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Surbhi Jain
Department of Agrometeorology, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

ASRAS Sastri
Department of Agrometeorology, Orissa University of Agriculture and Technology, Bhubaneswar, Odisha, India

Bhirendra Kumar
Department of Agrometeorology, Orissa University of Agriculture and Technology, Bhubaneswar, Odisha, India

Correspondence
Surbhi Jain
Department of Agrometeorology, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Comparison of DSSAT and InfoCrop simulation model for rice production under irrigated and rainfed conditions

Surbhi Jain, ASRAS Sastri and Bhirendra Kumar

Abstract
Comparison of the simulated value under DSSAT and InfoCrop models experiment was conducted during *kharif* season for different rice varieties viz., Swarna, Mahamaya, MTU-1010 and Karma Mahsuri. Based on the genetic coefficients generated in the field experiment conducted during *kharif* season 2014 Raipur simulation was carried out using DSSAT and InfoCrop models with the normal and within normal weather data based on 30 years weather data at Raipur (1981-2013) irrigated and rainfed conditions. Under irrigated conditions the potential yield with DSSAT model is 10.0, 10.3, 9.2, 8.9 and 10.9 t/ha for IR36, Swarna, Mahamaya, MTU1010 and Karma Mahsuri respectively. The potential yield under InfoCrop model is 6.0, 5.3, 5.8, 6.6 and 7.0 t/ha for the same varieties respectively. Thus, it is observed that the production potential under DSSAT model is very high as compared to InfoCrop model. On comparison with DSSAT and InfoCrop model, it was obtained that the production potential of DSSAT model output was very high in comparison to InfoCrop model output, under irrigated conditions. The potential yield of rice varieties under rainfed conditions in DSSAT model are 7.4, 6.0, 7.8, 7.4 and 7.8 tons/ha for IR36, Swarna, Mahamaya, MTU1010 and Karma Mahsuri respectively. The same potential yields estimated by InfoCrop model for the varieties are 6.0, 5.1, 5.3, 6.3 and 6.5 t/ha respectively. However the difference of potential yield under rainfed condition for the five varieties is less as compared to irrigated condition. Thus, under rainfed condition the output of InfoCrop matches with the output of DSSAT crop estimation.

Keywords: DSSAT Simulation model, InfoCrop model, Production potential, Irrigated and Rainfed condition

1. Introduction
Crop simulation models are useful to assess the production potential of a crop in a set of given conditions. DSSAT is the most popular dynamic crop simulation model and CERES- rice model is used for assessing the production potential of rice under a given set of conditions.

The development of dynamic crop growth models, which started more than thirty years ago, considerably improved analytic solution of problems in crop sciences but new scientific problems were created in the same time. One of the main advantages of crop model application is the possibility to use them under various weather and soil conditions and under irrigated and rainfed condition in different regions of the Chhattisgarh. One of the important preconditions of the applications of dynamic model is the evaluation of the model reliability in reproducing the real conditions at the given place and time.

Crop simulation models are useful to assess the production potential of a crop in a set of given conditions.

DSSAT is the most popular dynamic crop simulation model and CERES- rice model is used for assessing the production potential of rice under a given set of conditions. In recent years InfoCrop, another dynamic crop simulation model, is widely used in India and elsewhere. These two models have their own advantages and disadvantages in assessing crop growth and yield potential in a given set of conditions like rainfed and irrigated. Crop models can accelerate inter-disciplinary knowledge utilization in agricultural research and development. These models present an opportunity for assessing potential production in a region and facilitate analysis of the sustainability options for agricultural development including planning of resource allocation. Through crop growth simulation modelling it became possible to simulate a living plant through the mathematical and conceptual relationships that govern its growth in the soil-plant atmosphere continuum.

A major milestone was achieved by International Benchmark Sites for Agrotechnology Transfer (IBSNAT) with the integration of crop models, databases for weather, soil and crops and agro-technology transfer application programmes and their incorporation into a single computer software package, known as DSSAT(Decision Support System For Agrotechnology Transfer). The DSSAT is a programme shell that links three major elements-crop simulation models, a data base management system, and a management/risk assessment programme into a single integrated system. It is the end-product of a synthesis process involving systems developers from the Universities of Edenburgh (Scotland), Florida, Georgia, Guelph (Canada), Hawaii, & Puerto Rico, Michigan Department of Agriculture's Soil Conservation Service and Agricultural Research Service. DSSAT was designed for researchers to easily create "experiments" to simulate the crop. Outcomes of the complex interactions between various agricultural practices, soil and weather conditions on computers and to suggest appropriate solutions to site specific problems.

InfoCrop is a decision support system based on crop models that have been developed by a network of scientists to provide a platform to scientists and extension workers to build their applications around it and to meet the goals of stakeholders need for information. These models are designed to simulate the effects of weather, soils, agronomic management, nitrogen, water and major pests on crop growth and yield, water and nitrogen management, and greenhouse gases emission. There were some discrepancies in the simulated emission of these gases during first few days after sowing/transplanting possibly because of the absence of tillage effects in the model. The sensitivity of the model to change in ambient temperature, crop duration and pest incidence is similar to the available field knowledge. The application of the model to quantify multiple pests damage through iso-loss curves is demonstrated. Another application illustrated is the use of InfoCrop for analyzing the trade-offs between increasing crop production, agronomic management strategies, and their global warming potential.

Material and Methods

DSSAT Simulation model

The objectives of the study included the calibration and evaluation of the CERES-Rice model for three agroclimatic zones. The calibration and evaluation process consists of the following steps:

1. Collection (Observation or measurement) of the experimental data (anthesis, maturity dates and grain yields),
2. Collection of weather data at three different agroclimatic zones.

The CERES-Rice model is no exception. 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 are worked out by conducting field experiment during *Kharif* 2014 and for IR36, they were default in the model. The genetic coefficients for the five varieties are as follows:

Varieties	P1	P2R	P5	P2O	G1	G2	G3	G4
IR36	470	149	400	11.7	68	0.023	1	1
Swarna	541	150	523	11.5	79	0.019	1	1
Mahamaya	429	150	302	11.5	56	0.026	1	1
MTU1010	399	150	329	11.5	61	0.023	1	1
KarmaMahsuri	478	150	364	11.5	113	0.019	1	1

The details of these genetic coefficients are as follows:

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

Required inputs

1. Computation of solar radiation.
2. Preparation of weather files for models.
3. Soil data.

InfoCrop Simulation Model

Thermal time requirement (InfoCrop) for different stages for different varieties used in
InfoCrop given below:

Variety	Sowing to germination	Germination to flowing	50% flowering to physiology maturity
IR36	80	1550	520
Swarna	124	1553	406
Mahamaya	124	1296	421
MTU1010	124	1199	467
Karma Mahsuri	124	1434	483

Inputs

The input data required to run the InfoCrop shell include daily weather information (maximum as well as minimum temperatures rainfall and solar radiation), thermal temperature of the stage sowing to germination , germination to 50% flowering , 50% flowering to physiological maturity of different varieties, and crop management information, such as emerged plant population, row spacing and seedling depth and fertilizer and irrigation schedules.

The model can produce a large quantity of output data, including yield estimates, modified as appropriate by the stress factors noted above (water and nitrogen).

Computation of solar radiation (Rs)

The converted solar radiation from sunshine hours on DSSAT model weather man module has been used for InfoCrop model.

A regression equation relating solar radiation received on a horizontal surface at a particular time and place to clear day solar radiation and sun shine ratio was first proposed by As bright sun shine data were available at locations for compute solar radiation using the following equation:

Rs= Ra [(a + b * (n/N)]

Where,
a and b are empirical coefficient, Angstrom proposed value 0.25 and 0.75, respectively
Rs= Estimated solar radiation on ground surface ($MJm^{-2}\,day^{-1}$)
Ra= Extra-terrestrial solar radiation received on a horizontal surface at top of atmosphere ($MJm^{-2}day^{-1}$)
n= Measured sunshine hours
N= Maximum possible sunshine hours

Result and Discussion

Comparison of DSSAT and InfoCrop simulation model

Based on the genetic coefficients generated in the field experiment conducted during *kharif* season 2014 simulation was carried out using DSSAT and InfoCrop models with the normal and within normal weather data based on 30 years weather data at Raipur (1981-2013) under irrigated and rainfed conditions are shown in Tables 1.1(a,b).The results are discussed below.

Potential yield (Irrigated)

The potential yield under irrigated and rainfed conditions for the Raipur station are shown in the Tables (1.1) Under irrigated conditions the potential yield with DSSAT model is 10.0, 10.3, 9.2, 8.9 and 10.9 t/ha for IR36, Swarna, Mahamaya, MTU1010 and Karma Mahsuri respectively. The potential yield under InfoCrop model is 6.0, 5.3, 5.8, 6.6 and 7.0 t/ha for the same varieties respectively. Thus it is observed that the production potential under DSSAT model is very high as compared to InfoCrop model. The difference varied from 2.0 to 4.0 t/ha in different varieties. The reason for such a variation was analysed by assessing solar radiation estimation using sun shine hour data.

The estimated solar radiation value in MJ/d using DSSAT and InfoCrop model for the three stations are shown in fig 1 (a), (b), (c). It can be seen from the figure that the estimation InfoCrop was half of the value of DSSAT in the three stations. The reason for such variation needs to be investigated.

The solar radiation data estimated by DSSAT were used in the InfoCrop model. By using DSSAT model solar radiation in InfoCrop model the potential yield was only 0.5 to 0.8 t/ha. By using DSSAT model solar radiation in InfoCrop model the potential yield levels increased substantially yield in all the varieties but still the potential yields are less by 4.02 to 2.4 t/ha in all the varieties as compared to DSSAT model potential yields.

Therefore it is necessary to make a study of the input values of each parameter to identify the reason for estimating lower values of production potential in InfoCrop model.

Table 1.1: Comparison of the output of DSSAT and InfoCrop simulation models of different rice varieties under irrigated conditions at Raipur. **A Irrigated**

Yield and yield attribute	IR36		Swarna		Mahamaya		MTU1010		Karma Mahsuri	
	D	I	D	I	D	I	D	I	D	I
Anthesis (days)	68	73	73	77	67	77	66	77	70	77
Maturity (days)	101	103	116	102	94	103	94	106	102	107
Yield (Kg/ha)	10029	6000	10331	5331	9236	5778	8949	6567	10883	7045
Biomass (Kg/ha)	18035	10157	21190	10567	16514	10684	16636	11051	18323	11166
LAI	8.20	2.9	9.01	3.24	7.98	3.24	7.72	3.24	8.49	3.24
HI	0.55	0.59	0.48	0.50	0.55	0.54	0.53	0.59	0.59	0.63

B. Rainfed

Yield and yield attribute	IR36		Swarna		Mahamaya		MTU1010		Karma Mahsuri	
	D	I	D	I	D	I	D	I	D	I
Anthesis (days)	68	73	73	77	67	77	66	77	70	77
Maturity (days)	94	102	105	101	90	102	90	105	95	106
Yield (Kg/ha)	7363	5991	6072	5137	7785	5354	7401	6327	7782	6549
Biomass (Kg/ha)	15278	9694	16111	9869	15020	9996	14939	10335	15326	10449
LAI	7.11	2.93	8.05	3.24	7.04	3.24	6.78	3.24	7.41	3.24
HI	0.48	0.62	0.37	0.52	0.51	0.54	0.49	0.61	0.50	0.63

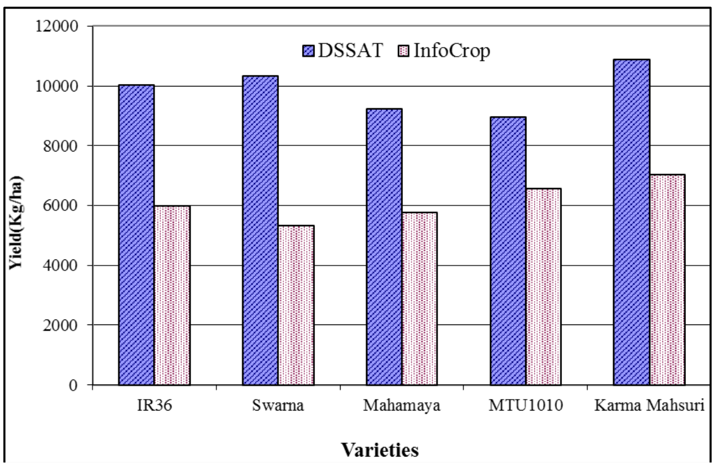

Fig 1 (a): Comparison of the output of using DSSAT and Info Crop simulation models of different rice varieties under irrigated conditions at Raipur.

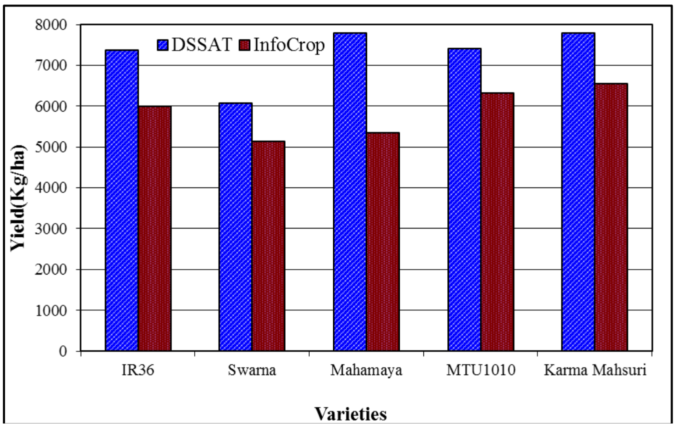

Fig 1 (b): Comparison of the output of using DSSAT and InfoCrop simulation models of different rice varieties under rainfed conditions at Raipur.

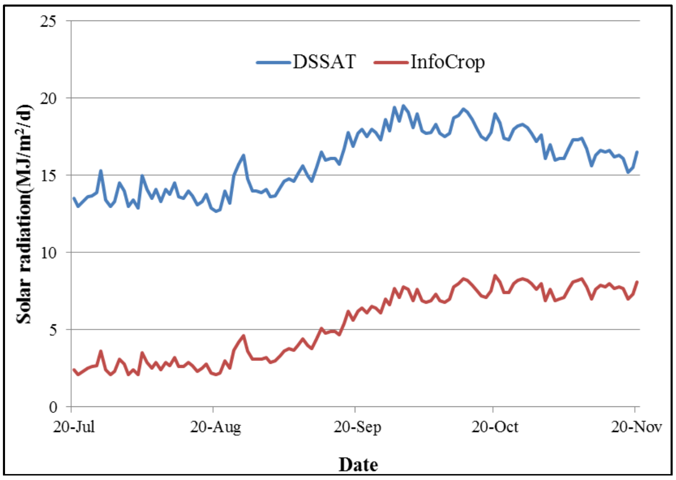

Fig 1 (C): Solar radiation estimated during growing season for rice crop in DSSAT and InfoCrop simulation models at Raipur stations.

Potential yield (Rainfed)

The potential yield of five rice varieties under rainfed conditions in DSSAT model are 7.4, 6.0, 7.8, 7.4 and 7.8 tons/ha for IR36, Swarna, Mahamaya, MTU1010 and Karma Mahsuri respectively. The same potential yields estimated by InfoCrop model for the five varieties are 6.0, 5.1, 5.3, 6.3 and 6.5 t/ha respectively. However the difference of potential yield under rainfed condition for the five varieties is less as compared to irrigated condition. The difference in potential yields between irrigated and rainfed conditions at Raipur for the five varieties is 1.3, 0.9, 2.4, 1.1 and 1.2 tons/ha respectively. Thus, under rainfed condition the output of InfoCrop matches with the output of DSSAT crop estimation. However, under rainfed conditions the potential yields of the five varieties is very high in DSSAT and InfoCrop models output. This is because under average daily weather data the rainfall is averaged every day and there is the rainfall in each day in the crop growing season and hence rainfall is well distributed. The estimated potential yields were higher than the simulated value for the year 2014. Under DSSAT programme in irrigated condition the yields were 9.1, 9.7, 8.6, 8.3 and 10.3 t/ha for IR36, Swarna, Mahamaya, MTU1010 and Karma Mahsuri under Raipur condition. Using the InfoCrop model the potential yield estimated was 4.0, 3.8, 3.9, 4.2 and 4.3 t/ha for the same varieties respectively.

The crop duration

Crop duration for five varieties under DSSAT and InfoCrop models are also shown in Tables 1.1(a,b). It is seen from the table that under irrigation the crop duration from planting to maturity was 101, 116, 94, 94 and 102 days for the five varieties namely IR36, Swarna, Mahamaya, MTU1010 and Karma Mahsuri respectively. For total duration of the crop 30 days to be added as the transplanting was done with 30 day seedlings. Under that condition the duration of IR36 variety works out to be 130 days which is over estimate. In fact, under Raipur condition the duration of IR36 is about 115 days. This is mostly because IR36 is a default model under DSSAT programme, Therefore the GDD is estimated using 80C base temperature. In other varieties the duration is estimated as 146 for Swarna 124 for Mahamaya, 124 for MTU1010 and 132 for Karma Mahsuri. In this the estimation of maturity duration for Mahamaya was under estimated as 124 day but it is infact 130 days, for other varieties it is more or less matches with the duration.

Under rainfed condition the rightly estimated difference in duration varied from 1 to 11 days as compare to irrigated condition, In fact rainfed condition the duration should be less by 5 to 10 days but with the average weather data used there is rainfall in each day and hence the maturity duration was not affected. However when the 2014 data was examined (table: 4.4) the maturity duration less by 3 to 13 days less as compared to normal condition.

Conclusion

Comparison study between performance of DSSAT and InfoCrop models with normal database on 30 years weather data at Raipur under irrigated and rainfed condition was conducted. The result showed that the production potential under DSSAT model output is very high as compared to InfoCrop model output. However, under rainfed condition the potential yield, of all five varieties was higher in DSSAT than InfoCrop model output.

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