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Deriving Genetic Coefficients for Cotton using the DSSAT CROPGRO-Cotton Model

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ABSTRACT: The Decision Support System for Agricultural Technology Transfer (DSSAT) was calibrated and evaluated using experimental data in different dates of sowing for simulation. Genetic coefficient for DSSAT CROPGRO-Cotton model such as CSDL, PPSEN, EM-FL, FL-SH, FL-SD, SD-PM, FL-LF, LEFAX, SLAVR, SIZLF, XFRT, WTPSD, SFDUR, SDPDV, PODUR, THRSH, SDPRO, SDLIP were evaluated. The model was calibrated and evaluated with the days to flowering, days to physiological maturity, biomass at maturity and seed cotton yield during 2019 in all different dates of sowing. The Suvin cotton variety was used in the experiments which are grown under ideal conditions with no water or nutrient limitations in monitoring site of farmer's field. The model simulated values for days to flowering and days to physiological maturity were similar to the observed data, with an RMSE of less than 4 days. The highest simulated biomass yield at harvest maturity was found to be 3211 kg ha^{-1} followed by 3183 kg ha^{-1} when crop sown on 25th August, 2019 and 18th August, 2019, respectively. The seed cotton yield was found to be 2171 to 1834 kg ha^{-1} (observed yield) and simulated yield recorded 2248 to 2014 kg ha^{-1} and with R^2 values of the regression between the simulated and observed seed cotton yield was 0.94.

Keywords: DSSAT, CROPGRO- Cotton model, calibration and validation.

INTRODUCTION

Cotton is one of the most important fibre and cash crop of India and plays a dominant role in the industrial and agricultural economy of the country. It provides the basic raw material (cotton fibre) to cotton textile industry. It occupies the second premier position next to food crops in providing clothing. Only four *Gossypium* species namely, *viz., Gossypium herbaceum, Gossypium arboreum, Gossypium hirsutum* and *Gossypium barbadense* are cultivable among 53 species and *Gossypium hirsutum* is the widely cultivated species also known as upland cotton, constituting more than 92% of the world's cotton production (Krishna *et al*., 2021). The top cotton producing countries include India, China, United States, Brazil and Pakistan. Cotton is produced in more than 12 states in India. The most cotton producing states in India are Madhya Pradesh, Maharashtra, Tamil Nadu, Karnataka, Punjab, Haryana, Gujarat and Rajasthan. Tamil Nadu is one of the leading producers of cotton in the country (Aarthi *et al.*, 2021). Crop simulation modelling allows researchers to test the effectiveness of new varieties and 65 crop management approaches in varied environment (soil, climate, and management) before they were released (MacCarthy *et al.*, 2017). DSSAT can simulate crops like wheat, soybean, maize, rice and cotton. Crop growth and yield can be simulated using the crop growth model (Hoogenboom *et al*., 2017). Daily weather, soil conditions, crop genetic parameters, and management information are some of the most basic variables necessary for model implementation. Crop genetic characteristics are used to classify and differentiate different crop varieties. Due to the difficulty of obtaining crop genetic characteristics by measurement, accurate estimation is required for model application (He *et al*., 2010). The "trial-and-error" method was used to calculate the genetic coefficients of the cultivar in the CROPGRO models (Hunt *et al*., 1993). For DSSAT model implementation, calculating crop genetic parameters quickly and accurately has been a focused (He *et al.*, 2009, Van *et al*., 2013). The study's was conducted to determine the performs of DSSAT CROPGRO-Cotton model in simulating growth and yield of Suvin cotton.

MATERIALS AND METHODS

DSSAT CROPGRO-Cotton model calibration was carried in the selected monitoring site of farmer's field during July, 2019 to January, 2020. The selected monitoring site is located in the Salem district of Tamil Nadu at 11° 30′ N, 78° 47′E and at an altitude of 148 m AMSL.

A. Selection of Cotton variety and Data collection

Suvin cotton variety was chosen with six different dates of sowing to simulate growth and seed cotton yield. DSSAT CROPGRO-Cotton Model (version 4.7.5) was used in this study and the data was collected according to technical reports of the software. Plant physiological observations are recorded to create data sets. To create weather file daily maximum and minimum air temperature (°C), precipitation (mm), Relative Humidity (%) and solar radiation (MJ m^{-2} day^{-1}) were needed throughout growing season. Model requires soil data such as soil class, texture, bulk density, organic carbon percent, sand percent, silt percent, clay percent, pH, and cation exchange capacity in the surface layer and subsurface layer were needed to create SBuild. Crop management data (XBuild) such as planting method, planting date, plant density, row spacing, fertilizer application, irrigation data, harvesting date, harvesting method, seed cotton yield m^{-2}, and leaf area index were gathered.

B. Crop management

Cotton was sown in the winter season for the study area. The Suvin cotton was sown at the one third of ridges evenly at one meter apart with plant to plant to spacing of 60 cm. The crop was grown without any water stress condition throughout the cropping season. Fertilizer application (NPK 80:40:40 kg ha^{-1}), weeding, plant protection measures are considered as per the TNAU crop protection guide.

C. Model description

The model used in the study was DSSAT CROPGRO-Cotton Model (version 4.7.5) and the detailed description of the CROPGRO-Cotton of DSSAT can be found in Jones *et al*. (2003). The model can simulate growth and yield components as a function of soil and weather conditions, crop management practices, and variety characteristics. The model uses a standardized system for model inputs and outputs that have been described elsewhere (Anothai *et al*., 2008; Paz *et al*., 1998). The input system enables the user to select crop genotype (variety), weather, soil, and management data appropriate to experiment being simulated. Required crop genetic inputs for CROPGRO-Cotton are given in Table 1.

Table 1: Definition of DSSAT CROPGRO-Cotton genotype specific parameters.

Coefficient	Description
CSDL	Critical Short Day Length below which reproductive development progresses with no day length effect (for short day plants) (hour)
PPSEN	Slope of the relative response of development to photoperiod with time(positive for short day plants) (1/hour)
EM-FL	Time between plant emergence and flower appearance (R1) (photothermal days)
FL-SH	Time between first flower and first pod (R3) (photothermal days)
FL-SD	Time between first flower and first seed (R5) (photothermal days)
SD-PM	Time between first seed (R5) and physiological maturity (R7) (photothermal days)
FL-LF	Time between first flower (R1) and end of leaf expansion (photothermal days)
LFMAX	Maximum leaf photosynthesis rate at 30 C, 350 vpm CO_2, and high light (mg CO_2/m^2-s)
SLAVR	Specific leaf area of cultivar under standard growth conditions (cm^2/g)
SIZLF	Maximum size of full leaf (three leaflets) (cm^2)
XFRT	Maximum fraction of daily growth that is partitioned to seed + shell
WTPSD	Maximum weight per seed (g)
SFDUR	Seed filling duration for pod cohort at standard growth conditions (photothermal days)
SDPDV	Average seed per pod under standard growing conditions
PODUR	Time required for cultivar to reach final pod load under optimal conditions (photothermal days)
THRSH	Threshing percentage. The maximum ratio of (seed/(seed + shell)) at maturity. Causes seeds to stop growing as their dry weight increases until the shells are filled in a cohort.
SDPRO	Fraction protein in seeds (g(protein)/g(seed))
SDLIP	Fraction oil in seeds (g(oil)/g(seed))

D. Initialization of soil, weather and management parameters

In DSSAT models, genotype-specific parameters (GSPs) are unique to each cultivar and allow the model to mimic the performance of several cultivars under a variety of soil, weather, and management conditions (Hunt *et al*., 1993). There are three input files were created in DSSAT to run model namely, Weather file; Soil file: S-Build program; Experimental data file: XBuild program and crop management data

E. DSSAT CROPGRO-Cotton Model calibration and validation

Default values in DSSAT were utilised to estimate genetic coefficients for the Suvin cotton variety. Then the variety coefficient values are modified in relation to each simulated and observed measurement. The model algorithm then examines the output file, deciding whether to increase or decrease the value of the predicted coefficient based on the difference between simulated and observed variables. Validation is the process of comparing model simulation results with several criteria were used to quantify the differences between observed and simulated data. The methodology of DSSAT CROPGRO-Cotton model was presented in the Fig. 1.

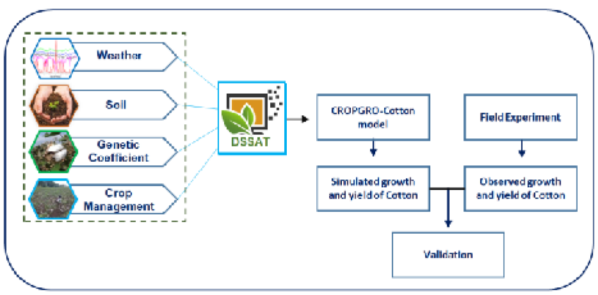

Fig. 1. Methodology of DSSAT CROPGRO-Cotton.

F. Statistical Approach of Model Evaluation

The root mean square error (RMSE) denotes the good fit for each observation (Wallach and Goffinet, 1987). A larger RMSE means high deviation of the simulated values from the observed values and indicates low performance (Wallach and Goffinet, 1989; Loague and Green, 1991) and *vice versa*, represented in Table 2.

Table 2: Root Mean Square Error (RMSE) values and their performance.

Root Mean Square Error (RMSE) values	Model prediction Performance
<10%	Excellent
>10-20%	Good
>20%	Medium
>30%	Poor

$$\text{RMSE} = \left[\frac{\sum_{i=1}^{n}(Pi-Oi)^2}{n}\right]^{\frac{1}{2}}$$

$$\text{NRMSE}\ \frac{RMSE}{Oi} \times 100$$

where, P - Predicted data, O - Observed data and n - the number of observations

RESULTS AND DISCUSSION

Suvin cultivar was used to evaluate the genetic coefficients and the model was validated for different planting days. For the evaluation of genetic coefficients, the DSSAT model was calibrated using various data sets on phenology, days to flowering and physiological maturity biomass, and seed cotton yield. Genetic coefficients from calibration experiments are shown in Table 3.

Table 3: Calibrated genetic coefficient of Suvin Cotton - DSSATCROPGRO-Cotton model.

Suvin variety	**CSDL**	**PPSEN**	**EM-FL**	**FL-SH**	**FL-SD**	**SD-PM**	**FL-LF**	**LFMAX**	**SLAVR**
	23	0.01	54	14	15	43	77	1.01	170
	SIZLF	**XFRT**	**WTPSD**	**SFDUR**	**SDPDV**	**PODUR**	**THRSH**	**SDPRO**	**SDLIP**
	227	0.66	0.09	33	20	10	68	0.153	0.12

For validation, information for key phenological events such as days to flowering, days to physiological maturity, seed cotton yield and biomass at harvest are utilized and represented in Table 4.

A. Days to flowering

The observed days to flowering for Suvin cotton are 66, 68, 67, 68, 67 and 68, whereas the model simulated 67, 69, 69, 70, 71 and 72 days, respectively (Table 4). The RMSE was found to 1 for 28th July 28, 2019 and 11th August, 2019. This showed that model performance was found to be good for Suvin cotton cultivar for all different dates of sowing for simulation of days to flowering. The difference between observed and simulated values for flowering and physiological maturity dates over the control treatment was two days, according to Ortiz *et al*., (2009).

B. Days to Physiological maturity

The Suvin cultivar matured in 153, 155, 154, 156, 156, 156, and 157 days whereas the model simulated 154, 157, 158, 158, 159 and 160 days, respectively as sown in Table 4. The model's simulation performance in terms of days to maturity was found to be the best, with an RMSE of less than 10%. Similarly, Singh *et al*., (1994); Soler *et al*., (2007) reported the results of maize phenological stages simulated by the crop growth model.

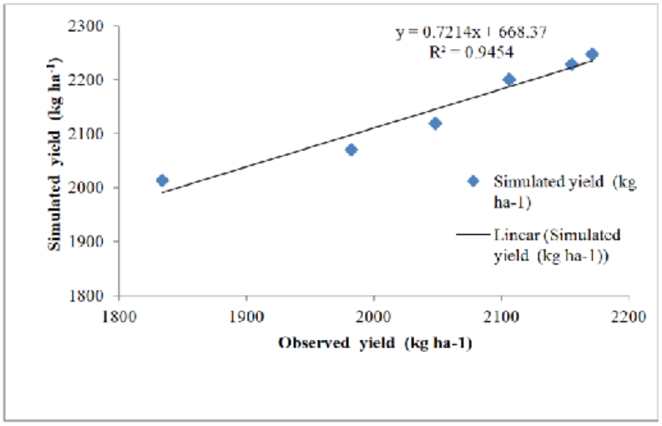

Fig. 2. Validation of simulated (DSSAT) and observed seed cotton yield.

Table 4: Observed and predicted days to flowering, days to physiological maturity seed cotton yield, biomass yield at harvest (kg ha^{-1}) at harvest maturity under different planting dates.

Day After Planting	Observed Value	Simulated Value	RMSE	NRMSE
28th July, 2019				
Days to flowering	66	67	1	1.52
Days to Physiological maturity	153	154	1	0.65
Seed cotton yield (kg ha^{-1})	2048	2119	71	3.47
Biomass yield at harvest (kg ha^{-1})	2846	3021	175	6.15
11th August, 2019				
Days to flowering	68	69	1	1.47
Days to Physiological maturity	155	157	2	1.29
Seed cotton yield (kg ha^{-1})	2106	2201	95	4.51
Biomass yield at harvest (kg ha^{-1})	2983	3144	161	5.40
18th August, 2019				
Days to flowering	67	69	2	2.99
Days to Physiological maturity	154	158	4	2.60
Seed cotton yield (kg ha^{-1})	2155	2228	73	3.39
Biomass yield at harvest (kg ha^{-1})	2934	3183	249	8.49
25th August, 2019				
Days to flowering	68	70	2	2.94
Days to Physiological maturity	156	158	2	1.28
Seed cotton yield (kg ha^{-1})	2171	2248	77	3.55
Biomass yield at harvest (kg ha^{-1})	3062	3211	149	4.87
8th September, 2019				
Days to flowering	67	71	4	5.97
Days to Physiological maturity	156	159	3	1.92
Seed cotton yield (kg ha^{-1})	1982	2070	88	4.44
Biomass yield at harvest (kg ha^{-1})	2877	2956	79	2.75
15thSeptember, 2019				
Days to flowering	68	72	4	5.88
Days to Physiological maturity	157	160	3	1.91
Seed cotton yield (kg ha^{-1})	1834	2014	180	9.81
Biomass yield at harvest (kg ha^{-1})	2462	2877	415	16.86

C. Seed cotton yield and biomass at harvest

The seed cotton yield was found to be 2171 to 1834 kg ha^{-1}(observed) and simulated yield recorded 2248 to 2014 kg ha^{-1}. The R^2 values of the regression between the simulated and observed seed cotton yield was 0.94. These results are supported by Torre *et al*. (2021) for rice, Patil and Patel (2017) for chick pea, Kumar *et al*. (2017) for cotton, Venkatesan and Pazhanivelan (2018); Angel *et al*., (2019) for maize, Deiveegan and Pazhanivelan (2016); Setiyono, (2019); Thirumeninathan *et al*., (2021) for groundnut and Sabarinathan *et al*., (2021) for sorghum. The highest DSSAT simulated biomass yield at harvest maturity was found to be 3211 kg ha^{-1} when the crop was sown during 25th August, 2019 followed by 3183 and 3144 kg ha^{-1} with sowing dates on 18th August and 11th August, 2019, respectively.

CONCLUSION

In conclusion, genetic coefficients were evaluated and CROPGRO-Cotton was validated for Suvin cotton cultivars. For all of the different days of sowing, the model performed well in modeling phenology for a selected Suvin cotton cultivar. The model predicted seed cotton yield and biomass yield with an acceptable root mean square error between observed and simulated data. The model can be used to forecast the impact of rising temperatures, CO_2 levels, and changing rainfall patterns on seed cotton production quality in the future.

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Conflicts of Interest. None.

REFERENCES

Aarthi, S., Kanagasabapathi, K., & Sakthivel, V. (2021). Obstacles experienced in practising improved agricultural methods to overcome the adverse effects of climate change. *Plant Archives*, *21*(1): 1811-1813.

Angel, M., Ballesta, A., Santiveri, F., & Lloveras, J. (2019). Sowing date affects maize development and yield in irrigated Mediterranean Environments. *Agriculture*, *9*(3): 67.

Anothai, J., Patanothai, A., Pannangpetch, K., Jogloy, S., Boote, K. J., & Hoogenboom, G. (2008). Reduction in data collection for determination of cultivar coefficients for breeding applications. *Agricultural Systems*, *96*(1-3): 195-206.

Deiveegan. M and S. Pazhanivelan (2016). Modeling groundnut (*Arachis hypogea*) yield at spatial level in Tiruvannamalai and Villupuram districts by using DSSAT crop simulation model. *Advances in Life Sciences* *5*(17): 6863-6867.

He, J., Dukes, M. D., Jones, J. W., Graham, W. D., & Judge, J. (2009). Applying GLUE for estimating CERES-Maize genetic and soil parameters for sweet corn production. *Transactions of the ASABE*, *52*(6), 1907-1921.

He, J., Jones, J. W., Graham, W. D., & Dukes, M. D. (2010). Influence of likelihood function choice for estimating crop model parameters using the generalized likelihood uncertainty estimation method. *Agricultural Systems*, *103*(5): 256-264.

Hunt, L. A., S. Pararajasingham, J. W. Jones, G. Hoogenboom, D. T. Imamura, and R. M. Ogoshi. (1993). "GENCALC: Software to facilitate the use of crop models for analyzing field experiments. *Agronomy Journal*, *85*(5): 1090-1094.

Jones, J. W., Hoogenboom, G., Porter, C. H., Boote, K. J., Batchelor, W. D., Hunt, L. A., & Ritchie, J. T. (2003). The DSSAT cropping system model. *European journal of agronomy*, *18*(3-4): 235-265.

Krishna, S. S., Kumar, M., Premalatha, N., Senguttuvan, K., & Mahalingam, L. (2021). Studies on inheritance of okra leaf shape and genetic parameters for morpho-yield related traits in two F2 populations of cotton (*Gossypium hirsutum* L.). *Electronic Journal of Plant Breeding*, *12*(3): 637-642.

Kumar, S., Niwas, R., Khichar, M. L., Kumar, Y., & Premdeep, A. S. (2017). Sensitivity analysis of DSSAT CROPGRO-Cotton model for cotton under different growing environments. *Indian J. Ecol.*, *44*(4): 237-241.

MacCarthy, D. S., Adiku, S. G., Freduah, B. S., & Gbefo, F. (2017). Using CERES-Maize and ENSO as decision support tools to evaluate climate-sensitive farm management practices for maize production in the northern regions of Ghana. *Frontiers in Plant Science*, *8*, 31.

Ortiz, B. V., Hoogenboom, G., Vellidis, G., Boote, K., Davis, R. F., & Perry, C. (2009). Adapting the CROPGRO-Cotton model to simulate cotton biomass and yield under southern root-knot nematode parasitism. *Transactions of the ASABE*, *52*(6): 2129-2140.

Patil, D. D., & Patel, H. R. (2017). Calibration and validation of CROPGRO (DSSAT 4.6) model for chickpea under middle GUJARAT agroclimatic region. *International Journal of Agriculture Sciences*.

Paz, J. O., Batchelor, W. D., Colvin, T. S., Logsdon, S. D., Kaspar, T. C., & Karlen, D. L. (1998). Calibration of a crop growth model to predict spatial yield variability. In *ASAE Annual International Meeting, Paper*.

Setiyono, T. (2019). Modelling the spatial level yield variability of groundnut (*Arachis hypogea*) in rain fed districts of Tamil Nadu using crop simulation model. *Journal of Agrometeorology*, *217*.

Sabarinathan, B., Pazhanivelan, S., Ragunath, K. P., Sivamurugan, A. P., Sudarmanian, N. S. (2021). Calibration and validation of CERES-sorghum module of DSSAT model for rabi sorghum under rainfed condition. *The Pharma Innovation Journal*, *10*(1): 715-718.

Singh, P., Boote, K. J., Rao, A. Y., Iruthayaraj, M. R., Sheikh, A. M., Hundal, S. S., & Singh, P. (1994). Evaluation of the groundnut model PNUTGRO for crop response to water availability, sowing dates, and seasons. *Field Crops Research*, *39*(2-3): 147-162.

Soler, C. M. T., Sentelhas, P. C., & Hoogenboom, G. (2007). Application of the CSM-CERES-Maize model for planting date evaluation and yield forecasting for maize grown off-season in a subtropical environment. *European Journal of Agronomy*, *27*(2-4): 165-177.

Thirumeninathan, S., Pazhanivelan, S., S Sudarmanian, N., P Ragunath, K., Gurusamy, A., & Sritharan, N. (2021). Calibration and Validation of DSSAT CROPGRO Peanut Model for Yield and Yield Attributing Characters of Groundnut Varieties in Northern Agro-Climatic Zone of Tamil Nadu.

Van Oijen, M., Reyer, C., Bohn, F. J., Cameron, D. R., Deckmyn, G., Flechsig, M., & Rammer, W. (2013). Bayesian calibration, comparison and averaging of six forest models, using data from Scots pine stands across Europe. *Forest Ecology and Management*, *289*, 255-268.

Venkatesan, M., & Pazhanivelan, S. (2018). Estimation of Maize Yield at Spatial Level Using DSSAT Crop Simulation Model. *Madras Agricultural Journal*, *1*, 105.

Wallach, D., & Goffinet, B. (1987). Mean squared error of prediction in models for studying ecological and agronomic systems. *Biometrics*, 561-573.

Wallach, D., & Goffinet, B. (1989). Mean squared error of prediction as a criterion for evaluating and comparing system models. *Ecological Modelling*, *44*(3-4): 299-306.

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