Journal of Agrometeorology 23 (3) : 348-351 (September 2021)

Short communication

Sensitivity of rainfed cotton to the changes in climatic factors and CO_2 concentrations

K.BHUVANESWARI*, V.GEETHALAKSHMI, R.RAJALAKSHMI and K. SENTHILRAJA

Agro Climate Research Centre, TNAU, Tamil Nadu, India
*Corresponding Author email: *bhuviagm@gmail.com*

The continuing rise in atmospheric carbon dioxide concentration is one of the main causes for global warming and a resultant change in the climate. Global average air temperature is expected to be 1.8-4.0 °C above the current level in the 21st century that might impact agriculture dramatically in terms of larger variability in food, feed and fiber production (Aggarwal, 2008). Temperature is the main factor affecting plant growth and development and higher air temperatures above a certain level significantly affect crop productivity (Sacks and Kucharik, 2011). Most of the climate model prediction indicates frequent flood and drought-like situations in the future. High-temperature compounding with the changes in rainfall patterns will adversely affect crop production. It is an important aspect to be understood that the relationship between rainfall and crop productivity as the rainfall directly influencing the growth and productivity of crops. Crops grown under rainfed condition are already finding difficult to cope with temperature and rainfall changes induced by the climate change. Cotton is an agro-industrial crop grown in developing and developed countries including China, United States, India, Pakistan and Brazil. It contributes more than fifty percent of all fibers used for clothing and household furnishings. Changes in climate is likely to impact cotton growth and productivity due to increasing CO_2 concentration, temperature and changes in rainfall behaviours(Bange, 2007). Effect of climate change on productivity of crops has been largly studied by employing crop models coupling with climate change scenarios (Tao *et al*., 2008). For adapting the crop systems in view of climate change, it is necessary to know the effect of climate change on crop production. Quantifying the effect of various climatic factors on cotton paves the way for developing suitable adaptation strategies and thereby minimize the deleterious effect of varying climatic factors. The present investigation aimed to assess the response of cotton to the changes in temperature, rainfall and CO_2 concentrations over Tamil Nadu.

CROPGRO-Cotton model

The CROPGRO-Cotton model of DSSAT (V. 4.7), designed by International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) was used for assessing the sensitivity of rainfed cotton to the changes in climatic factors and CO_2 concentrations.

Estimation of genetic coefficients in CROPGRO-Cotton (DSSAT) model

In the CROPGRO-Cotton model, parameterization was done for cotton cultivar SVPR4 using the weather data, soil information, crop management details and biometric observations pertain to the experimental field located at the Agricultural College and Research Institute, Madurai. Data obtained from the experiments conducted in two years with two dates of sowing (21st September and 6th October) at two nitrogen levels (N80 and N60) were used in the crop simulation model for deriving the genetic co-efficient of cotton cultivar SVPR4.

Genetic coefficients

In the crop simulation model, traits of the plants and physiological features are included in the form of genotype coefficientsto to describe the physiological processes such as plant growth and development, photosynthesis, yield and yield attributes for individual crop varieties. The genetic coefficients in the crop simulation models that are linked with the development stages and yield of the crop were derived by iteration, through manipulating the related coefficients to simulate the numbers of days for the occurrence of different phenological events and yield closely matching to the

Table 1: CROPGRO-Cotton model statistics for (SVPR 4) cotton cultivar

Model stat.	Days to anthesis	Days to maturity	Seed cotton yield
r^2	0.80	0.83	0.89
RMSE	3	2	169 (kg ha^{-1})
d	0.86	0.88	0.93

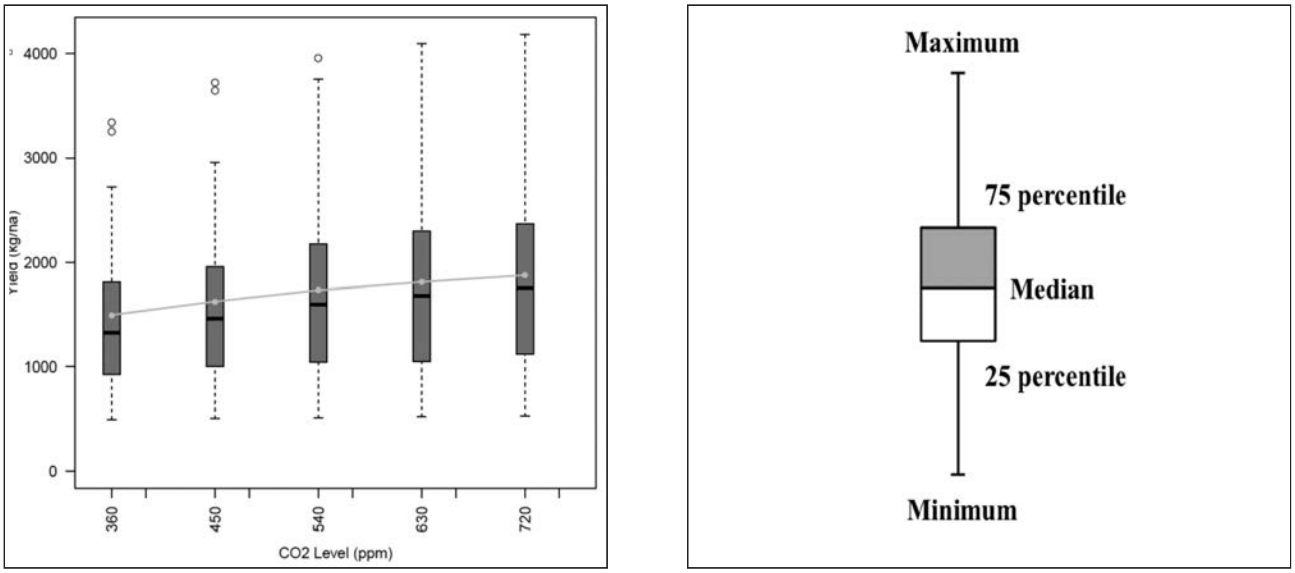

Fig. 1: Effect of CO_2 enrichment on Cotton

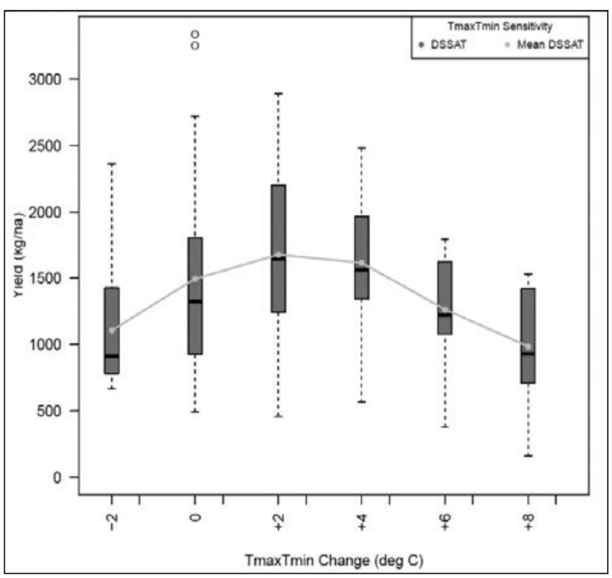

Fig. 2: Sensitivity of cotton to the changes in temperature

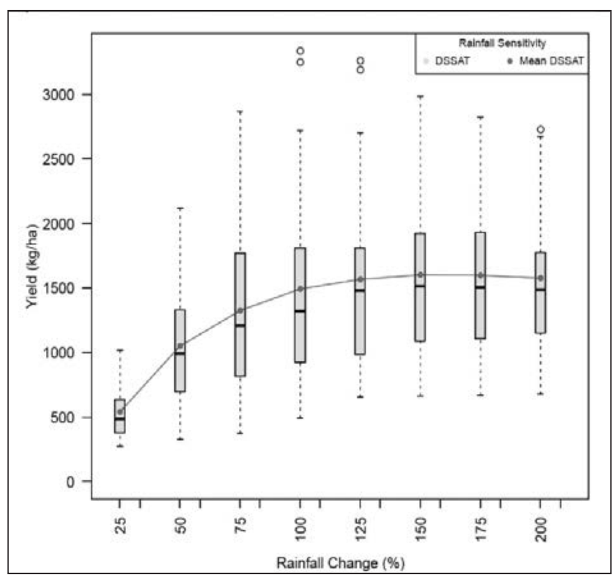

Fig. 3: Response of cotton to the changes in rainfall

observed values. The Genetic coefficients derived for cotton cultivar SVPR4 in the CROPGRO-Cotton model have been given as below:

Critical Short-Day Length below which reproductive development (CSDL) - 23.00; Slope of the relative response of development to photoperiod with time (PPSEN) -0.01; Time between plant emergence and flower appearance R1 (EM-FL) - 36.0; Time between first flower and first pod (R3) photothermal days (FL-SH) -8.0; Time between first flower and first seed (R5) photothermal days (FL-SD) - 13.0; Time between first seed (R5) and physiological maturity R7 (SD-PM)- 46.00; Time between first flower (R1) and end of leaf expansion (FL-LF)- 69.00; Maximum leaf photosynthesis rate at 30 °C, 350 vpm CO2, and high light (LFMAX)-1.08; Specific leaf area of cultivar under standard growth conditions (SLAVR) -169; Maximum size of full leaf (three leaflets) cm^2 (SIZLF) -285; Maximum fraction of daily growth that is partitioned to seed + shell (XFRT) -0.63; Maximum weight per seed g (WTPSD)- 0.180; Seed filling duration for pod cohort at standard growth conditions (SFDUR)- 35.0; Average seed per pod under standard growing conditions #/pod (SDPDV) -27.00; Time required for cultivar to reach final pod load under optimal (PODUR) -9.0; The maximum ratio of (seed/(seed+shell)) at maturity (THRSH) -70.0; Fraction protein in seeds (g(protein)/g(seed)) SDPRO-0.153; Fraction oil in seeds (g(oil)/g(seed)) SDLIP-0.120

Evaluation statistics of CROPGRO-Cotton model

The reability of CROPGRO-Cotton model simulations was tested using the different statistical indexes such as i. root mean square error (RMSE), ii. coefficient of determination (r^2), iii. index of agreement (d).

Sensitivity analysis

Sensitivity of cotton for the changes in temperature, rainfall and carbon dioxide was assessed with 19 combinations as detailed below

i. 5 levels of CO_2 concentrations (360, 450, 540, 630 and 720 ppm),

ii. 6 levels of maximum and minimum temperature changes (-2°C, 0°C, 2°C, 4°C, 6°C and 8°C)

iii. 8 levels of change in rainfall quantity (25, 50, 75, 100, 125, 150, 175 and 200 %)

The simulations were made using the CROPGRO-Cotton model embedded in DSSAT under the 39 years (1981-2019) baseline period and averaged the yield for each level of temperature, rainfall and CO_2 concentration considered in the study.

Statistics on the prediction efficiency of CROPGRO-Cotton model

The performance statistics of the CROPGRO-Cotton model for SVPR4 showed the r^2 values of 0.80, 0.83 and 0.89 for the days taken to anthesis, days to atttain the physiological maturity and yield respectively signifying a good match between actual and model-simulated data. RMSE values of the period taken for anthesis, maturity and seed cotton yield are found to be 3 days, 2 days and 169 kg ha^{-1} indicating a good match between simulated and observed values. The model statistics indicated that the d values are 0.86, 0.88 and 0.93 for days taken to anthesis, days taken to maturity and seed cotton yield respectively which indicate good harmony between observed and model-simulated data (Table 1). The high r^2 and d values (>0.8) indicated the close agreement between observed and model-simulated yield and RMSE was in the acceptable range indicating the satisfactory performance of the model (Bhuvaneswari *et al*., 2014; Raja *et al*., 2018).

Influence of CO_2 enrichment on Cotton

DSSAT simulation indicated that cotton crops showed a positive response for the enriched CO_2 concentrations and the magnitude of increase in cotton productivity was higher with an increase in CO_2 concentration. It was found out that cotton yield increased by 8.7, 15.9, 21.1 and 25.4 percent from the current yield (1495 kg ha^{-1}) with the CO_2concentration of 450, 540, 630, 720 ppm respectively (Figure 1). Elevated atmospheric CO_2 could create favourable conditions for the growth and development of cotton to a certain extent.

Response of cotton to the changes in temperature

The cotton yield increased up to 4 °C increase in temperature and a further rise in temperature reduced the yield of cotton. Cotton yield was increased by 12.3 and 8.1 percent with 2 and 4 °C increase in temperature respectively. In contrast, for 6 °C rise in temperature, the cotton yield declined by 15.5 percent and yield reduction was 34.1 percent with 8 °C increase in temperature (Figure 2). The results are similar to the findings of Hebbar *et al*. (2013) who stated that productivity remain to be same or increase in central and southern India in future climatic conditions.

Effect of changes in rainfall on cotton

It could be seen from the DSSAT model simulation that the yield was less when the cotton crop receives 25 percent of normal rainfall and showed a gradual increase in yield up to 150 percent of rainfall (Figure 3). Rainfed cotton crop has responded up to an additional 50 percent increase in rainfall from the current rainfall quantity (100%). The cotton yield increased by 4.9 and 7.2 percent with 25 and 50 percent increase in rainfall respectively.

The results of the rainfall effect on cotton are in harmony with the study of Cetin Oner and Basbag Sema. (2010).

Enhanced CO_2 concentrations influenced the cotton yield positively. The cotton crop had a beneficial effect owing to increased temperature up to 4 °C and thereafter yield got declined. Rainfall increases up to 50 percent also enhances cotton productivity. It clearly indicated that cotton could be one of the best alternative crops under changing climatic conditions in the future.

ACKNOWLEDGMENTS

The authors would like to thank MoEF& CC and DST-CCP-SPLICE, Govt of India, New Delhi for the financial support to conduct this study. The authors are also thankful to AgMIP team for rendering the technical input for taking up this study.

Conflict of Interest Statement : The author(s) declare(s) that there is no conflict of interest.

Disclaimer : The contents, opinions, and views expressed in the research article published in the Journal of Agrometeorology are the views of the authors and do not necessarily reflect the views of the organizations they belong to.

Publisher's Note : The periodical remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

REFERENCES

Aggarwal, P K.(2008). Global climate change and Indian agriculture impacts, adaptation and mitigation. *Indian J. Agr. Sci.*, 78: 911–919.

Bange, M. (2007). Effects of climate change on cotton growth and development. *The Aus. Cott. Gro.*, 40-45.

Bhuvaneswari, K., Geethalakshmi, V., Lakshmanan, A., Anbhazhagan, R., and Nagothu Udaya Sekhar, D. (2014). Climate change impact assessment and developing adaptation strategies for rice crop in western zone of Tamil Nadu. *J. Agrometeorol.*, 16 (1):38-43.

Cetin Oner and Basbag Sema. (2010). Effects of climatic factors on cotton production in semi-arid regions - A review. *Res. on Crops*., 11. 785-791.

Hebbar, K.B., Venugopalan, M.V., Prakash , A.H. and Aggarwal ,P.K. (2013). Simulating the impacts of climate change on cotton production in India. *Clim. Change.*, 118(3-4):701-713.

Raja, Waseem, Raihana Habib Kanth, and Purshotum Singh. (2018). "Validating the AquaCrop model for maize under different sowing dates." *Water Policy,* 20 (4):826-840.

Sacks, W.J. and Kucharik. C.J. (2011). Crop management and phenology trends in the U.S. corn belt: Impacts on yields, evapotranspiration and energy balance. *Agric. For. Meteorol.*, 151:882-894.

Tao, F.L., Hayashi, Y., Zhang, Z., Sakamoto, T. and Yokozawa, M.(2008). Global warming, rice production, and water use in China: developing a probabilistic assessment. *Agric. For. Meteorol.*, 148:94-110.

Received : June 2020 : Accepted : May 2021