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Short Communication

Application of CROPGRO-Cotton model to optimize irrigation scheduling in Bt cotton on alfisols of Southern Telangana

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Crop models are being extensively used by researchers and policy makers as important decision making tools for studying the impacts of climate change, management practices, and irrigation strategies on crop yields across the globe (Thorp *et al.,* 2014a). Field experiments in these research areas are resource-intensive and challenging to implement. Under these circumstances, calibrated and validated crop models offer alternative solutions with comparable outcomes. The Decision Support System for Agrotechnology Transfer (DSSAT) (Hoogenboom *et al.,* 2012) crop models are complex, as they require many input parameters to provide in-depth assessments of crop growth and development and water and nutrient dynamics. The Cropping System Model (CSM) CROPGRO-Cotton model simulates crop growth and development in response to weather conditions, soil properties, cultivar characteristics, and crop management practices.

Thorp *et al.* (2014b) evaluated the CSM-CROPGRO-Cotton model and the results indicated that the model demonstrated appropriate responses to water deficit, nitrogen deficit, planting density and CO_2 enrichment. In rice, CERES-Rice model predicted the yield very close and was very effective to predict the phenological stages with high R^2 and d-Stat values indicated that model can be effectively used for yield prediction of the rice varieties (kamalkanth *et al.,* 2018). Crop simulation models have been used to study the effect of intra-seasonal variation in temperature on yield of wheat in India (Sandhu *et al.,* 2016); Patil *et al*. 2018a; Patil *et al*. 2018b) have reported the effect of intra-seasonal variation of temperature on tuber yield of potato and seed yield of pigeonpea in Gujarat using DSSAT group of models. All the studies reported the importance of calibrating the CSM-CROPGRO-Cotton model for particular cultivars and growing regions for successful model implementation.

Cotton (*Gossypium hirsutum* L.), is one of the major cash crops of India, grown in an area of 12.59 million ha with a productivity of 500 kg lint ha^{-1}, which is below the world's average of 619 kg ha^{-1} during 2017-18. Telangana is a major cotton growing state cultivating in an area of 1.89 million ha, mostly under rainfed condition with a production of 5.50 million bales and productivity of the 494 kg lint ha^{-1} during 2017-18.

Water and nitrogen are the key inputs for improving the cotton productivity, which must be used in most efficient manner to sustain the cotton productivity at higher level. Data collection for many years through field experimentation is time consuming and more expensive. Since the farmers of Southern Telangana region are economically poor and growing crop fully dependent on varied rainfall situations. Under these circumstances, calibrated and validated model in cotton helpful in taking tactical decisions by the extension specialists and policy makers for the betterment of the cotton farmers. Keeping this in view, a field experiment was carried out to calibrate and validate CROPGRO-Cotton model at Agricultural Research Institute, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad during *kharif* seasons of 2014 and 2015 in split plot design with three irrigation levels (I_1- 0.8 IW/CPE, I_2- 0.4 IW/CPE and I_3 - Rainfed) as main plots and four nitrogen levels (N_1- 0 kg ha^{-1}, N_2 - 75 kg ha^{-1}, N_3 - 150 kgha^{-1} and N_4 - 225 kg ha^{-1}) as sub plot treatments replicated thrice using cotton cultivar Mallika BG II sown at a spacing of 90 cm X 60 cm. Observations on plant height, occurrence of phenophases, leaf area index, above ground biomass production, amount of irrigation water, yield attributes and yield were recorded. For this study, the CSM-CROPGRO-Cotton model was chosen due to its successful application for different cropping systems under different climatic conditions by various researchers across the globe. The CSM-CROPGRO-Cotton model works by calculating various rate variables on a daily time step, integrating the

Table 1: Tukey's test (HSD) for seed cotton yield (kg ha^{-1}) under different irrigation levels

Depletion of available soil moisture (%) at 30 cm depth	Mean seed cotton yield (kg ha^{-1})	Mean above ground biomass (kg ha^{-1})	Mean nitrogen productivity (kg SCY/ kg N)	Mean water use efficiency (kg ha^{-1} mm^{-1})
30% DASM	1857a	2838a	12.32a	2.6a
40% DASM	1850a	2828a	12.27a	2.5ab
50% DASM	1837ab	2810a	12.19ab	2.4ab
20% DASM	1835ab	2805ab	12.17ab	2.2bc
60% DASM	1747ab	2661ab	11.59ab	2.0cd
10% DASM	1742ab	2660ab	11.54ab	1.7d
70% DASM	1698b	2580b	11.27b	1.3e

Note: Means with the same letter are not significantly different

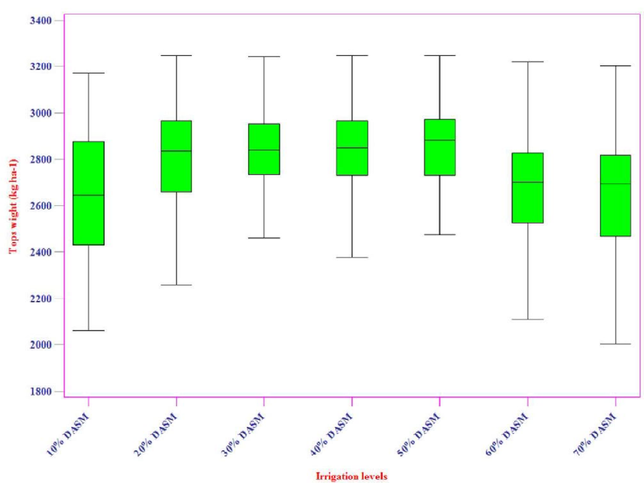

Fig. 1: Simulated above ground biomass (kg ha^{-1}) of cotton at harvest under different irrigation levels. Box limits represent the 25th and 75th percentiles, box central line represents the median, and whiskers represent the minimum and maximum values

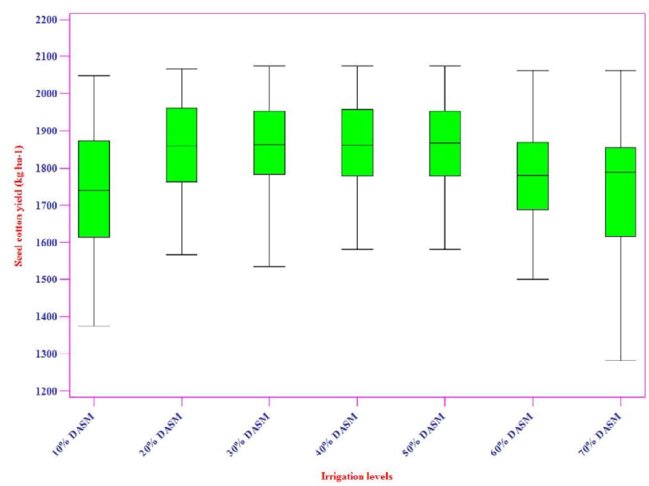

Fig. 2: Simulated seed cotton yield (kg ha^{-1}) under different irrigation levels. Box limits represent the 25th and 75th percentiles, box central line represents the median, and whiskers represent the minimum and maximum values

model state variables over time, and finally updating the state variables (Jones *et al.,* 2003).

The weather input data was collected from agrometeorological observatory, Agricultural Research Institute, Rajendranagar. The soil samples from the experimental field were collected on soil physical and chemical characteristics described layer wise used in the model as soil input.

The model was calibrated using observed data on phenology and yield components from the experiments conducted at Agricultural Research Institute, Rajendranagar, Hyderabad during the years 2011 to 2013. A manual calibration approach was followed in which sensitive model parameters were adjusted and their effects on modeled processes were studied by visually comparing simulated versus observed crop growth and yield data and simultaneously assessing the model performance statistics. Three different statistical parameters, including root mean square error (RMSE) (Willmott, 1982), normalised RMSE (NRMSE) (Loague and Green, 1991) and coefficient of agreement (Willmott, 1981) were used to assess the performance of the CSM-CROPGRO-Cotton model.

To check the accuracy of model simulations it was validated with data recorded for three irrigations and four nitrogen levels during the year 2014 and 2015. During all this process available data on anthesis date, maturity date, yield components, seed cotton yield and total crop biomass was compared with simulated values.

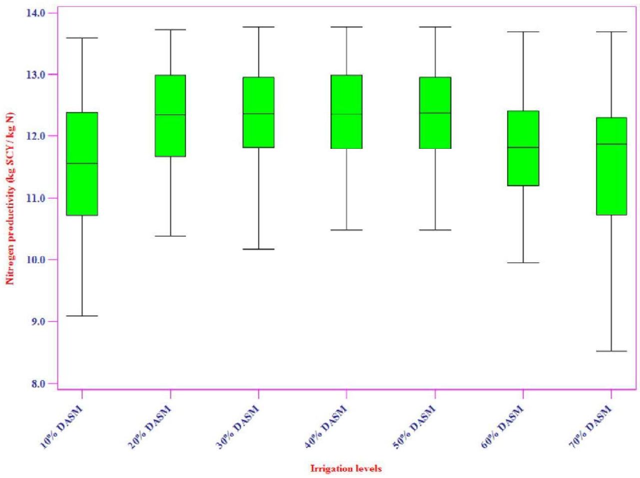

Fig. 3: Simulated nitrogen productivity (kg SCY / kg N) of cotton at harvest under different irrigation levels. Box limits represent the 25th and 75th percentiles, box central line represents the median, and whiskers represent the minimum and maximum values

If the calibrated models stand the test of validation with independent data sets, they can be potentially used as tools to take operational, tactical, and strategic decision to support on-farm crop management (Mathews *et al.,* 2002). An analysis was carried out with CROPGRO-Cotton model for identifying the optimum irrigation level for cotton production using seasonal analysis tool available in DSSATv4.6 to simulate seed cotton yield for 7 irrigation levels starting from 10% depletion of available soil moisture (DASM) to 70% depletion of available soil moisture at 10% depletion interval of irrigation levels for a semiarid environment for 30 years using historical daily weather data from 1986 to 2015.

The simulation scenarios of different irrigation levels subjected to one way analysis of variance and means were compared with Tukey's HSD test (Table 1). The highest mean seed cotton yield (1857 kg ha^{-1}), above ground biomass (2838 kg ha^{-1}) and nitrogen productivity (12.32 kg SCY/ kg N) were predicted with irrigation scheduled at 30% DASM followed by 40% DASM (1850 kg ha^{-1} of seed cotton yield). Increase in depletion levels gradually increased the water use efficiency from 1.3 to 2.6 kg ha^{-1} mm^{-1}. Similar results were reported by Cammarano *et al*. (2012) as cotton lint yield response to irrigation was closely related to amount of rainfall of particular location. The areas which received moderate rainfall had slower rate of yield increase as irrigation increased.

The simulation scenarios showed that the median above ground biomass decreased consistently with gradual decrease in available water (Figure. 1). However, the box plots showed that 30% and 50% DASM showed considerably less variability with higher median above ground biomass than irrigation at other depletion levels. Further this reduced variability gave the least downside risk (risk for achieving low yields) when compared to other depletion levels which had more variability to achieve minimum above ground biomass. Even though other depletion levels showed on par yield with 30 and 50% DASM, in terms of variability, risk for achieving minimum above ground biomass was more. So to achieve less variability in above ground biomass crop has to be irrigated either at 30% DASM or 50% DASM.

The simulation scenarios showed that the median seed cotton yield and nitrogen productivity decreased consistently with gradual decrease in available water. However, the box plots showed that 40 and 50% DASM showed considerably less variability with higher median seed cotton yield and nitrogen productivity than irrigation at other depletion levels (Fig. 2 & 3). Further this reduced variability gave the least downside risk (risk for achieving low yields) when compared to other depletion levels which had more variability in yields and nitrogen productivity. Even though other depletion levels showed on par yield and nitrogen productivity with 40 and 50% DASM, in terms of variability, risk for achieving minimum yields was more. So to achieve less variability in seed cotton yield crop has to be irrigated either at 40% DASM or 50% DASM.

It can be concluded that, validated CROPGRO-Cotton model can be successfully used in taking tactical decisions for obtaining optimal yields with minimal input using seasonal analysis tool in CROPGRO-Cotton model as indicated by higher above ground biomass, seed cotton yield and nitrogen productivity obtained when irrigation scheduled at 40% depletion of available soil moisture under semi-arid conditions of South Telangana Zone.

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