Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; 8(4): 2916-2919
Received: 19-05-2019
Accepted: 21-06-2019

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Calibration and validation of DSSAT model (v. 4.7) for rice in Prayagraj

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Abstract
The DSSAT model (v 4.7) was calibrated and validated for rice (var. NDR – 359, NDR – 97 and SARJU – 52) using experimental data of 6 years (2012 – 2018) of Research Farm, College of Forestry, SHUATS for Rice. 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. Based on these results it can be concluded that the model was very robust in predicting the yield of rice in Prayagraj condition.

Keywords: Rice, DSSAT, Simulation model, Yield and validation

Introduction
Rice (*Oryza sativa* L.) is a grain plant belonging to the family Poaceae and genus *Oryza* with chromosome no. = 24. Rice is one of the most important food grains produced and consumed all over the world. It is a subsistence crop for most farmers. Rice is the longest continuously grown cereal crop in the world and according to the International Rice Research Institute (IRRI) it is "one of the most important developments in history".
Worldwide, India stands first in rice area (44 million ha) and second in rice production (112.91 million metric tons) after China with a productivity of 2767 kg ha^{-1} (FAO 2017). It contributes 21.5 per cent of global rice production. India has to produce 130 – 140 million tons of rice by the year 2030 to meet the food grain requirement of burgeoning population.
In Prayagraj district, rice is produced in an area of 171824 hectare with a production of 370562 MT and productivity of 21.57 q/ha. (Status Paper on Rice in Uttar Pradesh, 2018). The productivity of the crop rice decrease due to biotic and abiotic stresses. Weather plays an important role in the growth and development of the rice and decide the year to year variability in rice yield. Fluctuations in the total seasonal rainfall and its intra – seasonal distribution along with temperature (both maximum and minimum) and solar radiation have strong influence on rice productivity.
The process – based dynamic simulation crop models based on soil, crop and weather factors could be effective research tools for planning alternative strategies for crop management, land use and water management and also a useful tool for planning and developing technological interventions in diverse areas like India1.The crop growth simulation models show considerable pattern and genetic potential pattern for yield. In this paper has been made to calibrate and validate the DSSAT model for rice in Prayagraj.

Materials and methods
Data sets
As of model (DSSAT v4.7) requirement, the following sets of data were collected and generated for the smooth running of the model.

Weather data
The weather data (daily basis) on maximum and minimum temperatures, rainfall and solar radiation of seven years (2012 – 2018) for centre Prayagraj was obtained from Department of Agrometeorology, College of Forestry, Sam Higginbottom University of Agriculture, Technology and Sciences from the year 20012 – 2018. Solar radiation was calculated by the model based on Hargreaves method, which is reported to be best suited for Indian conditions.

Soil data
Layer wise (0 – 120 cm) data of soil physical and chemical properties which includes Bulk density, Hydraulic conductivity, organic carbon content, clay and silt content etc. of Prayagraj district was collected from India Meteorological Department, New Delhi.

Cultivars

These coefficients are crucial because they strongly influence the simulation of growth and development of the crop. The CERES-Rice model uses eight genetic coefficients viz., P1, P2O, P2R, P5, G1, G2, G3 and G4. The eight coefficients for three cultivars (NDR – 359, NDR – 97 and SARJU – 52) are collected from IMD, New Delhi then again they are calibrated for Prayagraj condition via trial and error method. The genetic coefficients for the three varieties are shown in Table 1 below and description of genetic coefficients are as follows:

Table 1: Below and description of genetic coefficients are as follows:

GC	Description
P1	Juvenile phase coefficient
P2O	Critical photoperiod
P2R	Photoperodism coefficient
P5	Grain filling duration coefficient
G1	Spikelet number coefficient
G2	Single grain weight
G3	Tillering coefficient
G4	Temperature tolerance coefficient

Crop management and experimental data

The seven years (20012 – 2018) experimental data conducted at the College of Forestry farm, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, UP, India was used for the calibration and validation of model.

This experiment was carried out to assess the yield of three cultivar of rice var. NDR – 359, NDR – 97 and SARJU – 52 for seven years under Prayagraj condition. Experiment includes 3 cultivars which the experiments were conducted based on split plot design. Planting dates were 1st week of July for every cultivar. Grain yield was provided for the model as observed data for the calibration and validation of model.

Crop model calibration

CERES-Rice model was calibrated by an experimental data of seven years (2012 – 2018), conducted at the College of Forestry farm, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, UP, India.

Crop model validation and test criteria

Validation is the comparison of the results of model simulations with observations from crops that were not used for the calibration. A model should be rigorously validated under widely differing environmental conditions to evaluate the performance of major processes in addition to its ability to predict the phenology and yield. Before any model can be used with confidence, adequate validation or assessment of the magnitude of the errors that may result from its use should be performed. Model validation, in its simplest form is a comparison between simulated and observed values.

Several criteria were used to quantify the differences between observed and simulated data. Test criteria have been separated into two groups, called summary measures and difference measures. The summary measures describe the quality of simulation while the difference measures try to locate and quantify errors. The latter include the root mean square error (RMSE) and the normalised root mean square error (NRMSE). NRMSE gives a measure (%) of the relative difference of simulated verses observed data. The simulation is considered excellent with a normalized RMSE less than 10%, good if the normalized RMSE is greater than 10 and less than 20%, fair if the normalized RMSE is greater than 20% and less than 30%, and poor if the normalized RMSE is greater than 30% (Loague and Green, 1991).

They were calculated according to Willmott as follows and were based on the terms ($Sim_i - Obs_i$).

$$\text{RMSE} = \sqrt{\frac{\sum_{i-1}^{n}(X_{obs_i} - X_{sim_i})^2}{n}}$$

$$\text{nRMSE} = \sqrt{\sum_{i=1}^{n}\frac{(Si-Ob)^2}{n}} \times \frac{100}{M}$$

Varshneya (1999), who gave a simple indication of error in prediction, defined the Percent Error (PE). PE is defined as ratio of RMSE to mean observed value expressed as percentage. Percent Error seems to be accurate when its value is below 15% and was calculated as follows:

$$\text{Error Percent} = \sqrt{\frac{(X_{sim_i} - X_{obs_i})}{X_{sim_i}}} \times 100$$

Note: (i) In RMSE and PE equations, X_{obs} is observed values and X_{sim} is modelled (simulated) values at time/place *i*.

(ii) In NRMSE equation, S_i is simulated value and O_b is observed value.

Result and discussion

Grain yield

Simulated grain yield with observed yield is listed in table 1, 2 and 3 for cultivar NDR – 359, NDR – 97 and SARJU – 52 respectively. The average simulated yield of NDR 359 is 6256.58 kg $ha^{-1,}$ 4524 kg ha^{-1} and 4224.71 kg $ha^{-1.}$ The range of magnitude of deviation between simulated and grain yield varied between 89 kg ha^{-1} to 569 kg $ha^{-1.}$ The values of errors as computed in terms of RMSE is 335.31, 643.76 and 267.59 for NDR – 359, NDR – 97 and SARJU – 52 respectively, NRMSE is 0.05, 0.08, 4.45 for NDR – 359, NDR – 97 and SARJU – 52 respectively with an average percent error of 2.36, 4.84 and 3.23 for NDR – 359, NDR – 97 and SARJU – 52 respectively which indicated that model performed well in all the years in predicting the grain yield of rice for every cultivar. [Table 3 (a), 3 (b) and 3 (c)].

Table 2: Calibrated genetic coefficient for three different cultivars of rice at Prayagraj condition.

Cultivar	P1	P2R	P5	P2O	G1	G2	G3	G4
NDR 359	500.0	200.0	450.0	12.5	62.0	0.190	1.00	1.00
NDR 97	300.0	120.0	390.0	11.5	59.0	0.220	1.00	1.00
SARJU 52	450.0	170.0	365.0	12.2	47.0	0.238	1.00	1.00

Table 3 (a): Comparison of cultivar NDR – 359 observed value with simulated value for grain yield for year 2012 – 2018.

Year	Actual yield (kg/ha)	Simulated yield (kg/ha)	PE	RMSE	NRMSE
2012	6037	5846	-3.26	135.06	2.23
2013	5986	6555	8.68	402.34	6.65
2014	6071	6395	5.07	229.10	3.79
2015	6170	6509	5.20	239.70	3.96
2016	6079	6473	6.09	278.60	4.60
2017	6138	5986	-2.54	107.48	1.78
2018	6199	6032	-2.77	118.09	1.95
Average	6097.14	6256.58	2.36	335.31	0.05

Table 3 (b): Comparison of cultivar NDR – 97 observed value with simulated value for grain yield for year 2012 – 2018.

Year	Actual yield (kg/ha)	Simulated yield (kg/ha)	Percent error (%)	RMSE	NRMSE
2012	4213	4526	6.92	221.32	5.16
2013	4196	4658	9.92	326.69	7.61
2014	4232	3911	-8.21	226.99	5.30
2015	4290	4662	7.99	263.04	6.13
2016	4397	4713	6.70	223.44	5.20
2017	4345	4753	8.58	288.50	6.73
2018	4356	4445	2.00	62.93	1.47
Average	4289.86	4524	4.84	643.76	0.08

Table 3 (c): Comparison of cultivar SARJU 52 observed value with simulated value for grain yield for year 2012 – 2018.

Year	Actual yield (kg/ha)	Simulated yield (kg/ha)	Percent error (%)	RMSE	NRMSE
2012	4315	4453	3.09	97.58	2.32
2013	4134	3854	-7.27	197.99	4.71
2014	4142	4441	6.73	211.42	5.03
2015	4093	3582	-6.25	170.41	4.06
2016	4181	3871	-8.00	219.20	5.22
2017	4257	4539	6.21	119.40	4.75
2018	4279	4563	6.22	200.82	4.78
Average	4224.71	4200.14	3.23	267.59	4.41

Summary and conclusion

The salient findings related to calibration and validations are The CERES-RICE model (v 4.7) was used to simulate the yield of rice crop sown in mid-July with three variety NDR – 359, NDR – 97 and SARJU – 52. The model successfully predicted yield of crop with error values within 10%. In nutshell, the model prediction was reasonably good for predicting grain yield for rice cultivars used. In fact this study provides an insight into the complex issue of evaluation and model performance.

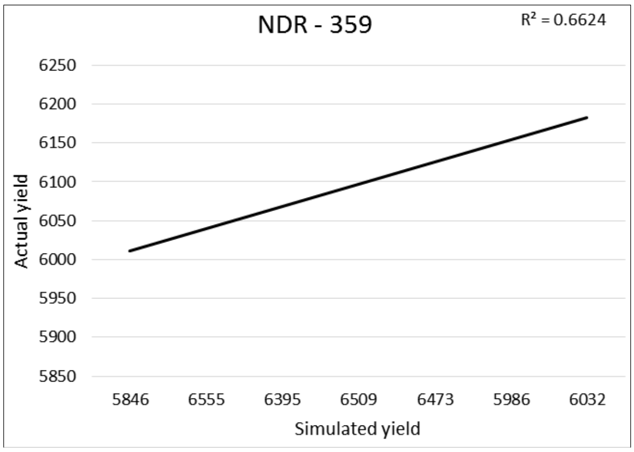

Fig 1: Actual vs Simulated yield of NDR – 359

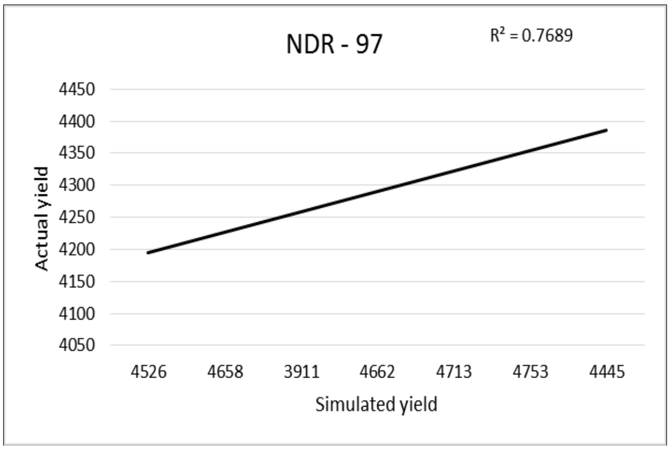

Fig 2: Actual vs Simulated yield of NDR – 97

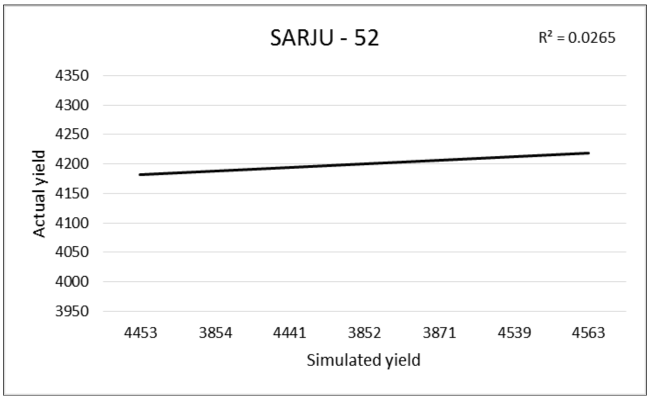

Fig 3: Actual vs Simulated yield of SARJU – 52

Acknowledgements

I am very thankful to professor and HOD of Environmental science and Natural Resource Management, SHUATS, Prayagraj and India Meteorological Department for providing the meteorological data and necessary guidance.

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