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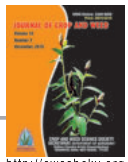

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Groundnut modeling for yield using CropSyst model under middle Gujarat

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ABSTRACT

The present study on groundnut modeling for yield using CropSyst model under middle Gujarat was carried out having three dates of sowing and three cultivars in factorial randomized block design. The calibration result showed much closed to simulation of growth and yield. Validation was worked out using mean absolute error, mean bias error, mean absolute per cent error, root mean square error and refined index of agreement. The performance of CropSyst for simulated growth and yield attributes were overestimated to be observed of GG 20, GJG 34 and TAG 37A cultivars under onset of monsoon. The simulation model showed good value of MBE, MAPE, RMSE and also d_r which was 0.75. Hence, it shows that the confidence level was more on model simulation with observed data. The model performs better for GG 20 as compared to GJG 34 and TAG 37A.

***Keywords**:* Calibration, CropSyst, Groundnut, Middle Gujarat, Modelling.

Crop models are used effectively all over the world as research and important support system tools in crop management and production. Also, the simulations of model have been useful tools to decide the best management practices for higher growth and yield of crop against environmental conditions (Parmar *et al*., 2013 and Yadav *et al*., 2012). CropSyst is a multi-year, multi-crop and daily time step simulation model for studying of effect of climate, soils and management on environment as well as crop production. In CropSyst, canopy, leaf area and absence of daily assimilates partitioning etc. had been simplified to make easy calibration with the reduced crop parameters compared to other models (Singh *et al.,* 2008). CropSyst model simulates cropping system and its relationship with environment as well as management (Stockle *et al.,* 1994 and Stockle *et al*., 2003). Calibration and validation of model were computed by adjusting cultivar crop parameters for yield prediction. Calibration of model was started with base and cutoff temperature and growing degree days, hence, simulated crop growth phases should match with data. Validated model can be used to predict groundnut yields with soil profiles and climatic conditions. Finally, suitable adaptation measures can be found out for increasing groundnut yields by using the Crop Syst modeling.

Groundnut is an important oilseed crop in tropical and subtropical zones of the world. It is also one of the most important cash crops in our country. Sowing, emergence, germination, flowering, vegetative and pod development of groundnut requires well distribution of rainfall. Optimum temperature for groundnut growth and development ranged from 25 to 30 ºC. India stands second highest producer of groundnut mainly because of the crop is mostly grown under rainfed condition in dryland zone, often subject to the vagaries of the weather and only 14-15 % area is under irrigation. It is grown mainly in rainfed season i.e. *kharif* (about 80% of the total groundnut production). In Gujarat, Junagadh district is the most productive among all the districts (Sahu *et al.,* 2000). Studies on validation of CropSyst model under rainfed condition in groundnut are lacking. Improved production management practices are the most crucial starting point for increasing the productivity of groundnut by adapting suitable crop simulation models (Anothai *et al.,* 2008). Hence, the present study was carried out for groundnut modeling of growth and yield using CropSyst model under middle Guajrat.

MATERIALS AND METHODS

Experimental data

The field experiments were carried out at Agronomy farm, Anand Agricultural University, Anand, Gujarat, India, during *kharif* season of 2019 and 2020. Anand is located at latitude of 22° 35"N, longitude of 72° 55" E and at an altitude of 45.1m above msl. The treatments consisted three dates of sowing i.e. first date of sowing was at onset of monsoon followed by 10 days interval i.e. second date of sowing (10 days after onset of monsoon), third date of sowing (20 days after onset of monsoon) with cultivars V_1: GG 20, V_2 : GJG 34 and V_3:TAG 37A. The experiment was replicated four times in randomized block design (factorial). The crop was grown with spacing of 30 cm x 10 cm. Supplementary

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irrigations were applied to the each plot as life saving irrigations. Interculture operations during field experiment were carried out as per recommendation. The model used 17 crop parameters to define different phonological stages of groundnut presented in Table 1. Onset of monsoon i.e. first sowing date of 2019 was considered in calibration and crop parameterization. The other two dates of sowing i.e. second and third date of sowing during 2019 and three dates of sowing during 2020 were used in validation of model.

Weather data

Daily weather data i.e. Tmax and Tmin (°C), morning and afternoon relative humidity (%), solar radiation (MJ m^{-2} day^{-1}), wind speed (m s^{-1}) and rainfall (mm) during field experiment period were collected from the Agrometeorological observatory, Department of Agricultural Meteorology, B A College of Agriculture, Anand Agricultural University, Anand. The observatory was adjacent to the experimental site.

Soil data

The field experiment was carried out on sandy loam soil having water table of 10 m deep, with a field capacity of 15.4 to 15.8 at different depths. Bulk density was 1.52 g cm^{-3} to 1.55 g cm^{-3} in 15 to 45 cm layer at field experiment site.

Model calibration

The calibration of CropSyst model was computed on growth and yield characters which were measured during harvesting time. The crop parameters of groundnut cultivars that influence the various stages of crop were calculated using "trial and error". The observed values of crop growth, phenology and yield with simulated values were matched and calibrated crop parameters lied within limits of error for the cultivars such as GG 20, GJG 34 and TAG 37A under first date of sowing i.e. onset of monsoon (Table 1). Subsequently, these crop parameters were used to validate the model performance.

Validation of the model

Validation is comparison between observed and simulated values which were not used for calibration. The CropSyst model was validated for second as well as third dates of sowing of 2019 and three dates of sowing of 2020. The model was evaluated with the test criteria viz; mean absolute error (MAE), mean bias error (MBE), root mean square error (RMSE), mean absolute percent error (MAPE) and refined index of agreement (d_r). According to Willmott *et al.* (2012) the observed and simulated values were computed.

RESULTS AND DISCUSSION

Calibration of the CropSyst model

Simulated and observed values for growth and yield of groundnut for three cultivars viz. GG 20, GJG 34 and TAG 37A under first date of sowing during 2019 was considered for calibration. The CropSyst model was calibrated using the measured data on growing degree days of different phenological crop growth stages, maximum expected LAI and Leaf/stem partition coefficient. The other parameters (Initial green leaf area index and fraction of maximum LAI at physiological maturity) for the crop file were taken as default. Thermal time accumulation i.e. base temperature (°C) and cutoff temperature (°C), rooting depth (m) and leaf area duration were used from literature. The crop parameters considered for calibration were leaf area, SLA (m^2 Kg^{-1}), canopy extinction coefficient for total solar radiation, evapotranspiration crop coefficient at canopy and unstressed harvest index (HI) (Table 1).

The model showed that measured peak leaf area, pod yield and biomass varied between 4.2 m^2 to 4.8 m^2, 2059 Kg ha^{-1} to 2317 Kg ha^{-1} and 5686 Kg ha^{-1} to 6161 Kg ha^{-1}, while model simulated ranged from 4.2 m^2 to 4.7 m^2, 2053 Kg ha^{-1} to 2334 Kg ha^{-1} and 5761 Kg ha^{-1} to 6325 Kg ha^{-1}, respectively (Table 2). Thus, the calibration resulted much closed simulation for days to growth and yield.

Growth Attributes

Peak leaf area index (LAI)

The validated peak LAI revealed that observed and simulated peak LAI varied from 3.3 to 4.6 and 3.1 to 5.3 respectively, with deviation - 8.2 % to 15.2 % under dates of sowing and varieties during both years (Table 3 and 4). Hence, model shows better performance in 2019 than 2020. CropSyst model overestimated about 0.33 over measured peak LAI. The peak LAI had very good agreement with MAE, MBE, RMSE and MAPE of 0.40 m^2, 0.36 m^2, 1.38 m^2 and 9.56 %, respectively (Table 5). Jat *et al.* (2016) reported similar results. Refined index of agreement (d_r) was 0.35 which indicate that the CropSyst model can simulate good performance with peak LAI.

Yield

Pod yield

The result showed that observed and simulated pod yield ranged from 1279 Kg ha^{-1} to 2102 Kg ha^{-1} and 1259 Kg ha^{-1} to 2248 Kg ha^{-1}, respectively, with deviation -11.1% to 16.5% during study period (Table 3 and 4). The CropSyst model overestimated observed

Table 1: Crop parameters used in CropSyst to simulate groundnut cultivars for first date of sowing (Onset of monsoon) during 2019

Crop parameters	First date of sowing			
	Variety			Source
	GG 20	GJG 34	TAG 37A	
Thermal Time accumulation				
Base temperature (°C)	10	10	10	L
Cutoff temperature (°C)	40	40	40	L
Phenology (°C day)				
Degree days emergence	155	172	155	M
Degree days end of vegetative growth	1607	1607	1607	M
Degree days begin flowering	677	712	693	M
Degree days begin pod filling	1441	1441	1423	M
Degree days physiological maturity	2125	2125	2125	M
Morphology				
Maximum rooting depth (m)	0.60	0.60	0.60	L
Initial green leaf area index (m^2 m^{-2})	0.011	0.011	0.011	D
Maximum expected LAI (m^2 m^{-2})	4.77	4.39	4.21	M
Specific leaf area, SLA (m^2 kg^{-1})	23.00	22.30	20.30	C
Fraction of max. LAI at physiological maturity	0.80	0.80	0.80	D
Leaf/stem partition coefficient	1.96	2.01	1.80	M
Leaf area duration	1000	1000	1000	L
Canopy extinction coefficient for total solar radiation	0.50	0.50	0.50	C
Evapotranspiration crop coefficient at full canopy	0.90	0.90	0.90	C
Growth				
Unstressed harvest index (HI)	0.43	0.43	0.45	C

* C= Calibrated, D= Default, L= Literature and M= Measured

Table 2: Calibration of observed (O) and simulated (S) days to yield of groundnut under first date of sowing (Onset of monsoon) during 2019

Treatment	Peak leaf area index		Pod yield(Kg ha^{-1})		Biomass (Kg ha^{-1})	
	O	S	O	S	O	S
GG20	4.8	4.7	2317	2334	6161	6325
GJG34	4.4	4.4	2153	2111	5881	6031
TAG37A	4.2	4.2	2059	2053	5686	5761

pod yield. The test criteria MAE, MBE, RMSE and MAPE of 188.2 Kg ha^{-1}, 150.9 Kg ha^{-1}, 584.5 Kg ha^{-1} and 11.1%, respectively showed simulated pod yield was very good agreement. The refined index of agreement (d_r) was 0.50 showed good accuracy (Table 5). Similar results were found by Jat *et al.* (2016). The evaluation of the model on an overall basis was found good.

Biomass

The observed biomass production varied from 2849 Kg ha^{-1} to 5060 Kg ha^{-1} and simulated 2797 Kg ha^{-1} to 5228 Kg ha^{-1}. The deviation ranged from -11.8 % to 14.7 % for both years (Table 3 and Table 4). CropSyst model overestimated about 343.0 Kg ha^{-1} over measured biomass. The CropSyst model was better performed in GG 20 than GJG 34 and TAG 37A cultivars. The model simulated the biomass with very good accuracy for second date of sowing during 2019 and all dates of sowing during 2020. However, third date of sowing showed poor performance as compared to other dates of sowing during 2019 as compared to other dates of sowing. Simulated biomass was very good agreement with the test criteria MAE, MBE, RMSE and MAPE of

Table 3: Validation of observed (O) and simulated (S) with deviation (D) for yield of groundnut during 2019

Treatments	Peak LAI			Pod yield(Kg ha^{-1})			biomass (Kg ha^{-1})		
	O	S	D (%)	O	S	D (%)	O	S	D (%)
Second date of sowing (10 days after onset of monsoon)									
GG 20	4.6	5.1	9.5	2102	2248	6.9	5060	5228	3.3
GJG 34	4.3	4.9	12.5	1970	2152	9.2	4910	5004	1.9
TAG 37A	4.1	4.2	1.4	1739	1965	13.0	4246	4540	6.9
Third date of sowing (20 days after onset of monsoon)									
GG 20	4.3	4.8	13.1	1709	1850	8.2	4802	4302	-10.4
GJG 34	4.1	4.7	14.5	1623	1887	16.3	4421	4389	-0.7
TAG 37A	3.7	4.0	7.0	1511	1654	9.5	4165	3675	-11.8

Table 4: Validation of observed (O) and simulated (S) with deviation (D) for yield of groundnut during 2020

Treatments	Peak LAI			Pod yield(Kg ha^{-1})			biomass (Kg ha^{-1})		
	O	S	D (%)	O	S	D (%)	O	S	D (%)
First date of sowing (onset of monsoon)									
GG 20	4.6	5.3	14.8	1936	2188	13.0	4818	5090	5.6
GJG 34	4.4	5.0	15.2	1853	2158	16.5	4664	5018	7.6
TAG 37A	4.3	4.6	7.5	1798	2071	15.2	4333	4603	6.2
Second date of sowing (10 days after onset of monsoon)									
GG 20	4.2	4.7	13.7	1716	1868	8.9	3873	4344	12.2
GJG 34	3.9	4.5	14.5	1603	1824	13.8	3699	4242	14.7
TAG 37A	3.8	4.0	6.9	1456	1694	16.3	3399	3765	10.8
Third date of sowing (20 days after onset of monsoon)									
GG 20	3.7	3.9	3.6	1451	1345	-7.3	3337	3129	-6.2
GJG 34	3.5	3.5	-0.8	1377	1223	-11.1	3020	2845	-5.8
TAG 37A	3.3	3.1	-8.2	1279	1259	-1.6	2849	2797	-1.8

Table 5: Evaluation of growth and yield of groundnut through test criteria using CropSyst model

Treatments	Peak LAI	Pod yield(Kg ha^{-1})	biomass (Kg ha^{-1})
MAE	0.40	188.2	285.9
MBE	0.36	150.9	91.6
RMSE	1.38	584.5	354.8
MAPE	9.6	11.1	7.1
d_r	0.37	0.50	0.75

285.9 Kg ha^{-1}, 91.6 Kg ha^{-1}, 354.8 Kg ha^{-1} and 7.1 %, respectively and refined index of agreement (d_r) was 0.75 (Table 5). The findings were in conformity with the results of Jat (2014), Parmer *et al.* (2013) and Yadav *et al.* (2012). The evaluation of the model showed that simulation performance was very good.

CONCLUSION

It could be concluded that CropSyst model for groundnut peak LAI, pod yield and biomass were satisfactorily simulated at middle Gujarat agro climatic zone. The model was overestimated growth and yield attributes. The validated CropSysts model can be further used for prediction of growth, phenology, water management and yields under environmental condition. The model may also be used to improve current management practices of groundnut to achieve higher groundnut production.

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