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Evaluation of DSSAT-CERES-Rice Model through different Dates of Planting in East and South Eastern Coastal Plain Zone of Odisha

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ABSTRACT: The Changing climatic scenario has become a global concern in the present context. Climate change will have a significant impact on agriculture. Risks associated with the climate change depend highly on near-term mitigation and adaptation strategies in securing a sustainable agricultural livelihood. Several studies have proven that crop simulation models have being effectively adopted to assess the impact of projected changing climate in agricultural production system. In the present study, CERES Rice model under Decision Support System for Agro-technology Transfer (DSSAT) is used to simulate the most popular rice cultivar Swarna (MTU 7029) under East and South Eastern Coastal Plain agro-climatic zone of Odisha and to predict potential crop yield on the basis of weather variables viz. daily rainfall, solar radiation, and maximum and minimum temperatures. This model aids in identifying the differences between expected possible crop yields and actual yields in a given environment. If the gap is identified between possible and actual crop yields, optimization of crop yields can be operated through this transfer of technology to minimize the gap through timely interventions. The findings revealed that the CERES-Rice model evaluation denotes a good agreement between observed and simulated growth and development characteristics for the Kharif rice variety.

Keywords: Crop simulation model, Swarna (MTU 7029), Crop Yields, DSSAT - CERES Rice.

INTRODUCTION

Crop weather models are effective tools for integrating knowledge and studying the complex interactions among a range of variables that influence the crop performance including weather, soil properties and management. With the help of a crop simulation model, we may compute the productivity of the rice crop in relation to climatic variability and then take appropriate action to minimize the impact of climatic variability on rice productivity. CERES Rice model is embedded in the Decision Support System for Agro-technology Transfer (DSSAT) programme and it has been determined to be an effective study tool for anticipating phenological occurrence, genetic coefficients, grain yield and harvest index of rice crop, which is utilized to facilitate farmers make decisions about crop management operations (Shamim *et al.,* 2012). Application of crop models to create methods for more effective crop production, enhanced risk management, sustainable cropping systems and exploring the effects of climate change on agricultural systems has advanced significantly (Holzworth *et al.*, 2015). DSSAT Model can be used to study the interactions between Genotype, Environment and Management and helps to achieve sustainable agricultural production by alternation of management strategies in approaching increase in crop yield and quality, optimum resource utilization and reducing the negative impact of environment (Desta Abayechaw, 2021). The performance of CERES-Rice model was found to be good, better data from field experiments designed to address these issues are lacking viz., biomass production, leaf area development, N uptake, soil water and mineral N dynamics and components of the water and N balances, etc.are also highly desirable to demonstrate the robustness of model processes. And further model evaluations, improvements and applications are needed to address the issues of yield stagnation or decline and increasing yield gaps, which finally contribute to solving the resource and food security problems (Goswami and Dutta 2020). DSSAT also helps to understand the response of a cropping sequence to a projected climate instead of a single crop in a sequence for developing well adaptation strategies (Chandran *et al.,* 2021) as well as in deriving seasonal crop forecasting using seasonal daily weather forecasts ((Lanie, 2021). Advancement in usage of DSSAT has also been done by integrated approach of Climate modelling, GIS and Remote Sensing to study drought management programs and measure the impact of crop water stress in terms of crop yield at a regional scale (Rajasivaranjan *et al.*, 2022).

MATERIALS AND METHODS

Description of the study area. Three districts namely Jagatsinghpur, Kendrapara and Nayagarhwere opted for the research representing East and South Eastern Coastal Plain agro-climatic zone of Odisha. Geographically, Jagatsinghpur is located at a latitude of 20°19′ N and a longitude of 86°31′E, Kendraparais located at a latitude of 20°30′ N and a longitude of 86°28′E and Nayagarhis located at a latitude of 20º 08′N and a longitude of 85°08′E. This Agro-climatic zone experiences hot and humid type of climate with mean annual rainfall of 1577 mm, mean maximum summer temperature of 39°C, mean minimum winter temperature of 11.5°C with broad soil types of Saline, Laterite, Alluvial, Red, Mixed Red and Black soils.

CERES-Rice model. The CERES (Crop Environment Resource Synthesis) Rice model is a process-based, dynamic and mechanistic model that can simulate how cereal crops grow and develop under different weather, soil conditions and levels of management. This model has been evaluated in a number of agro-environments and crop management strategies (Cheyglinted *et al*., 2001; Singh *et al*., 2007; Vilayvong *et al*., 2012; Yao *et al*., 2005) and also used to establish superior rice management systems in irrigated conditions (Ahmad *et al*., 2012) and assume rice yield under shifts in long term weather patterns with specific agronomic management practices (Lamsal and Amgain 2010). Rice is very sensitive to changes in the temperature and increase in air temperature can result in early physiological maturity and shorter growth period with reduction in yield (Dias *et al*., 2016).Accordingly, the CSM-CERES-Rice model provides possibility of this tool to explore crop management for enhancing rice productivity. Also, nitrogen fertilizer has a strong relationship with rice productivity and a strategy to enhance nitrogen-use efficiency, may be useful to achieve the desired rice yields (Amnuaylojaroen and Chanvichit 2022). In the present study, Crop simulation modelling is done for *cv*. Swarna using CERES-Rice model.

Simulation run and Validation. Simulation has been done for assessing the production potential of *cv*. Swarna under the East and South Eastern Coastal Plain agro-climatic zone of Odisha under the normal conditions in CERES model incorporated in DSSAT 4.6. Input files of weather, soil, genotype and crop management were composed for the specified simulation experiment utilizing the available datasets, thereby running the CERES- Rice model output files were generated. The results of this simulation study were compared with the observed data. If the simulated values lie within the predicted confidence level band, model can be considered valid. This may be determined using test criteria from statistical analysis. Therefore, validation serves as an assessment of the model's utility. The genetic coefficients used for Swarna variety of rice in CERES-Rice model were presented in Table 1.

Table 1: Genetic coefficients used for Swarna variety of rice in CERES-Rice model.

Sr. No.	Code	Description of Coefficients	Value
			Swarna
1.	P1	Time period (expressed as growing degree days [GDD] in °C above a base temperature of 9 °C) from seedling emergence during which rice plant is not responsive to changes in photoperiod. This period is also referred as the basic vegetative phase of the plant.	620
2.	P_2R	Critical photoperiod or the longest day length (in hours) at which the development occurs at maximum rate. At values higher than P_20 development rate is slowed, hence there is delay due to longer day lengths.	180
3.	P_5	Extent to which phasic development leading to panicle initiation delayed (expressed as GDD in °C) for each hour increase in photoperiod above P_20.	520
4.	P_20	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.	11.8
5.	G_1	Potential spikelet number coefficient as estimated from the number of spikelets per g of main culm dry weight (less leaf blades and sheath plus spikes) at anthesis. A typical value of 55.	70
6.	G_2	Single grain weight (g) under ideal growing conditions i.e. non limiting light, water, nutrients and absence of pests and diseases.	0.02
7.	G_3	Tillering coefficient (scaler value) relative to IR 64 cultivar under ideal conditions. A higher tillering cultivar would have coefficient greater than 1.0.	1
8.	G_4	Temperature tolerance coefficient. Usually 1.0 for varieties grown in normal environment.	1

*GDD=Growing Degree Days; *CERES=Crop Environment Resource Synthesis

Statistical analysis and interpretation of results. A more objective technique for evaluating the performance of the models is made possible by statistically based criteria (Ducheyne, 2000). The index of agreement (d) described by Willmott*et al.* (1985) was evaluated with the following equation. With respect to d-statistics, if the index value is nearer to 1, it implies a better agreement among the two compared variables and vice-versa. The degree of agreement among simulated and their respective observed values is determined by the d-value. With the help of following equation, the d-Index has been estimated.

$$d = 1 - \sum_{i=1}^{n} (S_i - O_i)^2 / \sum_{i=1}^{n} (S_i + O_i)^2$$

Where, n is the number of observations,

$\mathbf{S_i}$ is the simulated observation,

$\mathbf{O_i}$ is the observed value,

$\mathbf{S_i = S_i - M}$ and $\mathbf{O_i = O_i - M}$ (**M** is the mean of the observed variable)]

RESULTS AND DISCUSSION

Simulation modelling and Model evaluation of *cv.*Swarna. Simulation was run for the days taken from transplanting to panicle initiation, anthesis, physiological maturity and grain yield for variety Swarna using DSSAT-CERES-Rice model and Evaluation of the model has been done under four transplanting dates i.e, 7th July, 22nd July, 6th August and 1st September transplanting in East and South Eastern Coastal Plain agro-climatic zone (Jagatsinghpur, Kendrapara and Nayagarh districts) of Odisha. The results are displayed in the Tables 2-7.

Table 2: Observed and simulated phenology and grain yield of *cv.* Swarna in Jagatsinghpur district.

Variable	Observed				Simulated			
	Date of transplanting				Date of transplanting			
	7th Jul	22nd Jul	6th Aug	1st Sep	7th Jul	22nd Jul	6th Aug	1st Sep
Days to PI (DAT)	54	53	51	50	55	53	52	50
Days to Anthesis (DAT)	89	88	86	82	88	86	85	84
Days to Maturity(DAT)	122	120	122	120	121	120	121	120
Grain yield, kg/ha	4180	4620	4880	3800	4308	4644	4841	3921

Table 3: Observed and simulated phenology and grain yield of *cv.* Swarna in Kendrapara district.

Variable	Observed				Simulated			
	Date of transplanting				Date of transplanting			
	7th Jul	22nd Jul	6th Aug	1st Sep	7th Jul	22nd Jul	6th Aug	1st Sep
Days to PI (DAT)	55	53	52	52	56	54	53	51
Days to Anthesis (DAT)	89	91	87	85	91	89	88	86
Days to Maturity(DAT)	125	121	118	120	124	122	121	120
Grain yield, kg/ha	4214	4892	4985	3779	4144	4606	4863	4041

Table 4: Observed and simulated phenology and grain yield of *cv.* Swarna in Nayagarh district.

Variable	Observed				Simulated			
	Date of transplanting				Date of transplanting			
	7th Jul	22nd Jul	6th Aug	1st Sep	7th Jul	22nd Jul	6th Aug	1st Sep
Days to PI (DAT)	54	53	51	50	54	51	51	48
Days to Anthesis (DAT)	89	88	86	82	87	84	84	81
Days to Maturity(DAT)	119	116	118	116	118	116	117	114
Grain yield, kg/ha	4435	4775	4895	3935	4413	4870	4816	3974

Table 5: Model evaluation of *cv.* Swarna in Jagatsinghpur district.

Variable	Observed (Mean)	Simulated (Mean)	Mean Absolute difference	d-Stat	Used observations	Total no. of observations
Days to PI (DAT)	53	52	1	0.98	4	4
Days to Anthesis (DAT)	86	85	1	0.98	4	4
Days to Maturity (DAT)	122	120	2	0.96	4	4
Grain yield, kg/ha	4370	4428	78	0.98	4	4

Table 6: Model evaluation of *cv.* Swarna in Kendrapara district.

Variable	Observed (Mean)	Simulated (Mean)	Mean Absolute difference	d-Stat	Used observations	Total no. of observations
Days to PI (DAT)	53	54	1	0.98	4	4
Days to Anthesis (DAT)	88	86	2	0.96	4	4
Days to Maturity (DAT)	121	122	1	0.98	4	4
Grain yield, kg/ha	4468	4414	185	0.95	4	4

Table 7: Model Evaluation of *cv.* Swarna in Nayagarh district.

Variable	Observed (Mean)	Simulated (Mean)	Mean Absolute difference	d-Stat	Used observations	Total no. of observations
Days to PI (DAT)	52	51	1	0.98	4	4
Days to Anthesis (DAT)	86	84	2	0.96	4	4
Days to Maturity (DAT)	117	116	1	0.98	4	4
Grain yield, kg/ha	4510	4518	59	0.99	4	4

The results of CERES-Rice model evaluation for cv. Swarna in Nayagarh, Jagatsinghpur and Kendrapara districts indicated that the values of d-Stat are very close to 1 determining a very good agreement amongthe observed and simulated values. But,in case of Nayagarh district, simulation overestimated the grain yield but simulated phenology was same as observed phenology with minor variations.

In relation to the findings of Begum *et al.* (2000), the results of the present investigation are in general agreement which revealed that the days to panicle initiation, anthesis and maturity increased in delayed transplanting.The findings of Timsina *et al.* (2004) showed that the projected yield data coincided well with the actual yields (RMSE=815 kg ha^{-} 1; d-stat=0.94) and the simulated results of the present study were also found to be very similar to the observed data. The current results were generally consistent with those of Bhuvaneshwari *et al*. (2014), who discovered that NRMSE values less than 10% for validation of days to flowering (2.34%), physiological maturity (3.50%) and grain yield (4.54%) showed that the simulated data matched well with the observed data.

*RMSE=Root Mean Square Error

*NRMSE=Normalized Root Mean Square Error

SUMMARY AND CONCLUSION

In the present investigation, it was concluded that the CERES-Rice model evaluation showed a good agreement between observed and simulated growth and development characteristics for the Kharif rice variety. Among the four transplanting dates July 7, July 22, August 6 and September 1, Swarna variety of rice produced higher grain yield under mid-season planting on August 6. This is mostly due to the fact that the highest rainfall received is shifted from the month of July to the month of August. The duration from transplanting to panicle initiation, anthesis and physiological maturity is found to be increased in case of delayed transplanting condition.

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Conflict of Interest. None.

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