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# Evaluation of crop simulation modeling in chickpea crop using DSSAT model under agroclimatic conditions of eastern U.P.

**Vimal Pandey, AK Singh, SR Mishra, Gulab Singh, Krishna Deo and Adita Mishra**

## Abstract
A field experiment was conducted during *Rabi season of* 2011-12 to generate the ground truth data of chickpea crop at Agrometeorological Research Farm of N.D.U.A&T, of Kumarganj, Faizabad (U.P.). The experiment was conducted in split plot design and replicated 4 times. The treatments comprised of three dates of sowing viz. October 26th ($D_1$); November 10th ($D_2$) and November 25th ($D_3$) kept as main plot and three varieties viz. Pusa-362 ($V_1$); PG-186 ($V_2$) and Awarodhi ($V_3$) kept as sub plot. DSSAT crop growth simulation model overestimated the days taken to anthesis, first pod formation, first seed formation, days taken to physiological maturity, test weight, grain yield, straw yield and harvest index while model underestimated the leaf area index and biomass yield of chickpea crop. Lowest error % was recorded in timely sown crop of chickpea (October 26th) and error % increased with delay in sowing. Successive decrease of T max. and T min by $1^0$C over normal temperature increased the simulated grain yield of chickpea. Higher percent change 35.8% and 34.4% from base yield of 2340 $kg^{-1}$ was recorded with decrease of T max. and T min. respectively by 3 $^0$C over normal temperature obtained during the crop period.

**Keywords:** Chickpea, DSSAT, crop production, error, crop simulation model

## Introduction
Chickpea (*Cicer arietinum* L.) is one of the most important pulse crop of India. It is also known as Bengal gram / gram in English and is popularly called as *Chana* in Hindi. Chickpea requires cool and dry weather for optimum growth and development. Chickpea is a good source of protein (21.1%) carbohydrate (61.5%), fat (4.5%), minerals (calcium, phosphorus, iron) and vitamins. It is an excellent animal feed and its straw has good forage value. Pulse occupies an unique position in Indian agriculture by virtue of its high protein content and its capacity to enrich the soil fertility through the mechanism of symbiotic nitrogen fixations. It is a superb energy umbrella for the people as dietary protein, for the livestock as green nutritious fodder and feed and for the soil as a mini nitrogen plant and green manure.

**(**DSSAT) Decision Support System for Agrotechnology Transfer. **(**DSSAT) is comprehensive software developed by International Consortium for Agricultural Systems Applications. The software integrates crop, weather, soil and management practices to simulate growth and development of various crops in isolation as in a cropping sequence. DSSAT is a computerized system to help resource planners and farmers make decisions as they seek solutions to specific agricultural problems. It is a result of the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) project supported by the U.S. Agency for International Development from 1983 to1993. It has subsequently continued to be developed through collaboration among scientist, from the University of Florida, the University of Georgia, University of Guelph, University of Hawaii, the International Center for Soil Fertility and Agriculture Development, Iowa State University and scientists associated with ICASA.

DSSAT was designed so that users can (1) input, organize, store data on crops, soils, and weather, (2) retrieve, analyze and display data, (3) calibrate and evaluate crop growth models and (4) evaluate different management practices at a site. Input requirements for DSSAT include weather, soil condition, plant characteristics and crop management. The minimum weather input requirements of the model are daily solar radiation (MJ $m^{-2}d^{-1}$), maximum and minimum temperature ($^0$C) and precipitation (mm). Soil inputs include albedo, evaporation limit, mineralization, photosynthesis factors, pH, drainage and runoff coefficients.

The model also requires water holding characteristics, saturated hydraulic conductivity, bulk density and organic carbon for each individual soil layer. The model required calibrated genetic coefficients of desire crop and cultivar. Management input information includes plant population, planting depth, and date of planting. Latitude is required for calculating day length. The model simulates phenological development, biomass accumulation, and its partitioning, leaf area index, root, stem, leaf-growth, the water and N-balance from planting to harvest on daily or desired time steps.

## Material and Methods

Geographically, the experimental site is situated at $26^{0}47'$ N latitude, $82^{0}12'$ E longitude and at an attitude of 113 meters above mean sea level (MSL) in the Indo-gangetic plain. The site comes under sub tropical climate and often subjected to extremes of weather condition i.e. cold winter and hot summer. Faizabad district enjoys sub humid climate and received average annual rainfall about 1100 mm. On an average about 85 per cent of the total rainfall is received during South-West monsoon period i.e. from June to September. However, occasionally 5 to 10 per cent showers occurs during winter season. The experiments was laid out in split plot design (SPD). Nine treatment combinations comprised of three sowing date viz., October.26th ($D_1$), Nov. $10^{th}$ ($D_2$) and Nov. $25^{th}$ ($D_3$) were kept in main plot and three varieties viz., Pusa-362 ($V_1$), PG-186 ($V_2$) and Awarodhi ($V_3$) were kept as sub plot treatment.

The package and practices for cultivation was followed as per the recommendation of crop parameters such as yield and yield attributes, LAI, harvest index and phenology were used for calibration of the DSSAT ver 4.6 model. Various statistical and mathematical techniques for developing these relationships have been used as the term 'crop weather model'. Crop weather models may be defined as a simplified representation of the complex relationship between weather or climate on one hand and crop performance such as growth, yield or yield components on the other. Using mathematical/statistical/computational techniques in the simulation models used the biological soil (physical/ chemical) and micrometeorological systems are considered. To evaluate the performance of the DSSAT crop growth simulation model in chickpea, first of all it was calibrated with historical crop data. To determine the genetic coefficients of chickpea crop and varieties, the sensitivity test was approached by changing their values to determine the variation in the magnitude of output. For the normal sowing date and varieties each of the genetic coefficients was interactively increased/ decreased from the given value and the simulated values of the relevant growth and yield parameters were compared with the observed values. Then, those values of the genetic coefficients that was found most realistically simulated the growth and yield of chickpea were selected.

## Result and Discussion

### Days taken to anthesis

Calibration was done with the historical data of the year 2009-10 and 2010-11 for improving model tuning. It is obvious from the data presented in Table No.1 revealed that in validation error percent were recorded lowest in pusa-362 and PG-186 under Nov. $10^{th}$ sowing. It is also obvious from the data that Pusa-362 recorded lowest error percent over PG-186 and Awarodhi in Nov. $10^{th}$ sowing. While highest error percent was observed in delayed sowing of $25^{th}$ Nov. Error percent increased with delay in sowing. Model provides accurate prediction of days taken to anthesis in case of mid sown crop. The similar results were also obtained by Patel *et al.*, 1998 [6].

**Table 1:** Calibration of observed days taken to anthesis of chickpea from simulated values under different dates of sowing and varieties

| Date of sowing Year | Varieties | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pusa -362($V_1$) | | | PG-186 ($V_2$) | | | Awarodhi($V_3$) | | |
| | Obs. | Sim. | Error % | Obs. | Sim. | Err. % | Obs. | Sim. | Err. % |
| **2009-10** | | | | | | | | | |
| $D_1$ | 105 | 116 | 10.48 | 104 | 113 | 8.65 | 103 | 108 | 4.85 |
| $D_2$ | 102 | 110 | 7.84 | 102 | 111 | 8.82 | 101 | 103 | 1.98 |
| $D_3$ | 91 | 101 | 10.99 | 88 | 101 | 14.77 | 89 | 96 | 7.87 |
| **2010-11** | | | | | | | | | |
| $D_1$ | 104 | 114 | 9.62 | 105 | 114 | 8.57 | 102 | 109 | 6.86 |
| $D_2$ | 101 | 113 | 11.88 | 101 | 113 | 11.88 | 100 | 110 | 10.0 |
| $D_3$ | 89 | 96 | 7.87 | 87 | 100 | 14.94 | 90 | 94 | 4.44 |
| Validation of observed days taken to anthesis of chickpea from simulated values under different dates of sowing and varieties | | | | | | | | | |
| **2011-12** | | | | | | | | | |
| $D_1$ | 105 | 111 | 5.71 | 104 | 110 | 5.77 | 105 | 112 | 6.67 |
| $D_2$ | 102 | 106 | 3.92 | 102 | 107 | 4.90 | 103 | 111 | 7.77 |
| $D_3$ | 88 | 95 | 7.95 | 87 | 93 | 6.90 | 92 | 97 | 5.43 |

### Days taken to first pod formation

Data with regard to calibration and validation of simulated days taken to first pod formation from observed in chickpea varieties sown under different dates of sowing for the year 2009-10 to 2011-12. It is raveled from the table No 2. The days taken to first for formation of chickpea, during 2010-11 in Pusa-362 and in Awarodhi. While validating them during 2011-12, it is evident that lowest error percent in Pusa-362 was recorded under $26^{th}$ Oct. sown crop. Second date of sowing i.e. $10^{th}$ Nov. of Pusa-362 under stimated the model. Error percent increased with delay in sowing. Overall model overestimated days taken to first pod formation in all the varieties sown under different dates of sowing. Reddy *et al.*, 2000 [7] also observed.

**Table 2:** Calibration of observed days taken to first pod formation of chickpea from simulated values under different dates of sowing and varieties

| Date of sowing Year | Varieties | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pusa-362($V_1$) | | | PG-186 ($V_2$) | | | Awarodhi ($V_3$) | | |
| | Obs. | Sim. | Error % | Obs. | Sim. | Error % | Obs. | Sim. | Error % |
| **2009-10** | | | | | | | | | |
| $D_1$ | 115 | 125 | 8.70 | 116 | 127 | 9.48 | 113 | 121 | 7.08 |
| $D_2$ | 111 | 122 | 9.91 | 112 | 122 | 8.93 | 113 | 114 | 1.79 |
| $D_3$ | 102 | 110 | 7.84 | 97 | 108 | 11.34 | 101 | 109 | 7.92 |
| **2010-11** | | | | | | | | | |
| $D_1$ | 115 | 123 | 6.96 | 116 | 124 | 6.90 | 114 | 120 | 5.26 |
| $D_2$ | 111 | 119 | 7.21 | 112 | 117 | 4.46 | 111 | 118 | 6.31 |
| $D_3$ | 97 | 109 | 12.37 | 97 | 104 | 7.22 | 99 | 107 | 8.08 |
| Validation of observed days taken to first pod formation of chickpea from simulated values under different dates of sowing and varieties | | | | | | | | | |
| **2011-12** | | | | | | | | | |
| $D_1$ | 116 | 118 | 1.72 | 116 | 126 | 8.62 | 115 | 123 | 6.96 |
| $D_2$ | 113 | 112 | -0.88 | 114 | 119 | 4.39 | 113 | 125 | 10.62 |
| $D_3$ | 95 | 125 | 8.70 | 96 | 127 | 9.48 | 99 | 121 | 7.08 |

Where, $D_1$-26th October, $D_2$-10th November and $D_3$-25th November

### Leaf Area Index (LAI)

Error percentage was worked out between simulated and observed LAI of chickpea. It is obvious from the data presented in Table 3 reveal that in validation error percent in Pusa-362 ranged between -7.14 ($D_1V_1$); to -12.50 ($D_3V1$) during 2011-2012, there was no any specific trend in error per cent. Lowest error in Pusa-362 was recorded in timely sown and increased with delay in sowing. Overall model underestimated the LAI in all the dates of sowing with all the chickpea variety used under calibration and as well as validation. The similar results were obtained by Meena and Dahama, 2004 [5].

**Table 3:** Calibration of observed days taken to leaf area index of chickpea from simulated values under different dates of sowing and varieties

| Date of sowing Year | Varieties | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pusa -362($V_1$) | | | PG-186($V_2$) | | | Awarodhi ($V_3$) | | |
| | Obs. | Sim. | Error % | Obs. | Sim. | Err. % | Obs. | Sim. | Err. % |
| **2009-10** | | | | | | | | | |
| $D_1$ | 2.8 | 2.6 | -7.14 | 2.5 | 2.2 | -12.00 | 2.5 | 2.3 | -8.00 |
| $D_2$ | 2.3 | 2.2 | -4.35 | 2.6 | 2.4 | -7.69 | 2.3 | 2.1 | -8.70 |
| $D_3$ | 2.5 | 2.3 | -8.00 | 2.3 | 2.1 | -8.70 | 2.3 | 2.2 | -4.35 |
| **2010-11** | | | | | | | | | |
| $D_1$ | 2.8 | 2.5 | -10.71 | 2.5 | 2.8 | 12.00 | 2.6 | 2.4 | -7.69 |
| $D_2$ | 2.5 | 2.4 | -4.00 | 2.3 | 2.1 | -8.70 | 2.4 | 2.3 | -4.17 |
| $D_3$ | 2.4 | 2.2 | -8.33 | 2.3 | 2 | -13.04 | 2.4 | 2.2 | -8.33 |
| Validation of observed days taken to leaf area index of chickpea from simulated values under different dates of sowing and varieties | | | | | | | | | |
| **2011-12** | | | | | | | | | |
| $D_1$ | 2.8 | 2.6 | -7.14 | 2.5 | 2.3 | -8.00 | 2.6 | 2.4 | -7.69 |
| $D_2$ | 2.6 | 2.4 | -7.69 | 2.5 | 2.4 | -4.00 | 2.4 | 2.1 | -12.50 |
| $D_3$ | 2.4 | 2.1 | -12.50 | 2.3 | 2.1 | -8.70 | 2.3 | 2.1 | -8.70 |

### Seed yield (kg ha$^{-1}$)

Error percentage was worked out between simulated and observed seed yield (kg ha$^{-1}$) of chickpea. In calibration with historical data of year 2009-10 and 2010-11 error percent recorded in the order of Pusa-362 < PG-186 < Awarodhi. Lowest error percent obtained between simulated or observed seed yield was recorded in Pusa-362 sown on Nov.10th followed by PG-186 under same date of sowing. It is obvious from the data presented in Table No 4 revealed that in validation error percent in Pusa-362 ranged between 3.52($D_1V_1$) to 6.44 ($D_2V_1$) while in PG-186 it ranged between 6.42($D_1V_2$) to 10.37 ($D_3V_2$). Lowest error percent was recorded in timely sown crop (Oct 26th). Lowest error % during 2011-12 was recorded in $D_2V_3$ (Nov.10th sowing with Awarodhi) and % error in estimated yield increased with delayed sowing.

**Table 4:** Calibration of observed seed yield (kg ha$^{-1}$) of chickpea from simulated values under different dates of sowing and varieties

| Date of sowing Year | Varieties | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pusa -362($V_1$) | | | PG-186 ($V_2$) | | | Awarodhi ($V_3$) | | |
| | Obs. | Sim. | Error % | Obs. | Sim. | Error % | Obs. | Sim. | Error % |
| **2009-10** | | | | | | | | | |
| $D_1$ | 2273 | 2412 | 6.12 | 2040 | 2231 | 9.36 | 2130 | 2235 | 4.93 |
| $D_2$ | 2050 | 2134 | 4.10 | 1870 | 2013 | 7.65 | 1990 | 2251 | 13.12 |
| $D_3$ | 1870 | 2013 | 7.65 | 1760 | 1954 | 11.02 | 1820 | 2013 | 10.60 |
| **2010-11** | | | | | | | | | |
| $D_1$ | 2265 | 2413 | 6.53 | 2120 | 2251 | 6.18 | 2150 | 2245 | 4.42 |
| $D_2$ | 2070 | 2140 | 3.38 | 1835 | 1910 | 4.09 | 2015 | 2140 | 6.20 |
| $D_3$ | 1865 | 2015 | 8.04 | 1835 | 2013 | 9.70 | 1805 | 2013 | 11.52 |

| Validation of observed seed yield (kg ha$^{-1}$) of chickpea from simulated values under different dates of sowing and varieties | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2011-12 | | | | | | | | | |
| $D_1$ | 2270 | 2350 | 3.52 | 2010 | 2139 | 6.42 | 2105 | 2312 | 9.83 |
| $D_2$ | 2080 | 2214 | 6.44 | 1850 | 2037 | 10.11 | 2000 | 2014 | 0.70 |
| $D_3$ | 1180 | 1230 | 4.24 | 1716 | 1894 | 10.37 | 1814 | 2014 | 11.03 |

Overall the model overestimated the grain yield (kg ha$^{-1}$) in all the dates of sowing of the chickpea used under validation. The model provided accurate grain yield (kg ha$^{-1}$) estimation in case of mid sown (10$^{th}$ Nov.) with Awarodhi variety ($D_2V_3$). Therefore, the seed yield prediction of chickpea genotype (Pusa-362) can be termed as moderately good. The similar results also were obtained by Kumar *et al.*, 1999 [4].

## Harvest index (%)

Error percentage was worked out between simulated and observed harvest index (%) of chickpea in all the years. In calibration with crop data 2009-10 and 2010-11, the lowest error in HI was recorded in Oct 26$^{th}$ sown crop and it increased with subsequent delay in sowing. It is evident from the data presented in Table 5 reveal that in validation, error percent in Puas-362 ranged between -2.49 ($D_1V_1$) to13.68 ($D_3V_1$) during 2011-12. Model underestimated the HI of Pusa-362 under timely sown crop.

**Table 5:** Calibration of observed harvest index (%) of chickpea from simulated values under different dates of sowing and varieties

| Date of sowing Year | Varieties | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pusa-362($V_1$) | | | PG-186 ($V_2$) | | | Awarodhi ($V_3$) | | |
| | Obs. | Sim. | Error % | Obs. | Sim. | Error % | Obs. | Sim. | Error % |
| 2009-10 | | | | | | | | | |
| $D_1$ | 40.6 | 42.3 | 4.19 | 39.3 | 41.2 | 4.83 | 40.3 | 42.1 | 4.47 |
| $D_2$ | 39.7 | 43.2 | 8.82 | 38.5 | 43.7 | 13.51 | 39.4 | 41.3 | 4.82 |
| $D_3$ | 37.8 | 42.1 | 11.38 | 37.4 | 42.1 | 12.57 | 37.9 | 40.2 | 6.07 |
| 2009-10 | | | | | | | | | |
| $D_1$ | 41.4 | 42.8 | 3.38 | 40.9 | 43 | 5.13 | 41.1 | 43.2 | 5.11 |
| $D_2$ | 40.1 | 42.1 | 4.99 | 39.9 | 41 | 2.76 | 37.8 | 42.2 | 11.64 |
| $D_3$ | 38.2 | 41.2 | 7.85 | 37.4 | 42.5 | 13.64 | 37.6 | 41 | 9.04 |
| Validation of observed harvest index (%) of chickpea from simulated values under different dates of sowing and varieties | | | | | | | | | |
| 2011-12 | | | | | | | | | |
| $D_1$ | 41.2 | 40.2 | -2.43 | 40.0 | 40.8 | 2.00 | 40.0 | 43.2 | 8.00 |
| $D_2$ | 39.8 | 41.6 | 4.52 | 37.3 | 42 | 12.60 | 39.8 | 42 | 5.53 |
| $D_3$ | 38.0 | 43.2 | 13.68 | 37.2 | 41.6 | 11.83 | 38.0 | 43.2 | 13.68 |

There was no any specific trend in error per cent observed in the varieties of different dates of sowing. Lowest error percent in PG-186 was recorded in $D_1V_2$ (Oct. 26$^{th}$) and increased with delay in sowing (Hoogenboom, 2000) [3].

## Conclussion

DSSAT crop growth simulation model overestimated the days taken to anthesis, first pod formation, first seed formation, days taken to physiological maturity, Test weight, yields, and harvest index while model underestimated the leaf area index and biomass yield of chickpea crop. Therefore the model can be used for predicting chickpea yield and phenological events under agroclimatic conditions of eastern U.P.

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