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Research Article

CALIBRATION AND VALIDATION OF CROPGRO (DSSAT 4.6) MODEL FOR CHICKPEA UNDER MIDDLE GUJARAT AGROCLIMATIC REGION

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Abstract- The DSSAT CROPGRO model was calibrated and validated using field experimental data of two consecutive *rabi* seasons 2014-15 and 2015-16 at Anand, Gujarat. The genetic coefficients for cultivar GG-1 of chickpea were estimated. Higher R^2(0.97) was obtained between measured and simulated for days to anthesis, with percent error (PE) 8.08 % and D-index 0.91. The PE between measured and observed for all the parameters were found below ±10 % error. The model could be used to predict the seed yield accurately under different management conditions. Hence, the CROPGRO model can be used to simulate the phenology and yield of chickpea.

Keywords- Chickpea, DSSAT, CROPGRO, Genetic coefficients, Validation

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Introduction

In India pulses are cultivated under rain fed conditions on marginal lands. Only fifteen percent of the area under pulses has assured irrigation. Fluctuations in pulse production (due to biotic and abiotic stress) and prices (in the absence of an effective government price support mechanism) farmers are not very keen on taking up pulse cultivation despite high wholesale pulse prices in recent years. Chickpea is generally known as Bengal gram or Gram and botanically called *Cicerarietinum* Linn. It has an important place in the diet of Indian people because it gives comparatively more protein than any other food grains. Gram contains 21.5 % protein, 61.5 % carbohydrates and 4.5 % fat [1].

The Decision Support System for Agrotechnology Transfer (DSSAT) was originally developed by an International Network of Scientists, cooperating in the International Benchmark Sites Network for Agrotechnology Transfer project. The systems approach provided a framework in which research is conducted to understand how the system and its components function. After one is confident that the models simulate the real world adequately, computer experiments can perform hundreds or even thousands of times for given environments to determine how to best manage or control the system. DSSAT was developed to operationalize this approach and make it available for global applications [2].

CROPGRO is a physiological based crop growth simulation model under DSSAT model, which predicts crop phenology, growth and yield prediction of chickpea depending on daily weather parameters for specific soils. Calibration of genetic coefficients of any particular crop cultivar requires detail field experiment with some desired treatments. Computer model simulation and actual (measured) crop parameters are to be matched by fine tuning of genetic coefficients, which called calibration of model. Once the calibration is complete for genetic coefficients then these genetic coefficients are to be used for yield and yield attributing simulation of respective crop and cultivar. The model is sensitive to cultivar choice, planting date, row and plant spacing and irrigation management. Various management options can also be altered for desired output.

Materials and Methods

Experimental details

The experiment was laid out at Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat during *rabi* seasons of 2014-15 and 2015-16 in split plot design with date of sowing as main plot (D_1- 15th October, D_2- 30th October and D_3- 15th November) and irrigation as sub plot treatment (I_1- Irrigation at critical growth stages (Branching, flowering and pod development), I_2- 0.4 IW: CPE, I_3- 0.6 IW: CPE and I_4- 0.8 IW: CPE). The soil type of the experimental site was sandy loam a true representative soil of the region.

CROPGRO model input

The pertinent daily weather, soil and crop management data for all the sowing dates and irrigation levels were used as input and experiment performance data file. The experiment performance files are needed only when simulated results are to be compared with data recorded in an experiment.

Calibration of the CROPGRO chickpea model

For calibration of the CROPGRO- Chickpea model, data on plant growth and development, soil characteristics, weather and crop management were collected as required for determining the cultivar coefficients of GG-1 following the procedures described in IBSNAT and [3]. The cultivar coefficients were estimated by repeated literations by running the GLUE coefficient estimator using the observed phenology and yield for all the sowing environments during both the years until a close match between simulated and observed phenology and yield was obtained. The calibrated genetic coefficients based on first season (*Rabi* 2014-15) of field experimental data for chickpea cv. GG-1 at Anand condition are mentioned in the [Table-1].

Validation of the model

Model validation, in its simplest form is a comparison between simulated and

observed values. Test criteria have been separated into two groups, called summary measures and difference measures. Summary measures include the mean of observed (Õ) and predicted values (P), the standard deviation of observations (So) and the predictions (Sp).

The summary measures describe the quality of simulation while, the difference measures try to locate and quantify the errors. The latter include the mean absolute error (MAE), mean bias error (MBE) and root mean square error (RMSE). They were calculated according to [4] as following and were based on the terms (P_i-O_i):

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

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

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

MAE and RMSE indicate the magnitude of the average error, but provide no information on the relative size of the average difference between (P) and (O). The statistic MBE describes the direction of error bias. The value of MBE is related to the magnitude of the values under investigation. A negative MBE indicates that the predictions are smaller in values than those of the corresponding observations. Test criteria have been separated into two groups, called summary measures and difference measures. Summary measures include the mean of observed values $(\bar{O})$ and predicted values $(\bar{P})$, the standard deviation of observations (S_o) and the predictions (S_p), the slope (b) and intercept (a) of the least square regression ($P_i = a + b + O_i$).

Willmott (1982) calculated an index of agreement (D) as follows:

$$D = 1 - \left[\sum_{i=1}^{n} (P_i - O_i)^2 \Big/ \sum_{i=1}^{n} (IP_i'I + IO_i'I)^2 \right]$$

$O \leq (D) \leq 1$

where,

$P_i' = P_i - P$ and $O_i' = O_i - O$.

Result and Discussion

Chickpea genetic coefficient

The data set for genetic coefficients calculations include days to anthesis, days to first pod, days to physiological maturity, days to harvest maturity, seed yield, by product leaf area and harvest index. The procedure for determining genetic coefficients involved in running the model using a range of values of each coefficient, in the order indicated above, until the desired level of agreement between simulated and observed values was reached. Iterations for the coefficients were stopped when the agreement reached ±10 %. For the present study the cultivar genetic coefficients for *cv.* GG-1 have been developed as per Hunt's [5] method.

Validation of CROPGRO- Chickpea model

The DSSAT family of CROPGRO- Chickpea model was employed to simulate growth, development and yield of chickpea crop, for comparison with those respective ones which were observed under field experiment with a view to assess the performance of the model in simulating the results of these characters. CROPGRO- Chickpea model was validated for second year (2015-16) field experiment data for different characters. The comparison of observed and simulated (1:1) is presented in [Fig-1].

Crop phenology: Simulated days to anthesis, days to first pod, days to physiological maturity and days to harvest maturity were compared with observed data for early, normal and late sown crop with different irrigation levels [Fig-1] The model predicted below 10 % error of the observed values. Lowest percent error 4.34 was observed for days to physiological maturity with RMSE 4.43, R^2 0.91 and index of agreement with 0.91. Keeping in view that even the field observed phonological dates can differ or be biased based on personal judgement of the observers, these trends showed that the model was able to simulate flowering period reasonably well for all treatments. The overall performance of the model simulation for crop phenology showed some lower variation in comparison to actual. Days to first pod and physiological maturity simulation showed overestimation results, while harvest maturity simulation showed over/ underestimation of results. Similar findings were observed by Srivastava *et al.* (2003)[6].

Seed and straw yield: Simulated seed and straw yield were compared with the observed data of different treatments [Fig-1]. The model predicted seed and straw yield below 10 % error of observed values. Seed yield observed the lower percent error 7.9 % with RMSE 147.93, R^2 0.83 and index of agreement 0.94. The seed yield simulation showed over/underestimation of results. Straw yield performed higher underestimation.

Results show that by various test criteria it is concluded that DSSAT CROPGRO-Chickpea model can be used to predict growth, development and seed yield of chickpea with some reasonable errors.

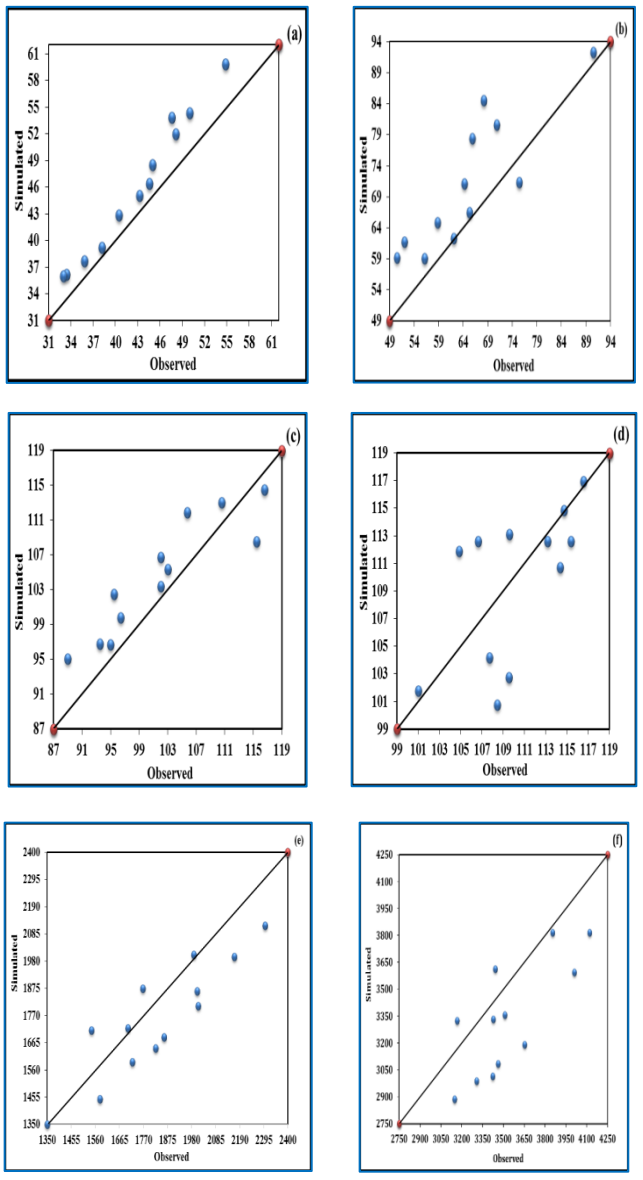

Fig-1 Mean simulated and observed (a) days to anthesis, (b) days to first pod, (c) days to physiological maturity, (d) days to harvest maturity, (e) seed yield (kg ha^{-1})and(f) straw yield (kg ha^{-1})

Table-1 *Test criteria in evaluation of model with respect to days to anthesis, days to first pod, days to physiological maturity and days to harvest maturity*

Parameters	Days to anthesis	Days to first pod	Days to physiological maturity	Days to harvest maturity	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})
RMSE	3.46	8.18	4.43	-0.05	147.93	295.72
R^2	0.97	0.85	0.91	0.93	0.83	0.75
PE	8.08	12.58	4.34	4.45	7.90	8.34
Index of agreement (D)	0.91	0.84	0.94	0.91	0.94	0.90

Conclusion

The validated outcomes of DSSAT-CROPGRO Chickpea model reveals that this model satisfactorily simulate the yield attributes of observed crop data and can be adopted for prediction of crop growth, phenology, potential and actual yields for chickpea crop over middle Gujarat region and can be used for agro advisory services and farmers at regional level and agro-advisory programs. These results are comparable with those published in recent literature, confirming that model performance is satisfactory.

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Author Contributions: All authors equally contributed

Abbreviations: GG-1 – Gujarat Gram 1
PE – Percent Error
IW: CPE – Ratio of Irrigation Water to Cumulative Pan Evaporation
IBSNAT - International Benchmark Sites Network for Agrotechnology Transfer
RMSE – Root Mean Square Error
ha – hectare
kg ha^{-1} – Kilogram per Hectare

Conflict of Interest: None declared

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