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Growth Indices of *Bt* and Non *Bt* High Density Planted Cotton as Influenced by Integrated Nutrient Management Practices

G. Vinay [a*], K. P. Vani [b], B. Padmaja [c++], G. Jayasree [d] and S. Triveni [e]

[a] *Department of Agronomy, College of Agriculture, Rajendranagar, India.*
[b] *Department of Agronomy, Agricultural College, Sircilla, India.*
[c] *AICRP on Weed Management Rajendranagar, India.*
[d] *Department of Soil Science and Agricultural Chemistry, Agricultural College, Rajendranagar, India.*
[e] *Department of Microbiology and Bio Energy, College of Agriculture, Rajendranagar, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyd-500030, India.*

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

A field experiment was conducted at College Farm, Agricultural College, Rajendranagar, Hyderabad, during *kharif* 2019-20 and 2020-21 to study the effect of genotypes and integrated nutrient management practices on growth of HDPS cotton. Experiment was laid out in Split plot design, with two genotypes as main plots (M) and nine Integrated Nutrient Management practices as sub-plots (S). Among genotypes, Leaf Area Index (LAI), Absolute Growth Rate (AGR), Relative

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[++] *Principal Scientist (Agro);*
**Corresponding author: E-mail: vinaygadipe6859@gmail.com;*

Growth Rate (RGR), Net Assimilation Rate (NAR) were recorded with *Bt* (KCH-14 K59 BG II) compared to Non-*Bt* (ADB-542) during *kharif* 2019-20 and 2020-21. Among integrated nutrient management treatments, significantly higher LAI, AGR, RGR, NAR were observed with 100% RDF + soil application *Jeevamrutha* @ 500 L ha^{-1} at 15 days interval up to harvest (S_5) during both years and which was comparable with 100 % RDF + Foliar spray of *Jeevamrutha* @ 5% at 15 days interval up to harvest (S_7) and 100 % RDF (S_3), respectively. Finally, *Bt* cotton had recorded LAI, AGR, RGR, NAR than non *Bt*. Among integrated nutrient management practices, S_5 had recorded maximum LAI, AGR, RGR, NAR.

Keywords: HDPS cotton; Jeevamrutha; INM; leaf area index; net assimilation ratio.

1. INTRODUCTION

"Cotton (*Gossypium hirsutum* L.) is one of the major cash crops of India, popularly known as 'White gold' and 'King of fibres' for its role in the national economy in terms of foreign exchange earnings and employment generation. Cotton provides fibre, feed, fuel and vegetable oil" [1]. "It is the world's leading source of natural textile fibre and fifth largest oilseeds crop which covers 40% of the global textile need and 3.3% of edible oil respectively" [2].

"Cotton is grown mainly in tropical and subtropical regions of more than 80 countries in the world. This crop provides livelihood to 60 million people in India by way of support of agriculture, processing and textiles and it contributes to 29% of the national GDP" [3]. In India it is grown in an area of 13.28 m ha with production of 35.24 m bales, and productivity of 491 kg ha^{-1}. In India, during 2020-21 higher area (4.54 m ha) and production (10.1 m bales) was recorded in Maharashtra and productivity was recorded from Punjab (690 kg ha^{-1}). Telangana ranked second in area (2.35 m ha) with a production of 5.7 m bales with a productivity of 418 kg ha^{-1} (CCI, 2021).

"Bt cotton in India was introduced in the year 2002 and the Bt period (2002-03 to 2010-11) brought a significant increase in the growth of cotton acreage, production and productivity from 13 million bales to 40 million bales in the past 13 years. However, this Bt period also registered a marked increase in the instability in production [4] as the cost of cotton production is escalating due to increased labour demand, increased labour costs, increased seed costs, and increased costs for cotton picking and nutrient requirements". Country's population is growing at 1.9% and demands for food and fibre continue to grow and putting pressure on the limited arable land available [5]. All these facts point to the dire need for sustainable practices. So, to sustain the productivity, high density planting systems, with narrow and ultra-narrow spacing, developing suitable management options for improving yields and also to improve input use efficiency is the need of hour.

"A high density planting system (HDPS) leading to more rapid canopy closure and decreased soil water evaporation, is becoming popular to address water scarcity challenges. In many countries, narrow row plantings have been adopted after showing improvement in cotton productivity" [6]. The adoption of HDP, along with good fertilizer management and better genotypes, is a viable approach to break the current trend of stagnating yields under primarily rainfed *hirsutum* (upland) cotton growing areas.

"Intensive cropping and indiscriminate fertilizer application depleted available NPK in almost all soils in India. Hence replenishment of shovelled out nutrients is very essential, especially when exhaustive crops like cotton is cultivated. The commercial cultivation of Bt hybrids is more profitable and relatively safe for the environment due to 50-75% reduction in pesticide application" [7]. "Bt cotton is known to draw huge quantities of nutrients especially nitrogen than the hybrids and varieties, which will have serious repercussions on the already depleted soil fertility status. Trends of high nitrogen requirement by fast expanding Bt hybrids in India on one hand and rapid depletion of nutrients in the soils warrants improvement in cotton yield through agronomic management by integrated nutrient management to restore the soil fertility and sustain crop productivity and fully harness its economic benefits" [8]. "Integrated use of chemical fertilizers and organic manures is not only essential for achieving higher yields but also plays crucial role in improving soil health. Hence, for maintaining soil physicochemical and biological properties and increasing soil productivity, use of FYM, vermicompost, *Jeevamrutha* alone or in combination may prove to be beneficial" [9].

Keeping the above facts in view, the present study was initiated to maximize the growth and yield of high density planted cotton under different Genotypes and Integrated Nutrient Management practices.

2. MATERIALS AND METHODS

The field experiment was conducted at College Farm, Agricultural College, Rajendranagar, Southern zone of Telangana State. The farm is geographically situated at 17°32'N Latitude, 78°41' E Longitude and altitude of 542.6 m above mean sea level. The soil of the experimental site was sandy clay loam in texture, slightly alkaline in reaction and non-saline. The fertility status of the experimental soil was low in organic carbon (0.51%), low in available N (138 kg ha^{-1}), high in phosphorus (65 kg ha^{-1}) and medium in potassium (286 kg ha^{-1}). The experiment was conducted during *kharif* 2019-20 and 2020-21 in split plot design with two genotypes *viz*., M_1-*Bt* (KCH – 14K59 BG II), M_2-Non- *Bt* (ADB – 542) as main plots and nine integrated nutrient management practices *viz.,* : S_1-No fertilizer, S_2-75 % RDF, S_3-100 % RDF, S_4-75 % RDF + Soil application of *Jeevamrutha* @ 500 L ha^{-1} at 15 days interval up to harvest, S_5-100 % RDF + Soil application of *Jeevamrutha* @ 500 L ha^{-1} at 15 days interval up to harvest, S_6-75 % RDF + Foliar spray of *Jeevamrutha* @ 5% at 15 days interval up to harvest, S_7-100 % RDF + Foliar spray of *Jeevamrutha*@ 5% at 15 days interval up to harvest, S_8-Soil application of *Jeevamrutha* @ 500 L ha^{-1} at 15 days interval up to harvest (Alone), S_9-Soil application of *Jeevamrutha* @ 500 L ha^{-1} + Foliar spray of *Jeevamrutha* @ 5% at 15 days interval up to harvest, as sub-plots replicated thrice. Fertilizer management was done as per the framed treatments following standard protocols of Bt and Non Bt cotton. In Bt cotton (RDF: 120:60:60 NPK ha^{-1}), Nitrogen and Potassium were applied in four equal splits (*i.e.,* at 20, 40, 60 and 80 DAS) whereas entire dose of Phosphorus was applied as basal. In Non Bt cotton (RDF: 90:45:45 NPK ha^{-1}), Nitrogen and Potassium were supplied in only three equal splits (*i.e.,* at 30, 60 and 90 DAS) and Phosphorus was applied at basal. Urea, DAP and MOP were the sources of N, P_2O_5 and K_2O respectively. *Jeevamrutha* was made by mixing 200 litres of water with 10 kg fresh cow dung and 10 liters of cow urine (desi), 2 kg jaggery, 2 kg flour of chickpea, and 100 g antennae soil in a barrel. The fermented mixture was kept in the shade and was stirred thoroughly twice a day (morning and evening) in clockwise direction with the help of wooden stick for three days. It will produce a mild foul odour after three days which indicates its readiness to use. *Jeevamrutha* @ 500 L ha^{-1} was applied manually directly in the soil in four treatments (S_4, S_5, S_8 and S_9) from 15 DAS to harvest of cotton crop with 15 days interval. Foliar spray of *Jeevamrutha* @ 5% was applied in the three treatments (S_6, S_7 and S_9) with Knapsack sprayer from 15 DAS to harvest of cotton crop with 15 days interval. Spacing adopted 60 cm x 30 cm, gross plot size and net plot size were 6.0 m x 4.2 m and 3.6 m x 3.0 m respectively during both seasons. Plant height was measured from the ground level up to the tip of growing point at 30, 60, 90, 120,150 DAS and at harvest in labelled five (5) plants and the mean was expressed as plant height in cm. The weight of dry matter accumulated in plant is an index of the plant growth. The roots of the plant uprooted for dry matter study, were removed and after removing the roots the plant were air dried under sun for eight days and subsequently dried in the thermostatic oven at 65 ± 2°C, till they were completely dried. The final constant dry weight was recorded as total dry matter weight in gram per plant. The other observations were recorded based on growth observations. They are mentioned below.

2.1 Leaf Area Index

Leaf area index (LAI) is defined as leaf area per unit land area. It was worked out by dividing the leaf area per plant by land area occupied by the plant as per Williams [10].

$$LAI = \frac{\text{Leaf area}}{\text{Land area}}$$

2.2 Absolute Growth Rate (cm day^{-1})

The rate of increase in growth variable at time 't' is called as absolute growth rate. It was expressed in cm/day. Absolute growth rate was calculated by following formula [11].

$$AGR = \frac{H_2 - H_1}{t_2 - t_1}$$

H_2 represent height of the plant at time t_2.

While H_1 represent height of the plant at time t_1.

2.3 Net Assimilation Rate (g cm^{-2} day^{-1})

It is the rate of increase in dry weight per unit leaf area and is expressed as g/cm^2 leaf area per day. This was calculated by following formula [12].

$$NAR = \frac{\log A_2 - \log A_1}{A_2 - A_1} \times \frac{W_2 - W_1}{t_2 - t_1}$$

W_1 and A_1 represent dry weight and leaf area of the plant respectively at time t_1.

While W_2 and A_2 represent dry weight and leaf area respectively at time t_2.

2.4 Relative Growth Rate (g g^{-1} day^{-1})

The parameter indicates rate of growth per unit dry mater. It is similar to compound interest wherein the increment in any interval adds to the capital for subsequent growth. This rate of increment is known as relative growth rate [13].

$$RGR = \frac{(\log_e W_2 - \log_e W_1)}{(t_2 - t_1)}$$

Where,

W_1 = Dry weight (g) of plant at t_1 days
W_2 = Dry weight (g) of plant at t_2 days
t_2-t_1 = The interval in days
Log_e = Natural logarithm (2.3026)

The data were analyzed statistically applying analysis of variance technique for split plot design. The significance was tested by 'F' test [14].

3. RESULTS AND DISCUSSION

3.1 Leaf Area Index

Leaf area index (LAI) is an elementary physiological parameter that decides the yield through the extent of assimilate synthesis. Optimum leaf area index is dependent on the canopy architecture which in turn is decided by the agronomic practices like plant density, variety and nutrient management etc. In general leaf area index increased in all treatments up to 90 DAS, thereafter a declining trend was observed towards maturity due to leaf senescence.

An overview of the data from Table 1, clearly indicated that leaf area index was significantly affected by genotypes at all the stages of observation with significantly higher leaf area index with M_1 [*Bt* KCH - 14K59 BG II] (0.259, 2.03, 3.26, 2.88, 0.83 and 0.176) at 30, 60, 90, 120, 150 DAS and harvest compared to M_2 [non *Bt* ADB – 542] with lower leaf area index (0.199, 1.74, 2.58, 2.28, 0.59 and 0.121).

Short plants, lesser number of leaves and leaf size, low photosynthetic ability, less vegetative growth reduced the leaf area in non Bt cotton. Inbuilt resistance against bollworm, nutrient uptake, photosynthetic ability, more vegetative growth thus lead to high leaf area index of Bt cotton. These results are supported by Ajay et al. [15], Sabale et al. [16] and Nagendar et al. [5].

Leaf area index did not vary significantly due to nutrient management treatments at 30 DAS during both the years of study. Contrary to this, significant differences in leaf area index across the treatments were observed at 60, 90, 120, 150 DAS and at harvest. Higher leaf area index observed under S_5 (100 % RDF + Soil application of *Jeevamrutha* @ 500 L ha^{-1} at 15 days interval up to harvest) at 60 DAS (2.23), 90 DAS (3.47), 120 DAS (3.13), 150 DAS (0.90) and at harvest (0.167) which was at par with S_7 (100% RDF + Foliar spray of *Jeevamrutha* @ 5% at 15 days interval up to harvest) (2.17, 3.42, 3.07, 0.87 and 0.163). Lower leaf area index was observed by S_1 (No fertilizers) (1.45, 2.29, 1.93, 0.48 and 0.126) at all the growth stages of the crop.

Increased leaf area index may be due to increased meristematic activity, vertical growth, synthesis of proteins involved in cell development, cell proliferation, development of cell wall and cytoskeleton due to extended period of availability of nutrients from combination of nutrients as compared to inorganic source alone and no fertilizer. The LAI fell as no fertilizer treatments failed to supply assimilate needed for growing sections, thus resulting in reduced leaf area. These results are in line with Munir et al. [17], Ali and Ahmad [18] and Subramanian et al. [19].

3.2 Absolute Growth Rate (cm day^{-1})

Absolute growth rate (cm day^{-1}) is function of amount of growing material present. From Table 2, it can be inferred that effect of genotype and nutrient management on absolute growth rate of HDPS cotton was found be significant during the intervals 0-30, 30-60,, 60-90, 90-120,120-150,150 DAS – harvest stage.

Among the main treatments, during 2019 and 2020, absolute growth rate was significantly higher in *Bt* KCH - 14K59 BG II at 0-30 DAS (0.76 cm day^{-1}), 30-60 DAS (1.39), 60-90 DAS (1.24), 90-120 DAS (0.74), 120-150 DAS (0.39) and 150 DAS-harvest (0.16) respectively. While, lowest AGR was recorded with non *Bt* ADB - 542 (0.60, 0.94, 1.07, 0.53, 0.32 and 0.14 cm day^{-1}) during 0-30, 30-60, 60-90, 90-120, 120-150 DAS and 150 DAS-harvest.

Bt plants are fast growing compared to non Bt plants as non Bt plants are less responsive to fertilizers which led to lesser growth rate. Improvement in growth rate due to application of higher level of fertilizers along with organics resulted in higher growth than with no fertilizer. Similar results were reported by Sabale et al*.* [16] and Thakur [20].

INM had significant effect on absolute growth rate. 100% RDF + Soil application of *Jeevamrutha* @ 500 L ha^{-1} at 15 days interval up to harvest (S_5) recorded significantly higher absolute growth rate (0.77, 1.43, 1.37, 0.72, 0.40 and 0.21 cm day^{-1}) at 0-30, 30-60, 60-90, 90-120, 120 -150 DAS and 150 DAS - harvest and statistically comparable to 100 % RDF + Foliar spray of Jeevamrutha @ 5% at 15 days interval up to harvest (S_7) (0.75, 1.35, 1.35, 0.69, 0.39 and 0.19). Minimum absolute growth rate (0.58, 0.84, 0.96, 0.54, 0.31 and 0.12) was observed with S_1 [No fertilizers].

These findings are in agreement with Ghule et al*.* [11] who reported that improvement in growth rate is due to application of higher level of fertilizers along with organics resulted higher growth than no fertilizer.

3.3 Relative Growth Rate (g $g^{-1}day^{-1}$)

Relative growth rate (RGR) is an index that takes into account the original difference in size of plants and, specifically, expresses growth in terms of the rate of increase in size per unit of size.

Perusal of data from Table 3, indicated that effect of genotype treatments on relative growth rate was found to be non - significant during all the stages of crop growth. However, *Bt* KCH - 14K59 BG II showed higher relative growth rate (0.0340, 0.0305, 0.0133, 0.0056 and 0.0025 g $g^{-1}day^{-1}$) at 30-60, 60-90, 90-120, 120-150 DAS and 150 DAS - harvest, while non *Bt* ADB - 542 resulted in lower RGR at all intervals,(0.0309, 0.0303, 0.0149, 0.0046 and 0.0029 g $g^{-1}day^{-1}$).

Growth parameters like RGR and NAR have been extensively used in recent years for better understanding of physiological basis of yield variation in crop plants. Bt plants have higher vegetative growth due to pest resistance, high nutrient uptake compared to non Bt plants as non Bt plants are prone to insect attack.

On contrary, INM treatments could produce non - significant effect only at 60-90 DAS and remained significant during other intervals. Among sub plots, application of 100% RDF + Soil application of *Jeevamrutha* @ 500 L ha^{-1} at 15 days interval up to harvest resulted in significantly higher relative growth rate at 30-60 DAS (0.0343 g $g^{-1}day^{-1}$), 60-90 DAS (0.0297), 90-120 DAS (0.0127), 120-150 DAS (0.0053) and 150 DAS-harvest (0.00024) and S_1 [No fertilizers] treatment had lowest relative growth rate (0.0308, 0.0293, 0.106, 0.0065 and 0.0028) of HDPS cotton at 30-60, 60-90, 90-120, 120-150 DAS and 150 DAS – harvest during *kharif,* 2019 and 2020.

Higher nutrient uptake through liquid organic and inorganic fertilizers might have increased photosynthetic efficiency, leaf thickness, higher chlorophyll content and efficient translocation of photosynthates, increasing growth rate compared to no fertilizer treatment. Ghule et al*.* [11] and Sabale et al*.* [16].

3.4 Net Assimilation Rate (g cm^{-2} d^{-1})

Net assimilation rate (NAR) represents the productive efficiency of plants in capturing light, assimilating carbon dioxide and storing photo assimilates. Combined analysis of variance presented in Table 4. showed that net assimilation rate was significantly influenced by genotypes and integrated nutrient management practices at 30-60, 60-90, 90 -120, 120-150 DAS and 150 DAS - harvest.

M_1 [*Bt* (KCH - 14K59 BG II] resulted in significantly higher net assimilation rate at 30-60 DAS (4.80 g cm^{-2} day^{-1}), 60-90 DAS (11.63) , 90-120 DAS (9.33), 120-150 DAS (4.33) and 150 DAS-harvest (1.90) which remained superior to M_2 [non *Bt* ADB 542] (3.48, 8.98, 8.37, 2.90 and 1.62 g cm^{-2} day^{-1}) at 30-60, 60-90, 90-120, 120-150 DAS and 150 DAS-harvest during 2020 and 2021 respectively.

The high NAR might be due to genetic constitution of Bt cotton, high nutrient uptake as well as high photosynthetic ability compared to non Bt cotton. The NAR decreased continuously from 90 DAS until harvest in both genotypes and decrease NAR at later stages could be due to mutual shading of leaves. Higher values of NAR in *Bt* cotton at all intervals was the result of retention of more numbers of bolls at an early stage compared to non-Bt Thakur [20] and Sabale et al*.* [16].

Table 1. Leaf area index of HDPS cotton as influenced by genotypes and integrated nutrient management

Treatment	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	Harvest
Main plot						
M_1	0.259	2.03	3.26	2.88	0.83	0.176
M_2	0.199	1.74	2.58	2.28	0.59	0.121
SE(m)±	0.009	0.04	0.08	0.08	0.015	0.004
CD (p=0.05)	0.057	0.24	0.51	0.48	0.09	0.025
Sub plot						
S_1	0.196	1.45	2.29	1.93	0.48	0.126
S_2	0.231	1.86	2.88	2.60	0.70	0.146
S_3	0.243	2.09	3.35	3.00	0.83	0.158
S_4	0.238	1.97	3.02	2.69	0.75	0.154
S_5	0.252	2.23	3.47	3.13	0.90	0.167
S_6	0.234	1.92	2.95	2.63	0.72	0.151
S_7	0.245	2.17	3.42	3.07	0.87	0.163
S_8	0.210	1.61	2.42	2.06	0.55	0.134
S_9	0.212	1.65	2.47	2.11	0.58	0.138
SE(m)±	0.012	0.05	0.13	0.11	0.032	0.004
CD (p=0.05)	NS	0.15	0.36	0.33	0.9	0.012
Interaction						
M×S						
SE(m)±	0.020	0.08	0.19	0.17	0.05	0.01
CD (p=0.05)	NS	NS	NS	NS	NS	NS
S×M						
SE(m)±	0.018	0.07	0.18	0.16	0.05	0.01
CD (p=0.05)	NS	NS	NS	NS	NS	NS

Main plots – Genotypes
M_1-Bt (KCH – 14K59 BG II)
M_2-Non- Bt (ADB – 542)
Sub plots-Integrated Nutrient Management:
S_1-No fertilizer
S_2-75 % RDF
S_3-100 % RDF
S_4-75 % RDF + Soil application of Jeevamrutha @ 500 L ha^{-1} at 15 days interval up to harvest
S_5-100 % RDF + Soil application of Jeevamrutha @ 500 L ha^{-1} at 15 days interval up to harvest
S_6-75 % RDF + Foliar spray of Jeevamrutha @ 5% at 15 days interval up to harvest
S_7-100 % RDF + Foliar spray of Jeevamrutha@ 5% at 15 days interval up to harvest
S_8- Soil application of Jeevamrutha @ 500 L ha^{-1} at 15 days interval up to harvest (Alone)
S_9-Soil application of Jeevamrutha @ 500 L ha^{-1} + Foliar spray of Jeevamrutha @ 5% at 15 days interval up to harvest

Table 2. Absolute growth rate (cm day^{-1}) of HDPS cotton as influenced by genotypes and integrated nutrient management

Treatment	0-30 DAS	30-60 DAS	60-90 DAS	90-120 DAS	120-150 DAS	150 DAS Harvest
Main plot						
M_1	0.76	1.39	1.24	0.74	0.39	0.16
M_2	0.60	0.94	1.07	0.53	0.32	0.14
SE(m)±	0.02	0.03	0.03	0.01	0.01	0.01
CD (p=0.05)	0.14	0.17	0.16	0.06	0.04	NS
Sub plot						
S_1	0.58	0.84	0.96	0.54	0.31	0.12
S_2	0.65	1.14	1.11	0.63	0.32	0.12
S_3	0.73	1.31	1.27	0.69	0.37	0.17
S_4	0.71	1.22	1.19	0.64	0.37	0.16
S_5	0.77	1.43	1.37	0.72	0.40	0.21
S_6	0.69	1.17	1.12	0.64	0.37	0.17
S_7	0.75	1.35	1.35	0.69	0.39	0.19
S_8	0.62	0.96	1.00	0.57	0.33	0.09
S_9	0.62	1.07	1.00	0.59	0.36	0.12
SE(m)±	0.02	0.05	0.05	0.02	0.01	0.01
CD (p=0.05)	0.07	0.13	0.14	0.05	0.03	0.02
Interaction						
M×S						
SE(m)±	0.04	0.07	0.07	0.02	0.01	0.01
CD (p=0.05)	NS	NS	NS	NS	NS	NS
S×M						
SE(m)±	0.03	0.06	0.07	0.02	0.01	0.01
CD (p=0.05)	NS	NS	NS	NS	NS	NS

Main plots – Genotypes
M_1-Bt (KCH – 14K59 BG II)
M_2-Non- Bt (ADB – 542)
Sub plots-Integrated Nutrient Management:
S_1-No fertilizer
S_2-75 % RDF
S_3-100 % RDF
S_4-75 % RDF + Soil application of Jeevamrutha @ 500 L ha^{-1} at 15 days interval up to harvest
S_5-100 % RDF + Soil application of Jeevamrutha @ 500 L ha^{-1} at 15 days interval up to harvest
S_6-75 % RDF + Foliar spray of Jeevamrutha @ 5% at 15 days interval up to harvest
S_7-100 % RDF + Foliar spray of Jeevamrutha@ 5% at 15 days interval up to harvest
S_8- Soil application of Jeevamrutha @ 500 L ha^{-1} at 15 days interval up to harvest (Alone)
S_9-Soil application of Jeevamrutha @ 500 L ha^{-1} + Foliar spray of Jeevamrutha @ 5% at 15 days interval up to harvest

Table 3. Relative growth rate (($g\ g^{-1}\ day^{-1}$) of HDPS cotton as influenced by genotypes and integrated nutrient management

Treatment	30-60 DAS	60-90DAS	90 -120 DAS	120 -150 DAS	150 DAS - Harvest
Main plot					
M_1	0.0340	0.0305	0.0133	0.0056	0.0025
M_2	0.0309	0.0303	0.0149	0.0046	0.0029
SE(m)±	0.0006	0.0007	0.0004	0.0002	0.0001
CD (p=0.05)	NS	NS	NS	NS	NS
Sub plot					
S_1	0.0308	0.0293	0.0106	0.0065	0.0028
S_2	0.0318	0.0309	0.0158	0.0042	0.0037
S_3	0.0330	0.0298	0.0140	0.0053	0.0029
S_4	0.0320	0.0306	0.0150	0.0048	0.0034
S_5	0.0343	0.0297	0.0127	0.0053	0.0024
S_6	0.0317	0.0310	0.0151	0.0048	0.0034
S_7	0.0341	0.0297	0.0128	0.0055	0.0022
S_8	0.0317	0.0308	0.0155	0.0049	0.0015
S_9	0.0326	0.0305	0.0154	0.0048	0.0022
SE(m)±	0.0008	0.0007	0.0005	0.0002	0.0002
CD (p=0.05)	0.0022	NS	0.0015	0.0006	0.0005
Interaction					
M×S					
SE(m)±	0.0012	0.0012	0.0008	0.0003	0.0003
CD (p=0.05)	NS	NS	NS	NS	NS
S×M					
SE(m)±	0.0011	0.0010	0.0007	0.0003	0.0002
CD (p=0.05)	NS	NS	NS	NS	NS

Main plots – Genotypes
M_1-Bt (KCH – 14K59 BG II)
M_2-Non- Bt (ADB – 542)
Sub plots-Integrated Nutrient Management:
S_1-No fertilizer
S_2-75 % RDF
S_3-100 % RDF
S_4-75 % RDF + Soil application of Jeevamrutha @ 500 L ha^{-1} at 15 days interval up to harvest
S_5-100 % RDF + Soil application of Jeevamrutha @ 500 L ha^{-1} at 15 days interval up to harvest
S_6-75 % RDF + Foliar spray of Jeevamrutha @ 5% at 15 days interval up to harvest
S_7-100 % RDF + Foliar spray of Jeevamrutha@ 5% at 15 days interval up to harvest
S_8- Soil application of Jeevamrutha @ 500 L ha^{-1} at 15 days interval up to harvest (Alone)
S_9-Soil application of Jeevamrutha @ 500 L ha^{-1} + Foliar spray of Jeevamrutha @ 5% at 15 days interval up to harvest.

Table 4. Net assimilation rate (g cm^{-2} day^{-1}) of HDPS cotton as influenced by genotypes and integrated nutrient management

Treatment	30-60 DAS	60-90DAS	90 -120 DAS	120 -150 DAS	150 DAS - Harvest
Main plot					
M_1	4.80	11.63	9.33	4.33	1.90
M_2	3.48	8.98	8.37	2.90	1.62
SE(m)±	0.16	0.23	0.15	0.06	0.04
CD (p=0.05)	0.95	1.43	0.93	0.38	0.26
Sub plot					
S_1	2.53	6.0	4.04	2.59	0.96
S_2	3.96	9.73	10.15	3.04	2.43
S_3	4.98	11.55	10.23	4.47	2.11
S_4	4.23	10.36	10.08	3.59	2.26
S_5	5.50	12.28	9.89	4.63	1.89
S_6	4.08	10.23	9.80	3.72	2.32
S_7	5.37	12.08	9.73	4.57	1.76
S_8	3.19	7.55	7.82	2.87	0.99
S_9	3.40	8.21	7.94	3.05	1.11
SE(m)±	0.23	0.39	0.28	0.08	0.07
CD (p=0.05)	0.69	1.13	0.81	0.25	0.19
Interaction					
M×S					
SE(m)±	0.36	0.60	0.40	0.13	0.10
CD (p=0.05)	NS	NS	NS	NS	NS
S×M					
SE(m)±	0.35	0.56	0.40	0.12	0.09
CD (p=0.05)	NS	NS	NS	NS	NS

Main plots – Genotypes
M_1-Bt (KCH – 14K59 BG II)
M_2-Non- Bt (ADB – 542)
Sub plots-Integrated Nutrient Management:
S_1-No fertilizer
S_2-75 % RDF
S_3-100 % RDF
S_4-75 % RDF + Soil application of Jeevamrutha @ 500 L ha^{-1} at 15 days interval up to harvest
S_5-100 % RDF + Soil application of Jeevamrutha @ 500 L ha^{-1} at 15 days interval up to harvest
S_6-75 % RDF + Foliar spray of Jeevamrutha @ 5% at 15 days interval up to harvest
S_7-100 % RDF + Foliar spray of Jeevamrutha@ 5% at 15 days interval up to harvest
S_8- Soil application of Jeevamrutha @ 500 L ha^{-1} at 15 days interval up to harvest (Alone)
S_9-Soil application of Jeevamrutha @ 500 L ha^{-1} + Foliar spray of Jeevamrutha @ 5% at 15 days interval up to harvest

Integrated nutrient management practices had significant effect on net assimilation rate. Maximum NAR (5.50, 12.96, 9.89, 4.63 and 1.89 g cm^{-2} day^{-1}) was observed with S_5 [100% RDF + Soil application of *Jeevamrutha* @ 500 L ha^{-1} at 15 days interval up to harvest] statistically comparable to S_7 [100 % RDF + Foliar spray of *Jeevamrutha* @ 5% at 15 days interval up to harvest] (5.37, 12.64, 9.73, 4.57 and 1.76) at 30-60, 60-90, 90-120, 120-150 DAS and 150 DAS - harvest. Minimum net assimilation rate (2.53, 6.20, 4.04, 2.59 and 0.96) was witnessed with S_1 [No fertilizer].

The NAR showed an increasing trend during early phases of cotton growth and reduced subsequently. Integrated use of organic liquid manure *(Jeevamrutha*) and inorganic fertilizers helped for more expansion of leaves, increased light interception, enhanced plant height, improved rate of cytokinin and chlorophyll contents which eventually enhanced the NAR. Higher respiration of leaves in comparison to photosynthesis and reciprocal shadowing of leaves, reduced mobilization of photo-assimilates from leaves towards bolls and minimized the NAR. Ali and Ahmad [18], Ghule et al*.* [11] and Araei and Mojaddam [21].

4. CONCLUSION

Finally, it can be concluded that *Bt,* KCH-14K59 BG II had recorded higher LAI, AGR, RGR, NAR than the non *Bt* ADB-542. Among the integrated nutrient management practices, application of 100 % RDF (S_3) had recorded maximum 100% RDF (S_3) over other treatments.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Kumar P, Karle AS, Singh D, Verma L. Effect of high density planting system (HDPS) and varieties on yield, economics and quality of Desi Cotton. International Journal of Current Microbiology and Applied Sciences. 2017;6(3):233-238.
2. Nagender T, Reddy DR, Rani PL, Sreenivas G, Surekha K, Gupta A, Sreekanth PD, Pallavi CH, Mahesh N. Studies on economic evaluation and nutrient uptake of Bt and non Bt cotton cultivars as influenced by varied plant densities and nitrogen levels. Agriculture Update. 2017;12(5):1357-1362.
3. Khadi BM, Santhy V, Yadav M.S. Highlights the advances in cotton biotechnology, the benefits and socioeconomic impacts. Cotton Biotechnological Advances. Zehr, U.B. (Ed.), XVI. 2010;245.
4. Narala A, Reddy AR. Analysis of growth and instability of cotton production in India. World Cotton Research Conference on Technologies for Prosperity. 2010;451-453.
5. Nagender T, Reddy DR, Rani PL, Sreenivas G, Surekha K, Gupta A, Sreekanth, PD. Response of nitrogen fertilization and plant densities on Bt and non-Bt cotton (Gossypium hirsutum L.) hybrids. International Journal of Current Microbiology and Applied Science. 2017; 6(9):3199-3207.
6. Ali ML, Ali M, Sattar, Ali MA. Response of seed cotton yield to various plant populations and planting methods. Journal of Agriculture Research. 2010;48(2):163-169.
7. Gangaiah B, Ahlawat IPS, Babu MBBP. Response of nitrogen fertilization on Bt and non Bt cotton (*Gossypium hirsutum*) hybrids. South Asian Association for Regional Corporation Journal of Agriculture. 2013;11(1):121-132.
8. Vani KP, Rekha, KB, Nalini N. Yield and nutrient uptake of Bt cotton as influenced by composted waste, organic and inorganic fertilizers. Chemical Science and Review Letters. 2020;9(34):432-441.
9. Patil HM, Udmale KB. Response of different organic inputs on growth and yield of soybean on Inceptisol. Scholarly Journal of Agricultural Science. 2016;6(5): 139-144.
10. Williams, RE. The physiology of plant growth with special reference to the concept of NAR. Annals of Botany. 1946; 10:41-71.
11. Ghule PL, Dahiphale VV, Jadhav JD, Palve DK. Absolute growth rate, relative growth rate, net assimilation rate as influenced on dry matter weight of Bt cotton. Internationl Research Journal of Agricultural Economics and Statistics. 2013;4(1):42-46.
12. Gardner FP, Pearce RB, Mitchell RL. Physiology of crop plants. Scientific Publishers Jodhpur. 1988;200-206.

13. Fisher, RA. Statistical method for research works. Oliver and Boyd Endinburgh, United Kingdom; 1921.
14. Gomez KA, Gomez AA. Statistical procedure for Agriculture research. 2nd Edition. John Willey and Sons, New York. 1984;680.
15. Ajay MY, Umesh, M.R, Shivaleela, Nidagundi JM. Light interception and yield response of cotton varieties to high density planting and fertilizers in sub-tropical India Journal of Applied and Natural Science. 2017;9(3):1835 -1839.
16. Sabale SS, Lahane GR, Dhakulkar SJ. Effect of Various Plant Growth Regulators on Growth and Yield of Cotton (*Gossypium hirsutum*). International Journal of Current Microbiology and Applied Sciences. 2017;6(11):978-989.
17. Munir MK, Tahir M, Saleem MF, Yaseen M. Growth, yield and earliness response of cotton to row spacing and nitrogen management. Journal of Animal and Plant Science. 2015;25:729-738.
18. Ali H, Ahmad MI. Agronomic efficiency and profitability of cotton on integrated use of phosphorus and plant microbes. Brazilian Journal of Biology. 2021;81(2):484-494.
19. Subramanian E, Sathishkumar, Rajesh. Influence of different organic manures on growth, yield components and productivity of cotton. Madras Agricultural Journal. 2020;107:7-9.
20. Thakur MR. Square formation, boll retention, yield and quality parameters of Bt and non-Bt cotton in relation to plant density and NPK levels. International Journal of Chemical Studies. 2020;8(1): 2741-2753.
21. Araei M, Mojaddam M. The effect of different levels of phosphorus from triple super phosphate chemical fertilizers and biological phosphate fertilizer (fertile 2) on physiological growth parameters of corn (SC704) in AHVAZ weather conditions. International Journal of Plant Animal and Environmental Sciences. 2014;4: 625-632.

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