Genetic Coefficient and Validation of DSSAT Model for Cotton under Different Growing Environments

Sagar Kumar*, Ram Niwas, M.L. Khichar, Amit Singh, Premdeep, Yogesh Kumar and Abhilash

Department of Agricultural Meteorology, College of Agriculture (COA), CCS Haryana Agricultural University, Hisar-125004, Haryana, India

*Corresponding author

A B S T R A C T

The field experiment was conducted at the research area of the Department of Agricultural Meteorology, CCS Haryana Agricultural University, Hisar, during the kharif season of 2015-16. The main plots treatments consisted of three date of sowing 2nd week of May (D1), 3rd week of May (D2) and 1st week of June (D3) and sub-plots consisted of three varieties (Pancham 541, SP 7121 and RCH 791. Genetic coefficient for DSSAT- CROPGRO model such as EM-FL, FL-SH, SD-PM, FL-LF, SLAVR, SIZLF, XFRT, SDPRO, SDLIP, SFDUR, THRSH, SDFDV, CSDL, PP-SEN, LFMAX, WTPSD and PO-DUR were evaluated. SLAVR, XFRT and THRSH were main coefficients which influenced LAI and seed cotton yield. The model performance in respect of phenology was good with error of ±5% for all the three cotton cultivars and growing environments. Also the model performance was within acceptable range of ±10.0% for LAI, seed cotton yield and biomass for all the cultivars and growing environments. But the model performance was not within acceptable range for the crop sown in 1st week of June.

K e y w o r d s
Cotton, growing environment, DSSAT, genetic coefficient and validation.

Introduction

The Decision Support System for Agrotechnology Transfer (DSSAT) is the major product of the IBSNAT (International Benchmark Site Network for Agrotechnology Transfer) project, initiated in 1982 (Uehara and Tsuji, 1998). Although this project ended in 1993, its developers have expanded since then and continue to update and maintain this software under the auspices of ICASA. The central components of the DSSAT software are crop simulation models and programs to facilitate their application in different regions of the world. It is the quantitative tool based on scientific knowledge that can evaluate the effect of climatic, edaphic, hydrological and agronomic factors on crop growth and yield. The decision support system for agrotechnology transfer (DSSAT) has been in use for the last 15 years by researchers worldwide (Hoogenboom et al., 2012; Jones et al., 2003). This package incorporates models of 28 different crops with software that facilitates the evaluation and application of the crop models for different purposes.

DSSAT was developed to assess yield, resource use and risk associated with different crop production practices (Tsuji et al., 1994). The system DSSAT (Tsuji et al., 1994) is an example of a management tool that enables
farmers to match the biological requirement of a crop to the physical characteristics of the land and ambient air to attain specified objectives. DSSAT software could help the decision makers to implement future agriculture strategies under different scenarios related to agriculture practices with the use of measured site-specific pedological, physiological, agronomical and meteorological data (Hoogenboom et al., 1994).

The study of impact of climate change on crops needs simulation model, as it provide a means to quantify the effects of climate, soil and management on crop growth, productivity and sustainability of agricultural production. These tools can reduce the expensive and time consuming field experimentation as they can be used to extrapolate the results of research conducted in one season or location to other season, location, or management (Boomiraj et al., 2007).

Materials and Methods

The field experiment was conducted at the research area of the Department of Agricultural Meteorology, CCS Haryana Agricultural University, Hisar, during the kharif season of 2015-16. The main plots treatments consisted of three date of sowing and the sub-plots consisted of three varieties. The twenty seven treatment combinations were tested in random block design with three replications.

Plant height was measured at important phenophases on three tagged plants in each plot. The height was measured from the root-shoot junction to the apical point with a wooden meter scale and mean values were calculated.

Three plants were uprooted from each plot and their leaves were used for measuring leaf area per plant (cm²) with the help of leaf area meter (LI-3000 Leaf Area Meter, LICOR Ltd., Nebraska, USA) at 30, 60, 90, 120 and 150 days after sowing. These samples were oven dried and weighted for dry biomass calculation on hectare basis. Yield, yield attributes and yield quality were recorded at harvest.

Input data for CROPGRO-Cotton model

‘CROPGRO-Cotton’ is a physiological based dynamic crop growth simulation model which is responsive to daily weather inputs. The minimum data required for running CROPGRO-Cotton are given in table 1.

Inputs required for creating a new soil profile for DSSAT Crop Model

1. General Information

| 1. Country: INDIA          | 2. Site Name: CCSHAU, HISAR |
|---------------------------|-----------------------------|
| 3. Latitude: 29° 10'      | 4. Longitude: 75° 46'       |
| 5. Soil Data source: NBSS | 6. Soil Series name: NINDANA|
| 7. Soil Classification:   | Typic ustochrept             |

| II. Surface Information   |                                    |
|---------------------------|-----------------------------------|
| 1. Colour                 | (a) Brown                         |
| 2. Drainage               | Moderate well                     |
| 3. % slope                | ONE                               |
| 4. Runoff potential       | Moderately low                    |
| 5. Fertility factor (0 to 1) | ONE                             |
| 6. Runoff Curve Number    |                                   |
| 7. Albedo                 |                                   |
| 8. Drainage rate          | III. Layer-wise soil information: No. of layers depends on the location. Here layers up to 120 cm depth (Table 2). |
Calibration of the model

Calibration of model involves computing and adjusting certain model parameters or relationships to make the model work for any desired location. When using a crop model, one has to estimate the cultivar characteristics if they have not been previously determined. The model requires twenty cultivar specific genetic coefficients. These genetic coefficients were computed as per details given below:

### Parameters Description of parameters

- **EXPON** Number of experiment used to estimate cultivar parameters
- **ECO#** Code for the ecotype to which this cultivar belongs
- **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) ---from Reddy Adv. Agron. 1997?
- **SLAVR** Specific leaf area of cultivar under standard growth conditions (cm$^2$/g)
- **SIZLE** 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 (#/pod)
- **PODUR** Time required for cultivar to reach final pod load under optimal conditions (photothermal days)
- **THRSH** Threshing percentage. The maxi. ratio of seed [seed/(seed+shell)]
- **SDPRO** Fraction protein in seeds [g(protein)/g(seed)]
- **SDLIP** Fraction oil in seed [g(oil)/g(seed)]

The model was run and validated by comparing the predicted output with observed parameters. Deviation of predicted value from observed were calculated and error of the model to predict different crop parameters was quantified using the methods given below:

$$M_{AE} = \frac{\sum_{i=1}^{n}|P_i - O_i|}{n}$$

$$M_{BE} = \frac{\sum_{i=1}^{n}[P_i - O_i]}{n}$$

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

$$PE = \{(P - O) / O\} * 100$$

Where, $O =$ observed, $P =$ simulated.
Results and Discussion

The genetic coefficients were evaluated and the model was validated for different sowing environment with different cultivars: Pancham 541, SP 7121 and RCH 791. DSSAT model was calibrated by different data sets on phenology, leaf area index, bolls weight/plant, biomass and seed cotton yield for the evaluation of genetic coefficients.

Genetic coefficients

The core coefficients such as maximum threshing percentage was calculated and observed in RCH 791(91%) followed by SP 7121(79%) and Pancham 541(74%) sown in table 3. The value of CSDL, PP-SEN, LFMAX and WTPSD used as default, the value of EM-FL, FL-SH, SD-PM, FL-LF, SLAVR, SIZLF, XFRT, SDPRO and SDLIP was computed and they are maximum in cotton cultivar RCH 791 followed by SP 7121 and Pancham 541. SFDUR, SDPDV and PDUR were computed and found equal in SP 7121 and Pancham 541 and maximum in RCH 791. SLAVR, XFRT and THRSH have maximum influence on LAI and seed cotton yield. Ortiz et al., (2009) also reported the values for most of the vegetative and reproductive cultivar coefficients were higher than those from the other commercial cotton cultivars that are part of the DSSAT data-base, suggesting that the cultivar grown in this experiment required more days to the beginning of the reproductive phase.

Validation

Days to flowering

The observed mean values of days to flowering for three cotton cv. Pancham 541, SP 7121 and RCH 791 were 70, 72 and 74, whereas the model simulated 70, 72 and 72 days, resp. (Table 4). The percent error was observed lower for cv. SP 7121 (0.0) followed by Pancham 541 (0.0) and RCH 791 (-3.3). Similarly, the percent error was observed lower for 3rd week of May (D2) followed by 1st week of June (D3) and 2nd week of May (D1). This clearly showed that model performance was found to be good for all the three cotton cultivars and for all the growing environments for simulation of days to flowering as percent error was ≤ 5. Ortiz et al., (2009) also showed the difference between observed and simulated values for the flowering and physiological maturity dates over the control treatment was two days.

Days to maturity

Pancham 541, SP 7121 and RCH 791 matured in 136, 138 and 141 days, while model simulated 137, 139 and 142 days, respectively as sown in table 5. SP 7121 performed better and the model percent error was observed lower for 3rd week of May (D2) overestimated the days to maturity. The percent error was over estimated by the model or error was negligible. The simulation performance of the model in respect of days taken to maturity was found to be the best as error was < 1.0%. Also, the results of phenological stages of maize simulated by InfoCrop model are supported by Singh et al., (1994), Akula (2003) and Soler et al., (2007).

Growth and yield parameters

Maximum LAI

LAI of Pancham 541, SP 7121 and RCH 791 were 2.9, 3.1 and 3.5, while model simulated LAI were 3.1, 3.4 and 3.6, respectively as sown in table 6. The percent error was ranged between -9.6 and 19.4%.The performance of model was not in acceptable range in 3rd date of sowing (D3).
### Table 1: List of input required by CROPGRO-Cotton model

| Input variables                          | Acronym | Units       |
|------------------------------------------|---------|-------------|
| **Site data**                            |         |             |
| Latitude                                 | LAT     | Degree      |
| Longitude                                | LONG    | Degree      |
| Elevation                                | ELEV    | M           |
| Average air temperature                   | TAV     | °C          |
| Height of temperature measurement        | TMHT    | M           |
| Height of wind measurement               | WMHT    | M           |
| CO₂ concentration                        |         | ppm         |
| **Daily weather data**                   |         |             |
| Maximum temperature                      | TEMPMAX | °C          |
| Minimum temperature                      | TEMPMIN | °C          |
| Rainfall                                 | RAIN    | Mm          |
| Sun Shine hours                          | SSH     | hours       |
| **Soil characteristics**                 |         |             |
| Soil texture                             | SLTX    |             |
| Soil local classification                | SLDESC  |             |
| Soil family SCS system                   | TACON   |             |
| Soil depth                               | SLDP    | M           |
| Colour, moist                            | SCOM    |             |
| Albedo (fraction)                        | SALB    | Fraction    |
| Evaporation limit                        | U       | Cm          |
| Drainage rate (fraction day⁻¹)           | SWCON   | Fraction day⁻¹ |
| Runoff curve number                      | CN2     |             |
| Mineralization (0 to 1 scale)            | SLNF    |             |
| Photosynthesis factor (0 to 1 scale)     | SLPE    |             |
| pH in buffer determination method        | SMPX    |             |
| Potassium determination method            | SMKE    |             |
| Horizon-wise                             |         |             |
| Lower limit drained                      | LL(L)   | cm³ cm⁻³    |
| Upper limit drained                      | DUL(L)  | cm³ cm⁻³    |
| Upper limit drained                      | SAT(L)  | cm³ cm⁻³    |
| Saturated hydraulic conductivity         | SWCN(L) | cm hr⁻¹     |
| Bulk density moist                       | BD(L)   | g cm⁻³      |
| Organic carbon                           | OC(L)   | %           |
| Clay (<0.002 mm)                         | CLAY(L) | %           |
| Silt (0.05 to 0.002 mm)                  | SILT(L) | %           |
### Input variables

| Variable                                           | Acronym     | Units     |
|----------------------------------------------------|-------------|-----------|
| Coarse fraction (>2 mm)                            | STONES(L)   | %         |
| Total nitrogen                                     | TOTN(L)     | %         |
| pH in buffer                                       | PHKCL(L)    |           |
| Cation exchange capacity                           | CEC(L)      | Cmolkg⁻¹  |
| Root growth factor 0 to 1                          | SHF(L)      |           |

### Management data

| Variable                                           | Acronym | Units     |
|----------------------------------------------------|---------|-----------|
| Sowing date                                        | YRPLT   |           |
| Emergence date                                     | IEMERG  |           |
| Plant population at seedling                       | PLNATS  | Plantm⁻²  |
| Planting method (TP/direct seeded)                 | PLME    |           |
| Planting distribution (row/broadcast/hill)         | PLDS    |           |
| Row spacing                                        | ROWSPS  | Cm        |
| Row direction (degree from north)                  | AZIR    |           |
| Plants per hill                                    | PLPH    |           |
| Seed rate                                          | SDWTRL  | kg ha⁻¹   |
| Sowing depth                                       | SDEPTH  | Cm        |
| Irrigation dates                                   | IDLAPL(J)| Mm       |
| Irrigation amount                                  | AMT(J)  | Mm        |
| Method of irrigation                               | IRRCOD(J)|          |
| Fertilizer application dates                       | FDAY(J)  |           |
| Fertilizer amount N                                | ANFER(J) | kg ha⁻¹   |
| Fertilizer type                                    | IFTYPE(J)|          |
| Fertilizer application method                      | FERCOD(J)|          |
| Fertilizer incorporation depth                     | DFERT(J) | Cm        |
| Tillage date                                       | TDATE(J) |           |
| Tillage implement                                  | TIMPL(J) |           |
| Tillage depth                                      | TDEP(J)  | Cm        |
| Residue management                                 | LNRES    |           |
| Chemical applications                              | LNCHE    |           |
| Environment modification                           | LNENV    |           |

### Harvest details

| Variable                                           | Acronym | Units     |
|----------------------------------------------------|---------|-----------|
| Harvest                                            | HDATE(J)|           |
| Harvest stage                                      | HSTG(J) |           |
| Harvest component                                  | HCOM(J) |           |
| Harvest percentage                                 | kg ha⁻¹ | %         |
Table 2 Layer-wise soil information for input of DSSAT model

| Depth (bottom) Cm | Master Horizon | Clay % | Silt % | Stones % | Organic Carbon % | pH in water | Cation Exchange Capacity C mol/kg |
|------------------|----------------|--------|--------|----------|------------------|-------------|----------------------------------|
|                  |                |        |        |          |                  |             |                                  |
| 5                | AP             | 10.7   | 22.3   | -99      | 0.41             | 8.1         | 11.4                             |
| 29               | A1             | 13.4   | 25.0   | -99      | 0.26             | 8.4         | 12.4                             |
| 57               | B2             | 14.3   | 26.2   | -99      | 0.26             | 8.3         | 13.4                             |
| 80               | B2             | 16.0   | 27.9   | -99      | 0.23             | 8.3         | 17.4                             |
| 103              | B2             | 16.5   | 28.3   | -99      | 0.22             | 8.2         | 17.7                             |
| 127              | B3             | 16.9   | 28.7   | -99      | 0.20             | 8.3         | 19.5                             |

| Depth (bottom) Cm | Lower limit | Drainage Upper Limit | Saturation | Bulk Density g/cm³ | Saturated Hydraulic Conductivity Cm/hr | Root growth Factor 0.0-1.0 |
|------------------|-------------|----------------------|------------|---------------------|---------------------------------------|----------------------------|
|                  |             |                      |            |                     |                                       |                            |
| 15               | 0.091       | 0.183                | 0.412      | 1.49                | 2.59                                  | 1.00                       |
| 29               | 0.100       | 0.196                | 0.407      | 1.59                | 2.59                                  | 0.644                      |
| 57               | 0.105       | 0.203                | 0.410      | 1.50                | 2.59                                  | 0.423                      |
| 80               | 0.112       | 0.215                | 0.410      | 1.50                | 2.59                                  | 0.254                      |
| 103              | 0.114       | 0.218                | 0.410      | 1.50                | 2.59                                  | 0.160                      |
| 127              | 0.116       | 0.220                | 0.411      | 1.50                | 2.59                                  | 0.100                      |

Table 3 Genetic coefficient of cotton cultivar evaluated under different growing environments

| VARITIES       | CSDL | PP-SEN | EM-FL | FL-SH | FL-SD | SD-PM | FL-LF | LF MAX | SLAVR | SIZLF |
|----------------|------|--------|-------|-------|-------|-------|-------|--------|-------|-------|
| SP 7121        | 23   | 0.01   | 42    | 13    | 18    | 55    | 70    | 1.3    | 390   | 390   |
| PANCHAM 541    | 23   | 0.01   | 40    | 11    | 16    | 54    | 68    | 1.3    | 380   | 380   |
| RCH 791        | 23   | 0.01   | 46    | 14    | 19    | 56    | 75    | 1.3    | 420   | 410   |

| VARITIES       | XFRT | WTPSD | SFDUR | SDPDV | PO-DUR | THRSH | SD PRO | SDLIP |
|----------------|------|-------|-------|-------|--------|-------|--------|-------|
| SP 7121        | 0.75 | 0.18  | 35    | 27    | 10     | 79    | 0.141  | 0.12  |
| PANCHAM 541    | 0.65 | 0.18  | 35    | 27    | 10     | 74    | 0.153  | 0.10  |
| RCH 791        | 0.91 | 0.18  | 40    | 30    | 12     | 91    | 0.145  | 0.13  |
Table 4 Test criteria of cotton phenology (Days to Flowering) using DSSAT model during 2015-16

| Days to Flowering | O  | S  | PE | RMSE | MBE  | MAE |
|-------------------|----|----|----|------|------|-----|
| D1(12MAY)         | 72 | 73 | -1.4 | 1.7  | 1.0  | 1.0 |
| D2(21MAY)         | 72 | 73 | -0.9 | 1.2  | 0.7  | 0.7 |
| D3(3JUNE)         | 69 | 70 | -1.0 | 1.2  | 0.7  | 0.7 |
| Pancham 541       | 70 | 70 |  0.0 |  0.0 |  0.0 |  0.0 |
| SP 7121           | 72 | 72 |  0.0 |  0.0 |  0.0 |  0.0 |
| RCH 791           | 72 | 74 | -3.3 |  2.4 |  2.3 |  2.3 |

Where: O:- Observed, S:- Simulated, E(%):- Error %, RMSE:- Root mean square error, MBE:- mean bias error, MAE:- mean absolute error

Table 5 Test criteria of cotton phenology (Days to physiological maturity) using DSSAT model in 2015-16

| Days to Physiological maturity | O  | S  | PE | RMSE | MBE  | MAE |
|--------------------------------|----|----|----|------|------|-----|
| D1(12MAY)                      | 139| 139|  0.0 |  0.0 |  0.0 |  0.0 |
| D2(21MAY)                      | 140| 139|  0.2 |  0.6 | -0.3 |  0.3 |
| D3(3JUNE)                      | 138| 137|  0.7 |  1.0 | -1.0 |  1.0 |
| Pancham 541                    | 137| 136|  0.2 |  0.6 | -0.3 |  0.3 |
| SP 7121                        | 139| 138|  0.2 |  0.6 | -0.3 |  0.3 |
| RCH 791                        | 142| 141|  0.5 |  0.8 | -0.7 |  0.7 |

Table 6 Test criteria of maximum LAI and bolls wt./plant using DSSAT model during 2015-16

| Maximum LAI | O  | S  | PE | RMSE | MBE  | MAE |
|-------------|----|----|----|------|------|-----|
| D1(12MAY)   | 3.5| 3.6|  4.5 |  0.3 | -0.2 |  0.3 |
| D2(21MAY)   | 2.7| 2.5| -9.6 |  0.3 |  0.3 |  0.3 |
| D3(3JUNE)   | 3.3| 4.0| 19.4 |  0.7 | -0.6 |  0.6 |
| Pancham 541 | 2.9| 3.1|  6.8 |  0.5 | -0.2 |  0.5 |
| SP 7121     | 3.1| 3.4|  7.7 |  0.5 | -0.2 |  0.4 |
| RCH 791     | 3.5| 3.6|  2.7 |  0.3 | -0.1 |  0.3 |

| Bolls Weight / Plant | O  | S  | PE | RMSE | MBE  | MAE |
|----------------------|----|----|----|------|------|-----|
| D1(12MAY)            | 27.7| 25.9| -6.7 |  2.1 | -1.9 |  1.9 |
| D2(21MAY)            | 19.7| 18.1| -7.7 |  1.6 | -1.5 |  1.5 |
| D3(3JUNE)            | 10.8| 9.6 | -11.8|  1.4 | -1.3 |  1.3 |
| Pancham 541          | 17.7| 16.2| -8.3 |  1.5 | -1.5 |  1.5 |
| SP 7121              | 19.3| 18.0| -7.0 |  1.4 | -1.3 |  1.3 |
| RCH 791              | 21.2| 19.4| -8.7 |  2.1 | -1.9 |  1.9 |
Table 7 Test criteria of Biomass and Seed cotton yield using DSSAT model during 2015-16

|                | O      | S      | PE     | RMSE   | MBE    | MAE    |
|----------------|--------|--------|--------|--------|--------|--------|
| **Biomass (q/ha)** |        |        |        |        |        |        |
| D1(12MAY)      | 36.3   | 37.8   | 4.1    | 3.3    | 1.5    | 3.1    |
| D2(21MAY)      | 28.1   | 29.2   | 4.0    | 2.3    | 1.1    | 1.9    |
| D3(3JUNE)      | 20.9   | 17.3   | -17.4  | 3.7    | -3.6   | 3.6    |
| Pancham 541    | 24.9   | 26.8   | 7.4    | 3.8    | 1.8    | 3.7    |
| SP 7121        | 28.6   | 28.4   | -0.5   | 2.4    | -0.1   | 2.1    |
| RCH 791        | 31.8   | 29.1   | -8.5   | 3.1    | -2.7   | 2.7    |

|                | O      | S      | PE     | RMSE   | MBE    | MAE    |
|----------------|--------|--------|--------|--------|--------|--------|
| **Seed cotton yield (q/ha)** |        |        |        |        |        |        |
| D1(12MAY)      | 17.7   | 19.3   | 9.0    | 1.7    | -1.6   | 1.6    |
| D2(21MAY)      | 14.8   | 14.2   | -4.0   | 2.1    | 0.6    | 1.7    |
| D3(3JUNE)      | 10.1   | 8.3    | -17.6  | 2.1    | 1.8    | 1.8    |
| Pancham 541    | 11.3   | 11.5   | 2.5    | 0.8    | -0.3   | 0.7    |
| SP 7121        | 13.2   | 13.6   | 3.2    | 1.4    | -0.4   | 1.4    |
| RCH 791        | 18.2   | 16.7   | -8.2   | 3.0    | 1.5    | 3.0    |

The evaluation of the model on an overall basis revealed that the simulation performance of the model in respect of LAI was found good with an accepted level (±10.0%) for 1st and 2nd date of sowing and all the three cultivars. Ortiz et al., (2009) reported that model under predicted maximum LAI for all fumigated treatments. The evaluation of the model on an overall performance of simulation was good.

**Bolls weight/plant**

Bolls weight/plant obtained for cv. Pancham 541, SP 7121 and RCH 791 were 17.7, 19.3 and 21.2 g, while model simulated 16.2, 18.0 and 19.4 g, respectively as shown in table 6. The average percent error was 8.7 (RCH 791). The model underestimated bolls weight/plant in all the three growing environments and in all the three cotton cultivars. The overall performance of simulation was found good within accepted level (±10%) for cotton. Ortiz et al., (2009) also reported the changes in boll weight accumulation throughout the season and the final boll weight at harvest were fairly well predicted by the CSM-CROPGRO-Cotton model.

**Biomass**

The biomass yield of RCH 791 and SP 7121 was underestimated and of Pancham 541 overestimated by the model (Table 7). The average percent error for biomass yield was found 8.5 (RCH 791), 0.5 (SP 7121) and 7.4 % (Pancham 541). The average percent error was 4.1(D1), 4.0(D2) and 17.4(D3). The biomass yield simulation was found good (±10.0%) for cotton for all cultivars and 1st and 2nd date of sowing, except 3rd date of sowing. Ortiz et al., (2009) also reported that calibrated coefficients improved the total biomass and boll weight predictions by 14.3% and 6.1%, respectively, when compared to the original default values.

**Seed cotton yield**

The seed cotton yield observed in field experiment for cv. Pancham 541, SP 7121 and RCH 791 were 18.2, 13.2 and 11.3 q/ha while
model simulated yield was 16.7, 13.6 and 11.5 q/ha, respectively (Table 7). The average percent error was within acceptable error limit in all the treatment except 1st week of June (D3) which was not within acceptable limit of the model. This shows that the evaluation of the model on an overall basis revealed that the simulated yield was good with an accepted level of percent error for cotton except 1st week of June (D3) sown crop. Also, these results are supported by finding of Soler et al., (2007) for maize and Singh et al., (1994) for groundnut yield and yield attributes simulated by PNUTGROW model.

In conclusion, genetic coefficients were evaluated and DSSAT Model was validated for cotton cultivars: Pancham 541, SP 7121 and RCH 791. The model performance in respect of phenology was found to be good for all the three cotton cultivars and for all the growing environments. Also the model performance was good for all the cultivars, 2nd and 3rd week of May sown crop in case of seed cotton yield, biomass and maximum LAI. But the model performance was not good for the crop sown in 1st week of June.

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