International Journal of Environment and Climate Change

Volume 13, Issue 11, Page 3654-3661, 2023; Article no.IJECC.109301
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

CROPGRO-Cotton Model Application for Predicting Cotton Sowing Time in Nagarkurnool District of Telangana State, India

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Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/IJECC/2023/v13i113542

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/109301

Original Research Article

Received: 18/09/2023
Accepted: 23/11/2023
Published: 24/11/2023

ABSTRACT

Aims: A study was carried out to find out the optimum sowing time with the validated CROPGRO-Cotton model using DSSAT v 4.7 seasonal analysis tool under rainfed situation at mandal level in Nagarkurnool district of Telangana state, India.
Study Design: CROPGRO-Cotton model using DSSAT v 4.7 seasonal analysis tool.
Place and Duration of Study: Nagarkurnool district, 2023.
Methodology: Cotton production was affected with changing climate in several ways and its impact on rainfed agriculture was higher and influences the Indian economy. The prevailing weather conditions during different phenophases of the crop influences the seed cotton yield. There is a need to optimize the sowing time so that the timing of critical growth stages to minimize stresses and enhance resource utilization. The adjusting of sowing environment proved to be an adaptation management technique for realising higher seed cotton yield.
A well calibrated and validated model was used for long term simulations using DSSAT seasonal

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analysis tool programme with Mallika Bt as test variety for 100 different scenarios (20 mandals × 5 sowing dates) using 32 years historical daily weather data from 1991 to 2022 starting sowing time from 1st June to 1st August at 15 days interval in twenty mandals of the district.

Results: The simulation results showed, significantly higher seed cotton yield (1505 kg ha-1) was predicted with crop sown on 1st June followed by 1st July sown crop (1337 kg/ha) which was comparable with 16th June (1324 kg/ha) and significantly differed with delayed sowings of 16th July sown crop (1203 kg/ha) and 1st August sown crop (1192 kg/ha). Among the different mandals of the district, the model simulated higher seed cotton yield (2136-2530 kg/ha) in Amrabad mandal and lower yields in Thimmajipet mandal (596-997 kg/ha) under different sowing environments.

Conclusion: Based on simulation scenarios, higher seed cotton yield can be obtained when crop sown between 1st June to 1st July in different mandals of the Nagarkurnool district of Telangana State. The mandals which have less yield potential and realising poor yields by the farmers can be advocated with location specific alternate best management practices to get the higher cotton yield.

Keywords: Bt cotton; seasonal analysis; CROPGRO-cotton model; rainfed situation.

1. INTRODUCTION

Cotton is one of the most important commercial crops cultivated in India and accounts for around 25% of the total global cotton production. It plays a major role in sustaining the livelihood of an estimated 6 million cotton farmers and 40-50 million people engaged in related activity such as cotton processing & trade. The Indian Textile Industry consumes a diverse range of fibres and yams and the ratio of use of cotton to non - cotton fibres in India is around 60:40 whereas it is 30:70 in the rest of the world. Apart from being the provider of a basic necessity of life i.e. clothing which is next only to food, cotton is also one of the largest contributor to India's net foreign exchange by way of exports in the form of raw cotton, intermediate products such as yam and fabrics to ultimate finished products in the form of garments, made ups and knitwear. Due to its economic importance in India, it is also termed as "White-Gold". India got 1st place in the world in cotton acreage with 120.55 lakh hectares area under cotton cultivation i.e. around 36% of world area of 331 lakh hectares. Around 67% of India's cotton is grown on rain-fed areas and 33% on irrigated area. In terms of productivity, India is on 40th rank with yield of 445 kg/ha. India is one of the largest cotton producing country in the world with estimated production of 315.43 lakh bales (5.36 Million Metric Tonnes during cotton season 2021 -22 which is 21% of world cotton production of 1522 lakh bales (25.89 Million Metric Tonnes). India is one of the largest consumer of cotton with estimated consumption of 326 lakh bales (5.54 Million Metric Tonnes i.e. 21% of world cotton consumption of 1538 lakh bales (26.16 Million Metric Tonnes).

"The impact of climate change on cotton crop is gaining momentum because of its association with the national economy and providing livelihood security to 60 million people including all stakeholders of the cotton value chain" [1]. "The changing climate has threatened the productivity of the agriculture sector making it vulnerable both economically and physically to climate unevenness and change. Productivity is being affected by many climate change variables including rainfall, high temperature, changes in sowing and harvesting dates, water availability and land suitability" [2]. "Climate change may not have huge overall effects but regional effects are more extensive. Variable sowing time is mostly dependent upon climate, species specificity and agro-climate (rainfed vs. irrigated). Most favourable sowing time provides favourable situation for adequate crop growth as it escorts to the realization of the productivity potential of the crop" [3].

Crop growth models such as the Decision Support System for Agrotechnology Transfer (DSSAT), allow researchers to conduct several hypothetical experiments rapidly and inexpensively, facilitating the development and evaluation of management strategies. DSSAT is a process-based model [4] that uses meteorological, soil, and crop management data to predict the growth and development of a particular crop in a set location. DSSAT has over 42 crop modules, each of which is designed to mimic the behaviour of a specific crop. The CROPGRO-Cotton [5] module in the DSSAT Cropping System Model (CSM) was used in this study.

The CROPGRO-Cotton model is a member of the CROPGRO group of models [6] in DSSAT.

Crop models have been described as a "quantitative schemes for predicting the growth, development and yield of a crop, given a set of genetic coefficients and relevant environmental variables" [7]. Models can be used to predict crop growth, development and yield as a function of soil, climate, weather, and crop management conditions. Crop simulation models have been used to study the effect of intra-seasonal variation in temperature on yield of wheat in India [8]. Patil et. al. [9] has used the CROPGRO-Cotton model applications to find out the effect of temperature on seed cotton yield and observed that elevated temperature had negative effect on seed cotton yield and reduced temperature had positive effect on seed cotton yield.

Crop growth and development are important aspects of DSSAT model evaluation and evaluation of DSSAT CROPGRO-Cotton model using phenological stages, in-season crop growth and development data, and crop yield has been attempted by Mahadevappa et al. [10]. The objective of this research was to use the evaluated model to determine the optimum sowing time to realize maximize yield under five sowing dates in twenty mandals of the Nagarkurnool district and identify the most effective date of sowing strategy for maximizing yield.

2. MATERIALS AND METHODS

A study was conducted on performance of Bt Cotton using Mallika Bt Hybrid in different mandals of Nagarkurnool district located in Telangana state under different sowing environments over 32 years using seasonal analysis tool of CROPGRO-Cotton model of DSSAT 4.7 version. A mandal is a local government area in parts of India, similar to a tehsil. In Telangana, a mandal is a sub-division of a district that is declared by the government. The mandal system was created as an administrative reform to reduce the size of taluks and make them more manageable. A mandal is made up of many villages maintains the village's land records. A mandal is headed by a Tahsildar, also known as a Mandal Revenue Officer (MRO). The MRO has the same powers and functions as the Tahsildars of former Taluks, including magisterial powers. Telangana state has 612 mandals whereas Nagarkurnool district has 20 mandals. Mandal wise daily weather data was created using weatherman tool in DSSAT model for seasonal analysis. Mandal wise dominant type of soil (light textured to fine textured soil) was selected to run the CROPGRO-Cotton model. Experimental file in the model was created adopting best management practices followed under rainfed situation. The Nagarkurnool district falls under semi arid climate and receives 480 mm of normal rainfall during south west monsoon season was the main source of soil moisture for the rainfed crops especially for the cotton grown in the district. The treatments comprised of five dates of sowing (1st June, 16th June, 1st July, 16th July and 1st August) in twenty mandals of the district comprising a total of 100 scenarios using the daily weather data for 32 years starting from 1991 to 2022. The recommended dose of 150 kg of Nitrogen applied in four equal splits at 20, 40, 60 and 80 days after sowing. The crop was sown adopting 90cm X 60 cm spacing. Since the experiment was carried out using 32 years weather data for seasonal analysis the environmental factors were not same in each district. A well calibrated and validated genetic coefficients developed by the Mahadevappa et al. (2018) were used for running the seasonal analysis tool. The data were analyzed statistically applying one way analysis of variance technique and critical difference for examining treatment means for their significance was tested with Tukey`s (HSD) test.

3. RESULTS AND DISCUSSION

An analysis was carried out using DSSAT seasonal analysis tool and simulations were generated. The simulation scenarios of different sowing dates subjected to one way analysis of variance and means were compared with Tukey's HSD test.

Significantly higher mean above ground biomass production (2283 kg ha^{-1}) was predicted with crop sown on 1st June under rainfed situation followed by 1st July sown crop (2038 kg ha^{-1}) and which was on par with 16th June sown crop (2015 kg ha^{-1}) and significantly lower seed cotton yield (1730 kg ha^{-1}) was predicted when crop sown on 1st August in Nagarkurnool district. Significantly higher mean seed cotton yield (1505 kg ha^{-1}) was predicted with crop sown on 1st June under rainfed situation followed by 1st July sown crop (1337 kg ha^{-1}) and which was on par with 16th June sown crop (1324 kg ha^{-1}) and significantly lower seed cotton yield (1192 kg ha^{-1}) was predicted when crop sown on 1st August in Nagarkurnool district. Similar observations were recorded with respect to cotton seed yield.

The simulation scenarios showed that the median seed cotton yield decreased consistently with delay in sowing of the crop from June to August. Similarly, the box plot showed that crop sown on 1st June has considerably less variability with higher median seed cotton yield than delayed sowings (Fig. 1). Further this reduced variability gave the least downside risk (risk for achieving low yields) when compared to later dates which had more variability in yields.

However, the date of onset of south west monsoon, which is the only source for soil moisture, has a significant role on time of sowing of the rainfed crops in a given region. The normal onset of south west monsoon in this region is 13th June. The normal rainfall of the district during summer season (March-May) amounts to 55 mm facilitates the farmers for land preparation and to be ready for sowing of rainfed crops after onset of monsoon. The model also predicted significantly higher median seed cotton yield when crop sown on 16th June and 1st July with less down risk of achieving lower seed cotton yields after 1st June sown crop over the delayed sowings. Considering the date of onset of monsoon, it is advisable to go for sowing of rainfed cotton from 16th June to 1st July to benefit the favourable weather realise the on in the district. Crop simulation models provide means to quantify the effects of climate, seasonal weather conditions, soil management, genotype and their interactions on crop growth, yield, resource use efficiency and environmental impacts [11]. These models can be used to quantify the gaps between actual and potential yields, to evaluate management options and to determine likely environmental impacts.

Similarly, Hundal and Prabhjyot-Kaur [12] has revealed that early (October) sown crop was mostly affected by the temperature increase

Table 1. Tukey's test (HSD) for seed cotton yield, cotton seed yield and above ground biomass (kg ha^{-1}) under different sowing dates

Sowing date	Mean above ground biomass	Mean Seed cotton yield	Mean Cotton Seed yield
1st June	2283 [a]	1505 [a]	1021 [a]
16th June	2015 [bc]	1324 [bc]	889 [bc]
1st July	2038 [bc]	1337 [bc]	897 [bc]
16th July	1796 [d]	1203 [d]	795 [d]
1st August	1730 [e]	1192 [e]	786 [e]

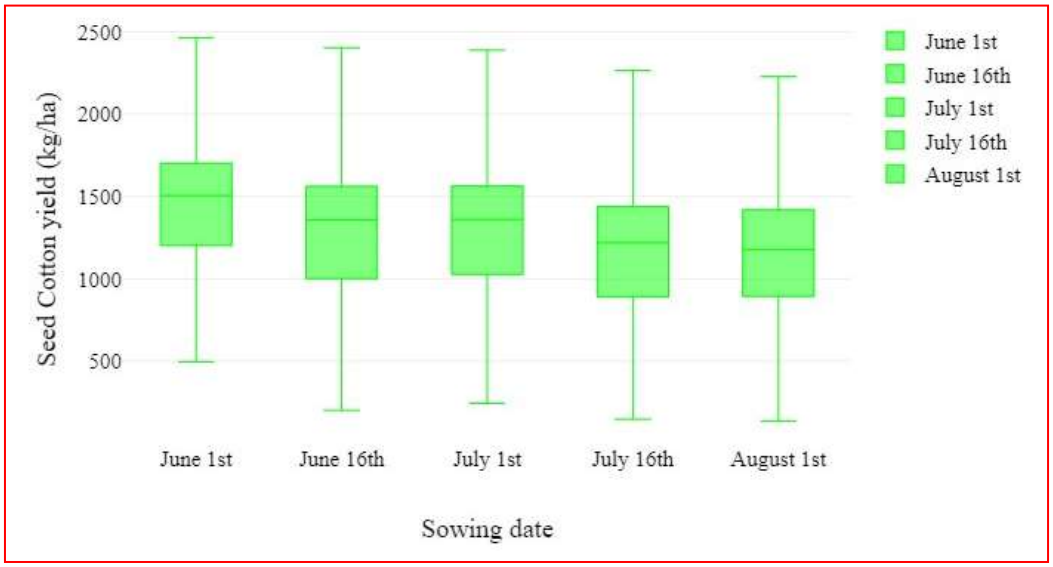

Fig. 1. Seed cotton yield simulated by seasonal analysis tool of CROPGRO-Cotton model

during 4th week of January, February and up to 1st fortnight of March; the timely (November) sown crop during February and March; the late (4th week of November) sown crop during March; whereas the very late (December) sown crop was most affected during March and 1st week of April in wheat crop using CERES-Wheat model.

Further, the simulation scenarios showed that the above ground biomass production / tops weight at maturity decreased consistently with delay in sowing of the crop from June to August. The bens plot showed that crop sown on 1st June has considerably less variability with higher median seed cotton yield than delayed sowings (Fig. 2). Further this reduced variability gave the least downside risk (risk for achieving low yields) when compared to later dates which had more variability in yields.

Among the different mandals of the Nagarkurnool district, simulation scenarios showed that the median seed cotton yield decreased consistently with postponement of sowings from June to August. Among the different mandals of the district, the model simulated higher seed cotton yield (2136-2530 kg/ha) in Amrabad mandal and lower yields in Thimmajipeta mandal (596-997 kg/ha) under different sowing environments.

Pal et al. [13] applied the CROPGRO-cotton model to analyze the influence of temperature and solar radiation indices on seed cotton yield but this study was limited to a single sowing date and that too on a single cultivar in Bathinda district of Punjab state. Similarly, Kumar et al. [14] also validated the CROPGRO-cotton model under three environments in Haryana state of India.

The significantly higher mean above ground biomass (2283 kg ha^{-1}) was predicted with crop sown on 1st June under rainfed situation followed by 1st July sown crop (2038 kg ha^{-1}) and which was on par with 16th June sown crop (2015 kg ha^{-1}) and significantly lower seed cotton yield (1730 kg ha^{-1}) was predicted when crop sown on 1st August in Nagarkurnool district. Among the different mandals of the district, the model simulated higher above ground biomass (3086-3782 kg/ha) in Amrabad mandal and lower yields in Thimmajipeta mandal (899-1535 kg/ha) under different sowing environments. Based on the model predictions mandals are grouped into below 1000, 1001-1500, 1501-2000 and above 2000 kg ha^{-1} categories of seed cotton yield production mandals (Table 2 and Fig 3) with different sowing environments. More than 75% mandals have the capability to produce 1001-1500 kg ha^{-1} seed cotton yield when crop sown between 1st June to 1st July.

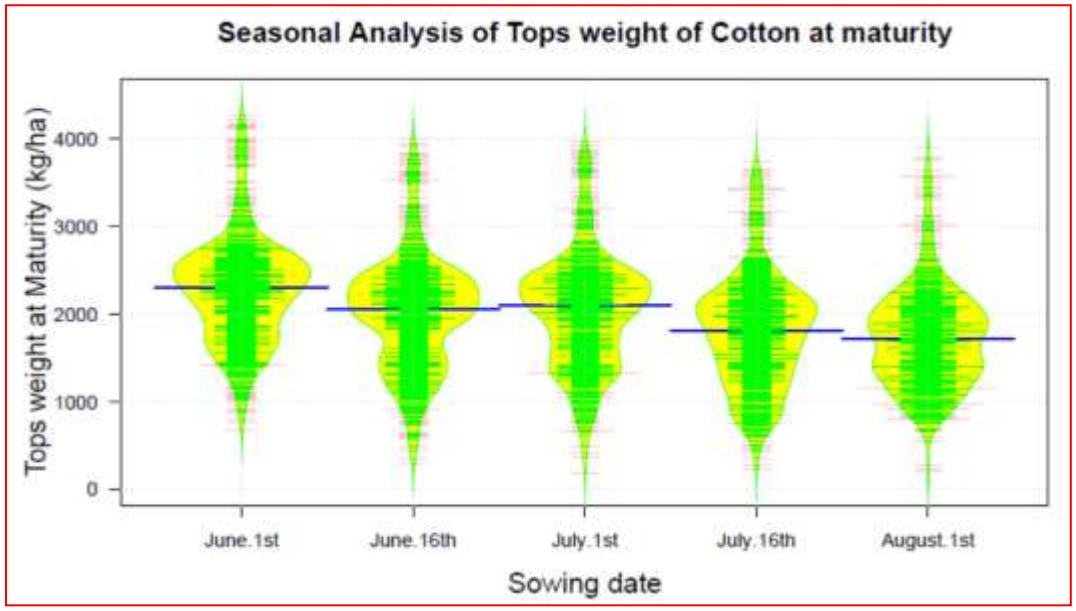

Fig. 2. Above ground biomass / tops weight (kg/ha) at maturity simulated by seasonal analysis tool of CROPGRO-Cotton model under rainfed situation in Nagarkurnool district

Table 2. Potentiality of the mandals of the Nagarkurnool district under different sowing dates for Seed Cotton Yield under rainfed situation as predicted by CROPGRO-Cotton model

Seed cotton yield (kg/ha)/ Sowing time	1st June	16th June	1st July	16th July	1st August	Average
>1000	Lingal, Vangoor, Thimmajipeta	Lingal, Vangoor, Thimmajipeta, Kollapur	Lingal, Vangoor, Thimmajipeta, Kollapur	Lingal, Vangoor, Thimmajipeta, Kollapur	Lingal, Vangoor, Thimmajipeta, Kollapur	Lingal, Vangoor, Thimmajipeta, Kollapur
1001-1500	Kollapur, Charakonda, Kodair, Bijinapalle, Padra, Balmoor, Veldanda	Charakonda, Kodair, Bijinapalle, Padra, Balmoor, Veldanda, Kalwakurthy, Urkonda, Uppunuthala, Peddakothapalle Telkapalle, Pentlavelli	Charakonda, Kodair, Bijinapalle, Padra, Balmoor, Veldanda, Kalwakurthy, Urkonda, Uppunuthala, PeddakothapalleTelkapalle, Pentlavelli	Charakonda, Kodair, Bijinapalle, Padra, Balmoor, Veldanda, Kalwakurthy, Urkonda, Uppunuthala, PeddakothapalleTelkapalle, Tadoor, Pentlavelli, NagarKurnool	Charakonda, Kodair, Bijinapalle, Padra, Balmoor, Veldanda, Kalwakurthy, Urkonda, Uppunuthala, PeddakothapalleTelkapalle, Tadoor, Pentlavelli, NagarKurnool	Charakonda, Kodair, Bijinapalle, Padra, Balmoor, Veldanda, Kalwakurthy, Urkonda, Uppunuthala, PeddakothapalleTelkapalle, Tadoor, Pentlavelli
1501-2000	Kalwakurthy, Urkonda, Uppunuthala, Peddakothapalle, Telkapalle, Tadoor, Pentlavelli, NagarKurnool	Tadoor, NagarKurnool	Tadoor, NagarKurnool	Achampet	Achampet	NagarKurnool, Achampet
2001-2530	Achampet, Amrabad	Amrabad	Amrabad	Amrabad	Amrabad	Amrabad

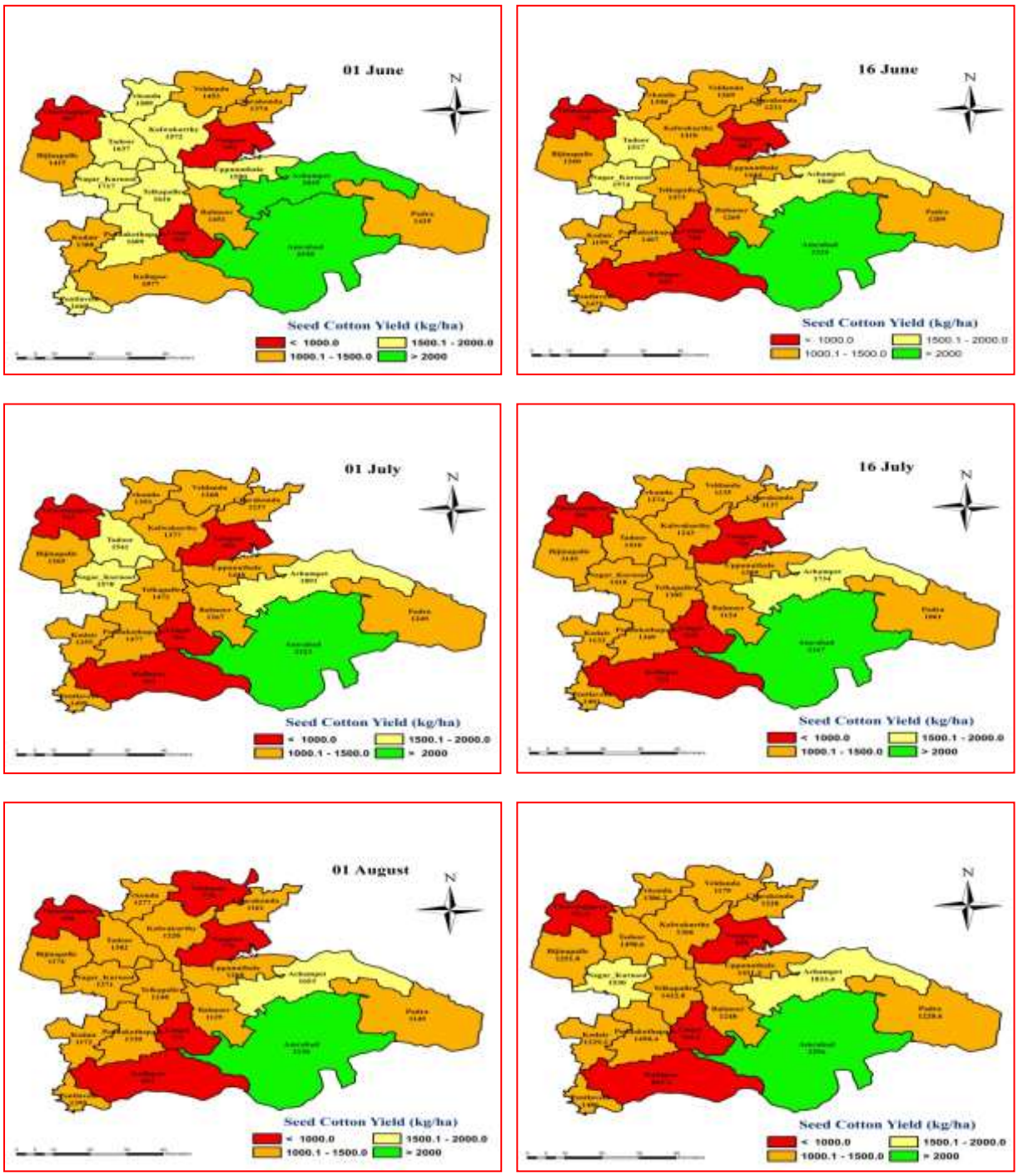

Fig. 3. Seed cotton yield as influenced by different sowing dates predicted by seasonal analysis tool of CROPGRO-Cotton model over 32 years period (1991-2022)

4. CONCLUSION

Based on simulation scenarios, higher seed cotton yield can be obtained when crop sown between 1st June to 1st July in different mandals of the Nagarkurnool district of Telangana State. The mandals which have less yield potential and realising poor yields by the farmers can be advocated with location specific alternate best management practices to get the higher seed cotton yield.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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    Available:https://doi.org/10.20546/ijcmas.2017.604.128

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/109301