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Seasonal Influence on Yield of Maize and Its Validation with CERES-Maize Model

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ABSTRACT

It would be preferable to use a reliable crop growth model for studies on climate change impact assessment. The objectives of this study were to evaluate simulation performance for models CERES-Maize included in the DSSAT model (version 4.5) in terms of yield. Three hybrids D.S 900M, Pinnacle and CP818 were grown under four dates June II FN, July I FN, July II FN and August I FN during kharif season, 2016 at S.V. Agricultural college, Tirupati to study the 'Seasonal influence on yield of maize and its validation with CERES-Maize model'. The results indicated that among the hybrids Pinnacle recorded numerically higher yield (3006.58 kg ha^{-1}) than D.S 900 M but was significantly higher than CP818. Among the dates of sowing D_1 (June II FN) recorded significantly higher yield (3684.36 kg ha^{-1}) than D_2, D_3 and D_4. CERES Maize model validated excellent for grain yield. The simulated and observed yields are within the bounds of experimental uncertainity. CERES Maize model v.4.5 can be used to forecast maize yield in Southern agro-climatic conditions.

Introduction

Climate change is a global phenomenon and has now emerged as one of the most burning environmental issue to confront the humanity. The fifth assessment report of Intergovernmental Panel on Climate Change (IPCC, 2013) makes it clear that the global average temperature has increased by 0.74^{o}C over the last 100 years and projected increase is about 1.8 to 4.0^{o}C by 2100.

Maize growth is affected by temperature conditions during vegetative and reproductive stages (Hardacre and Turnbull, 1986). Under future climate conditions, e.g., at the end of 21st century, temperatures during growing seasons in the tropic and subtropics would exceed the most extreme temperatures recorded at present.

High temperature during the reproductive stage would reduce the number of kernels per ear because the number of ovules that could have been fertilized and developed into kernels would decrease result in the decline of crop yield and quality (Schoper *et al.*, 1987).

To better understand the responses of crops to their environments, computer models are being used to study both the simple and complex aspects of this plant system. Crop growth and yield are the outcomes of complicated interactions between plant and environments including soil and weather, which makes it challenging to assess the seasonal impacts on crop growth and yield through field experiments.

Crop growth simulation models facilitate quantitative understanding of the effects of environmental factors and agronomic management on crop growth and yield. Crop simulation models have been used for many different applications in various countries around the world. A well validated crop simulation model can simulate crop growth, development and yield with accuracy. It also serves as a viable tool for optimizing crop production. The Decision Support System for Agro technology Transfer (DSSAT v 4.5) is a comprehensive decision support system (Hoogenboom *et al.,* 2010) that includes the CERES-Maize model (Jones *et al.,* 2003).

Materials and Methods

Keeping above in view, a field experiment was conducted during *kharif* 2016 at S.V Agricultural College, Tirupathi to study the 'Seasonal influence on phenology and growing degree days in relation to yield of maize and its validation with CERES-Maize model.' The soil of the experimental site was sandy loam in texture, neutral in soil reaction, low in available nitrogen and organic carbon, high in phosphorus and medium in potassium. The experiment was laid out in a split plot design with twelve treatments and replicated thrice. Three maize hybrids D.S 900M, Pinnacle and CP818 with four dates of sowing (June II FN, July I FN, July II FN and August I FN).

For Validation the Decision supporting system for Agro-technology Transfer (DSSAT) v4.5 CERES-Maize model was used. DSSATv4.5 is an upgrade model of technology DSSAT v4.0. DSSAT v4.5 is MS Window-based model. The preferred operating system is Windows XP. Performance of the model was evaluated using absolute and normalized root mean square error (RMSE and NRMSE), and the Wilmot d index (Willmott *et al.,* 1985).

Results and Discussion

Kernel yield and growing degree days

The results revealed that Kernel yield and GDD accumulation was higher in case of Pinnacle (3006.6 kg/ha, 3053.3°C) followed by D.S 900M (2748.9 kg/ha, 3049.1°C) and CP818 (2678.4 kg/ha, 2994.1°C) respectively. Therefore Pinnacle performance was superior to D.S 900M and CP818 (Table 1). The shifting of sowing dates corresponds to fluctuations in temperatures either lengthening or shortening of the growing periods. Among the dates of sowing D1 (June II FN) recorded highest kernel yield and GDD (3684 kg/ha, 3170.4°C) followed by D2, D3 (July II FN) and D_4 recorded lowest kernel yield and GDD (1724 kg/ha, 2079.6°C).

Early sowing (June II FN) significantly influenced the yield of maize than subsequent dates of sowing because of higher accumulation of heat units. Delay in sowing resulted in reduction of kernel yield which might be due to minimum accumulation of heat units. Therefore the Second fortnight of June is always better to avoid abiotic stress and biotic stress problems in maize. Similar variability was also reported by Pandey *et al.,* (2010), Girijesh *et al.,* (2011) and Ahmad *et al.,* (2016).

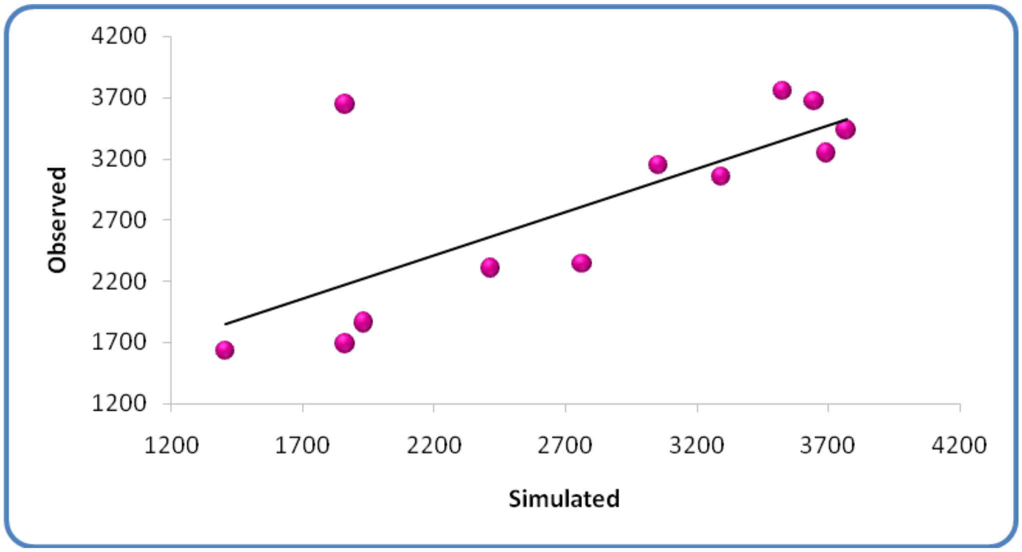
Table.1 Comparison of kernel yield and growing degree days of maize

Treatments		
	Kernel yield (kg/ha)	**Growing degree days**
Hybrids		
H_1 : D.S 900M	2748.9	3049.1
H_2 : Pinnacle	3006.6	3053.3
H_3 : CP818	2678.4	2994.7
CD (P=0.05)	304.7	-
Dates of Sowing		
D_1 : June II FN	3684.4	3170.4
D_2 : July I FN	3207.7	2990
D_3 : July II FN	2628.8	2920.8
D_4 : August I FN	1724.3	2079.6
CD(P=0.05)	238.8	-

Table.2 Comparison of simulated and observed grain yield (kg ha^{-1}) in maize

Treatment	Simulated	Observed	Error (%)
D.S 900M (H_1)			
D_1 : June II FN	3529	3748	-5.8
D_2 : July I FN	3294	3048	8.1
D_3 : July II FN	2766	2339	18.3
D_4 : August I FN	1935	1860	4
Pinnacle (H_2)			
D_1 : June II FN	3647	3666	-0.5
D_2 : July I FN	3769	3430	9.9
D_3 : July II FN	3693	3244	13.8
D_4 : August I FN	1863	1686	10.5
CP818 (H_3)			
D_1 : June II FN	1864	3640	-1.4
D_2 : July I FN	3055	3145	-2.9
D_3 : July II FN	2417	2302	5
D_4 : August I FN	1407	1626	-13.5
Average	**2769.92**	**2811.7**	
Sd±	**846.1**	**802.8**	
Test parameter			
MBE	-102		
MAE	202		
RMSE	244.3		
NRMSE	8.6		
d-stat	0.9		

Fig.1 Simulated vs observed values for grain yield (kg ha^{-1}) of maize hybrids at different dates of sowing



Validation with CERES –maize model

Using the data obtained from the field experiments conducted during *kharif*, 2016. The experimental file (AGCG1601MZ), weather file (AGCG2016), soil file (AGCG060016) were created for CERES-Maize validation. The crop genetic coefficients already developed for the three hybrids were also used as input for CERES-Maize validation v 4.5.

Grain yield (kg ha^{-1})

The data on grain yield (kg ha^{-1}) was computed at all the treatments of maize Table 2 and Figure 1. The results showed that grain yield of maize varied from 3748 kg ha^{-1} (June II FN, D.S 900M) to 1626 kg ha^{-1} (August I FN, CP818) while the model simulated grain yield ranged from 3769 kg ha^{-1} (July I FN, Pinnacle) to 1407 kg ha^{-1} (August I FN, CP818).

The percent error between simulated and observed yield ranged from -0.5 (June II FN, Pinnacle) to 18.3 (July II FN, D.S 900M). The error percentage between simulated and observed for kernel yield was lower at First and second dates of sowing (June II FN and July I FN) for all the hybrids compared to third and fourth date of sowing (July II FN and August I FN). Evaluation of the model showed that observed mean yield was 2811.2 ± 802.8 during the crop season while the simulated mean yield was 2769.9 ± 846.1. The MAE computed was found 202 and the RMSE was 244.3 kg ha^{-1} which shows reasonably good agreement with the observed values.

During the crop growth season simulation can be considered excellent with NRMSE values being less than 10 per cent. The d-index value was 0.99 indicating that the model was able to simulate grain yield well within the bounds of experimental uncertainity. Similar variability was also reported by Tojoseller *et al.*, (2007), Ramawath *et al.*, (2012) and Leela *et al.*, (2014).

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