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# Evaluation of the DSSAT Crop Growth Model with Maize (*Zea mays* L.) Cultivars Validated for NEPZ Region of Eastern U.P. India

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**A B S T R A C T**

A field experiment was conducted during *Kharif* 2011 to generate the ground truth data of maize crop at Crop Research Station Bahraich of N.D.U.A&T, Kumarganj, Faizabad (U.P.) as to assess the "Evaluation of the DSSAT Crop Growth Model with Maize (Zea mays L.) Cultivars Validated for NEPZ Region of Eastern U.P." The experiment was conducted in Split Plot Design. The treatment comprised of three dates of sowing viz. 20$^{th}$ June ($D_1$), 30$^{th}$ June ($D_2$) and 10$^{th}$ July 2011 ($D_3$) kept as main plot with three varieties viz. Seed Tech -940 ($V_1$), ProAgro-4212 ($V_2$) and HQPM-1 ($V_3$) kept as sub plot. The historical field crop data of year 2009 and 2010 were used for calibration and validation in addition to field crop data of year 2011. The performance of model tested using SD and RMSE. Result reveal that The simulated grain yield and phenological events were close to observed values in timely sown crop suggested that the simulated yield were well within the accepted limits, therefore the model can be used for predicting maize yield and days taken to phenological stages in north eastern U.P.

## Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops in the world agricultural economy both as food for man and feed for animals. It is grown almost all over the world under various agro-climatic conditions. Over 85% of maize production in the country is consumed as human food. It holds third place in cropped area among the cereals in the world with the average yield of 30-32 q ha$^{-1}$ in India. It occupies an area of about 7.32 m ha with the production of 14.93 m tones and productivity of 2039 kg ha$^{-1}$ (Anonymous, 2010). In Uttar Pradesh, it covers an area of 5.0 m ha with production of 80 tons and productivity of 1600kg ha$^{-1}$ (U.P. Agriculture Statistics). Several foods dishes including "Chapaties" are prepared from its flour and grains. Green cobs are roasted and eaten by people.

It is also a good feed for consumption of poultry, piggery and other animals. Maize grain has fairly good source of vitamin A, vitamin B complex, phosphorus, nicotinic acid and riboflavin. Agriculture will have to meet rising demands for food, feed, fiber, and fuel over the course of the current century while satisfying constraints with respect to product safety, the landscape, and the environment (Spiertz, 2010). Crop growth models will become essential tools for optimizing agriculture production with regard to environmental forcing conditions while facing these growing challenges. Crop growth models predict yield potential and nitrogen and water use under given climatic conditions and account for growth-limiting factors such as drought, heat, and frost (Gonzalez-Dugo *et al.*, 2010). Crop growth models can be used to refine management practices, especially for fertilizer usage and timing, by simulating crop productivity in response to regionally observed climatic variations (Singh *et al.*, 2008). For producers and crop insurance companies, crop models can be used to explain and gage the main abiotic-limiting factors leading to crop yield reduction. The basic spatial scale of most crop models is the homogeneous field plot unit (CERES, Ritchie and Otter 1984; EPIC, Williams *et al.*, 1984; CropSyst, Stockle *et al.*, 1994; STICS, Brisson *et al.*, 1998, 2002, 2003; DSSAT, Jones *et al.*, 2003). However, there are advantages to analyzing an agricultural system from a regional perspective. Indeed, agricultural recommendations and policies defined to address future agriculture challenges are generally implemented at the regional level. Using crop models over a region is helpful for estimating productivity, environmental impact, and water needs for agriculture and thus refining land use and crop rotation sequences accordingly. Regional crop modelling requires input data on soil, weather from national or regional databases, and management practices, data that are not always readily available. Information on management practices can to some extent be derived from multitemporal remote sensing observations. Because crop classification will not give any insight into the kind of cultivars being planted, the definition, calibration, and evaluation of a minimal set of generic cultivars in the crop growth model can be helpful for regional modeling.

## Materials and Methods

The experiment was conducted at Agronomy Research Farm of N.D university of Agriculture & Technology, Kumarganj, Faizabad (UP). on the topic entitled "Evaluation of the DSSAT Crop Growth Model with Maize (Zea mays L.) Cultivars Validated for NEPZ Region of Eastern U.P." It is situated on Faizabad-Raibareily road at the distance of 42km from Faizabad district head quarter. Geographically experimental site falls under sub-tropical climate of Indo-gangetic plains having alluvial soil and is located at 26° 47' N latitude and 82° 12' E longitude and at an altitude of 113 meters above mean sea level. The details of materials and methods employed and techniques adopted during the course of experimentation have been described in this experiment. The experiment was conducted in Split Plot Design (SPD) and replicated the four times. The different growth parameters studied were maize as anthesis, physiological maturity, LAI, test weight.

## Results and Discussion

Validation of simulated days taken to anthesis from observed in maize varieties sown during different dates of sowing for the year 2009 to 2011 are presented in Table 1. Error percentage worked out between simulated and observed days taken to anthesis of maize. It is evident from the data presented in Table 2 revealed that error % ranged between 1.37 ($D_3V_1$) to 15.79 ($D_3V_3$); -2.99 ($D_3V_1$) to 16.67 ($D_2V_1$) and -3.70 ($D_3V_2$) to 16.42 ($D_2V_1$) during 2009, 2010 and 2011 respectively. There was no any specific trend in error per cent observed in different dates of sowing in varietal treatments in all the years of estimation in all the varieties under different dates of sowing. Lowest error (4.17%) during year 2011 was recorded in $D_1V_1$ (July $10^{th}$ sown with Pro-Agro-4212). Overall lowest error % was recorded in $V_1$. Overall, model overestimated the days taken anthesis in all the dates of sowing of the maize used under study. Overall, the lowest error % was recorded in $V_1$ as compared to $V_2$ and $V_3$ variety sown under different dates of sowing conclusively, the model provides a mean error value of 7.15, 7.71, 9.41% in $V_1$, $V_2$ and $V_3$ variety respectively. The SD was 7.3, 5.66 and 6.33 days with RMSE value 6.78, 6.67 and 7.93 days in $V_1$, $V_2$ and $V_3$ variety respectively.

Validation of simulated days taken to physiological maturity from observed in maize varieties sown in different dates of sowing for the year 2009 to 2011 are presented in Table 2. Error percentage worked out between simulated and observed days taken to physiological maturity of maize. It is evident from the data presented in Table 3 revealed that error % ranged between 3.77 ($D_1V_2$) to 15.84 ($D_3V_3$); -0.99 ($D_2V_3$) to 11.76 ($D_3V_1$) and 1.87 ($D_1V_2$) to 18.63 ($D_2V_1$) during the year 2009, 2010 and 2011 respectively. There was no any specific trend in error per cent were observed in different dates of sowing in $V_2$ and $V_3$ varietal treatments during 2010, in all the varieties under different dates of sowing. Lowest error % during 2011 was recorded in $D_1V_2$ (Pro-Agro 4212 sown on 20$^{th}$ June) and accuracy decreased with delay in sowing. Overall lowest error % was recorded in $V_2$ (Pro-Agro 4212) sown under different dates of sowing.

Overall, model overestimated the days taken to physiological maturity in all the dates of sowing of the maize used under study. Overall, the lowest error % was recorded in $V_2$ as compared to $V_3$ and $V_1$ variety sown under different dates of sowing conclusively, the model provides a mean error value of 10.95, 5.87, 7.13% in $V_1$, $V_2$ and $V_3$ variety respectively. The SD was 4.48, 4.10 and 4.90 days with RMSE value 12.01, 7.15 and 8.98 days in $V_1$, $V_2$ and $V_3$ variety respectively.

**Table.1** Validation of simulated days taken to anthesis from observed in maize varieties

| Date of sowing Year 2009 | Varieties | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Seed Tech-940($V_1$) | | | Pro Agro-4212($V_2$) | | | HQPM-1($V_3$) | | |
| | Obs. | Sim. | Error % | Obs. | Sim. | Error % | Obs. | Sim. | Error % |
| $D_1$ | 71 | 78 | 9.86 | 69 | 77 | 11.59 | 68 | 77 | 13.24 |
| $D_2$ | 67 | 73 | 8.96 | 68 | 69 | 1.47 | 68 | 75 | 10.29 |
| $D_3$ | 73 | 74 | 1.37 | 78 | 86 | 10.26 | 76 | 88 | 15.79 |
| Year 2010 | | | | | | | | | |
| $D_1$ | 73 | 79 | 8.22 | 71 | 78 | 9.86 | 67 | 74 | 10.45 |
| $D_2$ | 66 | 77 | 16.67 | 68 | 76 | 11.76 | 67 | 65 | -2.99 |
| $D_3$ | 74 | 69 | -6.76 | 76 | 81 | 6.58 | 77 | 78 | 1.30 |
| Year 2011 | | | | | | | | | |
| $D_1$ | 72 | 75 | 4.17 | 70 | 80 | 14.29 | 69 | 78 | 13.04 |
| $D_2$ | 67 | 78 | 16.42 | 69 | 74 | 7.25 | 69 | 75 | 8.70 |
| $D_3$ | 73 | 77 | 5.48 | 81 | 78 | -3.70 | 74 | 85 | 14.86 |
| Mean | | | 7.15 | | | 7.71 | | | 9.41 |
| SD | | | 7.30 | | | 5.66 | | | 6.33 |
| RMSE | | | 6.78 | | | 6.67 | | | 7.93 |

Where, $D_1$=20$^{th}$ June, $D_2$=30$^{th}$ June and $D_3$=10$^{th}$ July

**Table.2** Validation of simulated days taken to physiological maturity from Observed in maize varieties

| Date of sowing | Varieties | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Seed Tech-940($V_1$) | | | Pro Agro-4212($V_2$) | | | HQPM-1($V_3$) | | |
| Year 2009 | Obs. | Sim. | Error % | Obs. | Sim. | Error % | Obs. | Sim. | Error % |
| $D_1$ | 103 | 108 | 4.85 | 106 | 110 | 3.77 | 106 | 112 | 5.66 |
| $D_2$ | 101 | 110 | 8.91 | 97 | 112 | 15.46 | 102 | 110 | 7.84 |
| $D_3$ | 102 | 118 | 15.69 | 108 | 115 | 6.48 | 101 | 117 | 15.84 |
| Year 2010 | | | | | | | | | |
| $D_1$ | 105 | 115 | 9.52 | 108 | 113 | 4.63 | 107 | 111 | 3.74 |
| $D_2$ | 102 | 112 | 9.80 | 104 | 111 | 6.73 | 101 | 100 | -0.99 |
| $D_3$ | 102 | 114 | 11.76 | 107 | 112 | 4.67 | 105 | 109 | 3.81 |
| Year 2011 | | | | | | | | | |
| $D_1$ | 104 | 110 | 5.77 | 107 | 109 | 1.87 | 108 | 115 | 6.48 |
| $D_2$ | 102 | 121 | 18.63 | 106 | 108 | 1.89 | 104 | 116 | 11.54 |
| $D_3$ | 103 | 117 | 13.59 | 109 | 117 | 7.34 | 106 | 118 | 10.28 |
| Mean | | | **10.95** | | | **5.87** | | | 7.13 |
| SD | | | **4.48** | | | **4.10** | | | 4.96 |
| RMSE | | | 12.01 | | | 7.15 | | | 8.98 |

Where, $D_1$=20th June, $D_2$=30th June and $D_3$=10th July

**Table.3** Validation of simulated LAI from observed in maize varieties

| Date of sowing | Varieties | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Seed Tech-940($V_1$) | | | Pro Agro-4212($V_2$) | | | HQPM-1($V_3$) | | |
| Year 2009 | Obs. | Sim. | Error % | Obs. | Sim. | Error % | Obs. | Sim. | Error % |
| $D_1$ | 4.1 | 3.8 | -7.32 | 3.7 | 3.2 | -13.51 | 3.5 | 3.4 | -2.86 |
| $D_2$ | 4.0 | 3.5 | -12.50 | 3.5 | 3.0 | -14.29 | 3.4 | 3.2 | -5.88 |
| $D_3$ | 3.8 | 3.2 | -15.79 | 3.6 | 3.5 | -2.78 | 3.3 | 3.0 | -9.09 |
| Year 2010 | | | | | | | | | |
| $D_1$ | 4.3 | 4.1 | -4.65 | 3.8 | 3.4 | -10.53 | 3.8 | 3.1 | -18.42 |
| $D_2$ | 4.1 | 4.0 | -2.44 | 3.6 | 3.1 | -13.89 | 3.5 | 3.2 | -8.57 |
| $D_3$ | 3.9 | 3.2 | -17.95 | 3.5 | 3.0 | -14.29 | 3.2 | 3.1 | -3.13 |
| Year 2011 | | | | | | | | | |
| $D_1$ | 4.2 | 4.0 | -4.76 | 3.9 | 3.2 | -17.95 | 3.7 | 3.2 | -13.51 |
| $D_2$ | 3.9 | 3.1 | -20.51 | 3.7 | 3.6 | -2.70 | 3.4 | 3.6 | 5.88 |
| $D_3$ | 3.5 | 3.2 | -8.57 | 3.4 | 3.5 | 2.94 | 3.1 | 3.0 | -3.23 |
| Mean | | | **-10.50** | | | **-9.67** | | | -6.53 |
| SD | | | **6.46** | | | **7.07** | | | 6.99 |
| RMSE | | | 0.47 | | | 0.43 | | | 0.33 |

Where, $D_1$=20th June, $D_2$=30th June and $D_3$=10th July

**Table.4** Validation of simulated test weight (g) from observed in maize varieties

| Date of sowing Year 2009 | Varieties | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Seed Tech-940($V_1$) | | | Pro Agro-4212($V_2$) | | | HQPM-1($V_3$) | | |
| | Obs. | Sim. | Error % | Obs. | Sim. | Error % | Obs. | Sim. | Error % |
| $D_1$ | 224 | 225 | 0.45 | 235 | 245 | 4.26 | 226 | 234 | 3.54 |
| $D_2$ | 223 | 235 | 5.38 | 234 | 230 | -1.71 | 225 | 230 | 2.22 |
| $D_3$ | 221 | 243 | 9.95 | 233 | 243 | 4.29 | 224 | 228 | 1.79 |
| **Year 2010** | | | | | | | | | |
| $D_1$ | 226 | 236 | 4.42 | 237 | 254 | 7.17 | 227 | 245 | 7.93 |
| $D_2$ | 225 | 243 | 8.00 | 234 | 230 | -1.71 | 225 | 243 | 8.00 |
| $D_3$ | 223 | 234 | 4.93 | 232 | 237 | 2.16 | 224 | 234 | 4.46 |
| **Year 2011** | | | | | | | | | |
| $D_1$ | 225 | 228 | 1.33 | 239 | 243 | 1.67 | 228 | 230 | 0.88 |
| $D_2$ | 224 | 243 | 8.48 | 237 | 233 | -1.69 | 225 | 231 | 2.67 |
| $D_3$ | 221 | 230 | 4.07 | 232 | 234 | 0.86 | 221 | 226 | 2.26 |
| **Mean** | | | **5.23** | | | **1.70** | | | **3.75** |
| **SD** | | | 3.18 | | | 3.14 | | | 2.60 |
| **RMSE** | | | **13.43** | | | **8.04** | | | **10.09** |

Where, $D_1$=20[th] June, $D_2$=30[th] June and $D_3$=10[th] July

Validation of simulated LAI from observed in maize varieties sown in different dates of sowing for the year 2009 to 2011 are presented in (Table 3). Error percentage worked out between simulated and observed LAI of maize. It is evident from the data presented in Table 4 revealed that error % ranged between -2.78 ($D_3V_2$) to -15.79 ($D_3V_1$); -2.44 ($D_2V_1$) to -18.42 ($D_1V_3$) and -2.70 ($D_2V_2$) to 5.88 ($D_2V_3$) during 2009, 2010 and 2011 respectively. There was no any specific trend in error per cent were observed in different dates of sowing and varietal treatment during 2011, in all the varieties under different dates of sowing. Lowest error % during 2011 was recorded in June 30[th] ($D_2V_2$) sown on Pro Agro-4212. During 2009 the overall, lowest error % was recorded in timely sown crop (20[th] June) and increased with delay in sowing. Overall, model underestimated LAI in all the dates of sowing of the maize variety during year 2009 and 2010, while during year 2011 model overestimated the LAI. Overall, model overestimated the leaf area index in all the dates of sowing of the maize used under study. Overall, the lowest error % was recorded in $V_3$ as compared to $V_2$ and $V_1$ variety sown under different dates of sowing conclusively, the model provides a mean error value of -10.50, -9.67 and -6.53 in $V_1$, $V_2$ and $V_3$ variety respectively. The SD was 6.46, 7.07 and 6.99 days with RMSE value 0.47, 0.43 and 0.33 days in $V_1$, $V_2$ and $V_3$ variety respectively.

Validation of simulated test weight (g) from observed in maize varieties sown in different dates of sowing for the year 2009 to 2011 are presented in Table 4. Error percentage worked out between simulated and observed test weight (g) of maize. It is evident from the data presented in Table 4 revealed that error % ranged between -1.71 ($D_2V_2$) to 9.95 ($D_3V_1$); -1.71 ($D_2V_2$) to 8.0 ($D_2V_3$) and -1.69 ($D_2V_2$) to 8.48 ($D_2V_1$) during 2009, 2010 and 2011 respectively. There was no any specific trend in error per cent were observed in different dates of sowing and varietal treatment during 2011, in all the varieties under different dates of sowing. Lowest error % during 2009 was recorded in

$D_1V_1$ (June 20th) in Seed Tech-940 and increased with delay in sowing. Overall, model overestimated the test weight (g) in all the dates of sowing of the maize variety used under validation. Overall, model overestimated the test weight (g) in all the dates of sowing of the maize used under study. Overall, the lowest error % was recorded in $V_2$ as compared to $V_3$ and $V_1$ variety sown under different dates of sowing conclusively, the model provides a mean error value of 5.23, 1.70 and 3.75 in $V_1$, $V_2$ and $V_3$ variety respectively. The SD was 3.18, 3.14 and 2.60 with RMSE value 13.43, 8.04 and 10.09 days in $V_1$, $V_2$ and $V_3$ variety respectively.

It is concluded that study in DSSAT crop growth simulation model overestimated the days taken to anthesis, days taken to physiological maturity and test weight of maize crop grown in region. While model underestimated the leaf area index of maize crop. Lowest error % was recorded in timely sown crop of maize (June 20th) with Pro Agro-4212 variety ($D_1V_2$) and error % increased with delay in sowing.

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