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# Genetic Coefficient Calibration for Pigeonpea Cultivars in DSSAT Simulation Model Under Varied Dates of Sowing

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## Abstract

Decision Support System for Agro-technology Transfer (DSSAT) CROPGRO model is worldwide accepted for yield prediction. CROPGRO - Pigeonpea is added in newer version 4.6.1 of DSSAT. An attempt to calibrate the genetic coefficients for two cultivars (TTB-7 and BRG-2). The experiment was conducted at UAS, GKVK, Bengaluru during 2015-16 and 2016-17. The results revealed that the model under estimated the yield for all combination of two cultivars and dates of sowing for both the year. The maximum difference of observed and simulated yield was found for TTB-7 compared to BRG-2; similarly, 2016-17 compared to 2015-16 and for second date sown crop compared to others. Statistical measures like relative mean error (ME), rootmean square error (RMSE), coefficient of residual mass (CRM) and modeling efficiency (EF) were used to evaluate the model. Model performance for genetic coefficients generated from combination of dates of sowing for both cultivars were inferior or on par with models run with coefficients generated individually. Evaluation show that model with coefficients generated from second date sown crop during 2015-16 is better than other models for both cultivars. So as a future line of work these coefficients are to be fine tuned and calibrated.

Keywords: DSSAT, CROPGRO-Pigeonpea, observed yield simulated

Pigeonpea (*Cajanus cajan* (L.) Millsp) commonly known as red gram or arhar is the second most important pulse crop in India after chickpea. It is mainly cultivated and consumed in developing countries of the world. India is the largest producer and consumer of pigeonpea in the world. It accounts for about 11.8 per cent of the total pulse area and 17 per cent of total pulse production of the country. It is the rich source of protein and supplies a major share of the protein requirement of the vegetarian population of the country. It contains about 22 per cent protein which is almost three times than that of cereals. The pigeonpea grown in India in an area of 3.71 million hectares with production of 2.78 million tonnes with, the average yield 7.50 q $ha^{-1}$ (Anon., 2015). In Karnataka, it is cultivated in an area of 0.73 million hectares with an annual production of 0.48 million tonnes. The average productivity of this crop in Karnataka is 6.58 q $ha^{-1}$ (Anon., 2015). The major pigeonpea producing states are Maharashtra, Madhya Pradesh, Karnataka, Gujarat and Jharkhand (Anon., 2015).

In Karnataka, about 80 per cent of the crop is grown under rain-fed condition and due to vagaries of monsoon the year-to-year yield fluctuations are more. The productivity of pigeonpea is curtailed due to biotic and abiotic stresses. Weather is one of the important abiotic stress factor, which affects all stages of pigeonpea growth and finally the yield. The crop yield simulation models show considerable potential to evaluate crop cultivars, cropping pattern, sowing time and genetic potential pattern for yield. The Decision Support System for Agro-technology Transfer (DSSAT) has been found to be most widely used decision support system which includes models for cereals, legumes, oilseed and vegetable crops (Hoogenboom, 2000). Though different workers have evaluated the CROPGRO model for other crops *viz*. Suriharan *et al*. (2008) and Patel *et al*. (2013) validated the CROPGRO model for groundnut. Bhatia *et al*. (2008) for soybean and Srivastava *et al*. (2016) for chickpea. There is limited work on CROPGRO-Pigeonpea modeling. In this paper an attempt has been made to calibrate the DSSAT model for pigeonpea.

## Material and Methods

The input data required for running the crop simulation model (CROPGRO-Pigeonpea) of DSSAT (version 4.6.1) includes crop data, daily weather data, soil data and crop specific genetic coefficients.

*Crop management data* : To evaluate the model, field experiments were conducted at UAS, GKVK, Bengaluru (Lat. 13° 05'N and Long.77° 34'E and altitude of 924 meters above MSL) with three dates of sowing (Table I) and two cultivar (V1: TTB-7 and V2: BRG-2) during *Kharif* seasons of 2015-16 and 2016-17. Soil and crop management practices are same for all treatments as per UAS, GKVK, Bengaluru package of practices. Details of genetic expressions of selected cultivar were based on results from research work of Satheesh Naik *et al*., 2012 and Yadav *et al*. (2016).

Table I

*Dates of sowing for two year experiment*

| Date of sowing | Year | |
|---|---|---|
| | 2015 - 16 | 2016 - 17 |
| $D_1$ | 28 th May | 30 th May |
| $D_2$ | 20 th June | 16 th June |
| $D_3$ | 28 th July | 29 th July |

The daily weather data from 2015 to 2017 were collected from Agrometeorology observatory situated nearby (within 100 meter) the experimental plots. The layer wise soil physical composition (sand, silt and clay percentage), textural class, physical constrains (bulk density), soil chemical properties (soil pH, cation exchange capacity, organic carbon content and total N content) and soil *albedo* were recorded from the experimentation site.

The genetic coefficients for both cultivars are derived from field experimentation of two year. The genetic coefficients of pigeonpea were estimated by repeated iterations until a close match between simulated and observed phenology and yield was obtained inrespective treatments.

The statistical approach of model evaluation, involved the use of the following model evaluators as proposed by Loague and Green (1991): the relative mean error (ME) percentage, root mean square error (RMSE), coefficient of residual mass (CRM) and modeling efficiency (EF).

Relative mean error (ME) percentageis calculated as:

$$\mathrm{ME} = 100\frac{\left(\frac{1}{n}\sum_{i=1}^{n}(P_i - O_i)\right)}{\bar{O}}$$

*Coefficient of residual mass (CRM)* : The CRM is a measure of the tendency of the modelto overestimate or underestimate the measurements. Positive values for CRM indicatethat the model underestimates the measurements and negative values for CRM indicatea tendency to overestimate.The CRM is defined by

$$\mathrm{CRM} = \left(\sum_{i=1}^{n}(O_i) - \sum_{i=1}^{n}(P_i)\right) \Big/ \sum_{i=1}^{n}(O_i)$$

*Root mean square error (RMSE):* The RMSE values show how much thesimulations overestimate or underestimate the measurements.RMSE tests the accuracy of the model and set of RMSE values were calculated. A smaller RMSE indicated less deviation of the simulated from the observed values.

$$\mathrm{RMSE} = \left(\frac{1}{n}\sum_{i=1}^{n}(P_i - O_i)^2\right)^{\frac{1}{2}}$$

*Modeling efficiency (EF):* The EF value compares the simulated values to the average value of the measurements.A negative EF value indicates that the average value of the measurements gives a betterestimate than the simulated values.

$$\mathrm{EF} = \left(\sum_{i=1}^{n}(O_i - \bar{O})^2 - \sum_{i=1}^{n}(P_i - O_i)\right) \Big/ \sum_{i=1}^{n}(O_i - \bar{O})^2$$

Where, $P_i$= yield predicted by the model; n = number of samples

$O_i$ = yield observed, $\bar{O}$ = mean of all $O_i$ values.

## Results and Discussion

The seed yield of two cultivars TTB-7 and BRG-2, three dates of sowing ($D_1$, $D_2$ and $D_3$) with two years (2015-16 and 2016-17) model under estimated compared to the observed yield (Table II).

TABLE II

*Observed and simulated yield (kg ha$^{-1}$) under different dates of sowing and cultivars of pigeonpea.*

| Treatments | | 2015 - 16 | | 2016 - 17 | |
|---|---|---|---|---|---|
| Cultivars | Date of sowing | Observed | Simulated | Observed | Simulated |
| TTB-7 | $D_1$ | 1462.8 | 587 | 1030.2 | 128 |
| | $D_2$ | 994.0 | 559 | 932.9 | 78 |
| | $D_3$ | 866.7 | 248 | 443.2 | 21 |
| BRG-2 | $D_1$ | 1316.6 | 601 | 1024.4 | 133 |
| | $D_2$ | 963.6 | 441 | 874.5 | 55 |
| | $D_3$ | 708.6 | 343 | 395.9 | 31 |

This is due to the genetic coefficients are not yet stabilized. Because, process of stabilization requires minimum of four to five years experimental data under normal weather situation. Similar results are found for rice by Sreenivas and Reddy (2013). Yadav *et al.* (2012); Singh *et al.* (2014) also observed that the yield and yield attributes of groundnut as simulated by PNUTGRO model showed lesser efficiency when number of experimental years were minimum. Having said this, both the years under the research period being drought hit added to the lower efficiency of the model. Srivastava *et al.*, 2016 observed that the crop models were calibrated for unlimited water conditions. However, such results need to be used cautiously as the model has its inherent error in simulation.

The maximum difference was found for TTB-7 cultivar compared to BRG-2. This is substantiated by the results as expressed by Yadav *et al.*, 2016 that modeling in determinate and longer duration cultivars are tough than the shorter duration cultivars.

Genetic coefficients generated from 2016-17 recorded lower simulated and observed yield compared to 2015-16. 2016-17 weather condition experienced more water stress during reproductive stage of crop. Among the dates of sowing, $D_1$ (May) month sowing pigeonpea recorded higher yield compared to $D_2$ (June) and $D_3$ (July) month of both the years. Delayed planting of long duration pigeonpea, cultivar reduces the pod filling period, biomass and seed yield. The date of sowing causes the change in crop growing environment specially the precipitation, thermal requirement and solar radiation received by the crop

TABLE III

*The relative mean error (ME) percentage, rootmean square error (RMSE), coefficient of residual mass (CRM) and modeling efficiency (EF) of DSSAT CROPGRO-Pigeonpea model*

| | ME (%) | RMSE | CRM | EF |
|---|---|---|---|---|
| 2015-16 | -335.8 | 376264 | 0.56 | 1.01 |
| 2016-17 | -543.1 | 553733 | 0.91 | 1.01 |
| TTB-7 | -309.0 | 295876 | 0.51 | 1.01 |
| BRG-2 | -549.3 | 711441 | 0.92 | 1.01 |
| $D_1$ | -280.1 | 721917 | 0.70 | 1.02 |
| $D_2$ | -279.6 | 466114 | 0.70 | 1.34 |
| $D_3$ | -293.5 | 206964 | 0.73 | 1.01 |
| 2015-16*TTB-7 | -174.2 | 446347 | 0.58 | 1.01 |
| 2015-16*BRG-2 | -161.0 | 306181 | 0.54 | 1.01 |
| 2016-17*TTB-7 | -271.7 | 574357 | 0.91 | 1.01 |
| 2016-17*BRG-2 | -271.4 | 533109 | 0.90 | 1.01 |
| $D_1$*BRG-2 | -137.3 | 653339 | 0.69 | 1.04 |
| $D_2$*BRG-2 | -146.0 | 472189 | 0.73 | 1.34 |
| $D_3$*BRG-2 | -132.3 | 133408 | 0.66 | 1.01 |
| $D_1$*TTB-7 | -142.6 | 790495 | 0.71 | 1.02 |
| $D_2$*TTB-7 | -133.9 | 460040 | 0.67 | 1.69 |
| $D_3$*TTB-7 | -158.9 | 280521 | 0.79 | 1.01 |
| 2015-16*$D_1$ | -114.5 | 639555 | 0.57 | 1.15 |
| 2016-17*$D_1$ | -174.6 | 804279 | 0.87 | 107.63 |
| 2015-16*$D_2$ | -97.8 | 231011 | 0.49 | 3.03 |
| 2016-17*$D_2$ | -185.3 | 701217 | 0.93 | 1.98 |
| 2015-16*$D_3$ | -125.0 | 258227 | 0.62 | 1.08 |
| 2016-17*$D_3$ | -187.6 | 155702 | 0.94 | 1.70 |

canopy (Majumdar, 2011). These results indicated that modification should be incorporated in the model for acceptable yield simulation results.

Statistical evaluation of experimental yield using ME, RMSE, CRM and EF are presented (Table III). Simulation of TTB-7 grain yield was in good agreement with the observed values with comparatively low ME (-309.0), RMSE (295876) and CRM (0.51) than the BRG-2ME (-549.3), RMSE (711441) and CRM (0.92). But both are very far from observed seed yield, so that further calibrations are must. As a step towards calibration we have tested the coefficients for different combinations of dates of sowing over the years. The model performance for yield simulation for both the cultivars and different date of sowing under both years were not within the acceptable limit (±20%).

Lesser values of ME, RMSE and CRM for 2015-16 (-335.8, 376264 and 0.56, respectively) compared to 2016-17 (-543.1, 553733 and 0.91, respectively) indicated that the coefficients for 2015-16 are nearer to actual coefficients. However, need to be calibrated further.

TABLE IV

*Genetic coefficients of pigeonpea cultivars TTB-7 and BRG-2.*

| Genetic Parameter | Description | TTB - 7 | BRG - 2 |
|---|---|---|---|
| CSDL | Critical short day length below which reproductive development progresses with no day length effect (for short day plants) (hour) | 12.00 | 12.00 |
| PPSEN | Slope of the relative response of development to photoperiod with time (positive for short day plants) (1/hour) | 0.35 | 0.35 |
| EM-FL | Time between plant emergence and flower appearance (R1) (photothermal days) | 70.4 | 68.5 |
| FL-SH | Time between first flower and first pod (R3) (photothermal days) | 10.4 | 10.1 |
| FL-SD | Time between first flower and first seed (R5) (photothermal days) | 23.7 | 20.2 |
| SD-PM | Time between first seed (R5) and physiological maturity (R7) (photothermal days) | 60.04 | 55.84 |
| FL-LF | Time between first flower (R1) and end of leaf expansion (photothermal days) | 58.37 | 50.63 |
| LFMAX | Maximum leaf photosynthesis rate at 30°C, 350 vpm Co2, and high light (mg $Co_2/m^2$ s) | 1.10 | 1.10 |
| SLAVR | Specific leaf area of cultivar under standard growth conditions ($cm^2/g$) | 320.0 | 320.0 |
| SIZLF | Maximum size of full leaf (three leaflets) ($cm^2$) | 172.0 | 172.4 |
| XFRT | Maximum fraction of daily growth that is partitioned to seed + shell | 0.85 | 0.80 |
| WTPSD | Maximum weight per seed (g) | 0.11 | 0.14 |
| SFDUR | Seed filling duration for pod cohort at standard growth conditions (photothermal days) | 50.0 | 45.0 |
| SDPDV | Average seed per pod under standard growing conditions (#[seed]/pod) | 3.3 | 3.3 |
| PODUR | Time required for cultivar to reach final pod load under optimal conditions (photothermal days). | 25.0 | 22.0 |
| THRESH | The maximum ration of seed (seed/seed + shell) at maturity | 75.0 | 70.0 |
| SDPRO | Fraction protein in seed (g[protein]/g[seed]) | 0.225 | 0.225 |
| SDLIP | Fraction oil in seeds (g(oil)/g(seed)) | 0.015 | 0.015 |

Among the dates of sowing, $D_2$ (June) the simulated grain yield was in good agreement with the observed values with comparatively low in ME (-279.6), RMSE (466114) and CRM (0.70) than the $D_1$ (May) and $D_3$ (July) sowing.

As an attempt, coefficients for interaction of dates of sowing of both cultivars over different years were generated and evaluated. Initially combination of year and cultivars were considered. Lower ME (-161.0), RMSE (306181) and CRM (0.54) values for 2015-16 for both cultivars showed that 2015-16 is superior to 2016-17. Similar results were seen when years were considered individually so this combination is of no use for calibration. Model performance for combination of dates of sowing for both cultivars were inferior or on par with models run with coefficients generated individually.

Higher model efficiency of 107.63 for first date sown crop during 2016-17 is attributed to the reason that the ratio (TTB-7:0.125 and BRG-2: 0.129) of actual and simulated yield is almost same. Sreenivas and Reddy (2013) also quoted that the inherent error of the model could be systematic which cannot be corrected using genetic coefficients. Further, he added saying that sometimes the ratio obtained can be permanent correction for other models.

Interestingly combination of year and dates of sowing for both cultivars had lower ME (-97.8), RMSE (231011) and CRM (0.49) for 2015-16 second date sown crop. So, we conclude that coefficients generated from this combination are more applicable and needs further attention. Final set of genetic coefficients obtained from the said combination is present (Table-IV).

DSSAT model has proved to be robust and valuable tool for predicting yield. CROPGRO-Pigeonpea was started in 2015. As an attempt, experimental results of two years are used for generation of genetic co-efficient. Further these generated coefficients are evaluated statistically. The yield was underestimated by the DSSAT model. Since the present research data base is very less, the process of calibration is incomplete and it has to befine-tuned. The validated DSSAT model has wide range of applications from improving and evaluating the current growth and management practices forprediction of crop growth,phenology, potential and actual yield, performance of pigeonpea under climate change.

## References

ANONYMOUS, 2015, Agricultural Statistics at a glance. Visit at: *www.agricoop.nic.in* & *http://eands.dacnet.nic.in*

BHATIA, V. S., SINGH, P., WANI, S. P., CHAUHAN, G. S., RAO KESAVA, A. V. R., MISHRA, A. K. AND SRINIVAS, K., 2008, Analysis of potential yields and yield gaps of *rainfed* soybean in India using CROPGRO-Soybean model. *Agric. Forest Met.,* **148** : 1252 - 1265.

HOOGENBOOM, G., 2000, Contribution of agro-meteorology to the simulation of crop production and its application. *Agric. Forest Met.,* **103** : 137 - 157.

LOAGUE, K. M. AND GREEN, R. E., 1991, Statistical and graphical methods for evaluating solute transport model. *J. Contaminated Hyd.,* **7** : 51 - 73.

MAJUMUDAR, D. K., 2011, *Pulse crop production: Principles and technologies*. Print House India publisher, p. 62.

MOTE, B. M., 2013, Simulation modeling of rice (*Oryza sativa* L.) cultivars using DSSAT model (version 4.5) for South Gujarat heavy rainfall zone. *M. Sc. Thesis* (Unpub.), Navsari Agric. Univ., Navasari, Gujarat.

PATEL, H. R., LUNAGARIA, M. M., KARADE, B. L., PANDEY, VYAS, YADAV, S. B., SHAH, A. V., RAO, V. U. M. AND NARESH KUMAR, S., 2013, Impact of projected climate change on groundnut in Gujrat. *J. Agrometeorol.* (Special issue), p. 81 - 84.

SATHEESH NAIK, S. J., BYRE GOWDA, M., VENKATESHA, S. C., RAMAPPA, H. K., PRAMILA, C. K., MARY REENA, G. A. AND RAMESH, S., 2012, Molecular diversity among pigeonpea genotypes differing in response to pigeonpea sterility mosaic disease. *J. Food Legumes,* **25** (3) : 194 - 199.

SINGH, P., NEDUMARAN, S., NTARE,B. R., BOOTE, K. J., SINGH, N. P., SRINIVAS, K. AND BANTILAN, M. C. S., 2014, Potential benefits of drought and heat tolerancein groundnut for adaptation to climate change in

Indiaand West Africa. *An International Journal Devoted to Scientific, Engineering, Socio-Economic and Policy Responses to Environmental Change*, **18**(2) : 1-24.

SREENIVAS, G. AND REDDY, D. R., 2013, Evaluation of CERES-Rice model under variable weather conditions and nitrogen levels. *Proc. Nation. Symp. Climate Change and Indian Agriculture:Slicing Down the Uncertainties*. Association of Agro-meteorologists-AP Chapter & CRIDA 22-23 Jan 2013, p. 206 (S6-35).

SRIVASTAVA, A. K., SANDIP SILAWAT AND AGRAWAL, K. K., 2016, Simulating the impact of climate change on chickpea yield under *rainfed* and irrigated conditions in Madhya Pradesh. *J. Agrometeorol*., **18** (1) : 100 - 105.

SURIHARAN, B., PATANOTHAI, A., PANNAGPETCH, K., JOGLOY, S. AND HOOGENBOOM, G., 2008, Determination of cultivar coefficients of peanut lines for breeding applications of the CROPGRO-Peanut model. *Crop Sci.,* **47** : 606 - 620.

YADAV, M. K., SINGH, R. S., SINGH, K. K., MALL, R. K., CHANDRABHAN PATEL, YADAV, S. K. AND SINGH, M. K., 2016, Assessment of climate change impact on pulse, oilseed and vegetable crops at Varanasi, India. *J. Agrometeorol.,* **18** (1) : 13 - 21.

YADAV, S. B., PATEL, H. R., PATEL, G. G., LUNAGARIYA, M. M., KARNDE, B. I. AND PANDEY, V., 2012, Calibration andvalidation of groundnut for middle Gujarat agroclimaticzone. *J. Agrometeorol*. (Special issue), **14** : 292 - 297.

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