R^2 value was 0.88 and D-index value was 0.67. In the year 2018 the error percentage ranges between 8.8 to 9.4 with RMSE value of 6.0, R^2 value of 0.91 and D-index value of 0.39. When the model was validated in the year 2019 the error percent was in the range of 0.0 to 6.2 with RMSE, R^2 & D-index value of 2.58, 0.64 and 0.70 respectively indicate that simulation of outcome is under acceptable limit.

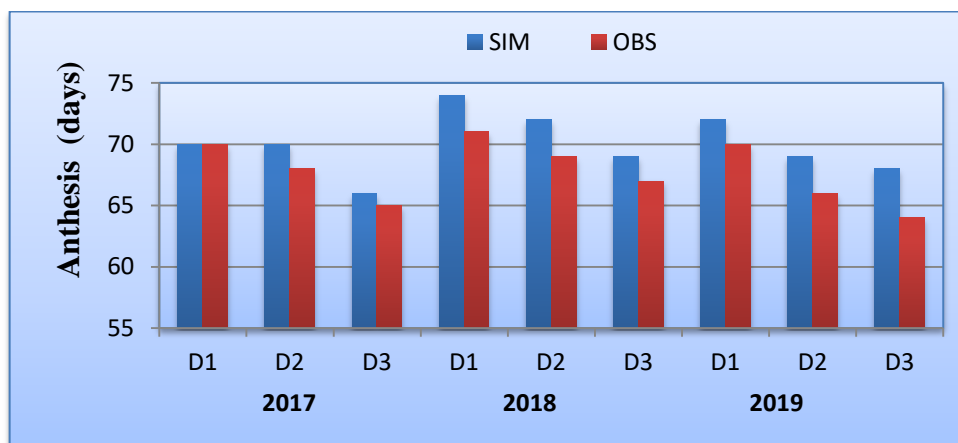
Data recorded for days taken to anthesis and compared with simulated value, it was observed that the error percent was in the range of 6.2 to 8.1 with the RMSE value of 5.35, R^2 value of 0.99 and d-static value of 0.58 in the year 2017. During 2018 in our results the error percent was in the range of 9.1 to 10.1% with RMSE value of 7.68, R^2 value of 0.99 and D-index value of 0.26. When the data of days taken for anthesis in variety CG Sugandhit Bhog was validated during 2019 the result was in the range of 1.2 to 10.5 percent in different date of transplanting with RMSE value of 5.20, R^2 value of 1.00 and D-index value of 0.55. It indicates it can be said that our results are in the range of in acceptable limits.

The results indicate that the model is able to predict the days required for anthesis of cultivar MTU-1010, Rajeswari and CG Sugandhit Bhog when planted in different growing environments of satisfactory level. The results obtained indicate that the coefficients was also satisfactorily level. The error percent of all

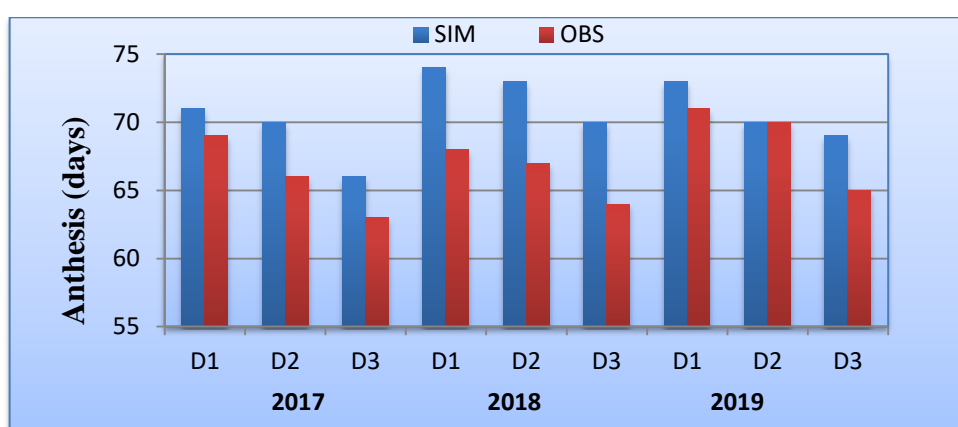
varieties underestimates with all three date of transplanting. The error percent of all varieties tested in different growing environments when under the acceptable limit.

Table: 4.3 Comparison of simulated and observed days required for anthesis for different rice cultivars i.e. MTU-1010, Rajeswari and CG Sugandhit Bhog under different growing environment.

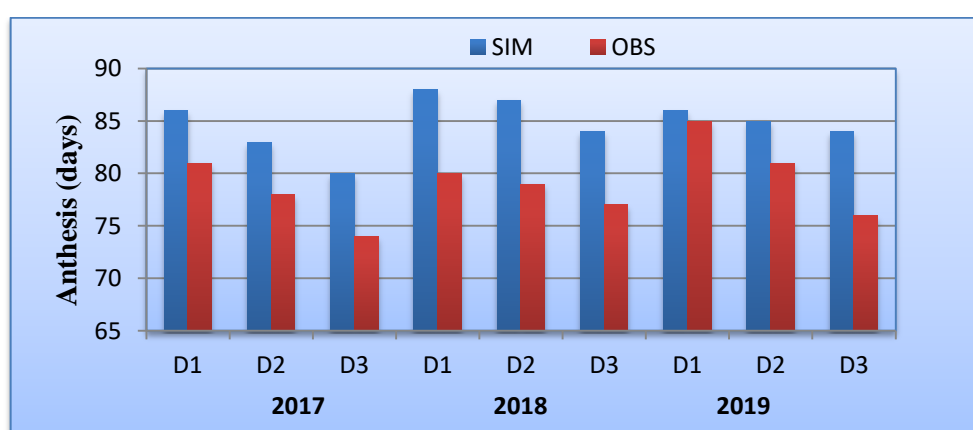
Date of transplanting Year 2017	Cultivars								
	MTU1010			Rajeswari			CG Sugandhit bhog		
	Obs.	Sim.	Error%	Obs.	Sim.	Error%	Obs.	Sim.	Error%
D1	70	70	0.0	69	71	2.9	81	86	6.2
D2	68	70	2.9	66	70	6.1	78	83	6.4
D3	65	66	1.5	63	66	4.8	74	80	8.1
R ²	0.84			0.88			0.99		
RMSE	1.29			3.11			5.35		
D - index	0.89			0.67			0.58		
Year 2018									
D1	71	74	4.2	68	74	8.8	80	88	10.0
D2	69	72	4.3	67	73	9.0	79	87	10.1
D3	67	69	3.0	64	70	9.4	77	84	9.1
R ²	0.98			1.00			0.99		
RMSE	2.70			6.00			7.68		
D -index	0.65			0.39			0.26		
Year 2019									
D1	70	72	2.9	71	73	2.8	85	85	1.2
D2	66	69	4.5	70	70	0.0	81	85	4.9
D3	64	68	6.3	65	69	6.2	76	84	10.5
R ²	0.99			0.64			1.00		
RMSE	3.10			2.58			5.20		
D -index	0.71			0.70			0.55		



(a)



(b)



(c)

Fig: 4.2 Comparison of simulated and observed days required for anthesis for different rice cultivars i.e. (a) MTU-1010 (b) Rajeswari (c) CG Sugandhit Bhog under different growing environment.

4.2.1.3 Days to maturity

The observed and simulated data on days taken to maturity (DAT) at different dates of transplanting of rice genotypes are presented in Table-4.4 and depicted in fig.-4.3

The error percentage of observed and simulated value of days required for maturity in variety MTU1010 was in the range of 1.1 to 3.5 % with different date of transplanting in the year 2017, where in the RMSE value was 2.16, R^2 value was 0.85 and D-index value was 0.75. During year 2018 the error percent ranges between 3.5 to 5.7 with RMSE value of 4.08, R^2 value of 0.85 and D-index value of 0.54. When the model was validated in the year 2019 the error percent was in the range of -2.2 to 3.4 with RMSE, R^2 & D-index value of 2.08, 0.42 and 0.60 respectively it indicates that outcome of simulation was in the limit of acceptable.

Data recorded for days taken to maturity were compared with simulated value indicates that the error percent was in the range of -1.9 to 3.2 with the RMSE value of 2.16, R^2 value of 0.95 and D-index value of 0.88 in the year 2017. During 2018 our error percentage was in the range of 1.0% to 8.5% with RMSE value of 5.8, R^2 value of 0.62 and D- index value of 0.47. When the error percent of days taken for maturity in variety Rajeswari was validated during 2019 the error percent was in the range of -2.9 to 5.2 in different date with RMSE value of 3.78, R^2 value of 0.95 and D-index value of 0.53. It means outcome of study can be used for prediction of maturity.

The error percent of days taken for maturity in CG Sugandhit Bhog variety was in the range of -5.3 to -1.8 percent during 2017 with RMSE value 4.66, R^2 value 0.43 and D-index value 0.48. While it was in the range of 0.0 to 3.7 during 2018 with RMSE, R^2 and D-index value 3.11, 0.71 and 0.46 respectively with three date of transplanting. After validation it was in the range of -4.3 % with D1 and 2.8 with D3. Which indicates that our observed and simulated results are in acceptable limit.

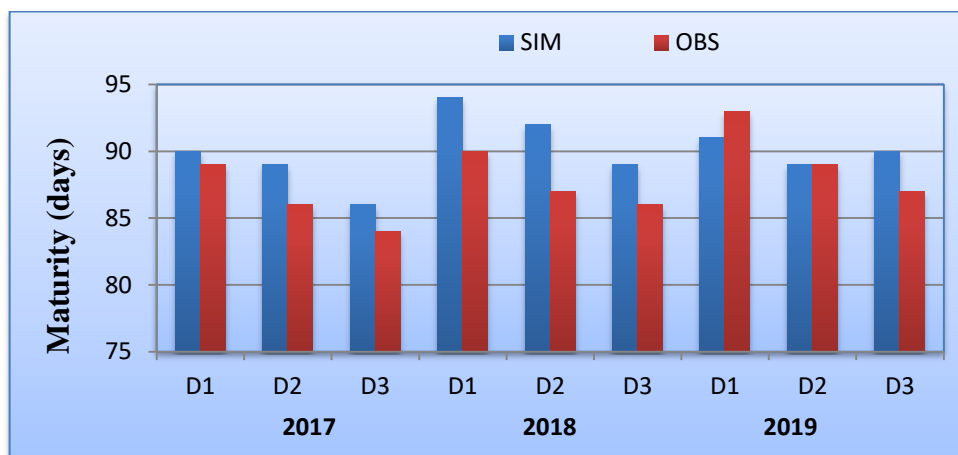
The above results indicate that the model can be used to predict the phenological events, panicle initiation, anthesis and maturity in MTU-1010,

Rajeswari and CG Sugandhit Bhog. Simulated phonological outcome were found to be in reasonable agreement with the observed ones and also error percentage was under the limit of acceptance.

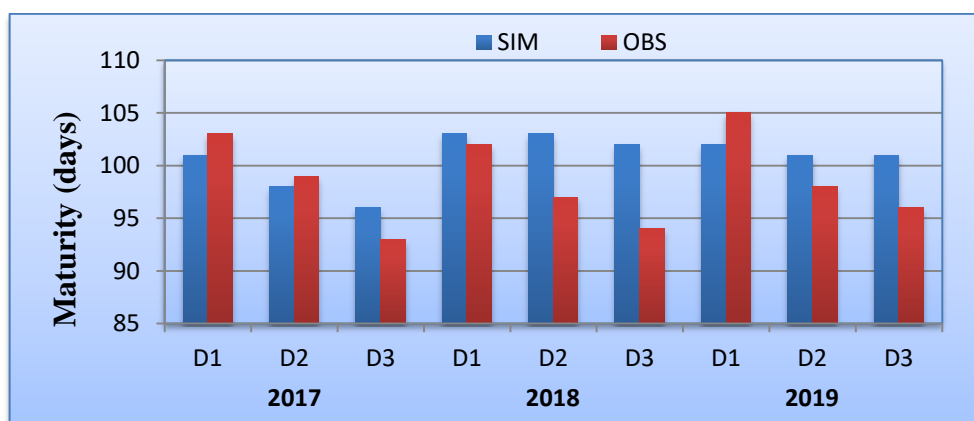
Ahmad *et al.* (2017) reported that phonological development and grain yield of rice were observed in close prediction and under the limit.

Table: 4.4 Comparison of simulated and observed days required for physiological maturity for different rice cultivars i.e. MTU-1010, Rajeswari and CG Sugandhit Bhog under different growing environment.

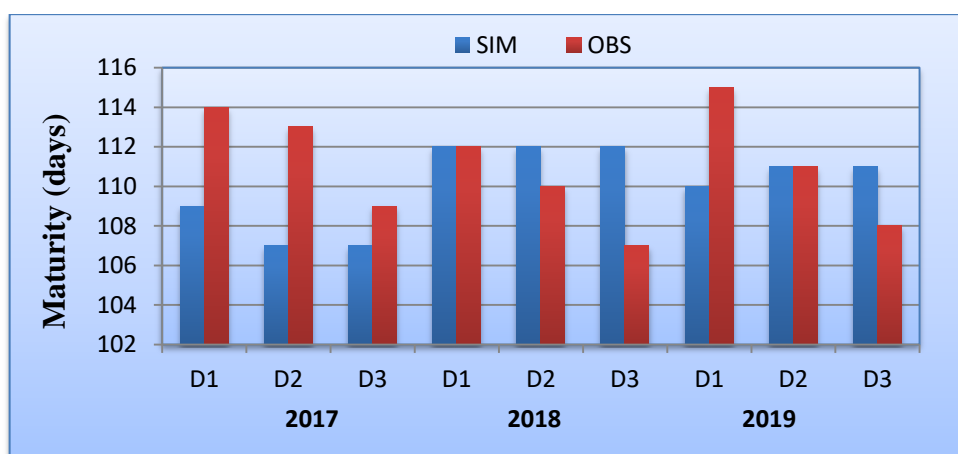
Date of transplanting Year 2017	Cultivars								
	MTU-1010			Rajeswari			CG Sugandhit bhog		
	Obs.	Sim.	Error %	Obs.	Sim.	Error %	Obs.	Sim.	Error %
D1	89	90	1.1	103	101	-1.9	114	109	-4.4
D2	86	89	3.5	99	98	-1.0	113	107	-5.3
D3	84	86	2.4	93	96	3.2	109	107	-1.8
R ²	0.85			0.95			0.43		
RMSE	2.16			2.16			4.66		
D - index	0.75			0.88			0.48		
Year 2018									
D1	90	94	4.4	102	103	1.0	112	112	0.0
D2	87	92	5.7	97	103	6.2	110	111	0.9
D3	86	89	3.5	94	102	8.5	107	111	3.7
R ²	0.85			0.62			0.71		
RMSE	4.08			5.80			3.11		
D -index	0.54			0.47			0.46		
Year 2019									
D1	93	91	-2.2	105	102	-2.9	115	110	-4.3
D2	89	89	0.0	98	101	3.1	111	111	0.0
D3	87	90	3.4	96	101	5.2	108	111	2.8
R ²	0.42			0.95			0.82		
RMSE	2.08			3.78			3.37		
D -index	0.60			0.53			0.13		



(a)



(b)



(c)

Fig: 4.3 Comparison of simulated and observed days required for physiological maturity for different rice cultivars i.e. (a) MTU-1010 (b) Rajeswari (c) CG Sugandhit Bhog under different growing environment.

4.2.2 Grain yield

The observed and simulated data for grain yield under different dates of transplanting of rice genotypes are presented in Table-4.5 and shown in Fig.-4.4

The error percentage of grain yield in MTU1010 variety was in the range of -3.9% to 10.9% during 2017 with RMSE value of 204.0, R^2 value of 0.18 and D-index value of 0.22. It was in range of -14.9 to 9.4 during 2018 with RMSE, R^2 and D-index value 398.7, 0.09 and 0.19 respectively with three date of transplanting. During validation it was in range of -13.9 % with D3 and 9.8 with D1. Which indicates that on observed and simulated results are in similar and under limit of acceptance.

The observed and simulated value of grain yield of Rajeswari was in the range of -3.4 to 11.7 % with different date of transplanting in the year 2017, where in the RMSE value was 249.1, R^2 value was 0.75 and D-index value was 0.35. During 2018 the error percentage ranges between -9.8 to 12.2 with RMSE value of 375.9, R^2 value of 0.01 and D-index value of 0.29. When the model was validated in the year 2019 the error percent was in the range of -6.5 to 5.6 with RMSE, R^2 & D-index value of 214.4, 0.94 and 0.87 respectively. The error percentage was in range of acceptable limit.

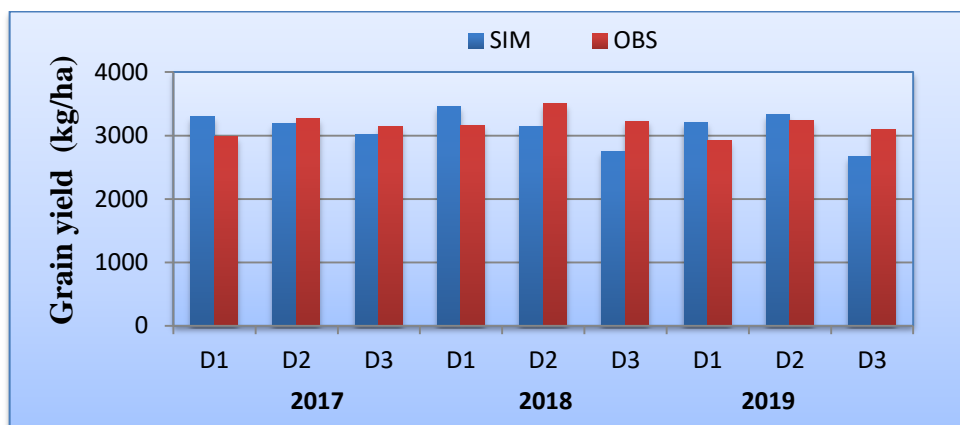
When the data are recorded grain yield and compared with simulated value, it was observed that the error percent was in the range of -0.3 to 10.9 with the RMSE value of 295.4, R^2 value of 0.74 and d-static value of 0.49 in the year 2017. During 2018 our result that the error percent was in the range of -15.3 to 6.6% with RMSE value of 333.6, R^2 value of 1.00 and D- index value of 0.77. When the error percent of days taken for maturity in variety CG Sugandhit bhog was validated during 2019 the result was in the range of 0.2 to 18.3 in different date with RMSE value of 538.9, R^2 value of 0.38 and D-index value of 0.36. It indicates it can be said that our results are in the range of acceptable limits.

The above results indicate that the model predicted the Grain yield with good agreement & satisfactory level for cultivar MTU-1010, Rajeswari and CG Sugandhit Bhog. all over Simulated phonological and yield were found to be in

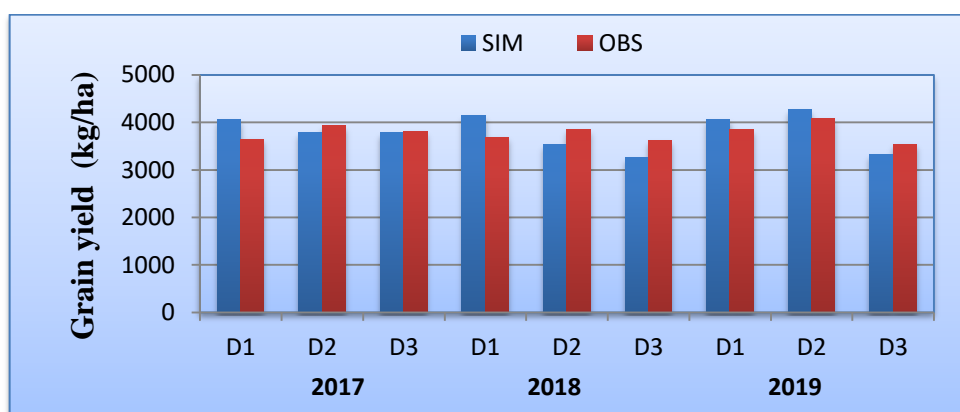
reasonable agreement with the observed ones. Simulation showed the increasing error % with delay in Transplanting but suit satisfactory at first and second dates of Transplanting Rai and Kushwaha, (2005); Agarwal *et. al.* (2010) were also reported the similar results.

Table: 4.5 Comparison of simulated and observed grain yield (kg ha⁻¹) different rice cultivars i.e. MTU-1010, Rajeswari and CG Sugandhit Bhog under different growing environment.

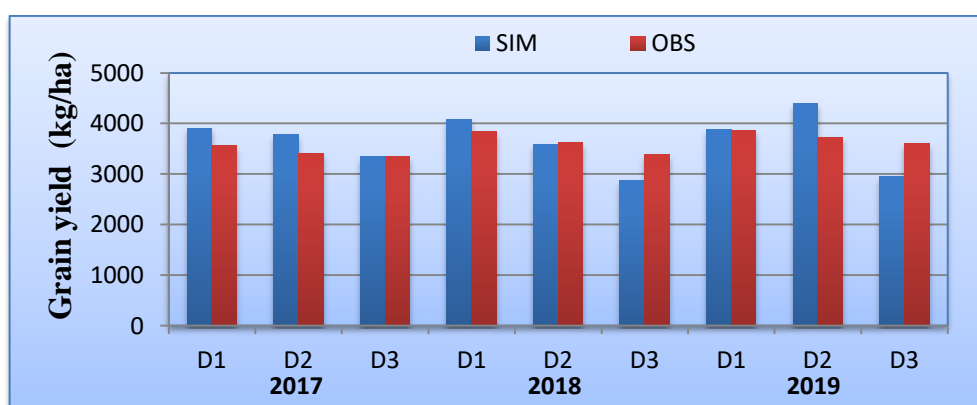
Date of transplanting Year 2017	Cultivars								
	MTU-1010			Rajeswari			CG Sugandhit bhog		
	Obs.	Sim.	Error%	Obs.	Sim.	Error%	Obs.	Sim	Error %
D1	2983	3307	10.9	3648	4051	11.7	3560	3911	9.9
D2	3264	3193	-2.2	3940	3787	-3.4	3417	3789	10.9
D3	3135	3013	-3.9	3801	3782	-0.5	3353	3342	-0.3
R ²	0.18			0.76			0.74		
RMSE	204.0			249.1			295.4		
D - index	0.22			0.34			0.49		
Year 2018									
D1	3166	3464	9.4	3690	4136	12.1	3839	4091	6.6
D2	3502	3135	-10.5	3847	3531	-8.2	3633	3588	-1.2
D3	3229	2747	-14.9	3619	3265	-9.8	3390	2872	-15.3
R ²	0.09			0.01			1.00		
RMSE	398.7			375.9			333.6		
D -index	0.19			0.29			0.77		
Year 2019									
D1	2925	3212	9.8	3841	4057	5.6	3872	3881	0.2
D2	3234	3327	2.9	4078	4275	4.8	3734	4392	17.6
D3	3098	2667	-13.9	3543	3314	-6.5	3609	2947	18.3
R ²	0.09			0.94			0.38		
RMSE	303.7			214.4			538.9		
D -index	0.34			0.87			0.36		



(a)



(b)



(c)

Fig: 4.4 Comparison of simulated and observed grain yield (kg ha^{-1}) different rice cultivars i.e. (a) MTU-1010 (b) Rajeswari (c) CG Sugandhit Bhog under different growing environment.

4.3 Determining optimum sowing date of rice crop

On the basis of CERES rice model, the suitability of sowing date can be analyzed transplanting of rice was done at an interval of 15 days i.e. 1st July(D1), 15th July(D2) & 30th July(D3) which were simulated using output of CERES rice model for three cultivars of rice viz. MTU-1010, Rajeswari & CG Sugandhit Bhog. These dates were selected because this common transplanting dates of our state and we receive sufficient amounts but its distribution is erratic in nature need to be find out suitable sowing/planting of rice crop varieties.

4.3.1 Phonological development

4.3.1.1 Days to panicle initiation

The data on days to panicle initiation analyzed for different transplanting dates are presented in table 4.6 and depicted in fig 4.5.

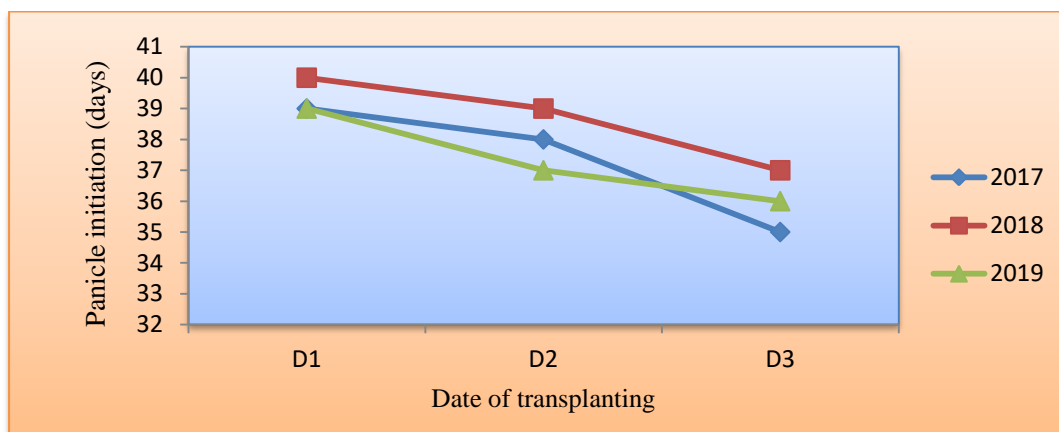
It is evident from the table 4.6 that during 2017 the maximum value was observed for panicle initiation in the variety MTU-1010 in transplanting date of 1st July (D1) followed by 15th July (D2) & 30th July (D3). Similar trend was notice during 2018 and the result of validation also falls in the similar line.

In cv. Rajeswari days required for panicle initiation was highest in planting on 1st July (D1) followed by transplanting on 15th July (D2) & 30th July (D3) during 2017. Similar trends was noticed during 2018 observed when on model was validated with the help of data on 2019 similar result were observed.

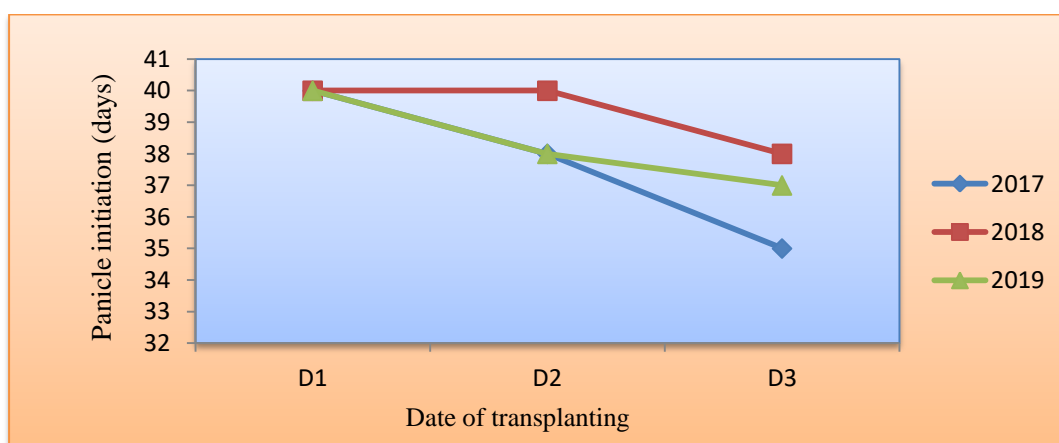
For CG Sugandhit Bhog variety, days required to panicle initiation was maximum in transplanting date of 1st July (D1) followed by 15th July (D2) & 30th July (D3) in the year 2017. Similar trend was notice during 2018 and the result of validation also falls in the similar line.

Table: 4.6 Days required for panicle initiation on simulated condition under different growing environment for different rice cultivars.

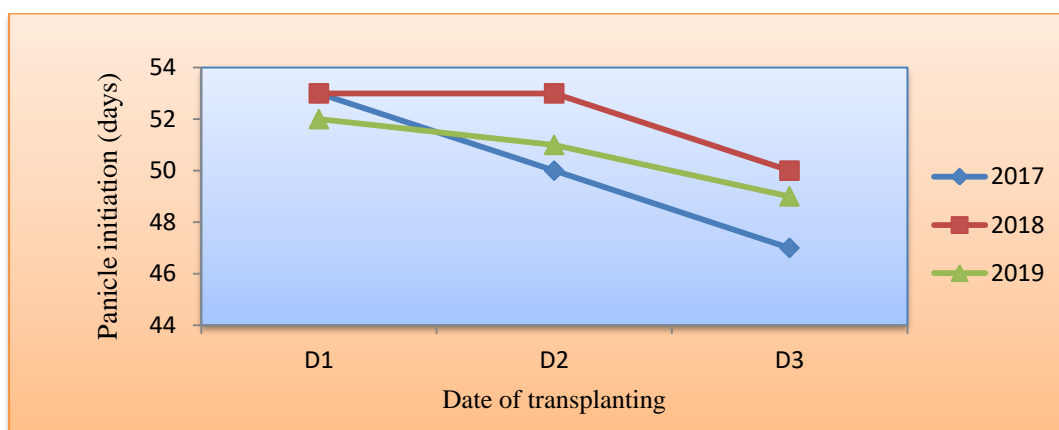
Date of transplanting	MTU1010	Rajeswari	CG Sugandhit Bhog
2017			
D1	39	40	53
D2	38	38	50
D3	35	35	47
2018			
D1	40	40	53
D2	39	40	53
D3	37	38	50
2019			
D1	39	40	52
D2	37	38	51
D3	36	37	49



(a)



(b)



(c)

Fig 4.5 Simulated panicle initiation for different cultivars (a) MTU-1010 (b) Rajeswari (c) CG Sugandhit bhog under different growing environment.

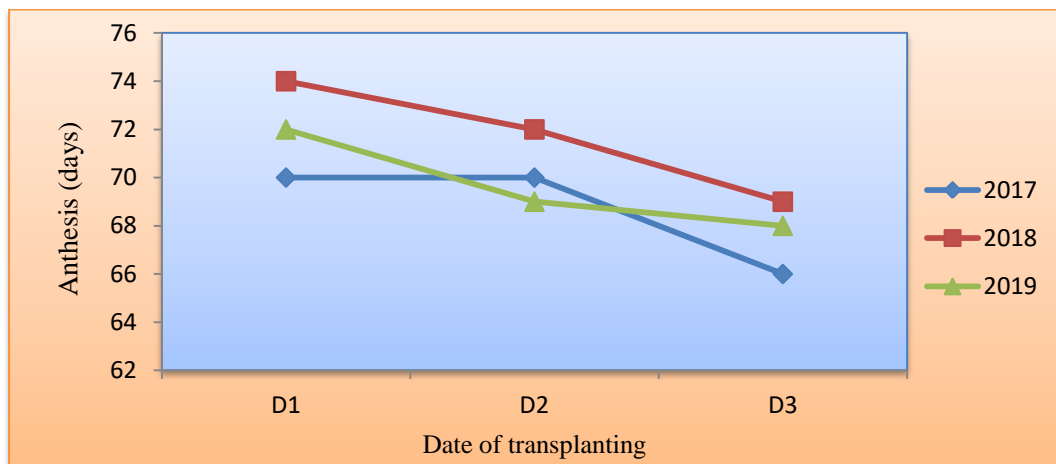
4.3.1.2 Days to anthesis

The data on days to anthesis analyzed for optimum date of transplanting are presented in table 4.7 and depicted in fig 4.6.

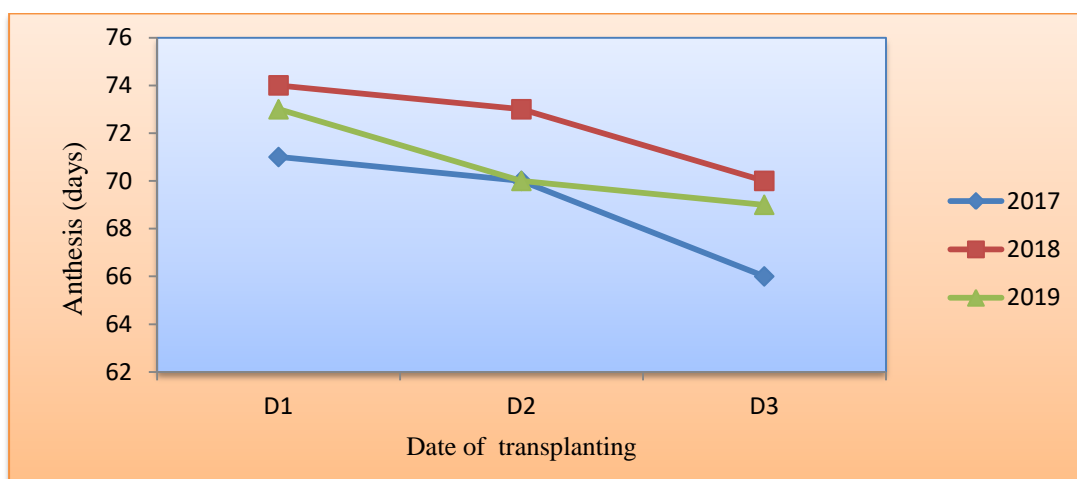
It is similar chain from the table that in all three variety i.e. MTU1010, Rajeswari and CG Sugandhit Bhog transplanted on 1st July(D1) required highest days for anthesis followed by transplanting of 15th July and 30th July during both the years (2017 & 2018). The result of validation also falls in the similar line.

Table: 4.7 Days required for anthesis on simulated condition under different growing environment for different rice cultivars.

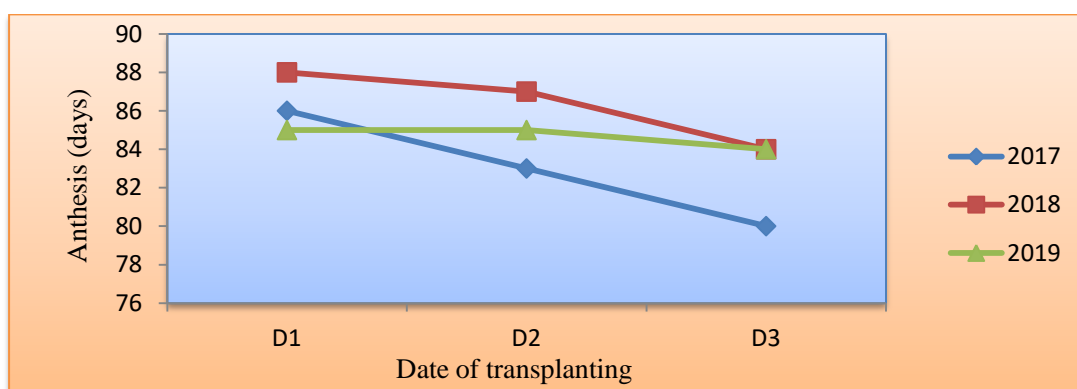
Date of transplanting	MTU1010	Rajeswari	CG Sugandhit Bhog
2017			
D1	70	71	86
D2	70	70	83
D3	66	66	80
2018			
D1	74	74	88
D2	72	73	87
D3	69	70	84
2019			
D1	72	73	85
D2	69	70	85
D3	68	69	84



(a)



(b)



(c)

Fig: 4.6 Simulated anthesis days for different cultivars (a) MTU-1010 (b) Rajeswari (c) CG Sugandhit bhog under different growing environment.

4.3.1.3 Days to maturity

The effect of different transplanting dates on days to maturity are presented in table 4.8 & depicted in fig 4.7.

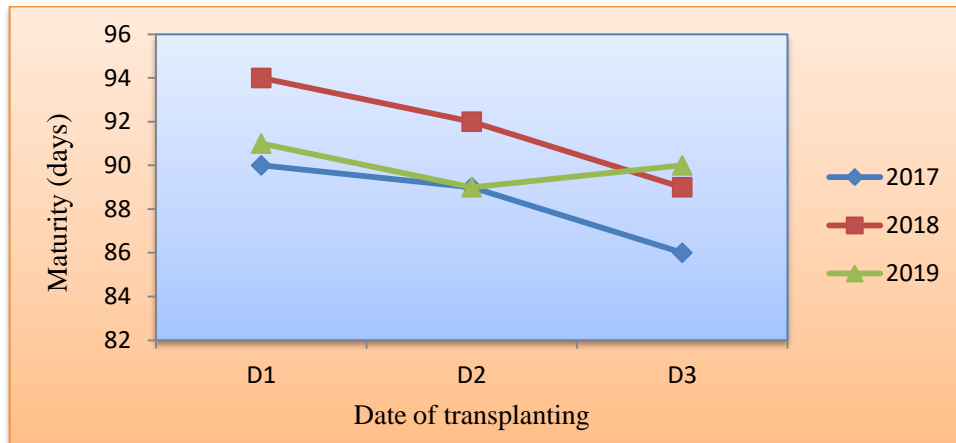
It is similar chain from the table that when varieties MTU 1010 & Rajeswari was transplanted 1st July, tooks maximum days for maturity during 2017. Similar trend was notice during 2018 and the result of validation also falls in the similar line.

When in CG Sugandhit Bhog days required for maturity was highest in transplanting i.e. 1st July (D1) followed by 15th July (D2) transplanting & 30th July (D3) transplanting during 2017 and 2018. While result of validation indicates that second and third date of transplanting maximum yield followed by first date.

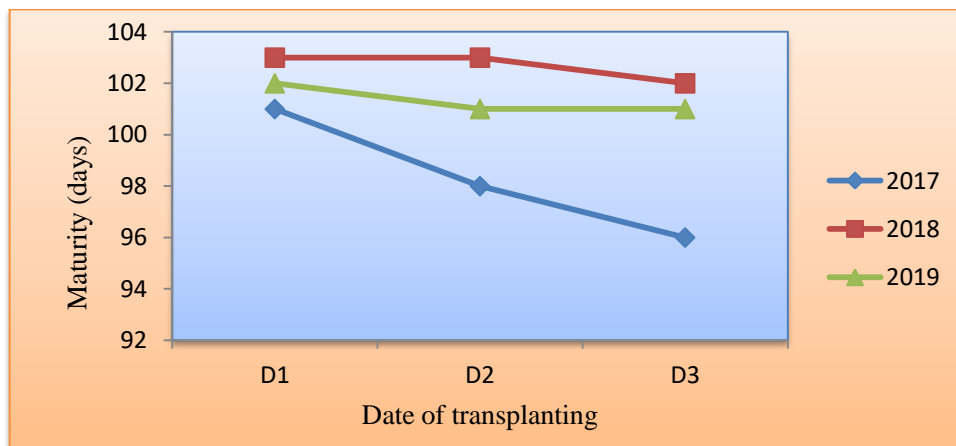
It can be said that transplanting of all varieties on 1st July required maximum days to maturity & delay of transplanting crop maturation earlier as compared to transplanting of 1st July.

Table: 4.8 Days required for maturity on simulated condition under different growing environment for different rice cultivars.

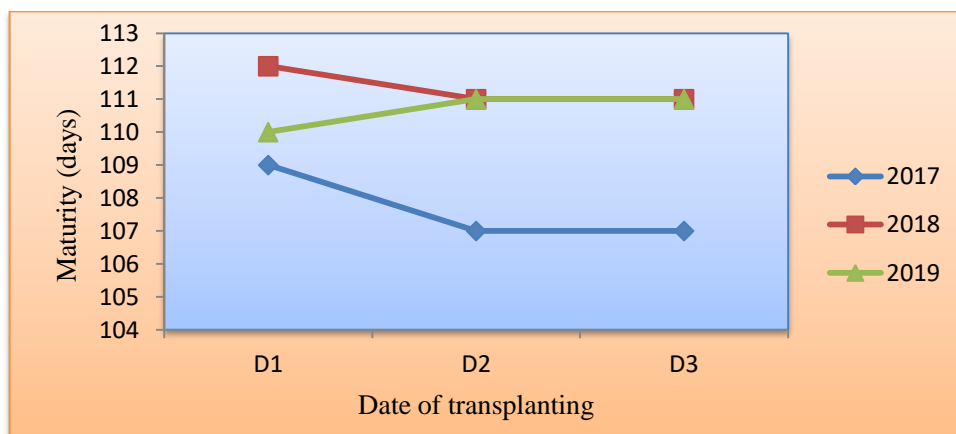
Date of transplanting	MTU1010	Rajeswari	CG Sugandhit Bhog
2017			
D1	90	101	109
D2	89	98	107
D3	86	96	107
2018			
D1	94	103	112
D2	92	103	111
D3	89	102	111
2019			
D1	91	102	110
D2	89	101	111
D3	90	101	111



(a)



(b)



(c)

Fig: 4.7 Simulated maturity days for different cultivars (a) MTU-1010 (b) Rajeswari (c) CG Sugandhit Bhog under different growing environment.

4.3.2 Grain yield

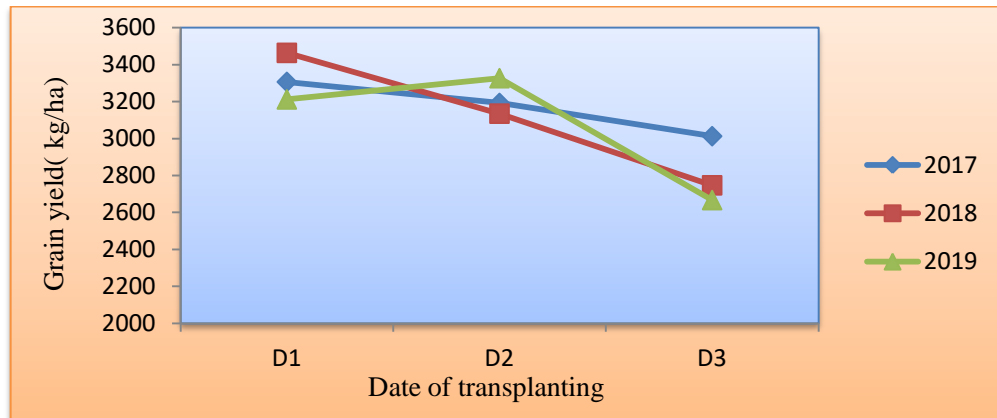
Data on grain yield are presented in table 4.9 and depicted in fig 4.8.

It can be observed from the table that highest grain yield of all variety viz. MTU1010, Rajeswari and CG Sugandhit Bhog was observed with the transplanting on 1st July followed by 15th & 30th July transplanting of the year 2017. Similar result of 2018 also falls in the same trends. While result of validation indicates that second date of transplanting maximum yield followed by D1 and D3.

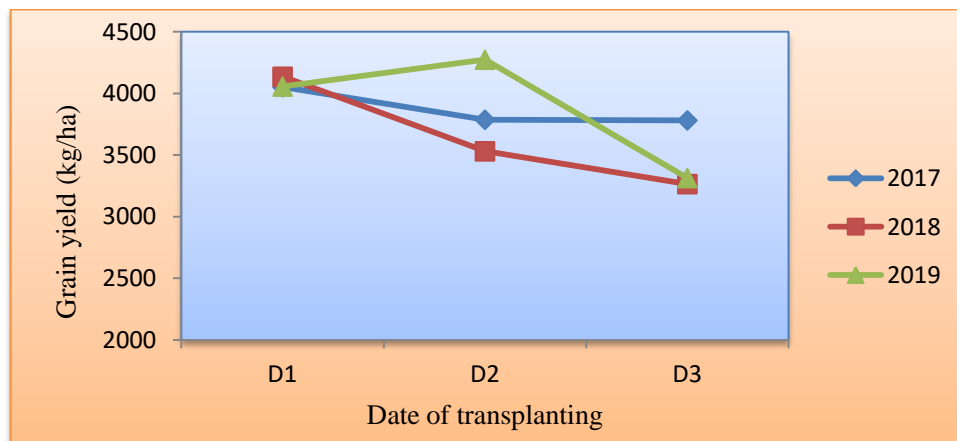
Gunawardena *et al.* (2003) reported that delay in planting of rice resulted increased sterility percentage.

Table: 4.9 Grain yield (kg/ha) on simulated condition under different growing environment for different rice cultivars

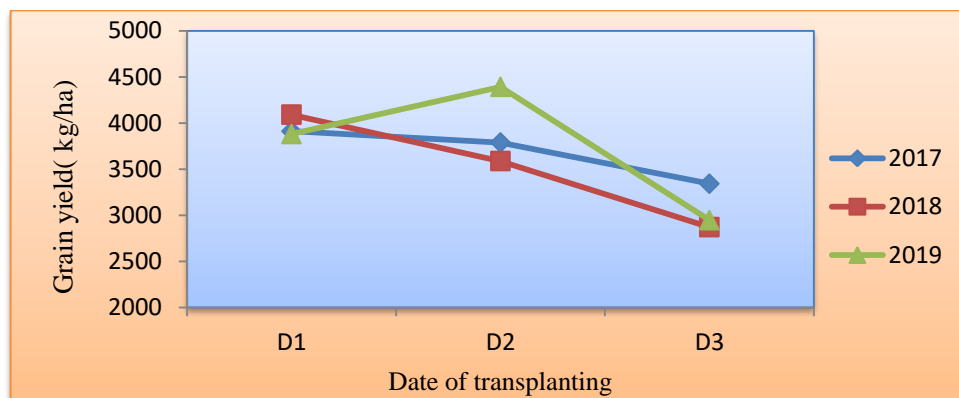
Date of transplanting	MTU1010	Rajeswari	CG Sugandhit Bhog
2017			
D1	3307	4051	3911
D2	3193	3787	3789
D3	3013	3782	3342
2018			
D1	3464	4136	4091
D2	3135	3531	3588
D3	2747	3265	2872
2019			
D1	3212	4057	3881
D2	3327	4275	4392
D3	2667	3314	2947



(a)



(b)



(c)

Fig: 4.8 Simulated grain yield (kg/ha) for different cultivars (a) MTU-1010 (b) Rajeswari (c) CG Sugandhit bhog under different growing environment.

4.4 Assessment of production potential of different rice varieties through DSSAT Model for Raipur district.

The production potential of different rice varieties viz. MTU1010, Rajeswari & CG Sugandhit Bhog has been assessed using DSSAT (Decision Support System for Agro-technology transfer) model in Raipur district. The duration of anthesis, maturity and grain yield were obtained from the simulation model.

4.4.1 Production potential of MTU-1010 under three dates of transplanting at Raipur district.

It is evident from data shown in table 4.10 that day taken for Anthesis of varieties MTU1010 was highest in first transplanting date i.e. 1st July (D1) for Raipur district in range of 72 to 68. The days taken for maturity of varieties MTU1010 was highest in first transplanting date i.e. 1st July (D1) for Raipur district in range of 91 to 90.

The outcome of grain yield of MTU1010 indicates that the highest grain yield was recorded in second date of transplanting Raipur district. It was 3326 kg/ha. The data on days required for anthesis, maturity and grain yield of MTU 1010 for Raipur district are presented in fig 4.9.

Table: 4.10 Production potential of cultivar MTU-1010 under three dates of transplanting.

Date of transplanting	Days to Anthesis	Days to Maturity	Grain Yield (Kg/ha)
D1(1 July)	72	91	3212
D2 (15 July)	69	89	3326
D3 (30 July)	68	90	2667

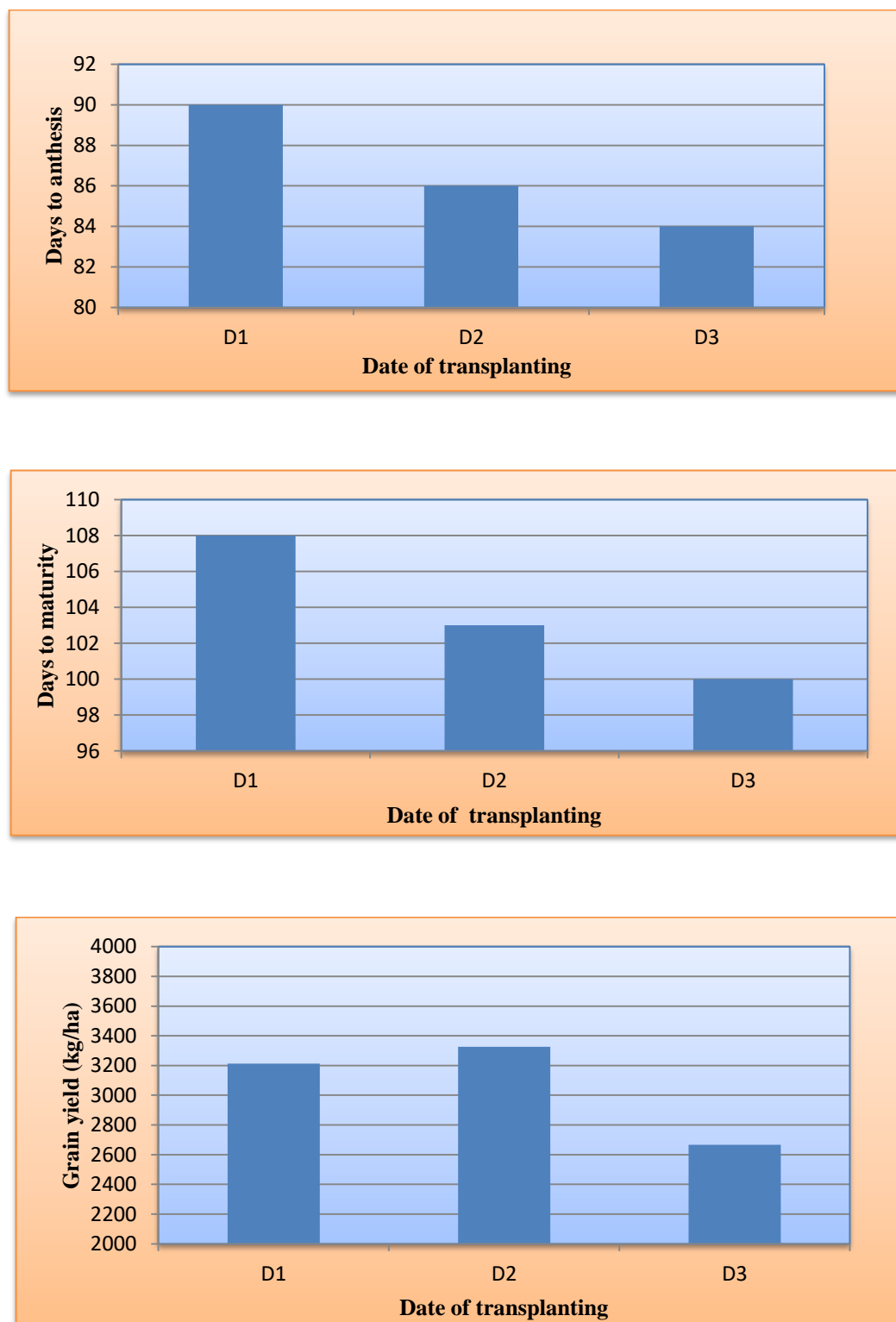


Fig: 4.9 Days to anthesis, maturity and grain yield (kg/ha) of MTU1010 under different dates of transplanting at Raipur district

4.4.2 Production potential of Rajeswari under three dates of transplanting at Raipur district.

The data of variety Rajeswari with respect to recorded for all the days to anthesis, Days to maturity & grain yield are presented in table 4.11.

It can be clearly observed that days taken for Anthesis of variety Rajeswari was highest in first transplanting date i.e. 1st July (D1) for Raipur district in the range of 73 to 69, The days taken for maturity of varieties Rajeswari was highest in first transplanting date i.e. 1st July (D1) for Raipur district in the range of 102 to 101.

The outcome of grain yield of Rajeswari indicates that the highest grain yield was recorded in second date of transplanting in Raipur district (Raipur in the range of 4275kg/ha to 3313kg/ha) (Fig 4.10).

Table: 4.11 Production potential of cultivar Rajeswari under three dates of transplanting.

Date of transplanting	Days to Anthesis	Days to Maturity	Grain Yield (Kg/ha)
D1 (1 July)	73	102	4057
D2 (15 July)	70	101	4275
D3 (30 July)	69	101	3313

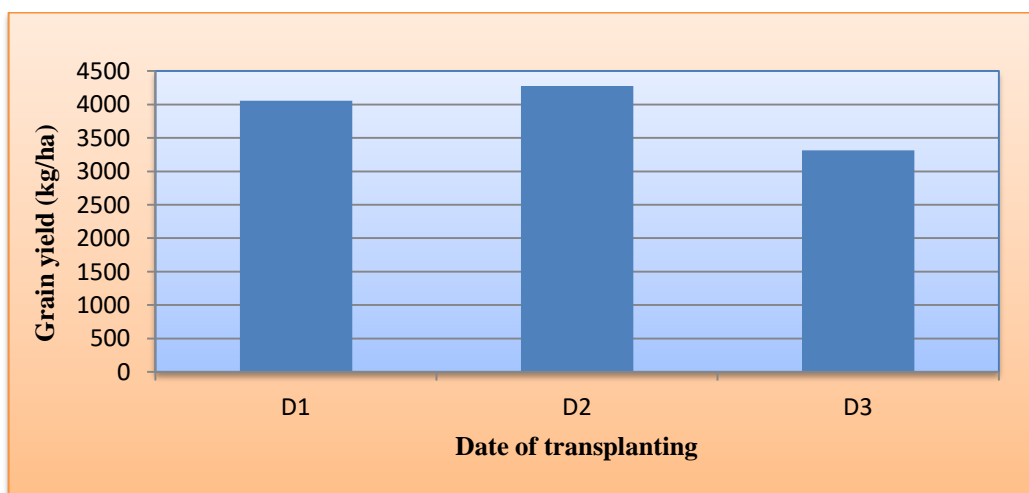
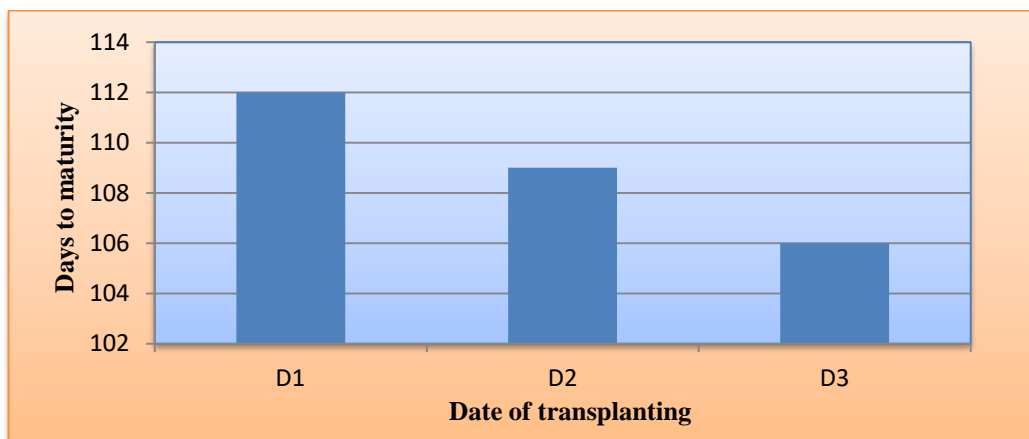
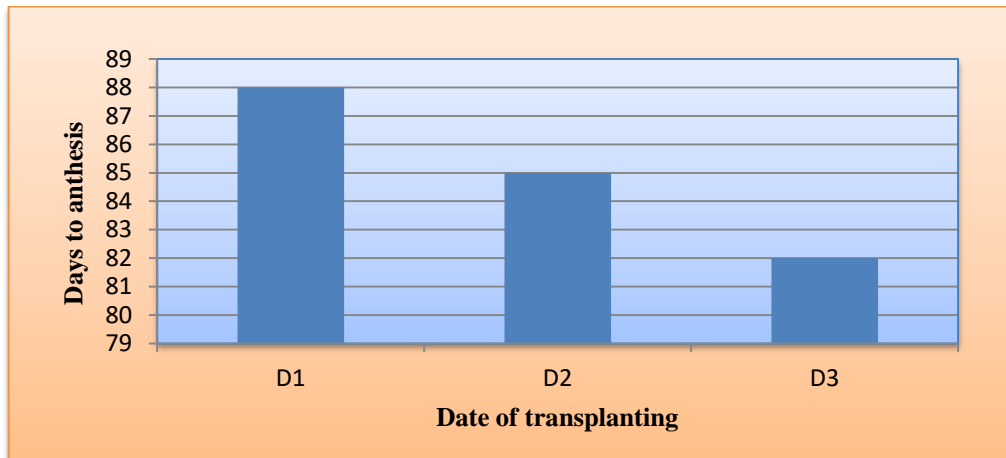


Fig: 4.10 Days to anthesis, maturity and grain yield (kg/ha) of Rajeswari under different dates of transplanting at Raipur district.

4.4.3 Production potential of CG Sugandhit Bhog under three dates of transplanting at Raipur district.

Table 4.12 indicates that days taken for Anthesis of varieties CG Sugandhit Bhog was highest in first transplanting date i.e. 1st July (D1) i.e. Raipur district (Raipur in the range of 86 to 84, The days taken for maturity of varieties CG Sugandhit Bhog was highest in third transplanting date i.e. 30th July (D1) Raipur district (Raipur in the range of 111 to 110).

The outcome of grain yield of CG Sugandhit Bhog shows that the highest grain yield was obtained in second date of transplanting in Raipur district (Raipur in the range of 4392kg/ha to 2947kg/ha).

Model estimated the days taken to anthesis and maturity among all the dates of transplanting and variety. Number of days to attain anthesis and maturity were found to be decreased as the sowing dates were delayed in all the three varieties (MTU1010, Rajeswari and CG Sugandhit Bhog). The analysis found that 3rd date of transplanting (30 July) is most vulnerable to possible increase of temperature followed by 2nd (15 July) and 1st date of transplanting (1st July). As yield reduction is lowest in 2nd date of transplanting (15th July) with all the cultivars i.e. MTU1010, Rajeswari and CG Sugandhit Bhog in Raipur district. It will be appropriate to go for mid season (15th July) transplanting of rice to minimize climate induced yield loss considering the future scenarios.

Similarly, Dongarwar *et al.* (2005) also reported that early sowing on 15 and 30 June resulted significantly higher grain yield 31.29 and 32.61 q/ha, respectively than late sowing on 15 August (28.40 q/ha)

Table: 4.12 Production potential of cultivar CG Sugandhit Bhog under three dates of transplanting at Raipur districts.

Date of transplanting	Days to Anthesis	Days to Maturity	Grain Yield (Kg/ha)
D1 (1 July)	89	110	3881
D2 (15 July)	85	111	4329
D3 (30 July)	84	111	2947

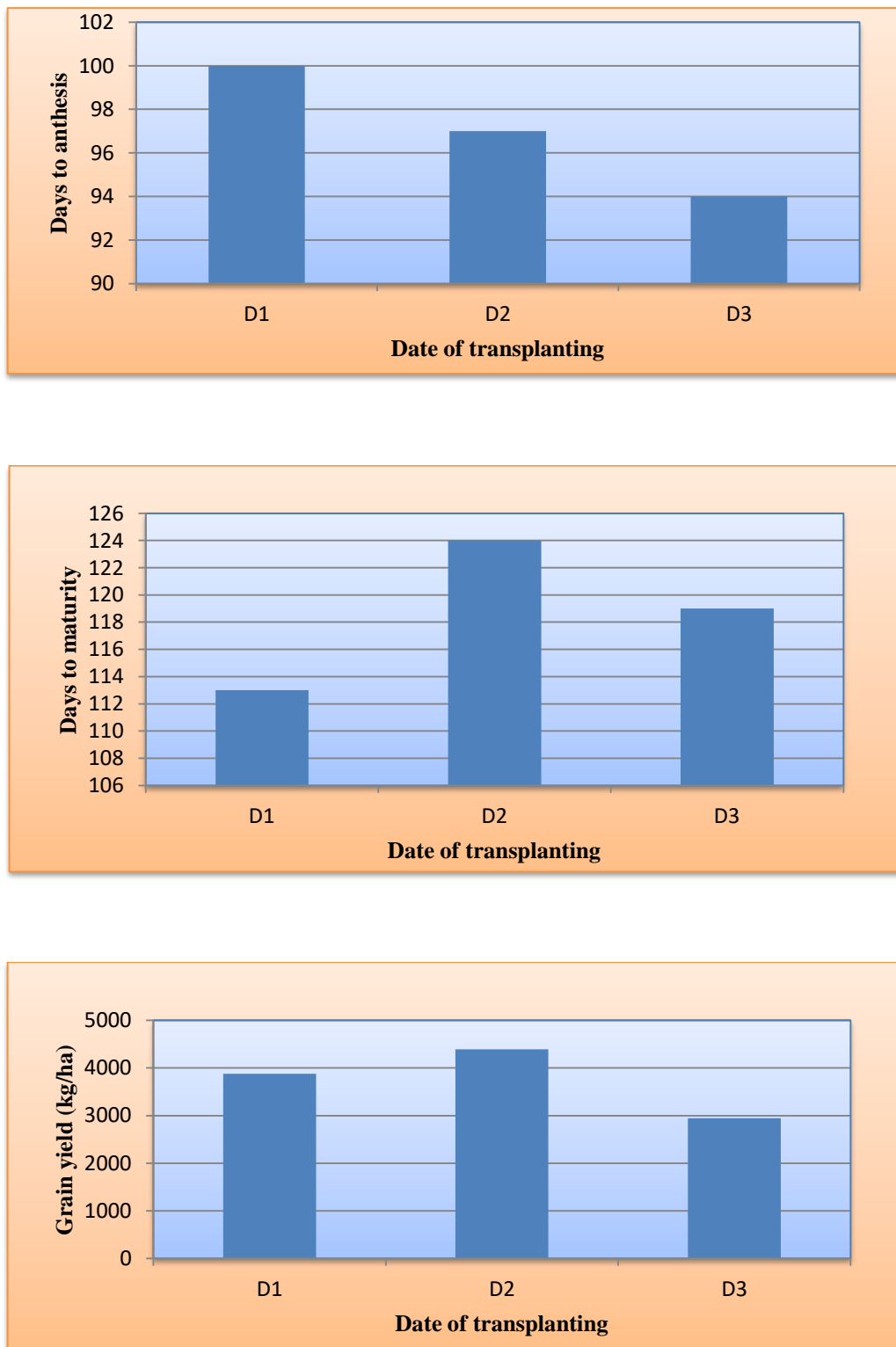


Fig: 4.11 Days to anthesis, maturity and grain yield (kg/ha) of CG Sugandhit Bhog under different dates of transplanting at Raipur district

4.5 Sensitivity analysis of different rice cultivars under different growing environment through CERES-Rice model for Raipur district.

The sensitivity analysis is an important step to use the simulation model, which explains that what will be impact of change in temperature on growth and development of plant. It also explains that what will happen if the normal value of temperature may increase or decrease. In present study sensitivity analysis has been carried out in different temperature scenarios, which are addition in daily temperature by 0.5°C, 1°C and 1.5°C in maximum and minimum ,only maximum, only minimum and decrease of minimum temperature. The effect of elevated temperature on grain yield of three rice varieties evaluated through CERES Rice model is given below.

4.5.1 Sensitivity analysis for grain yield of cultivar MTU1010.

Effect of increase on maximum and minimum temperature (+0.5 to +1.5°C) on grain yield of MTU 1010 transplanted on different date are presented in table 4.13 & depicted in fig 4.12.

It is quite clear from the table that increase of maximum and minimum temperature by 0.5°C, resulted increased grain yield of MTU1010 in all the date of transplanting. Where in the increase of maximum and minimum temperature by +1 and +1.5°C resulted decrease of grain yield of MTU1010 in D1 and D2 transplanting while transplanting in third date i.e. D3 reported increase grain yield.

Data on grain yield of MTU1010 affected by increase in only maximum temperature are given in table 4.14 and depicted in fig 4.13.

It is clear from the table that increase of only maximum temperature by 0.5°C, the grain yield of MTU 1010 also increased in between 1.5 to 5.7 percentages in different date of transplanting. Whereas the increase of maximum temperature by +1°C and +1.5°C resulted decrease grain yield of MTU1010 in the range of 0.3% to -2.4% in D1 and D3 transplanting. In D1 and D3 planting except in D2 transplanting where increased grain yield of variety MTU1010 was observed with increasing temperature of +1°C & 1.5°C and the percentage was in the range of 2.2 to 3.2.

Table: 4.13 Sensitivity analysis of increased maximum and minimum temperature ($^{\circ}\text{C}$) over normal temperature on grain yield of cultivar MTU-1010 for Raipur district.

Date of transplanting	(Base yield)(kg/ha)	Increased maximum & minimum temperature ($^{\circ}\text{C}$) over normal temperature					
		+0.5		+1		+1.5	
		Simulated grain yield kg/ha	(%) change from base yield	Simulated grain yield kg/ha	(%) change from base yield	Simulated grain yield kg/ha	(%) change from base yield
D1 (1st July)	3212	3463	7.8	3172	-1.2	3151	-1.8
D2 (15th July)	3326	3540	6.4	3288	-1.1	3190	-4.0
D3 (30th July)	2667	2871	7.6	2717	1.8	2741	2.7

Table: 4.14 Sensitivity analysis of increased only maximum temperature ($^{\circ}\text{C}$) over normal temperature on grain yield of cultivar MTU-1010 for Raipur district.

Date of transplanting	Base yield(kg/ha)	Increased maximum temperature ($^{\circ}\text{C}$) over normal temperature					
		+0.5		+1		+1.5	
		Simulated grain yield kg/ha	(%) change from base yield	Simulated grain yield kg/ha	(%) change from base yield	Simulated grain yield kg/ha	(%) change from base yield
D1 (1st July)	3212	3311	3.0	3174	-1.1	3197	-0.4
D2 (15th July)	3326	3516	5.7	3400	2.2	3433	3.2
D3 (30th July)	2667	2709	1.5	2601	-2.4	2659	-0.3

The grain yield of MTU 1010 affected by increase in only minimum temperatures are presented in table 4.15 & depicted in fig 4.14.

Outcome indicates that the grain yield of MTU1010 increased in all three transplanting dates when the minimum temperature was increased by 0.5°C . Where in the increase of minimum temperature by +1 and $+1.5^{\circ}\text{C}$ resulted decrease grain yield of MTU1010 in three date of transplanting and the reduction percentage was in between -0.30 to -2.8.

Effect of decrease of only minimum temperature on production of MTU1010 are presented in table 4.16 & depicted in fig 4.15.

The decrease of only minimum temperature by 0.5, 1 & 1.5°C resulted increase grain yield of MTU1010 in all three transplanting date the percent increase of grain yield was in the range of 1.8 to 8.5. Except in case of decrease in only minimum temperature by -1 and -1.5°C in third date of transplanting reported negative grain yield.

Table: 4.15 Sensitivity analysis of increase only minimum temperature (°C) over normal temperature on grain yield of cultivar MTU-1010 for Raipur district.

Date of transplanting	Base yield (kg/ha)	Increased minimum temperature (°C) over normal temperature					
		+0.5		+1		+1.5	
		Simulated grain yield (kg/ha)	(%) change from base yield	Simulated grain yield (kg/ha)	(%) change from base yield	Simulated grain yield (kg/ha)	(%) change from base yield
D1(1 st July)	3212	3302	2.8	3168	-1.3	3202	-0.3
D2(15 th July)	3326	3523	5.9	3300	-0.7	3243	-2.4
D3(30 th July)	2667	2705	1.4	2592	-2.8	2664	-1.5

Table: 4.16 Sensitivity analysis of decreased only minimum temperature (°C) over normal temperature on grain yield of cultivar MTU-1010 for Raipur district.

Date of transplanting	Base yield (kg/ha)	Decreased minimum temperature (°C) over normal temperature					
		-0.5		-1		-1.5	
		Simulated grain yield (kg/ha)	(%) change from base yield	Simulated grain yield (kg/ha)	(%) change from base yield	Simulated grain yield (kg/ha)	(%) change from base yield
D1(1 st July)	3212	3350	4.2	3297	2.6	3285	2.2
D2(15 th July)	3326	3612	8.5	3551	6.7	3546	6.6
D3(30 th July)	2667	2717	1.8	2628	-1.4	2599	-2.5

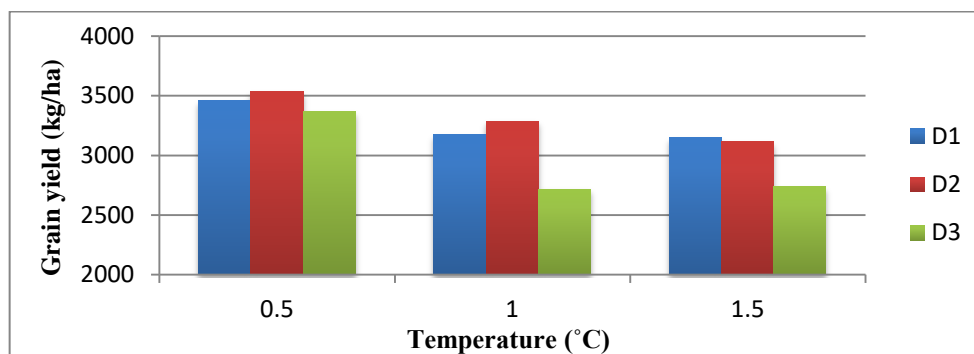


Fig: 4.12 Effect of increased maximum & minimum temperature on grain yield of MTU1010 for Raipur district.

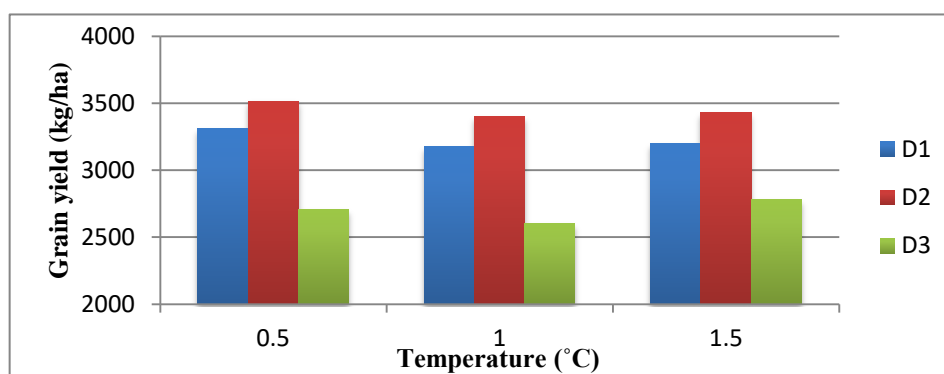


Fig: 4.13 Effect of increased only maximum temperature on grain yield of MTU1010 for Raipur district.

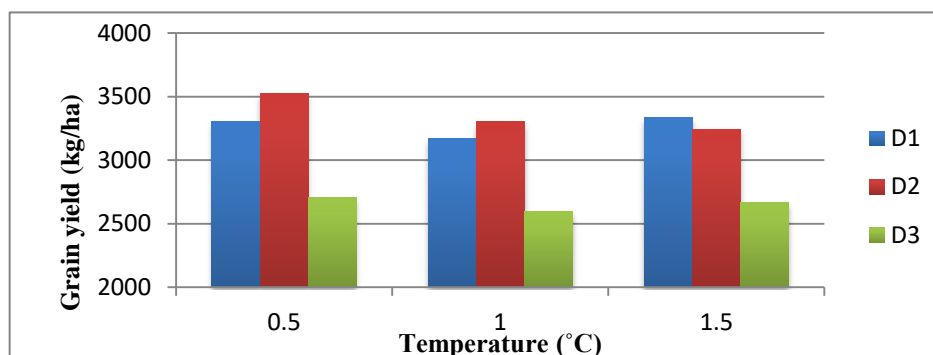


Fig: 4.14 Effect of increased only minimum temperature on grain yield of MTU1010 for Raipur district.

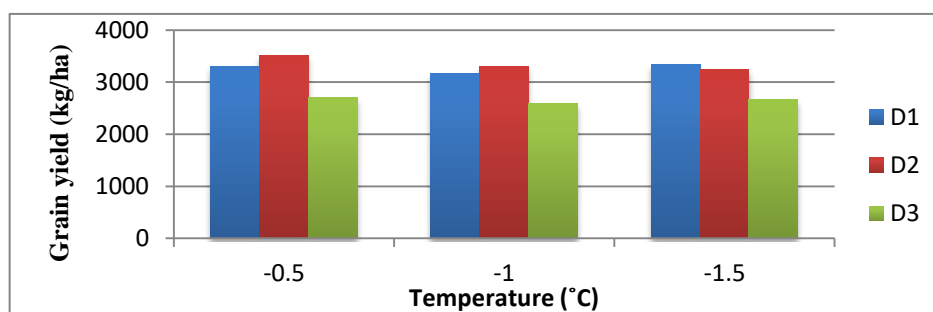


Fig: 4.15 Effect of decreased only minimum temperature on grain yield of MTU1010 for Raipur district.

4.5.2 Sensitivity analysis for grain yield of cultivar Rajeswari.

Effect of elevated maximum and minimum temperature on the grain yield of variety Rajeswari are presented in table 4.17 & depicted in fig 4.16.

The result reported that increased of maximum and minimum temperature by +0.5, +1 and +1.5°C, the reported decrease grain yield in first and second date of transplanting and the reduction of grain yield during D1 & D2 transplanting was in the range of -2.0 to -8.0. In third date of transplanting grain yield was increased and the range was in between 1.2 to 3.7 percent.

Table: 4.17 Sensitivity analysis of increased maximum & minimum temperature (°C) over normal temperature on grain yield of cultivar Rajeswari for Raipur district.

Date of transplanting	Base yield(kg/ha)	Increased maximum & minimum temperature (°C) over normal temperature					
		+0.5		+1		+1.5	
		Simulated grain yield kg/ha	(%) change from base yield	Simulated grain yield kg/ha	(%) change from base yield	Simulated grain yield kg/ha	(%) change from base yield
D1(1st July)	4057	3975	-2.0	3931	-3.1	3830	-5.5
D2(15th July)	4275	4092	-4.2	4155	-2.8	3930	-8.0
D3(30th July)	3313	3356	1.2	3368	1.6	3436	3.7

Effect of increase on only maximum temperature in the range of +0.5 to +1.5°C on grain yield of Rajeswari are presented in table 4.18 & depicted in fig 4.17.

It can be seen from the table that 0.5°C increase of only maximum temperature resulted negative grain yield of rice in D1 transplanting while in D2 & D3 transplanting gave higher yield. The increase percentage of grain yield in during D2 & D3 transplanting was in the range of 0.8% to 2.5%. Increase of temperature by 1°C & 1.5°C resulted decrease grain yield in D1 & D2 dates of transplanting except increase of temperature by 1.0°C in D3 transplant.

Table: 4.18 Sensitivity analysis of increased only maximum temperature (°C) over normal temperature on grain yield of cultivar Rajeswari for Raipur district.

Date of transplanting	Base yield(kg/ha)	Increase maximum temperature (°C) over normal temperature					
		+0.5		+1		+1.5	
		Simulated grain yield kg/ha	(%) change from base yield	Simulated grain yield kg/ha	(%) change from base yield	Simulated grain yield kg/ha	(%) change from base yield
D1(1 st July)	4057	3920	-2.7	3967	-2.2	3869	-4.6
D2(15 th July)	4275	4313	0.8	4216	-1.3	4209	-6.1
D3(30 th July)	3313	3391	2.3	3399	2.5	3308	-0.1

Table: 4.19 Sensitivity analysis of increased only minimum temperature (°C) over normal temperature on grain yield of cultivar Rajeswari for Raipur district.

Date of transplanting	Base yield(kg/ha)	Increase minimum temperature (°C) over normal temperature					
		+0.5		+1		+1.5	
		Simulated grain yield kg/ha	(%) change from base yield	Simulated grain yield kg/ha	(%) change from base yield	Simulated grain yield kg/ha	(%) change from base yield
D1(1 st July)	4057	3922	-3.2	3964	-2.2	3954	-2.5
D2(15 th July)	4275	4320	1.0	4093	-4.2	4111	-3.8
D3(30 th July)	3313	3331	0.5	3375	1.8	3425	3.3

Effect of increase of only minimum temperature by +0.5 to +1.5°C on different date of transplanting are presented in table 4.19 & depicted in fig 4.18.

On perusal of data indicates that increased of temperature by +0.5 resulted negative grain yield in D1 (-3.2%) planting while in D2 & D3 transplanting grain yield of Rajeswari increased (In the range of 0.5% to 1.0%). Decreased grain yield was also reported (In the range of -2.2% to -4.4%) with increased temperature by 1 & 1.5°C with D1 and D2 transplanting while in D3 transplanting grain yield was increased in with both temperatures with the range of 1.1 to 3.3 percentage.

Effect of decrease on only minimum temperature by -0.5 to -1.5°C on different date of transplanting are presented in table 4.20 & depicted in fig 4.19.

Decreased only minimum temperature by -0.5, -1 and -1.5°C resulted increase grain yield of Rajeswari variety in all three date of transplanting with the range 0.1 to 4.0 percentage.

Table: 4.20 Sensitivity analysis of decreased only minimum temperature (°C) over normal temperature on grain yield of cultivar Rajeswari for Raipur district.

Date of transplanting	Base yield (kg/ha)	Decrease minimum temperature (°C) over normal temperature					
		-0.5		-1		-1.5	
		Simulated grain yield (kg/ha)	(%) change from base yield	Simulated grain yield (kg/ha)	(%) change from base yield	Simulated grain yield (kg/ha)	(%) change from base yield
D1(1st July)	4057	4105	1.1	4063	0.4	4063	0.1
D2(15th July)	4275	4446	4.0	4364	2.0	4440	3.8
D3(30th July)	3314	3337	0.6	3388	2.2	3371	1.7

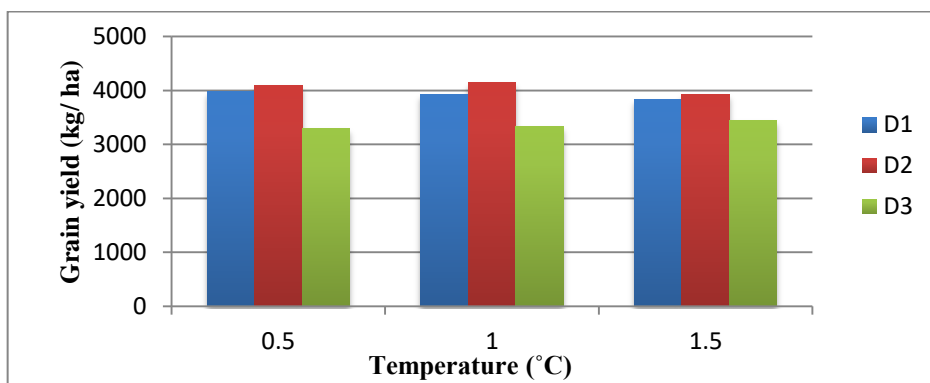


Fig: 4.16 Effect of increased maximum & minimum temperature on grain yield of Rajeswari for Raipur district.

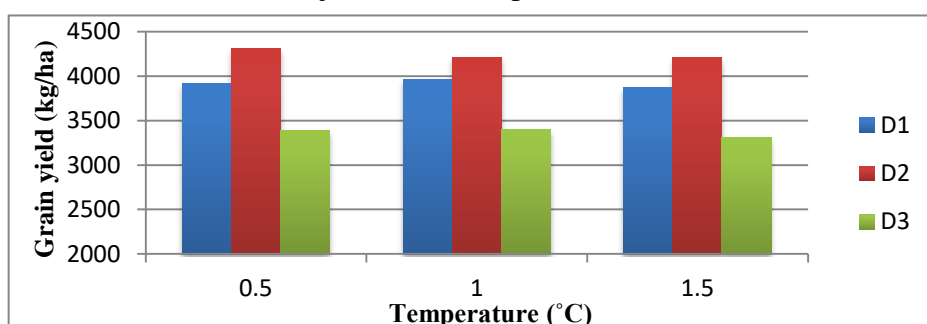


Fig: 4.17 Effect of increased only maximum temperature on grain yield of Rajeswari for Raipur district.

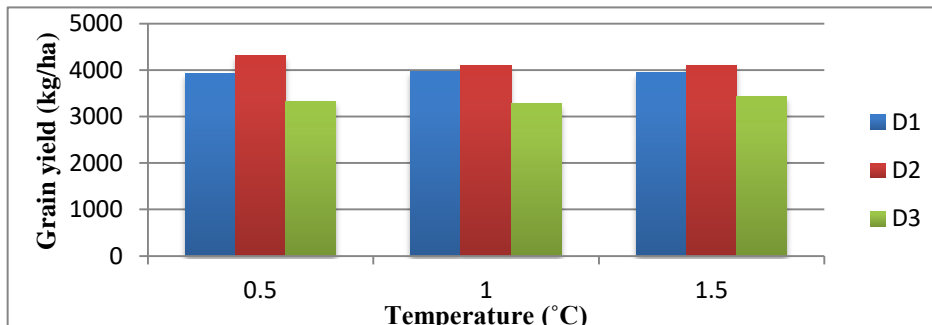


Fig: 4.18 Effect of increased only minimum temperature on grain yield of Rajeswari for Raipur district.

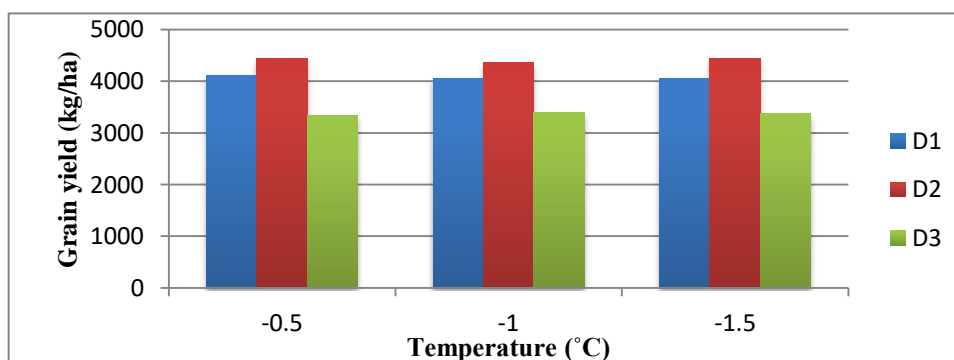


Fig: 4.19 Effect of decreased only minimum temperature on grain yield of Rajeswari for Raipur district.

4.5.3 Sensitivity analysis for grain yield of cultivar CG Sugandhit bhog

Grain yield of CG Sugandhit Bhog as affected by increased maximum and minimum temperature are presented in table 4.21 & depicted in fig 4.20.

The grain yield of rice cultivar CG Sugandhit Bhog increased with increase of temperature by 0.5°C in all three date of transplanting and increase of grain yield was in the range 0.8% to 3.7%. Increase temperature by 1 and 1.5°C reported increased grain yield in D1 & D3 transplanting with increase percentage was in the range of 2.3% to 7.7% while in D2 transplanting the grain yield was in a decreasing pattern.

Table: 4.21 Sensitivity analysis of increased maximum and minimum temperature (°C) over normal temperature on grain yield of cultivar CG Sugandhit Bhog for Raipur district

Date of transplanting	Base yield(kg/ha)	Increase maximum & minimum temperature (°C) over normal temperature					
		+0.5		+1		+1.5	
		Simulated grain yield kg/ha	(%) change from base yield	Simulated grain yield kg/ha	(%) change from base yield	Simulated grain yield kg/ha	(%) change from base yield
D1(1 st July)	3881	3915	0.8	3983	2.5	3971	2.3
D2(15 th July)	4392	4399	0.2	4320	-1.6	4289	-2.3
D3(30 th July)	2947	3057	3.7	3176	7.7	3150	6.8

Table: 4.22 Sensitivity analysis of increased only maximum temperature (°C) over normal temperature on grain yield of cultivar CG Sugandhit Bhog for Raipur district

Date of transplanting	Base yield(kg/ha)	Increase maximum temperature (°C) over normal temperature					
		+0.5		+1		+1.5	
		Simulated grain yield kg/ha	(%) change from base yield	Simulated grain yield kg/ha	(%) change from base yield	Simulated grain yield kg/ha	(%) change from base yield
D1 (1 st July)	3881	4137	6.5	3970	2.2	4040	4.0
D2 (15 th July)	4392	4395	0.1	4398	0.1	4521	2.9
D3 (30 th July)	2947	2986	1.3	3090	4.8	2988	1.3

Effect of increase on only maximum temperature from +0.5 to +1.5°C on different date of transplanting are presented in table 4.22 & depicted in fig 4.21.

It is quite clear from the table that increase of only maximum temperature by +0.5, +1 and 1.5°C, variety CG Sugandhit Bhog reported increase grain yield in all three date of transplanting and the increase of grain yield % percentage was in the range of 0.1 to 6.5 percent .

Effect of increase only minimum temperature from +0.5 to +1.5°C on different date of transplanting are presented in table 4.23 & depicted in fig 4.22.

Data in the table indicates that the increase of only minimum temperature by 0.5°C, the grain yield of rice variety CG Sugandhit Bhog gave increased grain yield in all three date of transplanting and increase percentage was in the range of 1.7% to 6.5%. Increase of minimum temperature resulted increased grain yield in the range of 0.8 to 5.1 percentage in D1 & D3 transplanting while in D2 transplanting the grain yield decrease in between 0.2% to 2.9%.

Table: 4.23 Sensitivity analysis of increased only minimum temperature (°C) over normal temperature on grain yield of cultivar CG Sugandhit Bhog for Raipur district.

Date of transplanting	Base yield(kg/ha)	Increase minimum temperature (°C) over normal temperature					
		+0.5		+1		+1.5	
		Simulated grain yield kg/ha	(%) change from base yield	Simulated grain yield kg/ha	(%) change from base yield	Simulated grain yield kg/ha	(%) change from base yield
D1 (1st July)	3881	4134	6.5	3914	0.8	4040	4.0
D2 (15th July)	4392	4471	1.7	4263	-2.9	4383	-0.2
D3 (30th July)	2947	3067	4.0	3088	4.7	3100	5.1

Effect of decrease only minimum temperature from -0.5 to -1.5°C on different date of transplanting are presented in table 4.24 & depicted in fig 4.23.

we can observed that decrease the minimum temperature by -0.5°C, responded increased grain yield in all three dates of transplanting with the increase percentage of 0.1% to 1.9%. Decreased grain yield of CG Sugandhit Bhog was observed in all three dates of transplanting with decreased minimum temperature

by 1 & 1.5°C and the reduction percentage was in the range 1.1 to 10.3. Similar result were also reported by Singh *et al.* (2018)

Mamta *et al.* (2008) they also reported that reduced yield with increase temperature.

Table: 4.24 Sensitivity analysis of decreased only minimum temperature (°C) over normal temperature on grain yield of cultivar CG Sugandhit Bhog for Raipur district.

Date of transplanting	Base yield(kg/ha)	Decrease minimum temperature (°C) over normal temperature					
		-0.5		-1		-1.5	
		Simulated grain yield kg/ha	(%) change from base yield	Simulated grain yield kg/ha	(%) change from base yield	Simulated grain yield kg/ha	(%) change from base yield
D1(1st July)	3881	3955	1.9	3866	-3.8	3802	-2.0
D2(15th July)	4392	4448	1.2	4434	0.9	4340	-1.1
D3(30th July)	2947	2952	0.1	2789	-5.3	2640	-10.3

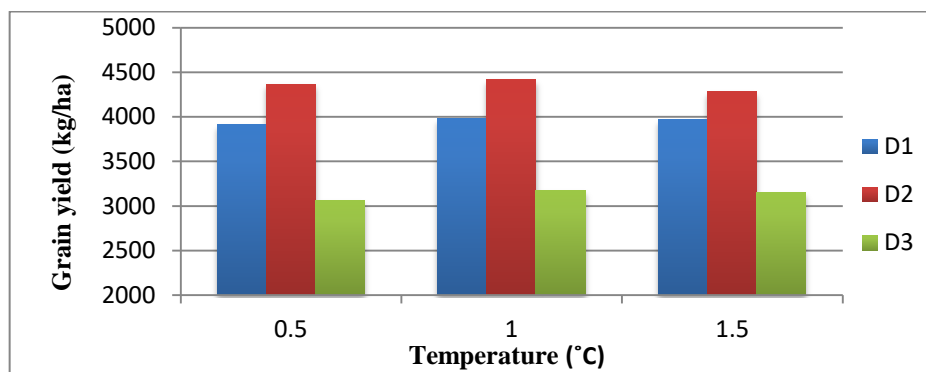


Fig: 4.20 Effect of increased maximum & minimum temperature on grain yield of CG Sugandhit Bhog for Raipur district.

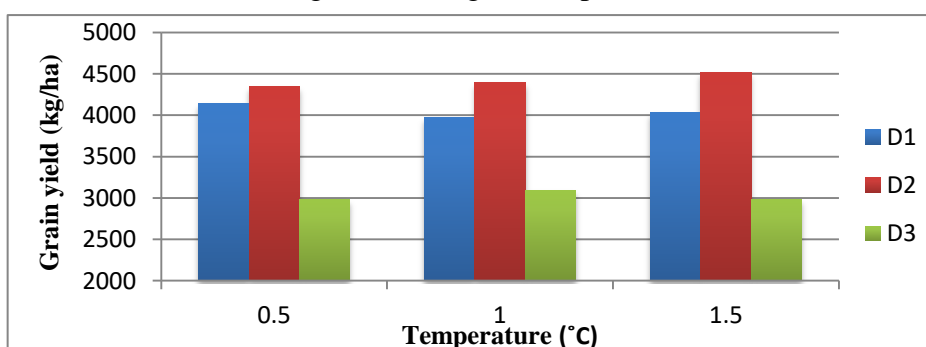


Fig: 4.21 Effect of increased only maximum temperature on grain yield of CG Sugandhit Bhog for Raipur district.

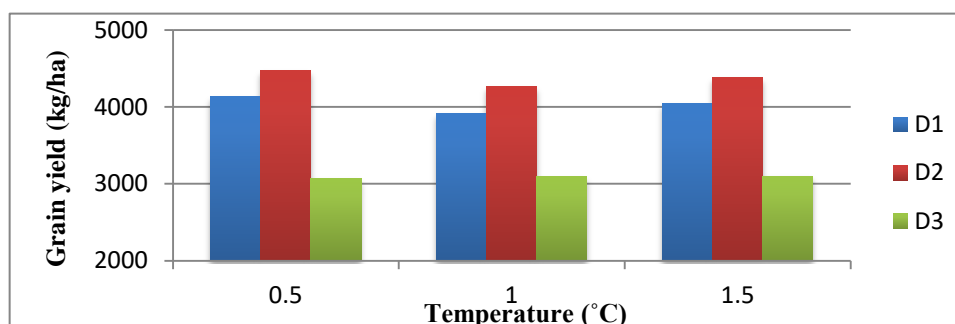


Fig: 4.22 Effect of increased only minimum temperature on grain yield of CG Sugandhit Bhog for Raipur district.

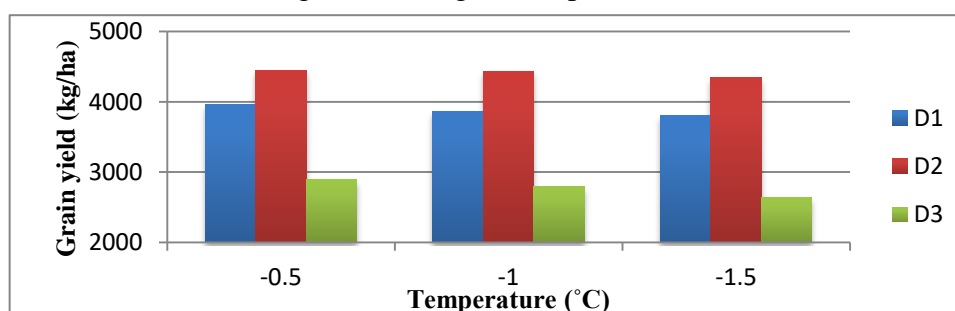


Fig: 4.23 Effect of decreased only minimum temperature on grain yield of CG Sugandhit Bhog for Raipur district.

CHAPTER-V

SUMMARY AND CONCLUSIONS

The present study entitled “Simulation and Calibration of DSSAT model for rice crop at Raipur weather condition” was carried out at Department of Agro meteorology, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) during 2019-2020

The crop yield depends on soil properties, agricultural practices, cultivars genetic makeup and prevailing weather conditions. The important reason for year to year variation in production is largely regulated by the weather. The livelihood of major segments of Indian population is depend on agriculture and allied sectors. Agriculture and allied sector contribution about 17.6% in national GDP. DSSAT crop simulation models (CSM) is very useful to quantify the yield and other parameters.

The meteorological data, soil data, crop data & crop management data were (year 2017, 2018 & 2019) collected from Department of Agro meteorology, IGKV, Raipur. Weather file consisted of daily maximum and minimum temperature, rainfall and solar radiation. For present study three varieties (MTU-1010, Rajeswari and CG Sugandhit Bhog) with 3 dates of transplanting (1st July, 15th July and 30th July) consisting of treatments replicated three times. The experiment was laid down in Randomized Block Design. We created carefully different DSSAT file i.e. weather file, soil file and experiment file. After that genetic coefficient was calibrated by using field crop data of the year 2017 and 2018 and validated with the help of field crop data of the year 2019. Production potential and sensitivity analysis of Rice crop in three Agro-climatic zones of Chhattisgarh were also done and summarized below:

CERES-Rice model was tested and evaluated using the genetic coefficients for all three varieties with their respective transplanting dates. Calibrated genetic coefficients for cultivar MTU-1010, Rajeshwari and CG Sugandhit Bhog are given below

Variety	P1	P2O	P2R	P5	G1	G2	G3	G4
MTU-1010	548	246	146	12	49	0.250	1	1
Rajeshwari	522	447	142	11.7	55	0.257	1	1
CG Sugandhit Bhog	741	320	148	11.4	51	0.265	1	1

In calibration study for CERES-Rice model the crop data of cultivar MTU1010, Rajeshwari and CG Sugandhit Bhog of Rice for the year 2017 & 2018 were used. The model performance was evaluated using prediction error (Pe), coefficient of determination (R^2), root means square error (RMSE) and Willmott's index of agreement (D). Variety MTU1010 and the value of R^2 , RMSE & D-index for panicle initiation was found 0.75 & 0.89, 1.33 & 2.16 and 0.86 & 0.77 in the year 2017 and 2018 respectively. Similarly, the value for anthesis was 0.84 & 0.98, 1.29 & 2.70 and 0.89 & 0.65 in 2017 and 2018 respectively. At maturity the value of R^2 was 0.85 in both the year i.e. 2017 and 2018, while RMSE value was 2.16 & 4.08 and D-index value 0.75 & 0.54 in 2017 and 2018 respectively. For grain yield, R^2 value was 0.18 & 0.71, RMSE value was 204.0 to 398.7 and D-index value was 0.22 & 0.19 in the year 2017 and 2018 respectively.

Variety Rajeshwari the value of R^2 , RMSE & D-index for Panicle initiation was found 0.95 & 0.93, 3.37 & 0.82 and 0.68 & 0.90 in the year 2017 and 2018, respectively. Similarly, the value of anthesis was 0.88 & 1, 3.11 & 6.0 and 0.67 & 0.39 in 2017 & 2018 respectively. At maturity the value of R^2 was 0.95 & 0.62, RMSE was 2.16 & 5.80 and D-index was 0.88 & 0.47 in the year 2017 and 2018 respectively. For grain yield, R^2 value was 0.76 to 0.01, RMSE value was 249.1 & 375.9 and D-index value was 0.34 and 0.29 in the year 2017 & 2018 respectively.

Variety CG Sugandhit Bhog the value of R^2 , RMSE & D-index for panicle initiation was found 1.0 & 0.48, 1.0 & 1.82 and 0.96 & 0.72 in the year 2017 & 2018 respectively. Similarly, at anthesis value of R^2 was of 0.99 in both the year 2017 & 2018 while RMSE value was 5.35 & 7.68, D-index value was 0.58 & 0.26 in 2017 and 2018 respectively. For maturity R^2 value was 0.43 & 0.09, RMSE value was 4.66 & 3.11 and D-index value was 0.48 & 0.46 in 2017 & 2018 respectively. For grain yield, R^2 value was 0.74 & 1.0, RMSE value was 295.4 & 333.6 and D-index was 0.49 & 0.77 in the year 2017 & 2018 respectively. The

results obtained with the model reveal satisfactory prediction of phenology with good agreement between the simulation and observation of growth and yield of rice. The results, revealed that calibrated CERES-Rice, model can be used for prediction of Rice growth and yield.

To validate of CERES-Rice model, the crop data of year 2019 was used. Days required for panicle initiation, anthesis, physiological maturity, & grain yield of different variety planted on various data were worked out & compared with observed data. This model was run for cv. MTU1010, and the R^2 value, RMSE value & D-index value were calculated for panicle initiation which was 0.99, 3.16 & 0.66. For anthesis the value was 0.99, 3.16 & 0.71, and for maturity the value was 0.42, 2.08 and 0.60 and for grain yield it was 0.09, 303.7 and 0.34 respectively.

The simulation work was done for cv. Rajeswari the R^2 value, RMSE value & D-index value calculated for panicle initiation was 0.99, 1.41 & 0.81. For anthesis it was 0.64, 2.58 and 0.70, for maturity it was 0.95, 3.78 and 0.53 and for grain yield it was 0.94, 214.4 and 0.87 respectively.

The simulation work was also carried out for cv. CG Sugandhit Bhog the R^2 value, RMSE value & D-index value calculated for panicle initiation was 0.79, 2.16 and 0.69, for anthesis was 1.0, 5.20 and 0.55, for maturity was 0.82, 3.37 and 0.13 and for grain yield was 0.38, 538.9 and 0.36 respectively. The predicted panicle initiation, anthesis, physiological maturity days and yield were found in reasonable agreement between the simulation and observation.

In all varieties (MTU1010, Rajeswari and CG Sugandhit Bhog) the days required to panicle initiation, anthesis, maturity were highest i.e. 53, 88 and 112 respectively in D1 (1st July) followed by D2 (15th July) and D3 (30th July) in the year 2017. Similar trends was also observed in the year 2018 and 2019, In all varieties (MTU1010, Rajeswari and CG Sugandhit Bhog) the grain yield was highest 4136 kg/ha in D1 (1st July) followed by D2 (15th July) and D3 (30th July) during the year 2017 and 2018 while in year the 2019 highest grain yield 4275 kg/ha was observed in D2 (15th July) followed by D1 (1st July) and D3 (30th July).

The production potential of different rice varieties viz. MTU1010, Rajeswari & CG Sugandhit Bhog was assessed using DSSAT model in Raipur district. The days taken for Anthesis in varieties MTU1010 was highest (81 days) in first planting date i.e. 1st July (D1) in Raipur district. Similar trend was observed for days required for maturity (109 days). The outcome of grain yield of MTU1010 indicates that the highest grain yield (3914kg/ha) was recorded in first date of transplanting in Raipur district. Delay transplanting responsible for reduction in grain yield of MTU1010.

It can be clearly observed that days taken for Anthesis of varieties Rajeswari was highest in first transplanting date i.e. 1st July (D1) in Raipur district it was 73 days. The days taken for maturity of varieties Rajeswari was highest in first transplanting date i.e. 1st July (D1) in Raipur district (Raipur in 102 days). The outcome of grain yield of Rajeswari indicates that the highest grain yield was recorded in second date of transplanting in Raipur district (4275kg/ha).

The days taken for Anthesis of varieties CG Sugandhit Bhog was highest in first transplanting date i.e. 1st July (D1) i.e. Raipur (86 days). The days taken for maturity of varieties CG Sugandhit Bhog was highest in third transplanting date i.e. 30th July (D3) in Raipur district (111 days). The outcome of grain yield of CG Sugandhit Bhog shows that the highest grain yield was obtained in second date of transplanting in Raipur district (4392kg/ha).

The sensitivity analysis was carried out by increasing or decreasing the temperature by 0.5, 1 and 1.5 °C. Model estimates the effect of changing temperature on rice production (yield) at Raipur district (CG). Three rice varieties tested i.e. MTU1010, Rajeswari and CG Sugandhit Bhog were tested under three date of transplanting i.e. 1st July, 15th July and 30th July. The results showed that grain yield were sensitive to change in temperature. The highest percent change 7.7 from the base yield was D3 for CG Sugandhit Bhog under rising up maximum and minimum temperature at Raipur district. Increase of only maximum temperature by 0.5°C the highest percent change from base yield was 6.5 % in D2. Increase of only minimum temperature by 0.5°C the highest percent change from base yield was 6.5 % in D1. In case of cv. MTU1010 the decrease of only minimum

temperature by 0.5 ° C the highest percent changes from base yield was 8.5 % in D2.

Conclusion

On the basis of outcome of the study the following conclusion can be drawn

1. Genetic coefficients generated for different varieties are given below

Variety	P1	P2O	P2R	P5	G1	G2	G3	G4
MTU-1010	548	246	146	12	49	0.250	1	1
Rajeshwari	522	447	142	11.7	55	0.257	1	1
CG Sugandhit Bhog	741	320	148	11.4	51	0.265	1	1

2. CERES Rice model can be utilized to predict the growth, development and yield of rice crop and it is satisfactorily simulated for phenology and grain yield of rice crop.
3. All three rice varieties i.e. MTU1010, Rajeswari and CG Sugandhit Bhog should be transplanted near on 15th July (D2) for getting maximum yield.
4. Simulated yield was also revealed higher yield in all three rice varieties planted on 15th July (D2) at Raipur district.
5. In Raipur district, productivity of MTU1010 will increase, if temperature rises up to 0.5 °C whereas productivity of CG Sugandhit Bhog and Rajeswari will increase with increasing temperature of 1 and 1.5 °C respectively from current prevailing temperature.

Suggestions for future research work

1. The model should be tested at least for more than six year.
2. Assessment of model performance for water and nitrogen dynamic under future climatic scenario studies is required.
3. More field experiment will be required in different soil type to evaluate the performance of model.

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