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Optical Characteristics, Thermal use Efficiency, Yield and Yield Attributes of *Bt* Cotton under Different Plant Spacing and Fertilizer Levels

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Field trail was conducted at the Research Farm of Cotton Section, Department of Genetics & Plant Breeding, CCS HAU, Hisar (Lat 29° 10' N, Long 75° 46' E and 215.2 m msl) during *Kharif* season of 2015. The experiment was conducted in split-split plot design with three replications. Three varieties *viz*. V_1=RCH 602, V_2=RCH 650 and V_3=Bunty were kept in main plots while three spacing *viz*. S_1=67.5 cm × 45 cm, S_2=67.5 cm × 60 cm and S_3=67.5 cm × 75 cm with three fertilizer levels *i.e*. F_1=RDF, F_2=125 % of RDF and F_3=150 % of RDF application of the recommended dose were kept in subplots. Recommended dose of fertilizer (RDF) was N:P:K=175:60:60 kg ha^{-1}. Optical characteristics, thermal use efficiency (TUE) were computed along with yield and yield attributes were also studied. V_1 (86.6 %), S_3 (84.8 %) and F_3 (85.1 %) absorbed maximum PAR among all the cv., plant spacing and fertilizer levels. TUE was found higher in the V_1 (0.35 g/m²/°C day), S_3 (0.34 g/m²/°C day) and F_3 (0.29 g/m²/°C day) among all the cv., plant spacing and fertilizer levels. Number of bolls plant^{-1} were found higher in V_1 (21.0), S_3 (14.7) and F_3 (16.0) among all the cv., plant

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spacing and fertilizer levels. Among all the cv., plant spacing and fertilizer levels boll weight (g) were found higher in V_2 (3.89 g), S_2 (3.66 g) and F_2 (3.62 g). Sympodial branches plant^{-1} at harvest were found highest in V_1 (23.7), S_1 (21.0) and F_1 (21.4) among all the cv., plant spacing and fertilizer levels. In seed cotton yield V_1 (1248.7 kg ha^{-1}), S_3 (1120.7 kg ha^{-1}) and F_2 (1094.3 kg ha^{-1}) have the maximum yield as compare to other cv., plant spacing and fertilizer levels.

Keywords: TUE; optical characteristic; yield and yield attributes.

1. INTRODUCTION

Cotton is a one of the most important fiber crop in the world. It is also called as white gold. The primary product of the cotton plant has been the lint that covers the seeds within the boll. Important cotton producing states are Gujarat, Maharashtra, Tamil Nadu, Punjab and Haryana in India. After introduction of transgenic *Bt* hybrid cotton in India, the productivity of cotton has increased substantially from 303 to 561 kg ha^{-1} within a span of seven years [1].

Cotton requires a minimum daily air temperature of 15 ℃ for germination, 21-27 ℃ for vegetative growth, and above 15 ℃ to produce a crop [2]. All processes leading to square, blossom and boll initiation, and maturation of the crop are temperature-dependent. When the temperature rises above 35 ℃, more of the anthers produced are sterile and therefore flower survival and fruit production is poor during that time. All stages of vegetative development from germination to initiation of floral structures are affected by high temperature [3].

The crop growth and development depends upon the thermal time or quantitative effect of temperature. Agroclimatic indices are useful for assessing the agroclimatic resources in crop planning and reflecting the impact of agrometeorological variables at different crop growth stages [4].. The solar energy in canopies influences the plant temperature, which control the rate of physiological and biochemical processes in plants. The variation in planting density modifies the macro and microclimate to which plants are exposed, hence there is need to study the effect of planting density on crop growth and yield.

2. MATERIALS AND METHODS

A field experiment was laid out in split-split design with three replications conducted during *kharif* seasons of 2015-16 and 2016-17 at the Department of Genetics & Plant Breeding, CCS HAU, Hisar (Lat 29° 10' N, Long 75° 46' E and 215.2 m msl). The experiment was conducted in split split plot design with three replications. The experiment consist of three varieties *viz.* V_1=RCH 602, V_2=RCH 650 and V_3=Bunty were kept in main plots while three spacing *viz.* S_1= 67.5 cm × 75 cm, S_2=67.5 cm × 60 cm and S_3= 67.5 cm × 45 cm with three fertilizer levels *i.e.* F_1= RDF, F_2= 125 % of RDF and F_3= 150 % of RDF application of the recommended dose were kept in subplots. Recommended dose of fertilizer is (RDF) N:P:K=175:60:60 kg ha^{-1}.

Thermal use efficiency (TUE): Thermal use efficiency is a ratio of dry matter and heat unit consumed by the crop. It can be represented by the following formula:

Thermal use efficiency = Dry matter / HU accumulated

Transmitted radiation (%): It is the ratio of transmitted PAR to the total incidence on the crop surface and multiplied by 100.

Reflected radiation (%): It is the ratio of reflected radiation by crop with the total incidence PAR over crop surface and multiplied by 100.

Absorbed radiation (%): It is calculated by subtracting transmitted and reflected radiation from 100.

APAR = 100 - transmitted – reflected

Yield and yield attributes: Three plants were randomly taken from each plot for recording of biological parameters at crop maturity.

Number of bolls per plant: Number of detached bolls was counted and mean number of boll per plant was calculated.

Yield of seed cotton: The seed cotton was picked from three randomly selected plants from each plot. The seed cotton yield was calculated on net plot area basis.

3. RESULTS

3.1 Optical Characteristics (Indices)

The optical characteristics (Transmitted, Reflected and Absorbed PAR) of cotton cultivars under different plant spacing and fertilizer levels were presented in Table 1. In case of cultivars, the maximum reflection (13.4%) was observed in Bunty, followed by RCH 650 (9.8%) and RCH 602 (5.7 %). Bunty showed maximum transmission (8.3%), followed by RCH 650 (8%) and RCH 602 (7.7%). But reverse trend was observed in case of PAR absorption.

In case of spacing, the maximum reflection (11.4%) was observed in 67.5 × 45 cm, followed by 67.5 × 60 cm (10%) and 67.5 × 75 cm (7.5%). Cotton crop with spacing of 67.5 × 45 cm showed maximum transmission (8.4%), followed by 67.5 × 60 cm (7.9%) and 67.5 × 75 cm and showed maximum absorption (84.8%), followed by 67.5 × 60 cm (82.1%) and 67.5 × 45 cm (80.2%).

The maximum reflection (11.1%) was observed in Recommended Dose of Fertilizer (RDF), followed by 12% of RDF (10.5%) and 150 % of RDF (7. %). Under different fertilizer levels RDF showed maximum transmission (8.3%), followed by 125 % of RDF (8.1%) and 150 % of RDF (7.6%). Cotton crop with 150% of RDF showed maximum absorption (85.1%) followed by 125 % of RDF (81.4%) and RDF (80.6%).

3.2 Thermal Use Efficiency

The thermal use efficiency (TUE) was computed at various phenophases of different cultivars, is presented in the Fig 1. In case of cultivars, TUE was found higher in the RCH 602 followed by RCH 650 and Bunty at all the phenophases *i.e.* 50% square formation, 50% flowering, 50% boll formation, 50% boll opening and at maturity. The TUE was found maximum in the cotton planted under wider plant spacing 67.5 × 75 cm followed by 67.5 × 60 cm and 67.5 × 45 cm at all the phenophases. The highest TUE was found maximum in the cotton applied with 150% of RDF followed by 125% of RDF and RDF at all phenophases under different fertilizer levels.

3.3 Yield and Yield Attributes

3.3.1 Number of bolls

The data pertaining to number of bolls plant^{-1} which was recorded at the time of picking of the cotton crop were presented in Table 2.

It was observed from that the numbers of picked bolls plant^{-1} were influenced by different plant densities. Cotton crop planted with spacing of 67.5 cm × 75 cm produced significantly higher number of bolls plant^{-1} (14.7) as compared to cotton crop with narrow plant spacing.

RCH 602 cultivar produced significantly higher number of bolls plant^{-1} (21) as compared to RCH 650 and Bunty. A level of fertilizers application does not affect the number of bolls plant^{-1}.

Table 1. Effect of different plant spacing and fertilizer levels on optical characteristics of cotton cultivars

	Reflection (%)	Transmission (%)	Absorption (%)
Cultivars			
RCH 602	5.7	7.7	86.6
RCH 650	9.8	8	82.2
Bunty	13.4	8.3	78.3
Spacing			
67.5 × 45 cm	11.4	8.4	80.2
67.5 × 60 cm	10	7.9	82.1
67.5 × 75 cm	7.5	7.7	84.8
Fertilizer levels			
RDF	11.1	8.3	80.6
125 % of RDF	10.5	8.1	81.4
150 % of RDF	7.3	7.6	85.1

RDF = Recommended Dose of Fertilizer

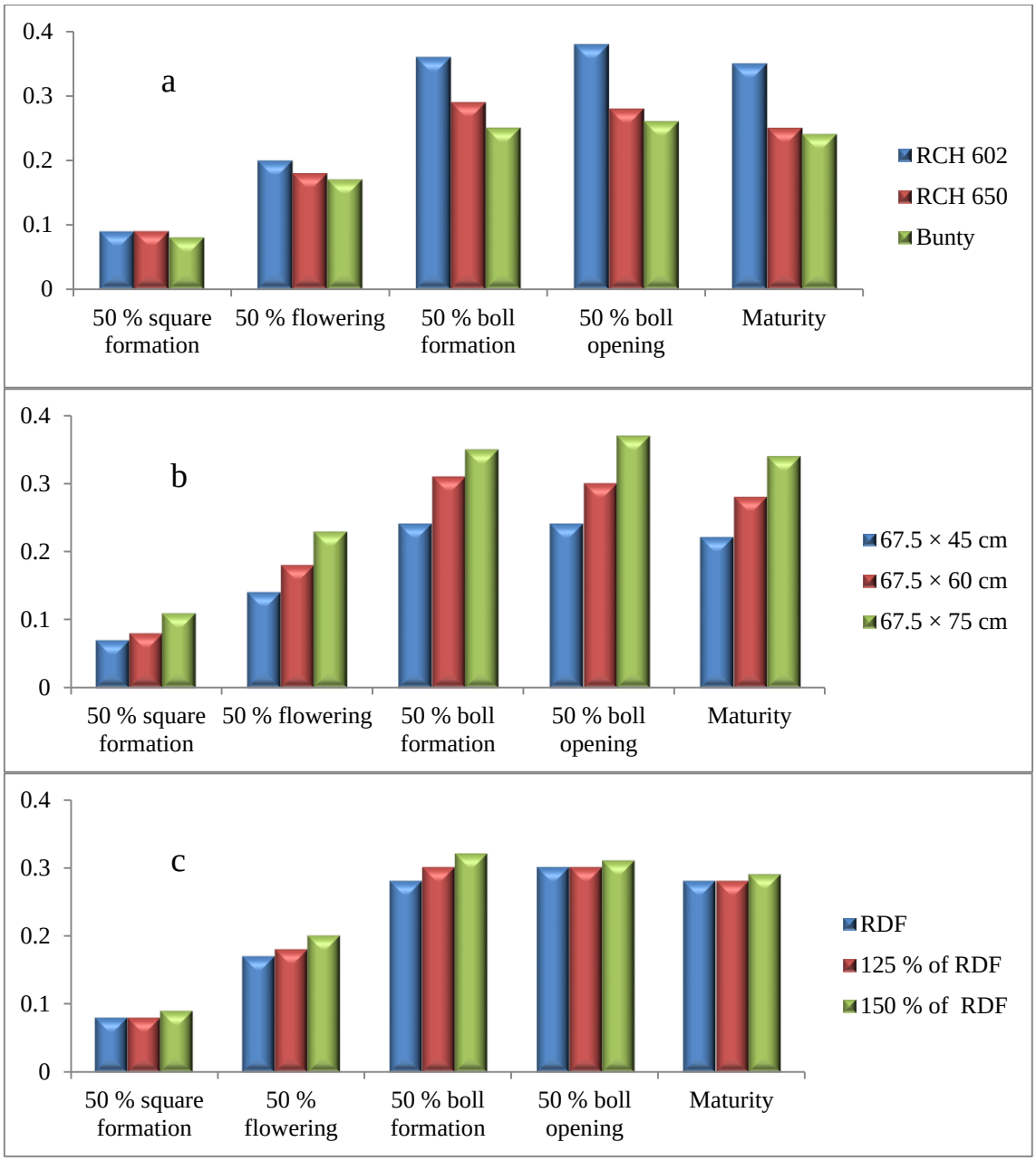

Fig 1. Effect of different plant spacing and fertilizer levels on thermal use efficiency (g/m^2/^{o}C day) of cotton cultivars as shown in a, b and c

3.3.2 Boll weight

The perusal of data presented in Table 2 indicates that the different plant spacing had no significant effect on boll weight, however numerically maximum boll weight (3.66 g) was recorded with spacing of 67.5 cm × 60 cm followed by 67.5 cm × 75 cm and 67.5 cm × 45 cm.

The boll weight was influenced significantly by different cultivars. The maximum boll weight 3.89 g/boll was observed in RCH 650 as compared to RCH 650 and Bunty. Application of 125 % of RDF produced significantly higher boll weight (3.62 g) as compared to RDF and 150 % of RDF.

3.3.3 Seed cotton yield

The data presented in Table 2 clearly shows that the seed cotton yield kg ha^{-1} was significantly influenced by different treatments. The highest seed cotton yield (1120.76 kg ha^{-1}) was observed under wider plant spacing (67.5 cm × 75 cm)

Table 2. Effect of plant spacing and fertilizer levels on yield and yield attributing characters of cotton

TREATMENTS	Number of bolls plant^{-1}	Boll Weight (g)	Sympodial branches plant^{-1} At Harvest	Seed cotton yield (Kg/ha)
Cultivars				
RCH 602	21.0	3.41	23.7	1248.7
RCH 650	13.4	3.89	20.0	1080.1
Bunty	12.3	3.39	18.2	868.7
CD at 5 %	2.6	0.27	1.4	81.1
Plantspacing				
67.5 × 45 cm	9.9	3.41	21.0	998.8
67.5 × 60 cm	10.0	3.66	20.6	1078.0
67.5 × 75 cm	14.7	3.62	20.3	1120.7
CD at 5 %	2.6	NS	NS	81.1
Fertilizerlevels				
RDF	14.9	3.61	21.4	1017.1
125 % of RDF	15.7	3.62	20.3	1094.3
150 % of RDF	16.0	3.46	20.3	1086.2
CD at 5 %	NS	NS	0.1	NS

RDF = Recommended Dose of Fertilizer

Table 3. Correlation coefficients of TUE at various phenological stages with yield and yield attributes of *Bt* cotton

Parameters	Number of bolls plant^{-1}	Boll Weight (g)	Sympodial branches plant^{-1} at harvest	Seed cotton yield (Kg/h)
TUE at 50 % Square Formation	0.44	0.27	0.05	0.49
TUE at 50 % Flowering	0.56	0.16	0.14	0.58
TUE at 50 % Boll formation	0.70*	0.12	0.53	0.87*
TUE at 50 % Boll Opening	0.76*	0.00	0.58	0.81*
TUE at Marurity	0.76*	0.02	0.58	0.79*

**Significance*

than other narrow plant spacing, however, seed cotton yield kg ha^{-1} (998.83 kg ha^{-1}) was found lowest with narrow plant spacing of 67.5 cm × 45 cm. Among cultivars RCH 602 had maximum seed cotton yield (1248.7 Kg/h) followed by RCH 650 and Bunty.

Fertilizer levels had positive effect on seed cotton yield kg ha^{-1} and increased with increase in fertilizer levels upto 125% of RDF. The maximum seed cotton yield kg ha^{-1} (1094.31 kg ha^{-1}) was recorded with 125 % of RDF.

3.3.4 Correlation of TUE with yield and yield attributes

The result of correlation studies between TUE and yield and yield attributes at various phenophages presented in Table 3. TUE at 50% boll formation, 50% boll opening and at maturity show significant positive correlation with number of bolls $plant^{-1}$ and Seed cotton yield (kg ha^{-1}).

4. DISCUSSION

Absorption was higher in wider plant spacing 67.5 cm × 75 cm than other plant spacing, cultivar RCH 602 absorbed maximum PAR in comparison to other cultivars and 150 % of RDF crop showed more absorption and less transmission as compared to cotton crop with 125 % of RDF which might be due to higher leaf area index produced in an above treatments. Similar results were found by Monga et al. [5].

Significantly higher number of sympodial branches $plant^{-1}$ was recorded with RDF but further increase in fertilizer had a significant effect on sympodial branches $plant^{-1}$. This may be due to the fact that fertilizer helped in cell division and cell elongation leading to increased number of lateral branches. Similar results were also reported by Kumar et al. [6] and Modhvadia et al. [7]. It was also observed from the results that there was not much variation in boll weight due to application of different levels of fertilizer. The boll weight was maximum with 125 % of RDF followed by RDF, 150 % of RDF. The observations were in conformity with Doli et al. [8]

Number of bolls $plant^{-1}$ increased with increasing levels of fertilizer from RDF to 150 % of RDF. The application of 150 % of RDF significantly enhanced the number of bolls $plant^{-1}$. Similar result obtained by Devraj et al. [9] and Gadade et al. [10] who reported that increase in fertilizer levels resulted in higher bolls $plant^{-1}$.

Fertilizer levels had positive effect on seed cotton yield kg ha^{-1} and increased with increase in fertilizer levels upto 125 % of RDF. The maximum seed cotton yield kg ha^{-1} (1094.31) was recorded with 125 % of RDF. Bhalerao and Gaikwad [11] reported higher seed cotton yield with the application of 125 % of RDF.

5. CONCLUSION

The PAR interception was highest in cotton sown in narrow plant spacing 67.5 cm × 45 cm followed by 67.5 cm × 60 cm and 67.5 cm × 75 cm. The transmitted PAR was lowest in cotton sown in wider plant spacing 67.5 cm × 75 cm as compared to other plant spacing. Transmitted PAR values were highest in cotton sown in narrow plant spacing 67.5 cm × 45 cm, whereas absorbed PAR values were highest in cotton sown in wider plant spacing 67.5 cm × 75 cm.

Maximum number of sympodial branches $plant^{-1}$ was obtained at RDF but it remained at par with 125 % of RDF and 150 % of RDF. Increase in levels of fertilizer significantly increased the number of bolls $plant^{-1}$ up to 150 % of RDF which remained at par with 125 % of RDF. However, boll weight did not differ significantly due to different fertilizer levels. Increase in levels of fertilizer increase seed cotton yield kg ha^{-1} up to 125 % of RDF which is greater than cotton crop with 150 % of RDF and RDF.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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