Journal of Tropical Agriculture 60(1): 130-135, 2022

Short Communication

Simulating groundnut (*Arachis hypogaea* L.) phenophase and yield in Kerala with DSSAT- CROPGRO model

K.S.Vinu*, P. Shajeesh Jan, B. Ajithkumar and Arjun Vysakh

College of Agriculture, Kerala Agricultural University, Thrissur 680 656, Kerala, India

Received 01 January 2022; received in revised form 30 May 2022; accepted 04 June 2022

Abstract

An experiment was conducted to simulate groundnut (*Arachis hypogaea* L.) phenophase and yield by using the DSSAT- CROPGRO model. The experiment was carried out at Instructional farm Vellanikkara, Kerala Agricultural University with four dates of planting, *viz.,* November 1st, November 15th, December 1st, and December 15th and three irrigation levels (IW/CPE 0.6, 0.8 and 1.0) with the variety TNAU CO-6. The phenological data collected from the field experiment during 2019-2020 was used for calibrating the genetic coefficient for groundnut variety TNAU CO-6. The DSSAT CROPGRO peanut model was used in the simulation studies. The pod yield, shelling percentage and phenological stages as simulated by model were compared with the observed data. The result revealed that, simulated values of pod yield, physiological maturity, days to germination, anthesis and shelling percentage were in good agreement with observed yield.

Keywords: Anthesis, DSSAT CROPGRO peanut model, Germination, Pod yield, Physiological maturity, Shelling percentage.

Groundnut (*Arachis hypogaea* L.), is an important oil seed crop in India and popularly known as king of oil seed crops. Groundnut is grown on a large scale in almost all the tropical and subtropical countries of the world. The crop maintains soil fertility by fixing the atmospheric nitrogen. The major groundnut producing states in India are Gujarat, Andra Pradesh, Karnataka, Tamil Nadu, Maharashtra and Rajasthan. In Kerala groundnut is cultivated in an area of 274 ha.Even though peanut crop is adaptable to both rainfed and irrigated conditions more than half of the production area is in the rainfed region (Woli et al., 2013; Kambiranda et al., 2011). Crop simulation modeling has the potential for simulating growth and yield of crops. The Decision Support System for Agro technology Transfer (DSSAT) model consists of a set of independent programs that operate simultaneously on simulation models using information from the soil, climate, crop and agronomic management databases. It has been developed by Boote et al., (1998) at University of Florida and University of Georgia. It was used to determine the genetic coefficient of groundnut. A crop model becomes an actual working tool capable of providing guidance on the practical management of agricultural systems. Development and calibration of groundnut "CROPGRO" model can improve the understanding of the underlying processes in groundnut and hence, support strategic agricultural research on the crop.

The field experiment was conducted at Instructional Farm, Kerala Agricultural University, Vellanikkara (10.31°N, 76.13°E) during 2019-2020 for determining genetic coefficients of groundnut variety TNAU CO-6. The soil texture of the

*Author for correspondences: Phone: 9544892158, Email: 444vinus@gmail.com

experimental field was sandy soil. The organic carbon content of the soil was medium (0.96%), the available phosphorous content was low (5.36 kg ha^{-1}), the available potassium content of the soil was medium (228.4 kg ha^{-1}), amount of available sulphur was sufficient (19.384 kg ha^{-1}) and amount of available calcium was sufficient (348.5 kg ha^{-1}). The experiment was laid out in split plot design with four dates of planting (from 1st November to 15th December 2019) as the main plot treatments and three irrigation levels (IW/CPE 0.6, 0.8 and 1.0) as sub plot treatments. The depth of irrigation channel was 3 cm and the treatments were replicated five times. Irrigation treatment was given based on IW/CPE (Irrigation water / cumulative pan evaporation) and the CPE values were 50, 37.5 and 30 mm respectively. All the other management practices were done according to the package of practices recommendations of KAU (2016).

DSSAT CROPGRO- peanut model was used in simulation studies. Parameters such as days to germination, days to anthesis, pod yield and shelling percentage were used for calibration of the DSSAT 4.5 model. Goodness of fitness between simulated and observed variables was examined. Two statistics were used to evaluate the model performances *viz.,* Root Mean Square Error (RMSE) and d-stat index.

The Genetic coefficients for the variety TNAU CO-6 were developed and are presented in the Table 1. The calibration result of the DSSAT model was evaluated in this study using the phenological observation and finalyield variables.

Days to germination

Model performance to predict number of days taken for germination was evaluated. The results showed that, the observed duration of days to germination varied between 5 to 8 days among the three levels of irrigation (I_1, I_2, I_3) treatments, while simulated value of days to germination was 6 days in all dates of sowing. It was found that the model underestimated the days to germination in all dates of sowing except for D_1 sowing (1st dates of sowing) (fig.1).The average errors as computed by RMSE

Table 1. Genetic coefficients calibrated for the variety TNAU CO-6 at Kerala condition

Growth and development aspects of the groundnutCrop	Description of parameter coefficients controlling developmentAspects	Genetic coefficients
CSDL	Critical Short Day Length below which reproductive development progresses with no day length effect (for short day plants) (hours)	11.84
PPSEN	Slope of the relative response of development to photoperiod with time (negative for long day plants) (1/ hour)	0.00
EM-FL	Time between plant emergence and flower appearance (R1) (photothermal days)	27.0
FL-SH	Time between first flower and first pod (R3) (photothermal days)	11.2
FL-SD	Time between first flower and first seed (R5) (photothermal days)	15.4
SD-PM	Time between first seed (R5) and physiological maturity (R7) (photothermal days)	84.69
FL-LF	Time between first flower (R1) and end of leaf expansion(photothermal days)	80.00
LFMAX	Maximum leaf photosynthesis rate at 30° C, 350 vpm CO_2 and highlight (mg CO_2 / m^2 /s)	1.54
SLAVR	Specific leaf area of cultivar under standard growth conditions (cm^2/g)	275
SIZLF	Maximum size of full leaf (three leaflets) (cm^2)	13.5
XFRT	Maximum fraction of daily growth that is partitioned to seed + shell	0.80
WTPSD	Maximum weight per seed (g)	0.950
SFDUR	Seed filling duration for pod cohort at standard growth conditions (photothermal days)	35.3
SDPDV	Average seed per pod under standard growing conditions	1.72
PODUR	Time required for cultivar to reach final pod load under optimal conditions (photothermal days)	15.4
TRESH	Threshing percentage. The maximum ratio of (seed/ (seed + shell)) at maturity. Causes seeds to stop growing as their dry weight increases until shells are filled in a cohort.	68.3
SDPRO	Fraction protein in seeds (g (protein)/g (seed))	270
SDLIP	Fraction oil in seeds (g (oil) /g (seed))	510

and MAE were 1.32 and 1 respectively and d-stat value was 0.42 (Table.2)

Days to anthesis

The model simulated values of days to anthesis was 35 days under all irrigation treatments (I_1, I_2, I_3). The observed anthesis days varied between 31-37 days. The model underestimated days to anthesis for all the dates of sowing. The overall performance of simulation of days to anthesis was found to be good in all dates of sowing except D_1 sowing (fig.1). The average errors as computed by RMSE and MAE were 2.21 and 2 respectively and d-stat value was 0.41 (Table 2).

Table 2. RMSE, MAPE and D-stat index for yield and phenophases

Variable name	RMSE	MAPE	D-stat
Days to germination	1.32	1	0.42
Days to anthesis	2.21	2	0.41
Days to physiological maturity	5.01	4	0.41
Total yield	185.23	143	0.73
Threshing percentage	4.07	3.56	0.42

Root mean square error (RMSE). Mean absolute error (MAE)

$$RMSE = \left[\sum_{i=1}^{n}(P_i - O_i)^2/n\right]^{1/2} \quad MAE = \sum_{i=1}^{n}[1P_i - O_i1]/n$$

Days to physiological maturity

The results showed that, the observed duration of physiological maturity varied from 142 to 149 days for three irrigation treatments whereas, simulated values by model ranged between 138-142. Model underestimated the duration of physiological maturity in all treatments. The overall performance of simulated shelling percentage was found to be satisfactory (fig.3). The average errors as computed

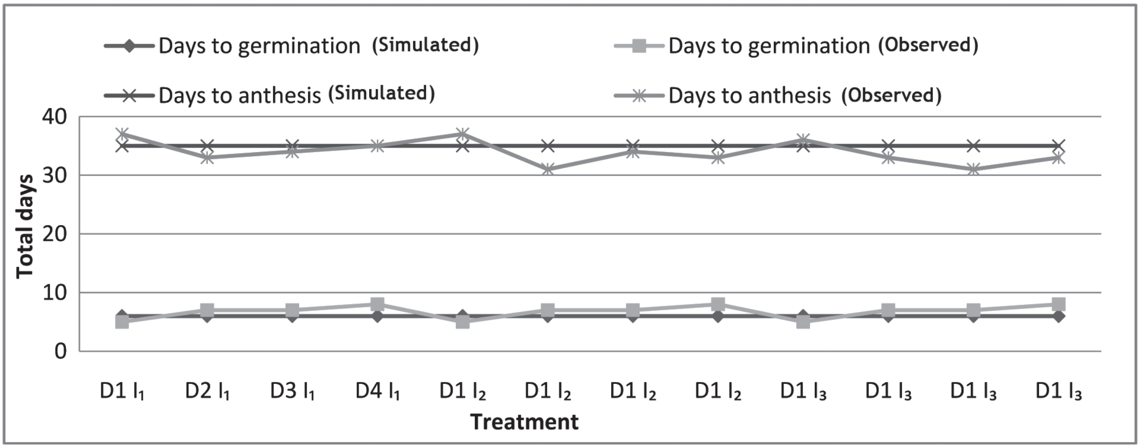

Figure 1. Predicted and observed days to germination and days to anthesis

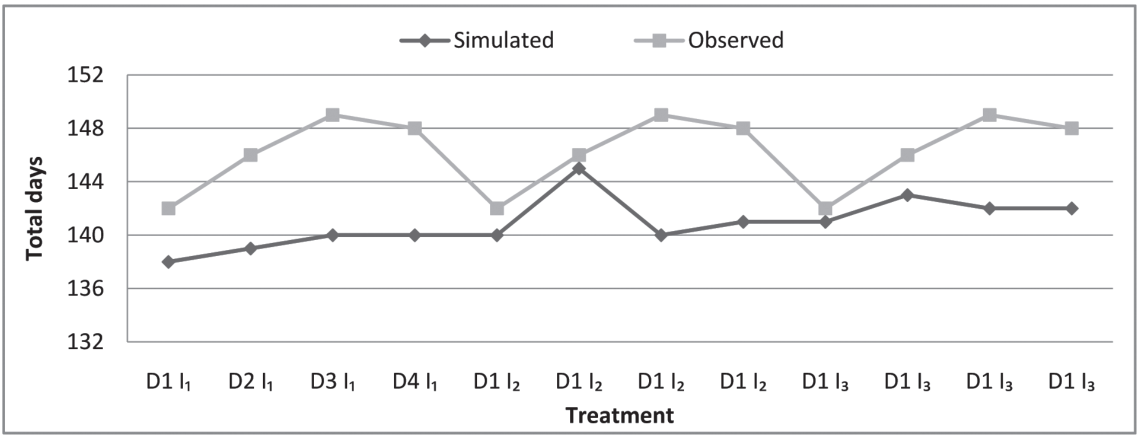

Figure 2. Predicted and observed days to physiological maturity

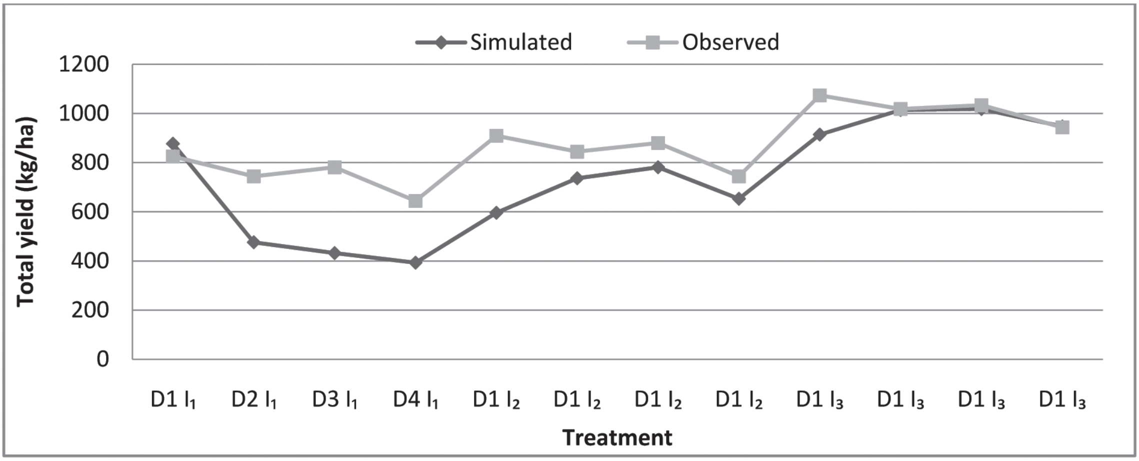

Figure 3. Predicted and observed yield

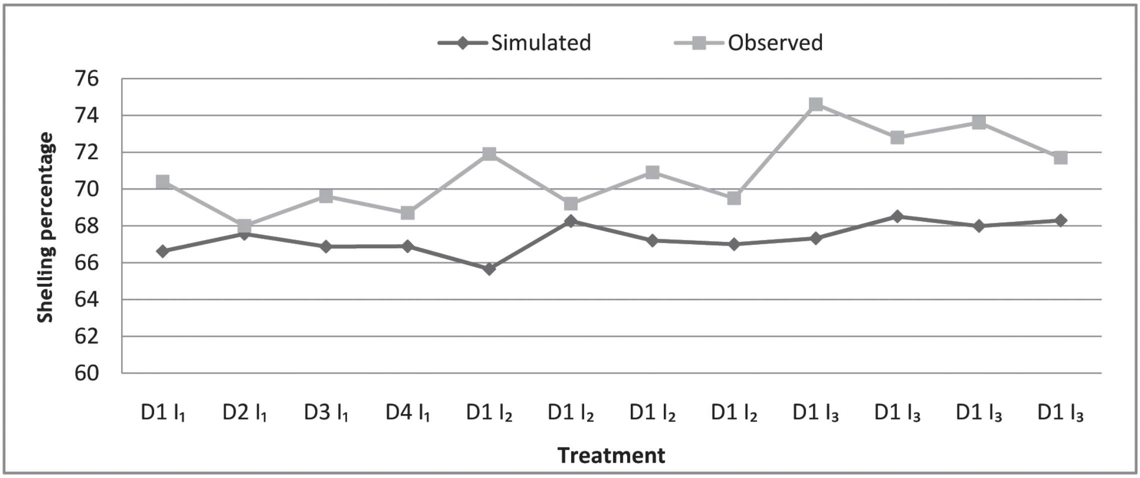

Figure 4. Predicted and observed Shelling percentage

by RMSE and MAE were 5.01 and 4 respectively and d-stat value was 0.41 (Table.2).

Total yield

The highest observed mean pod yield was recorded during November 1st sowing in I_3 treatment (1073 kg ha^{-1}) whereas, the highest simulated pod yield was observed for December 1st sowing in I_3 treatment (1033 kg ha^{-1}). Results showed that error percent remained in good confidence level and the model underestimated the pod yield in all treatments (fig.4).

Shelling percentage

The highest observed shelling per cent was recorded in I_3 treatment (71.7 -74.6%) in all dates of sowing (fig.4). and the highest simulated value was also observed in same treatment (67.3-68.5%) The evaluation of the model on an overall basis revealed that the model performance in simulation of shelling percentage was found to be good with an acceptable level The average errors as computed by RMSE and MAE were 4.07 and 3.56 respectively. The d-stat value is 0.42 (Table 2).

The model will help the farmers to make decisions in agricultural planning by prediction of groundnut yield based on weather variables. Genetic coefficients for TNAU CO-6 variety was calibrated for central zone of Kerala. Willmott (1982) stated that the d-stat index value should approach unity and the RMSE should approach zero for good performance of the model.

According to Vysakh et al. (2016), the percentage deviation between observed and predicted values within 10 per cent indicates good performance of the model. The average error percentage calculated for days to germination, anthesis, physiological maturity and shelling percentage was less than 10 per cent. Hence the model performance in predicting the above variables was good. Among the different phenophases it was observed that the model could predict days to germination more accurately.

Model predicted the pod yield more accurately than the other phenophases with a d-stat value of 0.73 and RMSE value 185.23. The d-stat value indicated that the model performance in predicting pod yield was excellent. Similar result was reported by Giridhar (2019).

Johns (1993) concluded that crop simulation models could be used effectively for research studies, decision making and yield response. Singh et al. (1994) reported that row spacing and plant population were influenced by light interception, canopy growth, dry matter production and yield of groundnut as predicted for the model used. DSSAT is a microcomputer software that combines the production and use of various crops, their possibilities as well as the soil and crops date base (Jones et al., 1998). The CROPGRO model is mainly used to increase the productivity of groundnut, measure the impact of climate change as well as to evaluate various agronomic conditions (Boote et al., 1998).

The genetic coefficients for DSSAT-CROPGRO Peanut model were calibrated using the data sets generated during the field experiment. The simulated values of phenological observations and yield of groundnut crop were using DSSAT-CROPGRO Peanut model was in good agreement with the observed values. Simulated values on number of days to germination, anthesis and physiological maturity day showed satisfactory agreement with observed values with an RMSE value of 1.32, 2.21 and 5.01 and d-stat index of 0.42, 0.41 and 0.41 respectively, indicating good performance of the model. However the model underestimated the yield with an RMSE of 185.23 and d-stat index of 0.73. Compared to phenology, the model predicted the crop yield more accurately. Simulated yield attributes like shelling percentage showed satisfactory agreement with observed values with an RMSE of 4.07 and d-stat index of 0.42 indicating good performance of the model. Genetic coefficients for TNAU CO-6 varieties were calibrated. Goodness of fitness between simulated and observed variable was examined. This model can be further used for applications such as prediction of crop growth, phenology, water management, potential and actual yield, performance of groundnut under climate variability and climate change scenarios etc. The model can also be used to improve and evaluate the current practices of groundnut growth management to achieve enhanced groundnut production.

References

Boote, K.J., Jones, J.W., and Hoogenboom, G. 1998. Simulation of crop growth: CROPGRO model. In: Peart, R.M.,Curry, R.B. (Eds.), Agricultural Systems Modeling and Simulation (Chapter 18). Marcel Dekker, Inc, New York, pp. 651-692.

Giridhar, B.S. 2019. Simulation of summer groundnut (*Arachis hypogaea* L.) yield using DSSAT model (version 4.6) under varied environmental condition in Parbhani district (*Arachis hypogea* L.). M. Sc.thesis. Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. pp. 39-79.

Jones, J.W. 1993. Decision support systems for agricultural development. In: Penning de Vries, F., Teng, P., Metselaar, K. (Eds.), Systems Approaches for Agricultural Development. Kluwer Academic Press, Boston, pp. 459-471.

Jones, J.W., Tsuji, G.Y., Hoogenboom, G., Hunt, L.A., Thornton, P.K., Wilkens, P.W., Imamura, D.T., Bowen, W.T., and Singh, U. 1998. Decision support system for agro technology transfer; DSSAT v3. In: Tsuji, G.Y., Thornton, P.K. (Eds.), Understanding

Options for Agricultural Production. Kluwer Academic Publishers, Dordrecht, the Netherlands, pp. 157-177.

Kambiranda, D.M., Vasanthaiah, H.K.N., Katam, R., Ananga, A., Basha, S.M., and Naik, K. 2011. Impact of drought stress on peanut (*Arachis hypogaea* L.) productivity and food safety. In: Vasanthaiah, H. (Ed.), Plants and Environment, InTech, pp. 249-272.

KAU [Kerala Agricultural University]. 2016. Package of Practices Recommendations: Crops (15th ed.). Kerala Agricultural University, Thrissur, 112p.

Singh, P., Boote, K.J., and Virmani, S.M. 1994. Evaluation of the groundnut model PNUTGRO for crop response to plant population and row spacing. Field Crops Res., 39: 163-170.

Vysakh, A., Ajithkumar, B., and Rao, A.S. 2016. Evaluation of CERES-Rice model for the selected rice varieties of Kerala. J. Agrometeorol., 18(1):120.

Willmot, C. J. 1982. Some comments on the evaluation of model performance. Am. Meteorol. Soc. Bull., 63: 1309-1313.

Woli, P., Joel, O., Paz, Hoogenboom, G., Garcia, A.G., and Fraisse. C.W. 2013. The ENSO effect on peanut yield as influenced by planting date and soil type. Agric. Sys., 121: 1- 8.