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Validation of DSSAT model of rice cultivars under different growing environment of Eastern plain zone of U.P.

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Abstract
A field experiment was conducted 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 as to assess the "Validation of DSSAT model of rice cultivars under different growing environment of Eastern plain zone of U.P.**"** The experiment was conducted in Randomized Block Design. The treatment comprised of three dates of Transplanting *viz*. 5th July (D_1); 15th July (D_2) and 25th July (D_3) with three varieties *viz*. NDR-80 (V_1); Pant Dhan-4 (V_2) and Swarna (V_3). The historical field crop data of year 2014 and 2015 were used for calibration and its validation was made from field crop data of year 2016.
Result reveals that crop growth simulation model was Model simulated the days taken to Panicle Initiation, Anthesis, Physiological Maturity, and Yield. And yield was closed in Accordance to Observed value and model overestimated the V_1 and V_2 Underestimated in 2016. And maturity was closed in Accordance to Observed value and model overestimated the V_3D_3 except D_1D_2 and V_1, V_2 Underestimated in 2016 and in Anthesis V_2, V_3 were overestimated and D_1V_1 were underestimated. Lowest error % was recorded in timely Transplanting crop of rice (5th July) with Swarna variety (D_2V_3) 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 for predicting rice yield and phenological events in eastern U.P.

Keywords: DSSAT, calibration, growing environment, anthesis and phenology

Introduction
Climate change and occurrence of extreme climate events are major concern for productivity of crop, and researchers are engaged in understanding its impact on various soil and crop processes, delineating vulnerable regions through growth and yield of crops and identifying suitable adaptation strategies to sustain systems productivity. Historic analysis of seasonal temperature indicates mixed trend of heating as well as cooling in various agro-climatic regions. There is a need to isolate the effect of other biophysical and socio-economic aspects, in order to work out the impact of climate change, which can be effectively done through use of mechanistic/dynamic simulation models.
The crop growth models are helpful to assess the impact of climate change on the stability of crop production under different management options. Crop growth simulation models provide means to quantify the effect of climate on soil, crop growth, productivity and sustainability of agriculture production. These tools can reduce the need for expensive and time consuming field experimentation and can be used to analyze yield gaps in various crops including wheat. Crop simulation model is quite useful as it forms a bridge between crop process analysis and performance assessment in which process operation are in their natural context.
The Decision Support System for Agro-technology Transfer (DSSAT) was originally developed by an International network of scientists. It is decision support system that encompasses process based computer models that predict growth development and yield as a function of a local weather soil condition, crop management scenarios and genetic information and also includes a basic set of tools to prepare the input data, as well as application programs for seasonal, crop rotation and spatial analysis. Hence the present investigation was undertaken.

Materials and Methods

To generate ground truth data for validation of the present investigation entitled "Validation of DSSAT model of rice cultivars under different growing environment of Eastern plain zone of U.P." an experiment was carried out during *kharif* season 2016 at the Agro-meteorological research farm, of N.D. University of Agriculture & Technology, Kumarganj, Faizabad (U.P.). The geographical situation of experimental site lies at latitudes 26^0 47' North longitude 82^0 12' East and altitude of 113 meter from main sea level in the Indo genetic alluvium of eastern Uttar Pradesh. The experiments consisted of 9 treatment combinations which comprised of 3 dates of Transplanting *viz* 05 July (D1), 15 July (D2) and 25 July (D3) and 3 varieties NDR–80 (V1), Pant Dhan–4 (V2) and Swarna (V3). The experiment was conducted in Randomized block design (RBD) and replicated Four times. DSSAT v4.6 was used for calibration and validation. For modeling purpose historical weather data of last three decades of the station; soil data and crop data of last four year used.

Resulta and Discussion

Calibration of different crop characters and determination of genetic coefficients of rice were determined with past year's (2014, 2015, 2016) crop & weather data and depicted in Table-1.

Days taken to Panicle initiation

The error percentage among the dates of Transplant during 2014 ranged between 4.04% (D_2V_3) to -12% (D_3V_2) and during 2015 & 2016 the values were ranged between -5.1% (D_1V_3) to 13.3% (D_3V_1) and 4.08%(D_2V_3) to -13.8 (D_3V_2) respectively (Table-2). During 2015 at first date of Transplanting (D_1) cultivar (V_3) possess lowest error % of simulated value (-5.1%) & overestimated for Panicle initiation followed by -6.0% in D_2 and 7.8% in D_3 Geethalakshmi *et al*. 2008; Goswami *et al*. 2016 also reported the similar results.

During the year of experimentation (2016) conducted to generate the data for validation, D_1V_1, D_2V_2, D_3V_2 and D_1V_3 were recorded over estimated simulation for Panicle initiation over observed in the range of 4.08 to -13.8 % of error**.** Simulation showed the increasing error % with delay in Transplanting but suit satisfactory at first and second dates of Transplanting (Table-2). The simulation model for Panicle initiation at different dates of Transplanting of rice cultivars under experiment may be supposed usable at satisfactory level for all the three cultivars only at first & second dates of Transplant.

Days taken to anthesis

The error percentage among dates of Transplanting during 2014 ranged between 2.6 (D_1V_1) to -10.1 (D_3V_2) but during 2015 & 2016 the values were between -4.6 (D_2V_3) to 10.3 (D_3V_1) and -4.6 (D_2V_3) to -10.6 (D_2V_2) respectively. During 2015 lowest error -4.65 percent was recorded in Mid Transplant crop (D_2) in cultivar V_3 (Swarna) with further increase in the error with delay in Transplanting (Table-3). Also simulated values in all dates of Transplanted for cultivars V_1, V_2 and V_3 were over estimated over observed value except D_3V_1 and D_3V_2.

Simulated value for cultivar V_3 (Swarna) at D_1, D_2 &D_3 were also over estimated over observed in the range of -5.6 to -8.1 % during 2014. During 2015 D_2 recorded lowest value over observed and error % ranged between -4.6 to -9.33 percentage. Increasing error % of simulated value was also observed with delay in Transplanted during 2015. The simulation model for days taken to Anthesis at different dates of Transplanted of rice cultivars under experiment may be supposed at satisfactory level for all three cultivars at first & second dates of transplanting only.

Days taken to physiological maturity

The error percentage among the dates of Transplanting during 2014 ranged between -3.6 % (D_2V_3) to 8.4% (D_3V_1) and during 2015 & 2016 the values ranged between -2.8% (D_1V_2) to -6.5% (D_3V_2) and 2.8% (D_1V_2) to 11.2% (D_3V_1) respectively (Table-4). During 2014 lowest error -3.6 percent was recorded in crop Transplanted on 2^{nd} date of Transplanting (D_2) in cultivar V_3 (Swarna). During 2015 at third date of Transplanting (D_3) cultivar (V_1, V_2, V_3) was over estimated for days taken to physiological maturity and lowest error percentage of simulated values (-2.8%).

During 2016 also the simulated values of all the cultivars at all dates of Transplanting were underestimated over observed value except D_3V_3 and error % increased considerably with delay in Transplanting in all the cultivars during 2016. The simulation model for days taken to physiological maturity at different dates of Transplanting of rice cultivars under experiment may be supposed almost satisfactory for all three cultivars with estimated error percentage in order of preference of early transplanting cultivars.

Grain yield

The error percentage among the dates of Transplanting during 2014 ranged between 1.7% (D_2V_3) to -9.6% (D_3V_1) and during 2015 & 2016 the values were ranged between 2.2% (D_1V_2) to 9.6% (D_3V_2) and 2.2%(D_2V_3) to-13.1 (D_3V_1) respectively. During 2015 at first date of Transplanting (D_1) cultivar (V_2) possess lowest error % of simulated value (2.2%) & under estimated for grain yield (kg ha^{-1}) followed by 5.6% in D_2 and 9.6% in D_3. During the year of experimentation (2016) conducted to generate the data for validation, all dates of Transplanting for all cultivars were recorded underestimated simulation for grain yield (kg ha^{-1}) except V_1, D_1V_3 over observed in the range of 2.2 to -13.1 % of error (Table-5).

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 reported the similar results. The simulation model for grain yield (kg ha^{-1}) at different dates of Transplanting of rice cultivars under experiment may be supposed usable at satisfactory level for all the three cultivars only at first & second dates of Transplant.

Sensitivity analysis

Maximum percent change from base yield (12.2%) was recorded with increase of temperature by 1.5^0C over normal, whereas 1.5^0C decrease in temperature reduced the yield to -4.1% only. Comparative study of 1^0C successive increase in temperature on yield of rice confirmed that successive temperature though increase the yield, but 1^0C successive decrease in temperature decreases the yield with greater magnitude as compare to reduction in yield caused by decreasing temperature. Maximum % of yield reduction change from base yield was recorded (-4.5%) with decreasing the solar radiation by -1.5 MJ m^{-2} day^{-1} over normal. Increase of solar radiation by 1.5 MJ m^{-2} day^{-1} increased the yield by 13.2% only from base yield (Table-6 & Table-7) Kumar *et al*. 2010; Kumar *et al*. 2013; Kumar *et al*. 2015 also reported the similar results. This showed that solar radiation was most sensitive parameter for rice production as compare to temperature because yield increase/decrease on unit basis was lower for temperature as compare to solar radiation.

Table 1: Genetic coefficient of Rice cultivars derived for Eastern Plain Zone (EPZ) of U.P.

Symbol	Description	NDR -80	Pant Dhan-4	Swarna
P1	Time period (expressed as growing degree days [GDD] in ØC above a base temperature of 9Ø) 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.	317	830	650
P2R	Critical photoperiod or the longest day length (in hours) at which the development occurs at a maximum rate. At values higher than P20 developmental rate is slowed, hence there is delay due to longer day lengths.	165	160	200
P2O	Extent to which phasic development leading to panicle initiation is delayed (expressed as GDD in ØC) for each hour increase in photoperiod above P20.	12.5	11.4	12.0
P5	Time period in FDD) from beginning of grain filling (3 to 4 days after flowering) to physiological maturity with a base temperature of 9Ø C.	460	300	520
G1	Potential spikelet number coefficient as estimated from the number of spikelet per g of main calm dry weight (less lead blades and sheaths plus spikes) at Anthesis. A typical value is 55.	64	45	59
G2	Single grain weight (g) under ideal growing conditions, i.e. no limiting length, water, nutrients, and absence of pests and diseases.	0.0180	0.0300	0.0250
G3	Tillering coefficient (scalar value) relative to IR64 cultivar under ideal conditions. A higher tillering cultivar would have coefficient greater than 1.0.	1	1	1
G4	Temperature tolerance coefficient. Usually 1.0 for varieties grown in normal environment. G4 for japonica type rice growing in warmer environment would be 1.0 or greater. Likewise, the season would be less than 1.0.	1	1	1

Table 2: Calibration and validation of simulated days taken to panicle initiation from observed in rice cultivars

Treatments	Cultivars								
	NDR-80 (V_1)			Pant Dhan-4 (V_2)			Swarna (V_3)		
	Obs.	Sim.	Error %	Obs.	Sim.	Error %	Obs.	Sim.	Error %
Year 2014									
D_1	66	69	-4.5	71	76	-7.04	97	102	-5.1
D_2	65	61	6.1	73	65	10.9	99	95	4.04
D_3	68	63	7.3	75	84	-12	100	106	-6.0
Year 2015									
D_1	65	70	-7.6	70	77	-10	98	103	-5.1
D_2	67	62	7.6	72	79	-9.2	99	105	-6.0
D_3	69	60	13.3	74	68	8.1	102	94	7.8
Year 2016									
D_1	67	74	-10.4	70	65	7.4	99	104	5.05
D_2	66	61	7.5	69	77	-11.5	98	94	4.08
D_3	68	68	11.7	65	74	-13.8	100	91	9

Where – D_1- 5th July, D_2- 15th July and D_3 - 25th July

Table 3: Calibration and validation of simulated days taken to Anthesis from observed in rice cultivars

Date of Transplanting Year 2014	Cultivars								
	NDR-80 (V_1)			Pant Dhan-4 (V_2)			Swarna (V_3)		
	Obs.	Sim.	Error %	Obs.	Sim.	Error %	Obs.	Sim.	Error %
D_1	75	72	2.6	76	80	-5.2	106	112	-5.6
D_2	74	78	-5.4	75	81	-8	108	115	-6.8
D_3	77	72	6.4	79	87	-10.1	110	119	-8.1
Year-2015									
D_1	76	83	-9.2	77	82	-6.4	104	110	-5.7
D_2	76	81	-6.5	75	82	-9.33	107	112	-4.6
D_3	79	71	10.3	78	70	10.2	109	117	-7.3
Year 2016									
D_1	76	80	-5.2	77	81	-5.1	108	116	-7.4
D_2	75	70	6.6	75	83	-10.6	109	110	-4.6
D_3	79	72	8.06	78	82	-5.1	111	121	-7.3

Where – D1- 5th July, D2- 15th July and D3 – 25th July

Table 4: Calibration and validation of simulated days taken to physiological maturity from observed in rice cultivars

Date of Transplanting Year 2014	Cultivars								
	NDR_80 (V_1)			Pant Dhan-4 (V_2)			Swarna (V_3)		
	Obs.	Sim.	Error %	Obs.	Sim.	Error %	Obs.	Sim.	Error %
D_1	104	99	4.8	101	94	6.9	136	128	5.8
D_2	106	102	3.7	104	97	6.7	137	142	-3.6
D_3	107	98	8.4	107	99	7.4	140	149	-6.4
Year 2015									

D_1	105	100	4.7	104	107	-2.8	135	141	-4.4
D_2	107	101	5.6	105	101	3.8	138	130	5.8
D_3	108	113	-4.6	107	114	-6.5	141	149	-6.38
Year 2016									
D_1	106	100	5.6	105	102	2.8	137	128	6.5
D_2	104	95	8.65	106	98	7.5	139	135	2.8
D_3	107	95	11.2	108	99	8.3	140	150	-7.1

Where – D_1- 5th July, D_2- 15th July and D_3 – 25th July

Table 5: Calibration and validation of simulated grain yield (kg ha^{-1}) from observed in rice cultivars

Date of Transplanting Year 2014	Cultivars								
	NDR-80 (V_1)			Pant Dhan-4 (V_2)			Swarna (V_3)		
	Obs.	Sim.	Error %	Obs.	Sim.	Error %	Obs.	Sim.	Error %
D_1	4490	4250	5.7	4579	4120	10.2	4479	4670	-4.2
D_2	4410	4167	5.4	4490	4360	2.9	4417	4340	1.7
D_3	4260	4669	-9.6	4367	3915	10.5	4360	4167	4.3
Year 2015									
D_1	4570	4367	4.4	4510	4411	2.2	4430	4569	-3.1
D_2	4480	4150	7.3	4485	4230	5.6	4401	4056	7.8
D_3	4375	4689	-7.1	4274	3860	9.6	4307	3960	8.4
Year 2016									
D_1	4130	4367	-5.3	4564	4202	7.9	4430	4719	-6.5
D_2	4110	4359	-6.0	4525	4207	7.2	4408	4310	2.2
D_3	3940	4160	-5.8	4207	3867	8.7	4150	3841	7.04

Where – D_1- 5th July, D_2- 15th July and D_3 - 25th July

Table 6: Sensitivity analysis of ambient temperature for simulate of grain yield.

Cultivar	NDR-80		Pant Dhan-4		Swarna	
Ambient temperature ^{0}C	Modified Simulation grain yield kg/ha	(%) change from base (4063) yield	Modified Simulation grain yield kg/ha	(%) change from base (4063) yield	Modified Simulation grain yield kg/ha	(%) change from base (4063) yield
0.5	4427	+9	4804	+3.3	4323	+2.4
1	4500	+10.8	4890	+5.1	4398	+4.1
1.5	4557	+12.2	4994	+7.4	4416	+4.6
-0.5	4390	-8.0	4597	-1.2	4197	-0.6
-1	4250	-4.6	4521	-2.8	4103	-2.8
1.5	4200	-3.4	4498	-3.3	4051	-4.1

Table 7: Sensitivity analysis of solar radiation for simulate grain yield.

Cultivar	NDR-80		Pant Dhan-4		Swarna	
Solar radiation Mj/m/ day	Modified Simulation grain yield kg/ha	(%) change from base (4063) yield	Modified Simulation grain yield kg/ha	(%) change from base (4063) yield	Modified Simulation grain yield kg/ha	(%) change from base (4063) yield
0.5	4329	+6.5	5089	+9.4	4420	+4
1	4497	+10.7	4980	+7.1	4453	+5.4
1.5	4600	+13.2	5068	+8.9	4395	+4.1
-0.5	4031	-0.8	4557	-2.0	4202	-0.5
-1	3956	-2.6	4532	-2.6	4130	-2.2
-1.5	3879	-4.5	4601	-1.1	4087	-3.2

Conclusions

On the basis of results, it may be concluded that lowest error % was recorded in timely Transplanting of rice (5th July) and error % increased with delay in Transplant. Among cultivars V_3 (Swarna) recorded better for yield prediction over other cultivars with higher accuracy in D_1 followed by V_1. 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 close to observed values in timely transplant 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 in eastern U.P. Lowering the temperature below the normal to rice crop for simulation of grain yield change from base yield was found having higher sensitivity as compare to increases in the temperature of same magnitude but same response of solar radiation sensitivity were observed i.e. Increased solar radiations possess higher yield response over base yield as compare to decreased solar radiation.

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