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Evaluation of crop simulation modeling in chickpea crop using DSSAT model ver4.6

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Abstract
A field experiment was conducted during the *Rabi* season of 2017-18 to access the "Evaluation of crop simulation modeling in chickpea crop using DSSAT model ver4.6" in silty loam soil at student's instructional Farm, N.D. University of Agriculture & Technology, Kumarganj, Faizabad. The experiment was conducted with Randomized block design and replicated four times with nine treatment combinations consisted of three dates of sowing viz. D_1 (5th November), D_2 (15th November) and D_3 (25th November) and three cultivars *viz.* V_1 (BG-372), V_2 (KPG-59) and V_3 (Pant G-186). The historical crop data of year 2015-16 and 2016-17 were used for calibration of the model. The yield and yield attributes, phonological stages, test weight, harvest index as simulated by model were compared with the observed data. The result revealed that the model underestimated the test weight, LAI, first pod initiation, physiological maturity and overestimated rest of the parameters.

Keywords: Crop growth model, DSSAT, chickpea, simulation, calibration validation

Introduction
Chickpea (Cicer arietinum L.) is the premier pulse crop of Indian sub continent. India is the largest chickpea producer as well as consumer in the world. In UP its total area is 0.27 million hectare, production 0.22 million ton and productivity is 805kg/ha. The UN declared 2016 the 'international year of pulses'. (Agriculture Statistics, 2016-17).

It has the highest nutritional compositions in the form of fiber and minerals. It can fix atmospheric nitrogen up to 140 kg/ha through its symbiotic association with Rhizobium and meets its 80 % requirement. It also helps in enhancing the soil quality for subsequent cereal crop. In India, acid exudates from the leaves were used medicinally for bronchitis, cholera, constipation, diarrhea, dysentery, snakebite, sunstroke and warts. The productivity of chickpea is curtailed due to biotic and abiotic stresses. Weather is one of the important factor, which affects all stages of chickpea growth and finally the yield (Abbo et al. 2005) [1]. The crop growth simulation models show considerable potential to evaluate crops, crop varieties, cropping pattern and genetic potential pattern for yield (Boote et al., 1987) [4]. In this paper attempt has been made to calibrate and validate to genetic coefficient of chickpea cultivar using DSSAT model.

Materials and Methods
Geographically the experimental site is situated at $26^0 47'$ N latitude, $82^0 12'$ E longitude and at an altitude of 113 meters above sea level in the Indo genetic alluvium of eastern Uttar Pradesh. The site comes under the subtropical climate and often subjected to extreme weather condition i.e. cold winter and hot summer. The experimental data (2017-18) of chickpea crop at Agro meteorological Research farm in the main campus of NDUA&T, Kumarganj, (Faizabad). Comprising three date of sowing (D_1-5 Nov, D_2-15 Nov, D_3-25 Nov) and three varieties (V_1-BG-372, V_2- KPG-59, V_3- Pant G-186). The package and practices for cultivation was followed as per the recommendation of crop parameters such as yield and yield attributes, LAI, harvest index and phenology were used for calibration of the DSSAT ver4.6 model. The genetic coefficient of chickpea were estimated by repeated interactions until a close match between simulated and observed phenology and yield was obtained in respective treatments. The values of genetic coefficients as derived from calibration of the model are the presented in Table1.

Generally, correlation coefficient (r) and regression coefficient (R) are determined to evaluate the association between the observed and simulated values despite the fact that their magnitudes are consistently not related to accuracy of prediction. Hence, to achieve accuracy, the test criteria suggested by Wiltlmott (1982) [9] were followed while evaluating the performance of the models. The observed (O) and simulated (P) values were used to calculate error percent (PE), mean absolute error (MAE), mean bias error (MBE) and root mean square error (RMSE).

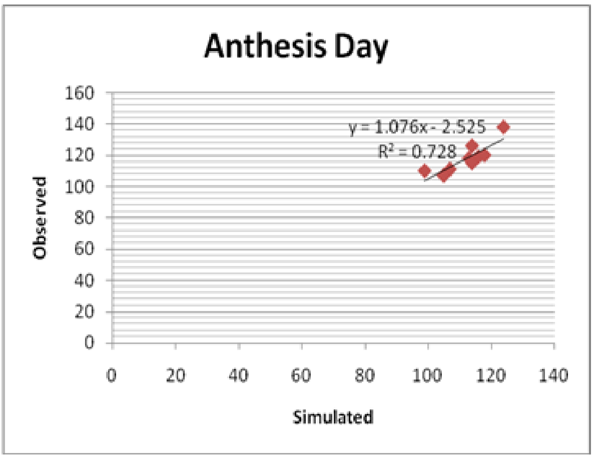
$$MAE = \sum_{i=1}^{n} [|P_i - O_i|] / n \quad MBE = \sum_{i=1}^{n} [P_i - O_i]/n$$

$$RMSE = [\sum (Pi - Oi)2/n]$$

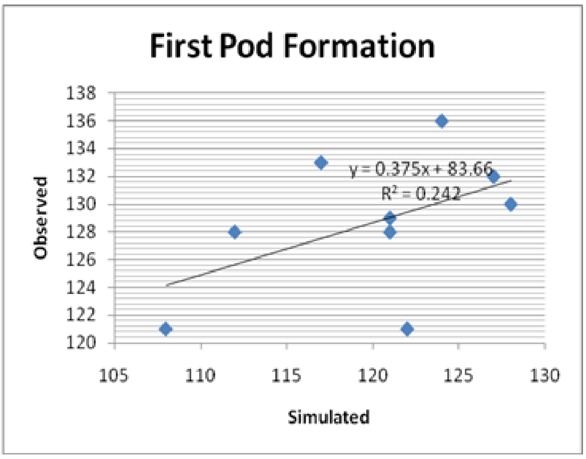
$$PE = \{(simulated\text{-}observed)/\ observed\}\times 100$$

Table 1: Genetic coefficient of chickpea cultivar for eastern Uttar Pradesh agro climatic region

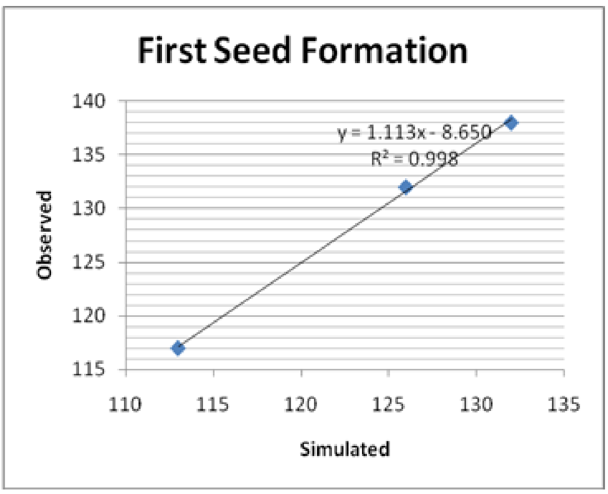
Parameter		BG-372	KPG-59	Pant G-186
Critical Short Day Length below which reproductive development progresses with day length effect (for long day plants) (hour)	CSDL	14	15	14
Slope of the relative response of development to photoperiod with time (negative for long day plants) (1/hour)	PPSEN	-157	-157	-157
Time between plant emergence and flower appearance (R1) (photo thermal days)	EM-FL	41	43	47
Time between first flower and first pod (R3) (photo thermal days)	FL-SH	13	15	11
Time between first flower and first seed (R5) (photo thermal days)	FL-SD	17	14	14
Time between first seed (R5) and physiological maturity (R7) (photo thermal days)	SD-PM	48	48	35
Time between first flower (R1) and end of leaf expansion (photo thermal days)	FL-LF	30	34	23
Maximum leaf photosynthesis rate at 30^0C, 350 vpm CO_2 and high light (mg CO_2/m^2-s	LFMAX	1.67	1.69	1.62
Specific leaf area of cultivar under standard growth conditions (cm^2/g)	SLAVR	145	145	156
Maximum size of full leaf (three leaflets) (cm^2)	SIZLF	17	17	19
Maximum fraction of daily growth that is partitioned to seed + shell	XFRT	1.00	1.01	1.00
Maximum weight per seed (g)	WTPSD	0.274	0.173	0.195
Seed filling duration for pod cohort at standard growing conditions (photo thermal days)	SFDUR	37	29	30
Average seed per pod under standard growing conditions (seed/pod)	SDPDV	1.00	1.38	1.75
Time required for cultivar to reach final pod load under optimum condition (photo thermal days)	PODUR	16.0	16.0	16.0
The maximum ratio of seed/seed +shell at maturity. Causes seed to stop growing as their dry weights increase until shells are filled in a cohort. (Threshing percentage).	THRSH	76.0	76.0	77.0
Fraction protein in seeds (gram)	SDPRO	.211	.211	.211



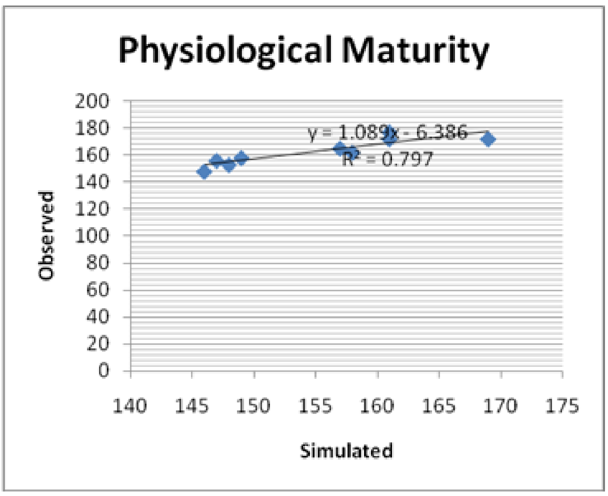
Anthesis Day



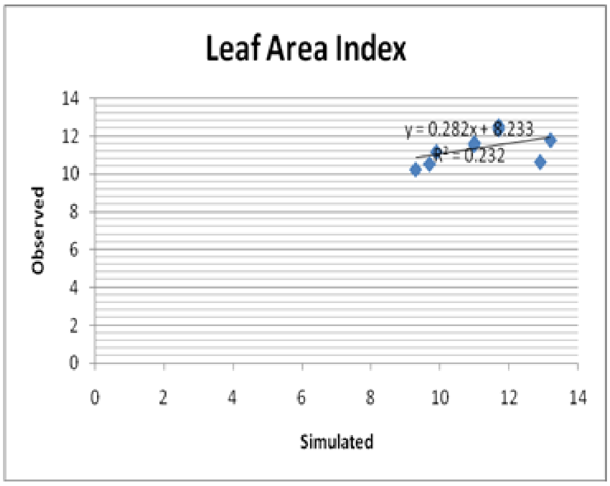
First Pod Formation



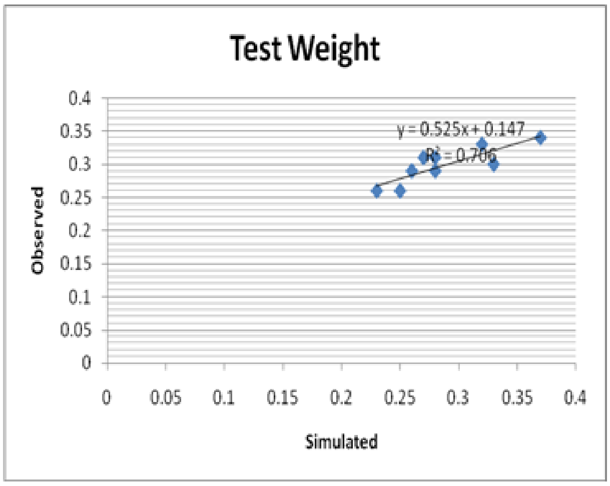
First Seed Formation



Physiological Maturity



Leaf Area Index



Test Weight

Results and discussion

Phenological stages

The observed days to anthesis for three cultivars BG- 372 and KPG-59 and Pant G-186 were 118, 115 and 104 respectively where as model simulated 127, 118 and 109 days respectively. The test criteria computed by simulated model for three cultivars BG- 372 and KPG-59 and Pant G-186 suggested that model performance was better for KPG-59 as compared to BG-372 and Pant G-186 for simulation of days to anthesis. For simulating days to first pod performance parameters for cv. BG-372 were higher than that for cv. KPG-59 and Pant G-186 (Table 2) although the model overestimated the days to first pod formation. The observed days to first seed formation for three cultivar BG-372, KPG-59 and Pant G-186 were 120, 123 and 123 days respectively, while model simulate 133, 134 and 129 days respectively. The test criteria for three cultivars BG- 372 and KPG-59 and Pant G-186 (Table 2) suggested that model performance was better for Pant G-186 as compared to BG-372 and KPG-59 for simulation of days to first seed. Days taken to physiological maturity for BG- 372 and KPG-59 and Pant G-186 were observed to be 158, 155 and 152 days respectively while model simulated 162, 164 and 161 days respectively. The test criteria for three cultivars BG- 372, KPG-59 and Pant G-186 (Table 2) suggested that model performance was better for BG-372 as compared to KPG-59 and Pant G-186 for simulation of days taken to physiological maturity. Thus, the model overestimated the days to physiological maturity. For LAI the performance criteria was good for cv. KPG-59 followed by BG-372 and Pant G-186. The results of phenological stages of chickpea simulated by CROPGRO chickpea model was in conformity with those of Ujinwal and Patel (2008); Babu (2006); Nokes and Young (1991).

Yield and yield attributs

The biomass yield obtained for three cultivars BG- 372 and KPG-59 and Pant G-186 were 10744, 10341 and 10105 while model simulated slightly differs 10462, 10209 and 10159 respectively. The test criteria computed by model for three cultivars BG- 372 and KPG-59 and Pant G-186 (Table 2) suggested model performance was good for Pant G-186 followed by KPG-59 and Pant G-186. Where KPG-59 is underestimated. The test weight obtained for three cultivars BG- 372 and KPG-59 and Pant G-186 were 0.25, 0.27 and 0.31 while model simulated slightly contrast 0.28, 0.31 and 0.31 respectively. The test criteria computed by model for three cultivars BG- 372 and KPG-59 and Pant G-186 (Table 2) suggested model performance was good for Pant G-186 and BG-372 as compare than KPG-59. However, for simulating grain yield the performance parameters for cv. Pant G-186 was higher than that for cv. KPG-59 and BG-372 (Table 2). The harvest index of three cultivars- 372 and KPG-59 and Pant G-186 were 62.1, 60 and 60 while model simulated 63.2, 63 and 63.7 respectively. For simulating harvest index the test parameters for cv. BG- 372 were better than cv. KPG-59 and Pant G-186. Thus, the model overestimated the harvest index. For straw yield the performance criteria was good for cv. BG-372 than cv. KPG-59 and Pant G-186. The results are in good agreement with the finding of Pandey *et al.*, (2001) [6]; Singh *et al.*, (1994) for yield and yield attributes of chickpea as simulated by CROPGRO model.

Conclusion

Days to anthesis, first seed, first pod, days to maturity, leaf area index, pod yield, straw yield, harvest index and biomass yield were satisfactorily simulated by DSSAT model, however LAI and straw yield were underestimated and rest of the parameters was overestimated by the model with reasonable agreement. DSSAT model has proved to be valuable tool for predicting chickpea yield. This shows the robustness of DSSAT model. Therefore, the validated DSSAT can further used for applications such as prediction of crop growth, phenology, potential and actual yield, performance of chickpea under climate change study etc. The model may also to be used to improve and evaluate the current practices of chickpea growth management to enhance chickpea production.

Table 2: Test criteria of various parameters of chickpea cultivars

Parameters	Observed			Simulated		
	BG-372	**KPG-59**	**Pant G-186**	**BG-372**	**KPG-59**	**Pant G-186**
Days to anthesis (DAS)	118	115	104	127	118	109
First Pod (DAS)	119	120	120	124	129	132
First seed (DAS)	120	123	123	133	134	129
Days to physiological maturity (DAS)	158	155	152	162	164	161
LAI	12.60	10.80	10.0	11.59	11.57	11.0
Biomass yield	10744	10341	10105	10462	10209	10159
Test weight	0.25	0.27	0.31	0.28	0.31	0.31
Grain yield	2267	1928	1891	2249	1897	1917
Harvest index	62.1	60	60	63.2	63	63.7
Straw yield	4264	4053	3814	4431	4246	4015

Parameters	MAE			MBE		
	BG-372	KPG-59	Pant G-186	BG-372	KPG-59	Pant G-186
Days to anthesis (DAS)	0.604	0.167	0.354	0.604	0.167	0.354
First Pod (DAS)	0.292	0.583	0.750	0.292	0.583	0.750
First seed (DAS)	0.792	0.688	0.333	0.792	0.688	0.333
Days to physiological maturity (DAS)	0.250	0.583	0.563	0.250	0.583	0.563
LAI	0.063	0.048	0.057	-0.063	0.048	0.057
Biomass yield	17.62	8.208	3.375	-17.62	-8.208	3.375
Test weight	0.001	0.001	0.0	0.001	0.001	0.0
Seed yield	1.083	1.938	1.583	-1.083	-1.938	1.583
Harvest index	0.062	0.210	0.206	0.062	0.210	0.206
Straw yield	10.45	12.06	12.54	10.45	12.06	12.54

Parameters	RMSE			PE		
	BG-372	KPG-59	Pant G-186	BG-372	KPG-59	Pant G-186
Days to anthesis (DAS)	4.670	1.369	2.969	3.958	1.191	2.864
First Pod (DAS)	3.298	4.541	5.385	2.763	3.785	4.463
First seed (DAS)	5.511	4.776	2.345	4.567	3.883	1.896
Days to physiological maturity (DAS)	1.768	4.077	4.617	1.116	2.631	3.037
LAI	0.687	0.334	0.417	5.451	3.095	4.148
Biomass yield	235.4	62.065	28.868	2.191	0.600	0.286
Test weight	0.011	0.015	0.008	4.302	4.859	2.675
Seed yield	33.858	30.652	16.609	1.494	1.589	0.878
Harvest index	1.228	1.621	1.442	1.967	2.691	2.382
Straw yield	72.90	84.29	88.30	1.710	2.080	2.31

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