Int.J.Curr.Microbiol.App.Sci (2021) *10*(12): 126-132

EXCELLENT PUBLISHERS

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 10 Number 12 (2021)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2021.1012.013

Validation of CERES-RICE Model in Wetland Condition using DSSAT-4.5

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Keywords

DSSAT, Rice, Percent error, Validation

Article Info

Received: 05 November 2021
Accepted: 30 November 2021
Available Online: 10 December 2021

A B S T R A C T

An agro-meteorological investigation was undertaken on "Crop weather pest relationship and validation of DSSAT model for rice varieties under different transplanting dates'' during *kharif*, 2016 and 2017 at Agricultural Research Station Farm, Vadgaon Maval, Dist. Pune, under Mahatma Phule Krishi Vidyapeeth, Rahuri, for the purpose to evaluate the heat efficiency of rice crop. An experiment was laid out in split plot design with three replications. The treatment comprised of four sowing dates *viz.*, S_1 : 26th MW (25 June-1 July), S_2 : 28th MW (9 July-15 July), S_3 : 30 MW (23 July-29 July) and S_4 : 32nd MW (06 August -12 August) as main plot treatments and four varieties *viz.*, V_1: VDN-99-29 (*Phule Samruddhi*), V_2 : VDN-3-51-18 (*Indrayani*), V_3 : IET-13549 (*Bhogavati*) and V_4 : RDN-99-1 (*Phule Radha*) as sub plot treatments.

Introduction

Rice (*Oryza sativa* L.) is a staple food for more than 65 per cent of the people and it provides employment and livelihood security to 70 per cent of Indian population.

India grows rice in highly diverse conditions starting from below sea levels to hill as high as > 2000 meters. India ranks first in area with about 44 m. ha under rice and second in production with 104.8 million tones with an average productivity of 2390 kg ha^{-1} (Rami *et al.*, 2016). Rice provides 21 per cent of global human per capita energy and 15 per cent of per capita protein. Although rice protein ranks high in nutritional quality among cereals, protein content is modest.

Crop model is a mathematical equation or the set of equations, which represents the behaviour of a system (Thornley, 1976). Crop models that use specific weather, soil, genetic and management information offer a good opportunity for assisting farm manager in several aspects of decision making to attain their goals. The crop growth models are helpful to assess the impact of climate change on the stability of crop production under different management options (Hoogenboom *et al.,* 1995).

The models of the CERES (Crop Estimation through Resource and Environment Synthesis) are employed to estimate the productivity of grains such as maize, rice, wheat, barley, millet and sorghum.

The CSM-CERES-Rice is part of the modular system called Crop System Model (CSM) present in the Decision Support System for Agro technology Transfer (DSSAT) version 4.5 (Jones *et al.,* 2003). It is based on the model CERES-Rice that describes the production and partitioning of the plant biomass and its phenology. The model interconnects the processes of environmental variations and plant management (Carbone *et al.,* 2003).

Validation may be defined as comparison of predicted values with observed values from the experiment. Validation increases our confidence in the model since the climatic management and fertilizer practices make much more effect on production of rice. After validation of the model it can be used to predict the grain yield of sorghum.

Materials and Methods

The present experiments related investigation entitled, "Crop weather pest relationship and validation of DSSAT model for Rice varieties under different transplanting dates" were conducted at Agriculture Research Station Farm, Vadgaon Maval, Tal. Dist. (M.S.) during *kharif* seasons of 2016-17 and 2017-18, to identify optimum transplanting date for Rice, to develop crop weather relationships, to develop pest weather relations and to validate the DSSAT model.

Experimental Details

The experiment was conducted in a split -plot design with three replications and sixteen treatment combinations were formed considering different varieties and transplanting. The details are listed below.

Name of crop : Rice

Varieties

VDN-99-29 (Phule Samrudhi)

VDN-3-51-18 (Indrayani)

IET-13549 (Bhogavati)

RDN-99-1 (Phule Radha)

Number of treatment combinations : 16

Number of replications : 3

Number of plots : 48

Experimental Design : Split plot Design

Plot size

Gross Plot: 4.80 m x 3.60 m

Net Plot: : 4.0 m x 3.0 m

Spacing : 20 cm x 15 cm

Seed rate : 20 kg ha^{-1}

Fertilizer dose : 175: 60: 60 NPK kg ha^{-1}

Seasons

Kharif, 2016

Kharif, 2017

Place of research work : Agricultural Research Station Farm,Vadgaon Maval, Tal. Maval, Dist. Pune

Transplanting dates

S_1 : 26th MW (25 June-1 July)

S_2 : 28th MW (16 July-15July)

S_3 : 30 MW (23 July-29July)

Validation is the comparison of the results of model simulations with observations that were not used for the calibration.

The experimental data collected will be used for independent model validation. Statistical index generally used for model validation is,

$$\text{RMSE (Root Mean Square Error)} = \sqrt{\frac{\sum_{t=1}^{n} (Pi\text{-}Oi)^2}{n}}$$

Where Pi and Oi refer to the predicted and observed values for the studied variables (e.g. grain yield and total biomass), respectively and n is the mean of the observed variables.

The normalized root mean square error (NRMSE) that is expressed in per cent, calculated as explained by Loague and Green (1991) with the help of following Equation;

$$\text{NRMSE} = \sqrt{\frac{\sum_{t=1}^{n} (Pi\text{-}Oi)^2}{n}} \times \frac{100}{M}$$

Where, n is the number of observations, Pi and Oi are predicted and observed values respectively and M is the observed mean value.

The simulation is considered excellent with RMSE<10 per cent, good if 10–20 per cent, fair if 20–30 per cent, and poor >30 per cent for yield and other growth parameters.

Results and Discussion

Phenology

Days to50 per cent flowering

The mean simulated number of days to 50 per cent flowering for the varieties was over estimated by the model but it was found to be nearer to the observed values Table 1.

The Coefficient of determination (R^2) and NRMSE (Normal Root Mean Square Error) values for simulations were found to be good enough for the model.

The RMSE (Root Mean Square Error) values for simulations were 1.55, 2.10, 2.6 and 1.00 for VDN-99-29 (V_1), VDN-3-51-18 (V_2), IET13549 (V_3) and RDN-99-1 (V_4) respectively According to Loague and Green (1991), if NRMSE is between 1–10%, simulations are good.

Physiological maturity

The simulated days to physiological maturity was found to be under estimated by the model for all varieties but the difference was not more than of 20 days. The RMSE (Root Mean Square Error) values for simulations were 1.22, 1.13, 1.22 and 1.44 for VDN-99-29 (V_1), VDN-3-51-18 (V_2), IET13549 (V_3) and RDN-99-1 (V_4) respectively.

The coefficient of determination (R^2) and NRMSE values that was obtained are given in Table 2. From the values it was clear that the simulations were good by the model.

Leaf area

Data pertaining to leaf area simulations are presented in (Table 3). The mean simulated leaf area was 20.7 as against observed leaf area of 20.94 in case of VDN-99-29(V_1).

Table.1 Number for days to 50 % flowering

Sowing window	**Number of days to 50 % flowering**							
Variety	V_1		V_2		V_3		V_4	
	Simulated	**Observed**	**Simulated**	**Observed**	**Simulated**	**Observed**	**Simulated**	**Observed**
S_1 (2016)	93	95	98	100	100	101	76	77
S_2 (2016)	98	100	97	103	97	103	80	81
S_3 (2016)	90	93	93	95	96	99	75	76
S_4 (2016)	90	92	90	92	94	94	72	71
S_1 (2017)	96	98	101	102	101	103	80	82
S_2 (2017)	97	99	101	103	105	104	85	87
S_3 (2017)	98	100	101	103	104	103	79	81
S_4 (2017)	96	98	100	101	104	103	79	78
Mean	94.75	96.87	97.62	99.87	100.125	101.25	78.25	79.12
MAE	0.18		0.21		0.15		0.12	
MBE	-0.18		-0.21		-0.15		-0.12	
RMSE	1.55		2.10		2.06		1.0	
PE	1.60		2.10		2.04		1.0	

Table.2 Number of days to physical maturity

Sowing window	**Number of days to physical maturity**							
Variety	V_1		V_2		V_3		V_4	
	Simulated	**Observed**	**Simulated**	**Observed**	**Simulated**	**Observed**	**Simulated**	**Observed**
S_1 (2016)	122	124	150	149	152	151	116	115
S_2 (2016)	130	129	156	155	152	154	123	121
S_3 (2016)	125	127	140	142	147	148	113	114
S_4 (2016)	124	125	137	138	138	140	110	113
S_1 (2017)	125	127	153	152	156	154	118	117
S_2 (2017)	134	132	159	158	155	157	120	123
S_3 (2017)	132	130	143	145	149	151	115	116
S_4 (2017)	125	128	138	140	138	143	113	115
Mean	127.12	126	147	148	148.37	149.75	116	117
MAE	0.06		0.01		0.06		0.04	
MBE	-0.06		-0.01		-0.06		-0.01	
RMSE	1.22		1.13		1.22		1.44	
PE	0.96		0.59		0.82		1.24	

Table.3 Leaf area

Sowing times	Leaf area							
	V_1		V_2		V_3		V_4	
	Simulated	Observed	Simulated	Observed	Simulated	Observed	Simulated	Observed
S_1 (2016)	21.7	22.5	21.6	22.3	16.7	17.5	14.7	15.3
S_2 (2016)	24.9	23.6	21.5	22.5	17.5	18.3	14.0	15.2
S_3 (2016)	20.6	20.1	18.3	18.7	13.9	13.2	12.6	13.6
S_4 (2016)	12.6	13.6	12.0	13.2	11.8	12.45	11.7	12.8
S_1 (2017)	23.7	22.9	21.8	20.9	18.2	18.9	15.7	16.5
S_2 (2017)	26.6	27.89	23.5	24.6	19.1	18.7	15.0	16.7
S_3 (2017)	22.0	23.1	19.8	20.4	15.01	15.09	13.5	14.2
S_4 (2017)	13.5	13.9	13.1	14.67	12.09	14.67	12.9	13.5
Mean	20.7	20.94	18.95	19.65	15.53	16.10	13.76	14.72
MAE	0.16		0.28		0.14		0.23	
MBE	-0.16		-0.28		-0.15		-0.15	
RMSE	1.78		2.89		2.67		1.89	
PE	1.82		2.23		2.56		1.67	

Table.4 Grain yield

Sowing window	Grain yield							
Variety	V_1		V_2		V_3		V_4	
	Simulated	Observed	Simulated	Observed	Simulated	Observed	Simulated	Observed
S_1 (2016)	60.4	59.6	52.1	53.8	46.0	45.9	42.1	40.3
S_2 (2016)	69.2	68.3	60.2	59.1	46	48.0	38.1	38.5
S_3 (2016)	57	56.4	52.4	50.3	40.2	38.1	36.3	34.5
S_4 (2016)	36.4	34.7	34.2	32.9	33.1	32.4	35.2	32.2
S_1 (2017)	64.2	65.0	61.3	59.9	52.2	50.1	45	43.2
S_2 (2017)	74.2	73.0	66.1	64.5	54.2	52.4	43.1	41.2
S_3 (2017)	61.2	60.4	55.3	54.3	42.1	41.2	38.1	37.0
S_4 (2017)	36.1	37.1	34.2	35.9	34.3	35.4	35.2	35.5
Mean	57.33	56.81	51.97	51.33	43.51	42.93	39.13	37.8
MAE	0.09		0.08		0.07		0.14	
MBE	0.09		0.08		0.07		0.14	
RMSE	1.15		1.11		1.17		1.37	
PE	2.61		2.16		2.74		3.62	

The mean simulated leaf area and observed leaf area were 18.95 and 19.65, 15.53 and 16.10, 13.76 and in 14.72 in case of VDN-3-51-18 (V_2), IET13549 (V_3) and RDN-99-1 (V_4), respectively.

The RMSE (Root Mean Square Error) values for simulations were 1.82, 2.23, 2.56 and 1.67 for VDN-99-29 (V_1), VDN-3-51-18 (V_2), IET-13549 (V_3) and RDN-99-1 (V_4) respectively. Simulated phenophases with good RMSE values are presented in Table 3.

Grain yield (kg ha^{-1})

The mean simulated and observed grain yield was found to be closer for all the varieties (Table 4).

The coefficient of determination (R^2) for the varieties was found good as reported by Tripathi *et al.*, 2016 and NRMSE (Normal Root Mean Square Error) values for simulations were found to be good enough for the model.

The RMSE (Root Mean Square Error) values for simulations were 1.15, 1.11, 1.17 and 1.37 for VDN-99-29 (V1), VDN-3-51-18 (V_2), IET13549 (V_3) and RDN-99-1 (V_4), respectively.

Simulated phenophases with good RMSE values are presented in (Table 4).If NRMSE is between 1–10%, simulations are good (Loague and Green, 1991).

DSSAT model was found able to predict the phenophases and grain yield of all the varieties with good R^2 and NRMSE values. It could be used for future climate change studies under wet condition. The climate change has become a great issue concerning the agricultural productions. Hence there is a need to select suitable crops and suitable dates of sowing for the changing weather conditions. Crop simulation models will find out the crop-environment relationships and thus helps in selecting suitable cultivars for a particular region. Validation of such crop simulation models should be carried out in different locations to find its suitability in predictions.

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How to cite this article:

Deshmukh, A. P., S. B. Kharbade, N. V. Kashid, S. V. Jadhav and Balasubramanian, R. 2021. Validation of CERES-RICE Model in Wetland Condition using DSSAT-4.5. *Int.J.Curr.Microbiol.App.Sci.* 10(12): 126-132. doi: https://doi.org/10.20546/ijcmas.2021.1012.013