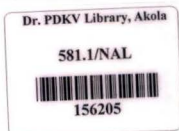


**EVALUATION OF DIFFERENT Bt COTTON (BG II)
HYBRIDS FOR MORPHOPHYSIOLOGICAL TRAITS
UNDER RAINFED CONDITION**

THESIS



**Submitted to
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola
in partial fulfilment of the requirements
for the Degree of**

**MASTER OF SCIENCE
IN
AGRICULTURE
(AGRICULTURAL BOTANY)
(PLANT PHYSIOLOGY)**

**By
NALAVADE ANNASAHEB NAVANATH**

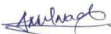
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DECLARATION OF STUDENT

I hereby declare that the experimental work and its interpretation of the Thesis entitled " **EVALUATION OF DIFFERENT Bt COTTON (BG II) HYBRIDS FOR MORPHOPHYSIOLOGICAL TRAITS UNDER RAINFED CONDITION**" or part thereof has neither been submitted for any other degree or diploma of any University, nor the data have been derived from any thesis / publication of any University or scientific organization. The source of materials used and all assistance received during the course of investigation have been duly acknowledged.

Place : Akola.


(Nalavade Annasaheb Navanath)

Date : 12 / 06 / 2013

Enrolment No. JJ-2167



CERTIFICATE

This is to certify that the thesis entitled **"EVALUATION OF DIFFERENT Bt COTTON (BG II) HYBRIDS FOR MORPHOPHYSIOLOGICAL TRAITS UNDER RAINFED CONDITION"** submitted in partial fulfillment of the requirement for the degree of **"Master of Science in Agriculture (Agricultural Botany)"** of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola is a record of bonafide research work carried out by Nalavade Annasaheb Navanath under my guidance and supervision.

The subject of thesis has been approved by the Student's Advisory Committee.

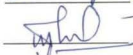
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TABLE OF CONTENTS

Sr. No.	Particulars	Page
A	List of Tables	I
B	List of Figures	iii
C	List of Plates	iv
D	Abbreviations	v
F	Thesis Abstract	vii
I	Introduction	1-6
II	Review of Literature	7-19
III	Material and Methods	20-28
IV	Results and Discussion	29-52
V	Summary and Conclusions	53-57
VI	Implications	58
VII	Literature Cited	59-65
	Vita	
	Appendix	

(A)

List of Tables

Table	Title	Page
1.1	Cotton progress in first decade of 21 st century.	4
1.2	Total fibre requirement change and share of fibre in 2050.	5
3.1	Treatments details.	21
3.2	ANOVA Table.	27
4.1	Plant height (cm) at different growth stages of Bt (BG II) Cotton hybrids.	30
4.2	Leaf area per plant (dm ²) at different growth stages of Bt (BG II) Cotton hybrids.	31
4.3	Leaf Area Index per plant at various growth stages of different Bt (BG II) Cotton hybrids.	32
4.4	Number of Monopodia and sympodia per plant (at harvest) in different Bt (BG II) Cotton hybrids.	33
4.5	Dry matter production (g/ plant) at various growth stages of different Bt (BG II) Cotton hybrids.	35
4.6	Phenological observations of different Bt (BG II) Cotton hybrids.	36
4.7	Relative water content (%) at various growth stages of different Bt (BG II) Cotton hybrids.	38
4.8	Chlorophyll content index at various growth stages of different Bt (BG II) Cotton hybrids.	39
4.9	Photosynthetic efficiency at various growth stages of different Bt (BG II) Cotton hybrids.	40

4.10	Crop growth rate (g /day) at various growth stages of different Bt (BG II) Cotton hybrids.	41
4.11	Relative growth rate (g/g/day) at various growth stages of different Bt (BG II) Cotton hybrids.	42
4.12	Net assimilation rate (g/dm ² /day) at various growth stages of different Bt (BG II) Cotton hybrids.	44
4.13	Specific leaf weight (mg/cm ²) at various growth stages of different Bt (BG II) Cotton hybrids.	45
4.14	Yield and yield attributes in different Bt (BG II) Cotton hybrids.	46
4.15	Fibre properties in different Bt (BG II) cotton hybrids.	48
4.16	To study the morphophysiological traits associated with yield in BG II Cotton hybrids.	52

(B)**List of Figures**

Figures	Title	After Page
1	Plan of layout.	20
2	Plant height (cm) at different growth stages of Bt (BG II) Cotton hybrids.	30
3	Leaf area per plant (dm ²) at different growth stages of Bt (BG II) Cotton hybrids.	31
4	Leaf Area Index per plant at various growth stages of different Bt (BG II) Cotton hybrids.	32
5	Number of Monopodia and sympodia per plant (at harvest) in different Bt (BG II) Cotton hybrids.	33
6	Dry matter production (g/ plant) at various growth stages of different Bt (BG II) Cotton hybrids.	35
7	Phenological observations of different Bt (BG II) Cotton hybrids.	36
8	Relative water content (%) at various growth stages of different Bt (BG II) Cotton hybrids.	38
9	Chlorophyll content index at various growth stages of different Bt (BG II) Cotton hybrids.	39
10	Photosynthetic efficiency at various growth stages of different Bt (BG II) Cotton hybrids.	40
11	Crop growth rate (g /day) at various growth stages of different Bt (BG II) Cotton hybrids.	41
12	Net assimilation rate (g/dm ² /day) at various growth stages of different Bt (BG II) Cotton hybrids.	42
13	Specific leaf weight (mg/cm ²) at various growth stages of different Bt (BG II) Cotton hybrids.	44
14	Yield and yield attributes in different Bt (BG II) Cotton hybrids.	45
15	Fibre properties in different Bt (BG II) cotton hybrids.	46

(C)

List of Plates

Plates	Title	After Page
1	Plant of Bunny Bt (BG II) hybrid (T1).	47
2	Plant of MRC 7301 Bt (BG II) hybrid (T2).	47
3	Plant of Brahma Bt (BG II) hybrid (T3).	47
4	Plant of Super Maruti Bt (BG II) hybrid (T4).	47
5	Plant of Akka Bt (BG II) hybrid (T5).	47
6	Bolls of Bunny Bt (BG II) hybrid (T1).	48
7	Bolls of MRC 7301 Bt (BG II) hybrid (T2).	48
8	Bolls of Brahma Bt (BG II) hybrid (T3).	48
9	Bolls of Super Maruti Bt (BG II) hybrid (T4).	48
10	Bolls of Akka Bt (BG II) hybrid (T5).	48

(D)

Abbreviations

%	- per cent
/ or -1	- Per
Anon.	- Anonymous
Agril.	- Agricultural
CCI	- Chlorophyll content index
CD	- critical difference
CGR	- Crop Growth Rate
cm	- Centimeter
DAS	- Days after sowing
Dev.	- Development
dm	- Decimeter
<i>et. al.</i>	- et alia (and others)
Fig.	- Figure
g	- Gram
ha.	- Hectare
i.e.	- That is
J.	- Journal
Kg.	- Kilogram
LA	- Leaf area
LAI	- Leaf area index
M.S.	- Maharashtra state
N	- Nitrogen
NAR	- Net Assimilation Rate
No.	- Number
NS	- Non-significant
P	- Phosphorus

PE	-	Photosynthetic efficiency
RBD	-	Randomized Block Design
RDF	-	Recommended dose of fertilizer
Res.	-	Research
RGR	-	Relative Growth Rate
RWC	-	Relative water content
SCY	-	Seed Cotton Yield
SE (m) $\pm$	-	Standard error of mean
Sig.	-	Significant
Std.	-	Standard
T	-	Treatment
Viz.	-	Namely

(F) Thesis Abstract

- a) Title of the thesis : "EVALUATION OF DIFFERENT Bt COTTON (BG II) HYBRIDS FOR MORPHOPHYSIOLOGICAL TRAITS UNDER RAINFED CONDITION"
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ABSTRACT

The present investigation entitled, "Evaluation of different Bt cotton (BG II) hybrids for morphophysiological traits under rainfed condition" was conducted at experimental field of Department of Agricultural Botany, Dr. PDKV Akola, during *kharif* season 2012 in randomized block design with four replications. The study included five

hybrids with net plot $2.7 \times 3 \text{ m}^2$. The hybrids were Bunny BG II, MRC 7301 BG II, Brahma BG II, Super Maruti BG II and Akka BG II all these hybrid were Bt *hirsutum* cotton. The observations recorded at 30 days interval from the date of sowing. The various observations were recorded on the basis of morphological, phenological, physiological, computation of growth parameters, yield and yield attributes and fibre qualities.

In that observations, the hybrid Akka Bt which having maximum plant height (106.93 cm), leaf area (68.52 dm^2), leaf area index (1.27), monopodial branches (3.40), sympodial branches (27.42), dry matter (269.16 g/plant), higher RWC at 120 DAS (74.81%), chlorophyll contents index (18.94), photosynthetic efficiency (fv/fm 0.748), all growth parameters, number of bolls per plant (22.40), boll weight (3.79 g) seed cotton yield (83.74 g/ plant). In respect to fibre properties the Akka Bt had maximum span length (33.30 mm), maximum fibre strength (25.67 g/tex), moderate fibre fineness (3.6 g/inch) and ginning percentage was maximum (37.70%).

In correlation (association) studies, the characters like number of bolls, dry matter, leaf area, chlorophyll content index, leaf area index, sympodia, harvest index, plant height, monopodia, photosynthetic efficiency, Boll weight, net assimilation rate showed significant and positive correlation with seed cotton yield in Bt (BG II) hybrids. This studies will helpful in determination of physiological traits responsible for yield of Bt cotton hybrids. Such traits can be useful in developing new Bt cotton hybrid for rainfed condition.

CHAPTER I

INTRODUCTION

1.1 Background Information

Cotton has been mentioned in the ancient Indian Vedas and is perhaps the first country to make use of the cotton. The Sanskrit word "Kdrpdsi" usually rendered cotton is connected with the Greek and Latin Karpasos and Carbasos respectively, but meant originally Spanish Flax. The antiquity of cotton has been traced to the fourth millennium B.C. The fabric pieces from Mohenjodaro excavation were found to be made of cotton.

Despite the advent of multiple of other fibres, king cotton (the white gold) rules the world of textiles. Even today, it is an unchanged as control textile fibre. It is an important fibre crop of more than 70 countries and will play important role in global and human economy in the 21st century. In addition to fibre for human clothing which is chief purpose for which cotton is grown in several countries such as India, USA, Russia, China, Pakistan and Egyptian countries, its seed and by-products also play an important role in the economics of agricultural cum industrial development.

Cotton belongs to genus *Gossypium* that is one among eight genera under tribe *Gossypeae* and family *Malvaceae*. There are four species of cotton which is generally cultivated *Gossypium arborium* and *Gossypium herbaceum* L. are called old world cotton. *Gossypium barbadense* L. and *Gossypium hirsutum* L. are known as new world cotton.

India ranks first in acreage of cotton crop and is third in total production in world only after Russia and America.

India has a place of pride in global scenario with the cultivation of all four cultivated species of cotton. The area under tetraploid cotton is around 72 per cent while only 28 per cent is covered by diploid cotton. The area of cotton in the World was 34.31 million ha, with an productivity 768 kg per ha. The total production of cotton was million 480 bales (USDA Foreign Agricultural service, 2012-2013). The area under

cotton in India was 117.73 lakh ha. with an annual production of 330 lakh bales and average productivity of 477 kg lint per ha..In Maharashtra area under cultivation were 41.46 lakh ha. with an annual production of 74 lakh bales and average productivity was 330kg lint per ha.(2012-2013). In Vidarbha area under cultivation during kharif 2012-2013 was 14.90 lakh ha. With an annual production of 27.4 lakh bales with average productivity of 312kg lint per ha.(CAB 2012-2013). The coverage under Bt hybrids in India is almost saturated and further improvement in cotton yield is possible. (Rao and Alapati, 2007)

All the Bt hybrids are *Gossypium hirsutum* which are grown on area of 87 per cent. This increase from 2002 to 2009. The yield increased by 8 to 10 per cent from BG II than BG I and non Bt. (Sudha *et al.* 2011). Cotton is warm climate crop and plant is sun loving but not water loving. It has perennial in nature, indeterminate behavior. Cottonseed oil has a nutritional value of 10 K. cal/gm and its average digestibility is 97%. Seed hull contence 30-60% alpha cellulose, 19-25% Pentosans, 15-20% lignin and 5% ash, protein fats etc. and represent a valuable feed and by-product potential(Narayanan,2011).

Shifts in cotton improvement in India

Cotton is a renewable natural fibre, a unique spinnable fibre with about 95% cellulose and proved to be a fibre that has conquered all fibres in the world from time immemorial and until this day. India being the largest grower and second largest producer of cotton in the world with an inviable textile industry has a big stake in cotton research and development for reaching the pinnacles of production and quality in 21st century. Real surge in cotton production and technological research gained momentum after attaining independence in 1947. The urge to gear up cotton research came at that point of time because as a nation that lost part of its growing lands and long staple cotton areas and production to Pakistan and also there was a need for using this cash crop for economic development of farming community, spinning industry and the nation which can benefit from intensification of cotton production.

After India's independence in 1947

There were several measures like increasing the area under cotton production and share of cotton under irrigation and enhancement of production and quality of *G. hirsutum* cotton. Improvement of staple length, improvement of yield potential through ball number, ginning out-turn and fiber quality parameters like maturity and length regularity and development of introgression products using wild species and hybrids for LS and ELS, jassids and black arm resistant were the breeding efforts. These efforts culminated in the release of the first superior- long to nearly extra long staple variety MCU 5 (*G. hirsutum*) in 1968 followed the first ELS variety Suvin of *G. barbadense*, both of which spectacular achievements of the 20th century in cotton research with persistent, innovative and sustained approaches. Some short duration (145 days) with short sympodia and big boll varieties/lines based on Russian germplasm material namely PRS 72 and PRS 74 in *G. hirsutum* and SB 289 E, SB 229 YF and SB 1085-6 in *G. barbadense* were also developed.

In Hybrid cotton Era after 1968

India was the first and only country to launch hybrid cottons for commercial production through the release of two unique hybrids namely H4 the long staple *G. hirsutum* and closely followed by extra-long staple Varalaxmi and DCH 32 (*G. hirsutum* x *G. barbadense* hybrids) for specified favorable areas. Further development of hybrids was achieved by selection of superior parents for various components developing hybrid cottons in MS, LS and ELS categories. Hybrid with higher boll weight, choice of parents not succumbing to New Wilt disease etc. Hybrids H6 RCH2, MECH1, Bunny, Brahma, Sigma, Dyna, Ankur 651 in H X H were popular in contributing to national yield improvement and fibre quality.

In Transgenic Hybrid Era (after 1996 and 2002)

Though the first Bt cotton varieties released in 1996 in USA, Australia etc. India had to wait for release of this technology in hybrid cotton versions till 2002-2003. By converting most of the private sector hybrid existing by introgression in to Bt. Cry 1 Ac (Mon 531 or similar gene versions of BG I followed by BG II of Monsanto genes adopting back crossing in a fast track, several new genotype were induced in to

cultivation without much regard to genetic vulnerability. As many modified versions as totaling beyond 2500 were made available, but probably 30-40 superior transgenic hybrids captured the major market share.

Consequently India is witnessing new attempts at broadening genetic divergence approach that is yet to reach seed distribution phase; also certain new disease and pest problems cropped up like CLCuV disease induced by white fly vector in northern India, massive mealy bugs occurrence on transgenic cottons and indicative scenario for emergence of bollworm resistance reports on BG I cotton etc.. The transgenic Bt- hybrid cotton has substantially enhanced cottonseed output and therefore importance of CS oil and byproduct have increased in the food, nutritional and feed economy. Sooner or later cottonseed may contribute to the largest extent for the edible oil pull in the world and India.

Table 1.1 Cotton progress in first decade of 21st century
(Transgenic era in India) and projections for 2020)

Parameters of progress	2002-03	2010-11	2020 (projected)
Cotton area (m. ha)	8.70	11.16	11.0
Bt cotton area (m. ha)	0.029	7.39	10.00
Percent area under Bt cotton	0.39	85.57	95.0
Average yield of lint (kg/ha)	302	475	734-750
Total lint production (million bales)	13.6	31.2	45.0
Total lint production (million tonnes)	2 312	5.304	7.65
Percent area under <i>G. hirsutum</i>	69	91	95
Long staple output (%of total production)	69	88	85
Cotton export (million bales)	0 084	5.5	9.0
Cotton consumption (million bales)	15.8	25.8	36.0
Estimated production of ginned cottonseed (million tons)	4 60	10.60	15.30
No. of seed packets of transgenic hybrids (units of 400g + 50g refugeal (in million pkts) demand for planting	35.0+	50.0+	60.0+

NB: Cols 2and3: based on CITI – CDRA Paper, June 2011 Mumbai and CAB Reports; For Col. 4projection based on Textile industry demand, past trends and future.

Table 1.2 Total fibre requirement change and share of fibre in 2050

Details	1960	2010	Projected for 2050
Human population (Billion)	3.3	6.1	9.3
Share of cotton	68	36	42.0
Share of wool	10.0	2.0	1.0
Share of synthetic	22.0	63.0	55.0
Share of other natural fibres	Low	Low	2
Total fibre market (Million tons)	15	70.0	140.0

(Narayanan, 2011).

1.2 Need of study

For year 2015-2020 and beyond, there may be broadening of biotechnology applications and new technologies for cotton yield increase will be based on 1. Stress tolerance eg. drought, water use efficiency, Novel lepidopteron and sap sucking insect control, nematode control, disease resistant. Superior novel herbicide and superior fibre quality and its parameters 2. Water use efficiency and nitrogen use efficiency are existing technologies and would be based on research focus on exploring ways to increase cotton yield and improve sustainability profile 3.Seed quality parameter like favourable fatty acid profile freedom from gossypol in seed and oil etc.

If our efforts to improve yield and quality have to be successful, changes are required 1 Area used to grow cotton and there efficient soil management, 2 Ways to adopt irrigation water use 3.Method used to plant cotton and harvest and process and changes in management practices – such as conservation tillage timing of application fertilizer technology and genetic improvement for further management options.

The increase in yield alone could not benefit the cotton growers as quality of cotton fibre is the primary concern for fetching higher price (Sreenivasan, 2004) The study emphasized necessity to develop hybrids having good yield potential coupled with desirable fibre quality parameters. Also, multilocal at multiseasonal testing of hybrids is

required for identifying region specific high yielding hybrids for recommending to farmers. (Sarang *et al.*, 2011). Genotypes having parameters required for drought adjustments may be much suitable to be grown under such environment. Yield is a character dependent on many other component character and environmental factors. Selection for yield alone may have adverse effect on other desirable characters. Knowledge of association between yield and its component characters themselves is also essential before resorting to selection for desirable genotypes (Adarsha *et al.*, 2004).

1.3 Objectives

1. To study the morphophysiological traits associated with yield in BG II cotton hybrids.
2. To study the fiber properties of BG II cotton hybrids.

1.4 Hypothesis

The present study will be helpful in determination of physiological traits responsible for yield of Bt cotton hybrids (*Gossypium hirsutum* L.). Such, traits can be useful in developing new Bt cotton hybrids for rainfed condition.

CHAPTER II

REVIEW OF LITERATURE

2.1 Morphological Observations

2.1.1 Plant height

Plant height plays an important role in determining the morphological frame work relating to plant type and canopy development in cotton. It is one of the important characters of growth and yield of cotton and is influenced by both genetic and environmental factors.

Ansari *et al.* (1989) reported that seed cotton yield was positively correlated with number of bolls per plant and plant height.

Gao and Jein (1989) reported that changes in leaf production is associated with changes in plant height.

Arshad *et al.* (1993) reported that plant height, number of bolls per plant and sympodial branches were positively correlated with seed cotton yield per plant. The number of bolls per plant was also positively correlated with plant height.

Meena *et al.* (2007) reported that plant height varied from 107 to 148 cm in undescriptive cultivars. The variety Ganeshgarhia had higher plant height (148 cm) followed by White gold 1 (147 cm) while lowest plant height was observed in Sikander Sultan (107 cm).

2.1.2 Leaf area / plant

Bhatt (1987) reported that three variety differing in height. Variety LRA recorded maximum leaf area.

Kudachkar *et al.* (1999) reported on evaluation of 9 hirsutum cotton genotypes for higher productivity under rainfed condition revealed that there was a marked difference in growth parameters and yield attributes among the genotypes where high yielding genotypes were associated with low leaf area, higher amount of total dry matter, high leaf efficiency. Higher harvest index and more bolls numbers. These attributes formed the physiological basis for higher productivity of hirsutum cotton under rainfed condition.

Adarsha *et al.* (2004) reported that significantly higher leaf area observed at 120 DAS after sowing than at harvest in DHH-542(59.13

dm²/plant) and DHB-105 (34.87 dm²/plant) as compared to CPD-448(23.87 dm²/plant) and Anjali 10.31 dm²/plant).

Tayade et al. (2011) they showed that the importance source (leaf area) in yield formation in transgenic Bt cotton.

2.1.3 Leaf Area Index / plant

Scott (1920) found that Increase in seed cotton yield which was basically because of more and bigger bolls. These in turn, were affected by greater LAI and increase photosynthetic efficiency resulting in higher biomass.

Ashlely *et al.* (1963) reported that the relationship between LAI and fruiting were dependent on concurrent vegetative growth they observed that late season boll set increased as long as LAI.

Bhatt *et al.* (1972) noticed that higher leaf area index occurred two weeks before the first boll opening in cultivars PRS-30/2 after 30 days of first boll opening in cultivar MCU-3 and at first boll opening in cultivar PRS-7 and also they studied leaf growth area indices in morphologically contrasting varieties of cotton(MCU-5 & PRS-72) showed that normal plant type with monopodial and sympodial branches had a higher leaf area index than a short branch variety with only to leaves per node (sympodial leaf and a main stem leaf) but that these expanded more quickly.

Channaveeraiah (1983) observed that for selection of high yielding genotypes under rainfed condition, the cultivars having moderate duration, moderate LAI, LAD (80-85 days) and with medium size of monopodial branches are more preferred.

Joshi *et al.* (2011) found that LAI an important growth parameter also varied significantly and the highest LAI was found in JK-Durga Bt which was 12.4% and 15.1% higher than the DCH-32 and DHH-11, respectively

2.1.4 Numbers of Monopodia

Channaveeraiah (1983) observed that for selection of high yielding genotypes under rainfed condition, the cultivars having moderate duration moderate LAI, LAD (80-85 days) and with medium size of monopodial branches are more preferred.

Meena *et al.* (2007) reported that the numbers of monopodia varied from 1.8 to 1.4 in undescriptive cultivars.

Joshi *et al.* (2011) their results obtained with respect to monopodial branches where JK-Durga Bt recorded significantly higher number of monopodial branches (3.80).

2.1.5 Numbers of Sympodia

Bhardwaj *et al.* (1971) showed that dwarf plant type with few sympodia and lower leaf area recorded high fruiting coefficient and seed cotton yield.

Hallikeri *et al.* (2004) noted that 10% higher number of sympodial branches in Bt genotypes than non-Bt DHH-11.

Sankaranaraya *et al.* (2004) observed that Bt cotton hybrids MECH-162 Bt recorded higher seed cotton yield, number of sympodial branches per plant and number of bolls per plant over non-Bt hybrids.

Buttar and Singh (2006) obtained that the significantly higher seed cotton yield recorded in Bt hybrids might be due to significantly higher number of sympodia and bolls per plant as compared to non Bt hybrid. This shows the superiority of Bt cotton hybrids over non Bt hybrid.

Gite *et al.* (2006) observed that number of sympodia per plant had positive and significant genotypic and phenotypic correlations with seed cotton yield.

Meena *et al.* (2007) reported that the numbers of sympodia varied from 8.2 to 12.8 in undescriptive cultivars.

Giri *et al.* (2008) They reported that Bt hybrid NCS-145 recorded significantly higher number of sympodia per plant (20.63) and seed cotton yield per plant (166g/plant) as against Bt hybrids RCH-2 with lower sympodia per plant (16.7) and seed cotton yield per plant (127.7g/plant).

Phad *et al.* (2010) they found that Bt cotton hybrids which were higher in number of sympodia per plant, number of bolls per plant and boll weight(g) contributed more seed cotton yield.

Joshi *et al.* (2011) they found that the main yield contributing factor in the cotton is sympodial branches which were found significantly higher in JK-Durga Bt.

Sudha *et al.* (2011) the yield contributing factor in cotton is sympodial branches, which were found significantly higher in MRC-6918 Bt as compared to non Bt hybrid. MRC-6918 Bt produced 26.5% more number of sympodial branches than DHH-11.

2.1.6 Dry matter production / plant

Constable and Gleeson (1977) recorded maximum dry matter accumulation at LAI of about 3.0 and showed that early and highest boll growth rate was sometimes associated with the lowest LAI.

Sing and Bhardwaj (1983) recorded that the seed cotton yield was associated with dry matter production.

Kudachikar *et al.* (1999) reported on evaluation of 9 *hirsutum* cotton genotypes for higher productivity under rainfed condition revealed that there was a marked difference in growth parameters and yield attributes among the genotypes where high yielding genotypes were associated with low leaf area, higher amount of total dry matter, higher leaf efficiency. Higher harvest index and more bolls numbers. These attributes formed the physiological basis for higher productivity of *hirsutum* cotton under rainfed condition.

Joshi *et al.* (2011) observed that total dry matter production was also found to be the highest in JK-Durga Bt (310.95 g/plant). Which was greater than other hybrids. They reported 13.20% higher dry matter in Bt genotypes than in non-Bt genotypes.

Thakare *et al.* (2011) obtained that all Bt hybrids were superior to non Bt hybrid with respect to the number of fruiting bodies, biomass and yield. Amongst the four Bt hybrids JKCH 99 Bt was giving the highest yield dualy substantiated by more number of fruiting forms.

2.2 Phenological Observation:

2.2.1 Days to 50% flowering

Jambunathan (1968) stated that maturity was not significantly affected by flowering date the early formed flowers matured into bolls in a lesser number of days than the later ones as these were prone to shedding.

Tian *et al.* (2003) revealed that introduction of Bt gene lead to reduced vegetative growth, early flowering onset and shorten effective flowering period in transgenic cotton.

Butter *et al.* (2007) found that all the Bt cotton hybrids differed significantly in respect to days taken for flowering.

Breznev *et al.* (2011) suggested that the Bt cottons significantly outperformed their non Bt counterparts in three qualitative characters viz. days to 50% flowering, number of bolls per Plant and seed cotton yield per plant.

2.2.2 Days to 50% boll busting

Ahlawat (1979) reported that percent of boll setting was highest from the flowers produced in the earlier part of flowering period but later decreased gradually.

Butter *et al.* (2007) reported that days taken for boll formation were significantly less in case of MRC-6301 (112 days) as compare to all other Bt cotton hybrids.

Hebbar *et al.* (2007) reported that Bt had more early formed boll on the lower canopy which contributed to higher biomass and seed cotton yield.

2.2.3 Days to maturity

Patil (1993) suggested that days to 50 percent flowering and boll opening were the reliable method of finding out earliness in cotton, while time of appearance of fruiting nodes on first sympodial branch and mean dates of maturity were the next best method in its reliability.

Mayee *et al.* (2004) they revealed that all the Bt hybrids tested were exhibited 20-30 days early maturity over their non Bt counterparts. The earliness and dwarfness might have resulted due to utilization of more nutrients energy in the nourishment of maximum numbers of balls which were saved from boll damage.

Butter *et al.* (2007) reported that significantly less number of days were taken for physiological maturity by MRC-6307 (143 days) as compared to all other Bt cotton hybrids.

2.3 Physiological Observations

2.3.1 Relative water content (%)

Ratnakumari *et al.* (2012) reported that cotton genotype possessing higher RWC (Relative water content) under rainfed condition.

Araujo *et al.* (2003) water deficits, show reduction in yield of up to 50% if compared to that have been irrigated especially when the stress factor was imposed during the period between flowering and fructification.

2.3.2 Chlorophyll content Index

Zhu *et al.* (2005) they postulated that increase in chlorophyll was an indicator of the primary reactions of photosynthesis.

2.3.3 Photosynthetic efficiency

Scott (1920) observed that increase in seed cotton yield which was basically because of more and bigger bolls. These in turn, were affected by greater LAI and increase photosynthetic efficiency resulting in higher biomass.

Liu *et al.* (2008) resumed that under drought during the flowering and boll-setting periods, photosynthetic index apparently decrease but the photosynthetic pigment content increased.

Levi *et al.* (2009) showed that the photosynthesis rates have been used to distinguish water deficit tolerance and sensitive genotypes in various species, including cotton.

Dongxiao *et al.* (2012) observed that the f_v/f_m decreased during later stages of growth (Boll set) under water stress and also, their result suggests that regulating photosynthetic system at crucial stage was the defense response of cotton plant to drought.

2.4 Computation of growth parameters

2.4.1 Crop growth rate

In terms of total dry matter production by a crop or by a crop community, leaf area index and photosynthetic rate appear to be the major determinants of crop growth rate. Increase in yield potential of a variety is not associated with an increase in photosynthetic rate and it is difficult to find out clear cut evidence that a variety with high leaf photosynthesis rate has really improved yield potential.

Godoy *et al.* (2000) reported that transgenic cultivars showed significant increase in biomass (crop growth rate) during 84-105 days after sowing. All the cultivars evaluated in this study had the same efficiency for rate of dry matter accumulation (Relative growth rate) Paymaster genotype had the highest net growth rate value.

2.4.2 Relative growth rate

Channaveeraiah (1983) assessed the performance of cotton (*G. hirsutum* L.) genotypes under rainfed condition and found that high yielding cotton genotypes (cv. Sharada) had moderate value of RGR (0.71 g/g/day).

Patil and Patil (1982) reported that the RGR was highest at 40 DAS thereafter gradually decreased up to 100 DAS and sharply upto 130 DAS.

Patil *et al.* (2002) reported that the RGR increased from 30 to 60 DAS and declined rapidly thereafter.

2.4.3 Net assimilation rate

Patil and Patil (1982) reported that NAR was highest during 40-70 DAS. Cotton genotypes with high NAR and LAI resulted in higher dry matter per plant, low HI and low seed cotton.

Wells and Meredith (1986) observed that the greater LAI of hybrids resulted from greater value of NAR and stimulated growth via greater interception of light and associated photosynthate production prior to the advent of significant interplant competition.

Patil *et al.* (2002) showed that the NAR was increasing trend up to 60 to 90 days after sowing

2.4.4 Specific leaf weight

Bharadwaj and Singh (1988) reported a new ideotype in upland cotton (*G. hirsutum* L.) based on foliage characteristics such as small and thick leaves (higher SLW) with more number of bolls and higher boll weight.

Singh *et al.* (1990) concluded that varieties with small thick leaves are usually drought resistant.

Adarsha *et al.* (2004) reported that Specific leaf Weight increased at 120DAS and decreased at harvest.

Ratnakumari *et al.* (2012) reported higher yield of cotton due to specific leaf weight under rainfed condition.

2.5 Yield and yield attributes

2.5.1. Number of bolls per plant

Singh *et al.* (1983) reported that the numbers of boll/ plant are major yield components in *G.hirsutum* cotton under rainfed condition.

Mayee *et al.* (2004) reported the difference among Bt hybrids for yield contributing characters as well as fiber properties indicating the existence of genotypic differences among the hybrids. They found that the highest yield of 2.13 tan per hector was recorded by MECH 162 (Bt) followed by MECH 184(Bt).The yield of MECH 12 (Bt) was only 1.77 tan per hectare. All the three Bt cotton hybrids recorded significantly higher seed cotton yield than there non Bt cotton counter parts which might be attributed to higher retention of bolls from the first flush of flowers contributed to lesser boll damage.

Rauf *et al.* (2004) found that among three yield component number of balls per plant was consider the first important contributor to seed yield of cotton, followed by boll weight

Singh *et al.* (2006) revealed that biomass accumulation was significantly lower in all Bt-hybrid as compared to non-Bt cotton hybrids. In facts better retention of early fruiting parts in Bt hybrids could have led to more efficient translocation of photosynthate into reproductive fruiting bodies and consequently the overall growth attained got reduced in Bt as compaired to non- Bt.

Alse and Jadhav (2011) reported that the sympodia and green balls per plant were significantly more in Dhroov Bt than Dhroov non Bt, Kashinath Bt and Nathbaba non Bt .Apparently better retention of early formed fruiting parts in Dhroov Bt has led to more efficient translocation of photosynthates into the reproductive sink component and consequently, the overall growth attainment got reduced in it as compared to other cultivar.

Jatav and Shastri (2011) found that Bt cotton hybrids were having higher sympodia and bolls per plant and also the boll weight (g) which contributed more towards seed cotton yield .

Sudha *et al.* (2011) studied that Bt cotton genotypes recorded higher total number of bolls per plant compared to non-Bt hybrid. Total number of bolls per plant was significantly higher in RCH-708 Bt (37.95) compared to all other cotton genotypes.

2.5.2 Boll Weight

Singh *et al.* (1983) reported that the boll weight is major yield components in *G.hirsutum* cotton under rainfed condition.

Nehra *et al.* (2004) observed that the Bt cotton hybrid produced significantly higher seed cotton yield in comparison to their respective non-Bt hybrids and local check and highest seed cotton yield was obtained. This increase in seed cotton yield might be due to more number of bolls per plant, boll weight and dry weight per plant as compared to local check.

Shrinivasan (2006) found that among the hybrids MECH 184 Bt recorded heaviest boll and was significantly superior to the rest of the hybrids.

Khadi *et al.* (2008) reported that increase in lint yield because of increasing ball weight and boll number, which clearly indicated that Bt gene offers protection against boll worm damage and which in turn contributes to the development of a number of healthy bolls.

Rao *et al.* (2009) found that the high number of bolls per plant and boll weight increases the seed cotton yield.

Sarang *et al.* (2011) stated that cotton hybrids which had high boll number per plant and boll weight depicted higher seed cotton yield.

Tayade *et al.* (2011) noted that the multiple regression and path analysis studies revealed that picked bolls and boll weight was more beneficial in increasing the seed cotton yield of MECH-184 Bt.

Thakare *et al.* (2011) found that among the four Bt hybrids, JKCH 99 recorded the highest seed cotton yield because of more number of fruiting forms (i.e. square, flower and bolls), boll weight and biomass.

2.5.3 Seed cotton yield

Bharadwaj *et al.* (1971) observed that high seed cotton yield of upland cotton (*G.hirsutum* L.) genotypes was related to higher fruiting coefficient, medium leaf area, optimum amount of dry matter, low to

medium photosynthetic rate and high to medium boll number and boll weight..

Singh *et al.* (2007) noted that the Rashi hybrid RCH-134 recorded significantly higher seed cotton yield per plant (247.7g) over Ankur 651, Ankur 2534 and MRC 6301.

Joshi *et al.* (2011) concluded that higher yield per ha. was supported by higher yield per plant which ranged between 179.03 g per plant (JK-CH 99 Bt) to 114.81 g per plant (DCH-32).

2.5.4. Harvest Index

Basu and Bhatt (1987) reported that the harvest index showed a high positive correlation with seed cotton yield, number of sympodial branches and number of bolls and negative correlation with fiber length and The harvest index was independent of plant height number of monopodial branches.

Kudachikar *et al.* (1999) they revealed that the higher harvest index and more bolls numbers. These attributes formed the physiological basis for higher productivity of *hirsutum* cotton under rainfed condition.

Singh *et al.* (2006) found that all the Bt hybrids had high potential obtained higher harvest index (%) than non Bt.

Patil *et al.* (2013) reported that the variety AKH-9916 has given higher seed cotton yield than PKV Rajat, AKH-8828, LRA-5166, NH-565, and NH-615, in different trials conducted at last eight years.

2.6 Fiber properties

Mayee *et al.* (2004) noted that Bt hybrids exhibited higher ginning percentage over their non Bt counterparts for lint index much difference was observed between Bt and non Bt hybrids.

Mayee *et al.* (2004) Bt hybrids exhibited slightly lesser 2.5% span length than their non Bt hybrids. This might be due to the earliness of Bt cotton hybrids which provide lesser period for fibre elongation.

Khadi *et al.* (2008) reported RCH2 Bt recorded 2.6% increasing ginning out turn when compare to its non Bt counterpart.

Bhongle *et al.* (2012) result of different Bt hybrids on different fibre qualities revealed that the range for 2.2% span length was 23.2mm to 35.7mm, for fibre strength range 15.4 g/tex and for micronaire it

ranged between (2.2g/inch) to (4.5g/inch).The uniformity ratio for all the hybrid was in the range of 43to 53 percent. The highest ginning outturn was obtained from the hybrid UPLHH-2Bt (36.5%).

Breznev *et al.* (2011) they observed increase in staple length in Bt cotton genotypes

Sudha *et al.* (2011) found that Bt cotton genotypes recorded significantly higher 2.5% span length than DHH-11(29.05 MM), Higher 2.5% span length of 37.03 mm was recorded in RCH-708 Bt and differed significantly to all other genotypes.

Chitranayak *et al.* (2012) found that, for the commercial cultivation of cotton varieties and hybrids, its full spinning potential were checked. This was ensured their acceptance by Indian and International textile industry. The present Indian cotton varieties and hybrids cover a wide spectrum of fibre quality and spinnability ranging from 16s count to 120s count. Most of the traded samples of cotton have good fineness and their value had mostly fallen in the range of 2.8to 5.1 micrograms per inch. The Indian cotton varieties developed so far range from short staple cotton of 17.5 mm to extra long cotton (ELS) up to 40.0 mm length, which include very coarse to very fine cotton.

Kaushik and singh (2012) found that the strain C4-9-2-1-2 showed highest mean seed cotton yield and highest lint yield with good fibre strength of 24.5g/Tex. Two strain P 56-4 and P 56-6 showed higher fibre strength of 28.1 and 27.3g/tex, respectively.

2.7 To Study the Correlation between physiological traits for seed cotton yields and its attributes

Ashley *et al.* (1963) reported positive correlation between LAI and between seed cotton yield .significant positive correlation between seed cotton yield and boll load/plant and boll weight (kumar and chaudhary, 1986) and boll number (Jagtap and Kolhe, 1984).

Butany *et al.* (1968) reported positive significant correlation between number of sympodia/plant, boll /plant and boll weight but negative correlation of yield with height in hirsutum cotton.

Bhatt (1970) reported that seed cotton yield was positively correlated with dry matter. Varieties giving similar seed cotton yield /ha differed widely in the production of DM and had different fruiting coefficient.

Bharadwaj *et al.* (1971) observed that high seed cotton yield of upland cotton (*G. hirsutum* L.) genotypes was related to higher fruiting coefficient, medium leaf area, optimum amount of dry matter and high to medium boll number and boll weight.

Constable and Gleeson (1977) showed a consistent positive relationship between CGR and LAI in cotton (*G. hirsutum* L.), during reproductive phase.

Mosande *et al.* (1981) revealed that the seed cotton yield was positively correlated with total dry matter per plant.

Shaikh and Upadhyay (1983) reported that indirect effect of sympodial branches and bolls were positive.

Singh and Bhardwaj (1983) opined that improvement in seed cotton yield could be achieved with varieties having high total dry matter, low shedding of squares and bolls and early setting of bolls at lower node positions and also they recorded that the seed cotton yield was associated with dry matter production.

Kumar and Choudhary (1986) revealed from correlation studies that seed cotton yield per hectare plant was strongly correlated with boll number and boll weight.

Basu and Bhat (1987) observed that positive correlation of harvest index with sympodial branches per plant and bolls per plant.

Bharadwaj and Singh (1988) noticed that, boll number depends on biomass produced which in turn was related to leaf area index.

Mehta and Singh (1988) reported that boll weight is positively correlated with the number of seeds per boll.

Ansari *et al.* (1989) reported that seed cotton yield was positively correlated with number of bolls per plant and plant height but not with number of monopodial branches.

Arshad *et al.* (1993) reported that plant height, number of bolls per plant and sympodial branches were positively correlated with seed

cotton yield per plant. The number of bolls per plant was also positively correlated with plant height.

Adarsha and patil (1999) reported that significant positive association of yield with TDM($r=0.761$), NAR ($r=0.535$).

Girase and Mehetre (2002) reported that boll Number, boll weight, sympodia number, total dry matter exhibited significant positive association with seed cotton yield.

Gite *et al.* (2006) observed that number of sympodia per plant had positive and significant genotypic and phenotypic correlations with seed cotton yield.

Anapurve *et al.* (2007) reported that Number of sympodia/plant had highly positive correlation with seed cotton yield at both phenotypic and genotypic levels. The characters days to 50% flowering and boll bursting had highly positive correlation with number of seed/boll at both phenotypic and genotypic levels and the number of boll/plant showed highly positive significant correlation with number of seed/boll at both phenotypic and genotypic levels.

Tayade *et al.* (2011) they showed that hybrid MECH 184 Bt Seed cotton yield per plant was positively and significantly correlated with independent characters namely. leaf area, dry matter accumulation. The multiple regression and path analysis studies revealed that picked bolls and boll weight was more beneficial in increasing the seed cotton yield of MECH-184 Bt.

CHAPTER III

MATERIAL AND METHODS

3.1 Location of experiment

The present investigation entitled "Evaluation of different Bt cotton (BG II) hybrids for morphophysiological traits under rainfed condition" was undertaken on the field of Department of Agricultural Botany, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during the *Kharif* season of 2012-2013. The details of material used and methods adopted during the course of investigation are described in this chapter.

3.2 Experimental Details and Technical Programme

The experiment was carried out on the experimental field of Department of Agricultural Botany, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola located at 304.415 meter altitude, 20°30' N latitude and 72°02' longitude during *Kharif* season of 2012.

3.3 Experimental Details

Name of crop	: Cotton (<i>Gossypium hirsutum</i> L.)
Variety	: Five (5)
Year of Study	: 2012-2013
Experimental design	: Randomized Block Design
Number of replications	: Four(4)
Number of treatments	: Five(5)
Season	: <i>Kharif</i> 2012-13
Plot size	: Gross – $4.5 \times 4.2 \text{ m}^2$ Net – $2.7 \times 3 \text{ m}^2$
Spacing	: Row to row 90cm Plant to plant 60cm
Fertilizer	: 50 : 25 : 25 N:P:K kg / ha.
Date of Sowing	: 4 th July 2012
Sowing method	: Dibbling

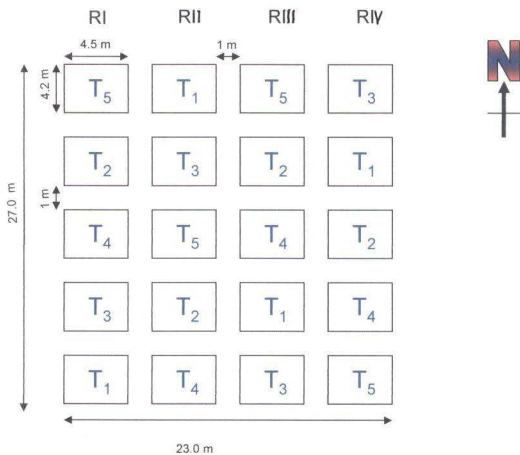


Fig.1. Plan of layout

3.4 Treatments Details

Table 3.1 Treatments details

Treatment	Hybrid	Seed company
T ₁	Bunny BG II	Nuziveedu seed
T ₂	MRC 7301 BG II	Mahyco
T ₃	Brahma BG II	Monsanto
T ₄	Super Maruti BG II	Krishidhan seeds
T ₅	Akka BG II	Ankur seeds

3.5 Climate and Weather

Akola is located at 304.415 m altitude, 20°32' N latitude and 72°02' longitude. The rainfall (mm), mean maximum and minimum temperature (°C) and humidity in percentage per week during the period of the present investigation are given in appendix.

3.6 Observations recorded

The various parameters of observations are indicated below

3.6.1 Morphological Observations:

3.6.1.1 Plant height (cm)

Observations on plant height were recorded in centimeter at 30, 60 and 90, 120 DAS. The height of the five selected plants from each replication and treatment was recorded in cm with scale from the base of a plant to top most developing node and then mean height (cm) was calculated.

3.6.1.2 Leaf area per plant (dm²)

Observation on leaf area per plant (dm²) was recorded at 30, 60, 90 and 120 DAS. Leaf area of selected five plants from each replication and treatment was measured with the help of the leaf area meter.

3.6.1.3 Leaf area index per plant

Leaf area index denotes leaf area in relations to ground area and was calculated from the data of the leaf area and land area occupied by the plant. The observations were recorded at various growth intervals i.e. 30, 60, 90 and 120 DAS. (Watson, 1947)

$$LAI = \frac{\text{Leaf area per plant (dm}^2\text{)}}{\text{Land area per plant (dm}^2\text{)}}$$

3.6.1.4 Number of monopodia per plant

The monopodial branches bearing at least one functional sympodial branch were counted separately in five tagged plants and the average value was recorded at the time of harvest.

3.6.1.5 Number of sympodia per plant

The total number of fruiting branches on the main stem were counted and recorded at the time of harvest.

3.6.1.6 Dry matter production per plant (g plant⁻¹)

Observation on total dry matter per plant (g) recorded at 30, 60, 90, 120 DAS and at harvest.

From each replication and treatment two plants were uprooted. Root portion was cut off and the plant samples were washed with water in order to remove soil and dust particles adhered to it. The surface was allowed to soak in dry air. The plant sample was then placed in big size brown paper bags. The brown paper bags were placed in the rack to allow the samples on open air basis the plant samples was finally dried in hot air oven at 61°C up to the constant weight. The total dry matter was recorded as gram per plant.

3.6.2 Phenological observation

3.6.2.1 Days to 50 percent flowering

Total number of days from the date of sowing to the date on which 50 percent of the plants initiated flowering in a plot was recorded.

3.6.2.2 Days to 50 percent boll opening

Total number of days from the date of sowing to the date on which 50 percent boll opened was recorded.

3.6.2.3 Days to maturity

The number of days required from sowing to the date of last picking was considered.

3.6.3 Physiological observation

3.6.3.1 Relative water content of leaves (%)

RWC of leaf gives an idea of water retaining ability of plant in leaf. Third leaf from top was selected from each treatment and replication. The leaves were labeled and were placed in polythene bags separately to avoid water loss. Leaves were weighted on electronic balance. Their fresh

weight was taken and then transferred to petridish containing water. The leaves were kept floating on water for 4 hrs and after that their weight was recorded. The weight of leaves was recorded after keeping it in hot air oven at 70°C (Barrs and Weatherley, 1962). The observations of RWC were recorded at 30, 60, 90 and 120 DAS.

$$\text{RWC(\%)} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Turgid weight} - \text{Dry weight}} \times 100$$

3.6.3.2 Chlorophyll content index

The chlorophyll content index of intact leaf was measured by using the instrument "CCM 200 plus". The observations were recorded during the day time at 11 am to 14 pm.

For recording the observations three representative plants were selected from each treatment plot. Three representative leaves (from bottom, middle and top portion of plant) were selected and recorded the observations. Mean values of chlorophyll content index of these three leaves and three plants was calculated.

The observations were recorded at 30, 60, 90 and 120 DAS.

3.6.3.3 Photosynthetic efficiency:

The photosynthetic efficiency (Fv/m) was measured by recording the chlorophyll fluorescence value by using the instrument "Chlorophyll fluorometer os-30p Optisciences". The observations were recorded at 30, 60, 90 and 120 DAS.

Determination of dark adaptation time:

For determination of dark adaptation time maximum dark period was measured by placing 20 clips on the third leaf of 20 cotton plants. Shutter plates were closed on leaves as such. The photosynthetic efficiency (ratio of Fv/m) was recorded at every 2 min time interval (100 percent light level was used).

For cotton crop 12 min maximum dark period was recorded. After that the photosynthetic efficiency of third leaf was measured by giving 12 min dark adaptation time period. After 12 min the sensor unit was brought over leaf clip and fitted so that the day light was excluded. Then a

shutter plate in leaf clip is open to expose the leaf ready for illumination and measurement by sensor unit. Run the instrument and record the observation of Fv/m. photosynthetic efficiency was recorded on three plants per treatment replication wise and mean values were calculated.

3.6.4 Computation of growth parameters

3.6.4.1 Crop growth rate (CGR)

The crop growth rate was calculated to estimate the production efficiency of a crop. It is calculated by using formula given by Watson (1952) it is expressed as gram per square meter land per day. The observations were recorded at 30, 60, 90 and 120 DAS.

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

Where, W_1 and W_2 are the dry weights of the plants at time t_1 and t_2 , respectively.

3.6.4.2 Relative growth rate (RGR)

RGR is the increase in dry weight per unit dry weight per unit time and is expressed as grams per gram per day and calculated by the formula of Blackman (1919). The observations were recorded at 30, 60, 90 and 120 DAS.

$$RGR = \frac{(\text{Loge } W_2 - \text{loge } W_1)}{(t_2 - t_1)}$$

Where,

W_1 and W_2 = Total dry weight of plants at time t_1 and t_2 respectively.

3.6.4.3 Net assimilation rate (NAR)

Net assimilation rate is the rate of increase in dry weight per unit leaf area per unit time (Watson, 1952) and is expressed as grams per dm^2 per day. It was calculated by the formula of Radford (1967). The observations were recorded at 30, 60, 90 and 120 DAS.

$$NAR = \frac{(W_2 - W_1)}{(t_2 - t_1)} \cdot \frac{(\text{loge } L_2 - \text{loge } L_1)}{(L_2 - L_1)}$$

Where,

L_1 and W_1 = leaf area (dm^2) and dry weight (g) of the plant respectively at time t_1

L_2 and W_2 = leaf area (dm^2) and dry weight (g) of the plant respectively at time t_2 .

3.6.4.4 Specific leaf weight (SLW)

The specific leaf weight was determined by the following formula and expressed by mg/dm^2 and observations were recorded at 30, 60, 90 and 120 DAS.

$$\text{SLW} = \frac{\text{Leaf dry weight (mg)}}{\text{Leaf area (cm}^2\text{)}}$$

3.6.5 Yield and yield attributes

3.6.5.1 Number of bolls plant⁻¹

Total number of bolls picked from the five-tagged plants was counted and the average was worked out.

3.6.5.2 Boll weight (g)

The total seed cotton yield from all the pickings from five tagged plants was recorded separately and the seed cotton yield divided by number of boll and average was expressed as gram.

3.6.5.3 Seed cotton yield (g plant⁻¹)

The total seed cotton yield from all the pickings from five tagged plants was recorded and the average was expressed as seed cotton yield per plant.

3.6.5.4 Harvest index (%)

Harvest index was calculated by using the formula of Donald (1962) and expressed as percent

$$\text{HI (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.6.6 Fibre Quality parameters

3.6.6.1 Span length

The span length was determined in Ginning and Training centre, Nagpur. The mean fibre length of the total fibre present in a sample was determined by "Ball's sorter method" and the value was expressed in mm at 2.5 per cent span (Sundaram, 1979).

3.6.6.2 Fibre strength (g tex⁻¹)

The span length was determined in Ginning and Training centre, Nagpur. Bundle strength is the ratio of the breaking strength of a bundle of fibre to its weight. The value is expressed as g per tex.

3.6.6.3 Fibre fineness (Micronaire value)

The span length was determined in Ginning and Training centre, Nagpur. Fibre fineness (fibre weight in mg per unit length of fibre) was assessed by using micronaire instrument following the procedure of Sundaram (1979) and values were expressed as micronaire value.

3.6.6.4 Ginning percentage (%)

A cleaned sample of seed cotton, (1000gm) was obtained from yield of each treatment and was ginned on hand gin.

Ginning percentage was calculated by using following formula,

$$\text{Ginning percentage} = \frac{\text{Lint Weight}}{\text{Seed Cotton Weight}} \times 100$$

3.7 Analysis of variance for the experimental design

The analysis of variance was performed to get the significance of differences between the treatment for all the characters as per the methodology suggested by Panse and Sukhatme (1954).

The statistical model used for the design was

$$Y_{ijk} = \mu + v_{ij} + b_k + e_{ijk}$$

Where,

Y_{ijk} = Performance of i_j^{th} treatment over k^{th} replication

μ = General mean

v_{ij} = The effect of the i_j^{th} treatment

b_k = Block effect

e_{ijk} = The environmental effect

The analysis of variance based on this model is given below

Table 3.2 ANOVA Table

Source of variation	d. f.	Mean squares	Expected mean squares
Replication	(r-1)	MSr	$\delta^2 e + t\delta^2 r$
Treatment	(t-1)	MSt	$\delta^2 e + r\delta^2 t$
Error	(t-1) (r-1)	MSe	$\delta^2 e$

Where r = Number of replications, t= Number of treatments

The standard error of difference for comprising any two progeny means. Computed by using appropriate error as follows:

$$\text{Correction factor} = \frac{(GT)^2}{\text{Number of observations}}$$

$$SSr = \frac{\sum (\text{Replications total})^2}{\text{Number of treatments}} - \text{correction factor}$$

$$SSt = \frac{\sum (\text{Treatments total})^2}{\text{Number of replications}} - \text{correction factor}$$

$$SSe = \text{Total S.S.} - (\text{Rep S.S.} + \text{Treat S.S.})$$

$$MSr = \frac{SSr}{(r-1)}$$

$$MSt = \frac{SSt}{(t-1)}$$

$$MSe = \frac{SSe}{(r-1) (t-1)}$$

The f – test were applied to determined the significance of all treatments. Standard error and critical difference at 5% level of probability was used for comparing treatment differences.

$$\text{Error mean sum of square (EMS)} = \frac{\text{ESS}}{\text{edf}}$$

S.E. (m) = standard error of treatment means

$$= \sqrt{\frac{\text{EMS}}{r}}$$

C.D. = critical difference = S.E. (d) x t (edf)

Where, edf = error degree of freedom

r = number of replications

t = number of treatments

t (edf) = Table value for degrees of freedom at 5%

3.8 Correlation studies

The relationship between two or more quantitative characters is of great interest and carries much practical significance. Correlation is a measure of the degree to which characters are associated with yield or among themselves (Burton, 1972)

3.8.1 Estimation of simple correlations

Simple linear correlation coefficients was computed for X_1 and X_2 as

$$r = \frac{\sum X_1 X_2}{\sqrt{X_1^2 X_2^2}}$$

Where,

X_1 = Deviation from the mean of variable X_1

X_2 = Deviation from the mean of variable X_2

The significance of correlation was tested with n-2 d.f.

Where,

n = Number of paired observations from which the computed r value is obtained.

CHAPTER IV

RESULTS AND DISCUSSION

An experiment was conducted on "Evaluation of different Bt Cotton (BGII) hybrids for Morpho-physiological traits under rainfed condition" was carried out at the experimental field of department of Agricultural Botany, Post Graduate Institute Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *kharif* season of 2012-13 with following objectives.

1. To study the morphophysiological traits associated with seed cotton yield in BG-II cotton hybrids.
2. To study the fibre properties of BG-II cotton hybrids.

The observations were recorded on various aspects viz. morphological, phenological, physiological, computation of growth parameters, along with yield and yield attributes and fibre properties. The observations recorded during the course of investigation are presented and discussed here under appropriate headings and sub headings.

4.1 Morphological Parameters

4.1.1 Plant Height (cm)

Plant height is an important morphological character in cotton which provides seat for nodes and internodes from where monopodial and sympodial branches emerges and thus play an important role in determining the morphological framework relating to productivity, Eaton (1955).

It is major component of seed cotton yield. It was recorded at different intervals of growth stages and were presented in table 4.1 & depicted by fig 2. The statistical difference among the Bt hybrids at 30 DAS found non significant, whereas at subsequent growth stages it remained statistically significant (table 4.1). All the Bt hybrids increased plant height as the crop grows till harvest.

Table 4.1: Plant height (cm) at different growth stages of Bt (BG II) cotton hybrids.

Bt (BG II) Hybrids	30 DAS	60DAS	90DAS	120DAS	At Harvest
Bunny Bt	27.25	63.00	87.65	94.53	97.25
MRC 7301 Bt	27.45	62.52	89.01	96.49	101.39
Brahma Bt	27.40	64.02	85.75	94.83	98.27
Super Maruti Bt	26.55	65.15	90.53	97.08	100.23
Akka Bt	25.80	71.90	95.15	101.87	106.93
Mean	26.89	65.31	89.61	96.96	100.81
SE(m)±	1.54	1.99	1.91	1.62	2.03
CD at 5%	-	6.16	5.89	5.01	6.27

At square formation stage (60DAS), the cotton hybrid Akka BG II recorded significantly more plant height (71.90 cm) than the other hybrids. At this stage the Bt hybrid MRC 7301 (62.52 cm) recorded statistically least height among all hybrids tested. At 90 DAS the same Bt hybrid Akka BG II recorded significantly more plant height (95.15 cm) which was at par with Super Maruti Bt and super over the other hybrids.

Similar results were also observed at 120 DAS. At harvest the same hybrid i.e. Akka BG II (106.93 cm) recorded statistically more plant height than other and least height was noted by Bunny BG II (97.25 cm).

The genotypes tested exhibited significant differences in plant height, braches and other morphotological characters. Similar result were found by Bharadwaj and Simolte (1968), Patil and Zode (1988), Meena *et al* (2007), Gao and Jein (1989).

4.1.2. Leaf Area per Plant (dm²)

The assimilatory surface of plant measured in term of LA (dm²) at various intervals are presented in table 4.2 and depicted by fig. 3. It was observed that LA was less at 30 DAS and increased up to 120 DAS, then it declined at 150 DAS due to shading and senescence. The statistical

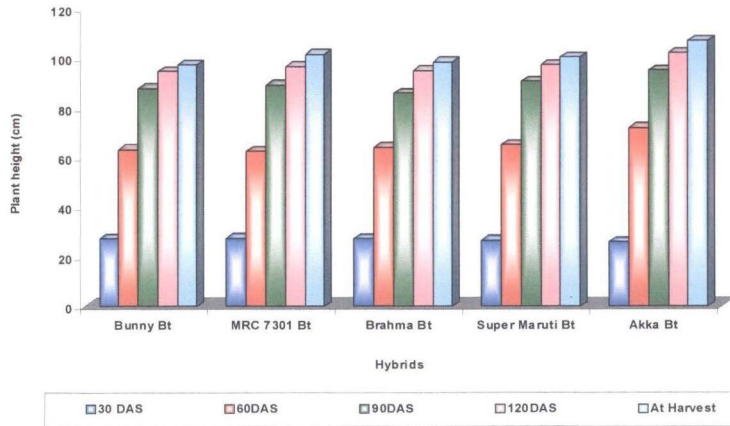


Fig.2. Plant height (cm) at different growth stages of Bt (BG II) Cotton hybrids

difference among the Bt hybrids at 30 DAS found non significant, along with at subsequent growth stages.

At 60 DAS the leaf area ranged from 20.05 to 33.09 dm². The hybrid Akka BG II observed maximum leaf area (33.09 dm²/plant). The hybrid Akka BG II was found at par with Super Maruti BG II (30.07 dm²). Least leaf area found in Bunny BG II (20.05 dm²) at this stage.

At 90 DAS, the significantly highest leaf area was observed in Akka BG II i.e. 66.84 dm². The statistically lowest leaf area occurred in Bunny BG II (27.72 dm²). At 120 DAS the highest leaf area was occurred in Akka BG II (68.52 dm²). The lowest leaf area per plant was occurred in MRC 7301 BG II (37.12 dm²). The highest leaf area was occurred at 120 DAS, thereafter it declined due to physiological maturity and shedding.

Table 4.2: Leaf area per plant (dm²) at different growth stages of Bt (BG II) Cotton hybrids.

Bt (BG II) Hybrids	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS
Bunny Bt	2.59	20.05	36.49	45.36	23.70
MRC 7301 Bt	2.24	25.81	27.72	37.12	18.37
Brahma Bt	2.32	23.69	42.65	47.21	17.77
Super Maruti Bt	1.97	30.07	49.79	52.89	26.06
Akka Bt	1.99	33.09	66.84	68.52	27.89
Mean	2.22	26.54	44.69	50.22	22.75
SE(m)±	0.21	1.15	4.12	3.21	0.99
CD at 5%	-	3.55	12.73	9.89	3.05

At 150 DAS the leaf area was decreased. The hybrid Akka BG II recorded significantly maximum leaf area (27.89 dm²). The Akka BG II was remained at par with Super Maruti BG II (26.06 dm²).

Significantly higher leaf area was observed at 120 DAS. Similar result was found by Adarsha *et al.* (2004). Bharadwaj *et al.* (1971) observed that high seed cotton yield of upland cotton (*G. hirsutum* L.)

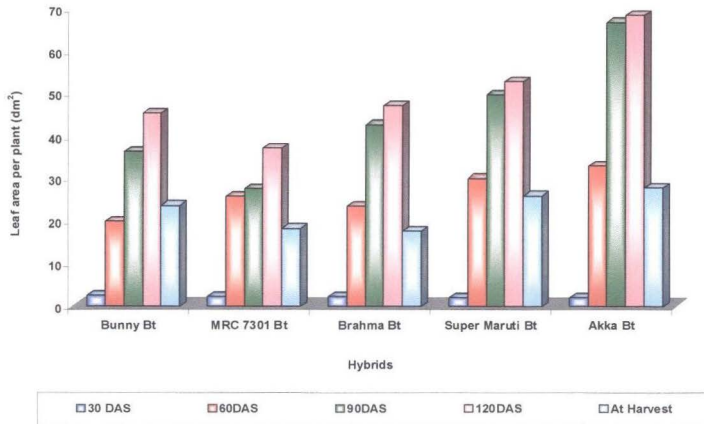


Fig.3. Leaf area per plant (dm^2) at different growth stages of Bt (BG II) Cotton hybrids

genotypes was related to medium leaf area. Tayade *et al.* (2011) revealed the importance of source (leaf area) in yield formation in transgenic Bt cotton.

4.1.3 Leaf Area Index

The LAI of various hybrids recorded at various growth stages was given in table 4.3 and depicted by fig.4. The statistical difference among the Bt hybrids at 30 DAS found non significant, whereas at subsequent growth stages it remained significant.

At 60 DAS the higher leaf area index found in hybrid Akka BG II i.e. 6.13. The treatment Akka BG II was found at par with hybrid Super Maruti BG II (5.56). The lowest LAI found in hybrid Bunny BG II (3.71).

At 90 DAS the highest LAI was recorded significantly higher in hybrid Akka BG II (12.38). The least LAI was found in hybrid MRC 7301 BG II (5.03). At 120 DAS the highest LAI observed in hybrid Akka BG II (12.68). The lowest LAI found in MRC 7301 BG II (6.87).

Table 4.3: Leaf Area Index per plant at different growth stages of Bt (BG II) Cotton hybrids.

Bt (BG II) Hybrids	30 DAS	60 DAS	90 DAS	120 DAS
Bunny Bt	0.47	3.71	6.75	8.40
MRC 7301 Bt	0.41	4.77	5.03	6.87
Brahma Bt	0.42	4.39	7.90	8.74
Super Maruti Bt	0.36	5.56	9.22	9.79
Akka Bt	0.36	6.13	12.38	12.68
Mean	0.40	4.91	8.26	9.30
SE(m)±	0.038	0.213	0.765	0.594
CD at 5%	-	0.639	2.357	1.832

Genotypes indicated considerable variation in LAI at different growth stages, different crops possess optimum LAI conducive to

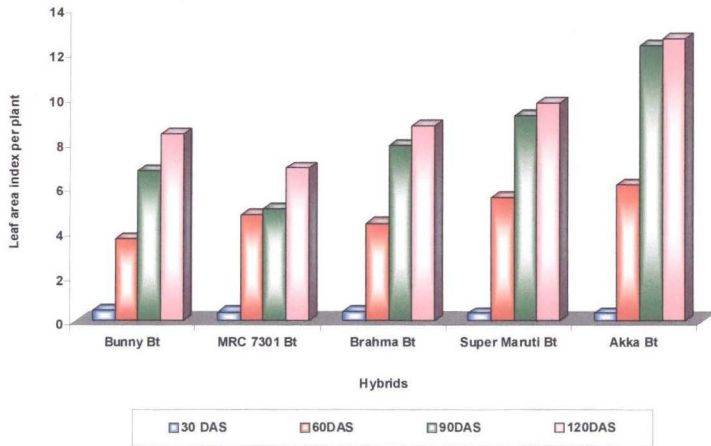


Fig.4. Leaf Area Index per plant at different growth stages of Bt (BG II) Cotton hybrids

maximum dry matter production, Watson (1952). While emphasizing the importance of leaf area, previous study revealed, varietal differences in LAI (Bhat *et al.*, 1974). In all treatment LAI higher at 120 DAS similar results found by Ashley *et al.* (1963).

Increase in yield due to greater LAI was reported by Scott (1920), Channaveerajah (1983) and Joshi *et al.* (2011).

4.1.4 Number of Monopodia

The number of monopodia was counted at harvest. It was an important component for determining seed cotton yield. The data was expressed at mean number of monopodial branches per plant, in table 4.4 and depicted by fig.5.

The hybrid Akka BG II recorded significantly higher monopodia i.e. 3.40/plant. The hybrid Akka BG II was found at par with hybrid Super Maruti BG II i.e. 2.90. The statistically lowest monopodia counted in hybrid Brahma BG II i.e. 2.40.

Table 4.4: Number of Monopodia and sympodia per plant (at harvest) in different Bt (BG II) Cotton hybrids.

Bt (BG II) Hybrids	Monopodia	Sympodia
Bunny Bt	2.62	23.20
MRC 7301 Bt	2.52	21.65
Brahma Bt	2.40	20.04
Super Maruti Bt	2.90	24.80
Akka Bt	3.40	27.42
Mean	2.76	23.42
SE(m)±	0.21	1.30
CD at 5%	0.66	4.01

Channaveeraiah (1983) observed that the plant with medium size of monopodial branches are more preferred. Joshi *et al.* (2011) obtained high yielding transgenic Bt had more number of monopodia. Similar results were also found by Meena *et al.* (2007).



Fig.5. Number of Monopodia and sympodia per plant (at harvest) in different Bt (BG II) Cotton hybrids

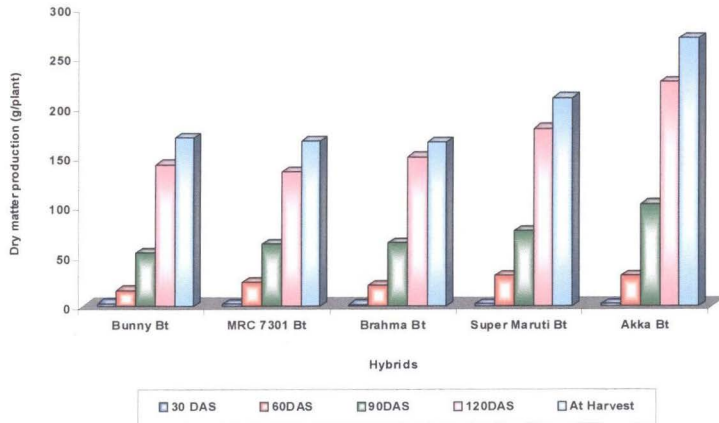


Fig.6. Dry matter production (g/ plant) at various growth stages of different Bt (BG II) Cotton hybrids

4.2 Phenological observations

4.2.1. Days to 50% flowering

Data on days to 50% flowering showed in table 4.6 and depicted in fig. 7. 50% flowering in all treatments statistically differ significantly with respect to each other. The minimum days required for the hybrid Super Maruti BG II i.e. 78 days and maximum days required for the hybrid Bunny BG II (84 days). The hybrid Bunny BG II was found at par with the hybrid MRC 7301 BG II. (82 days) and hybrid Brahma BG II (80.75 days). The Bt hybrid Super Maruti found earliness in days for 50% flowering.

The maturity was not significantly affected by flowering data the early formed flowers matured in to bolls in a lesser number of days than the later ones as these were prone to shedding as per Jambunathan (1968)

Tian *et al.* (2003) found that introduction of Bt gene lead to reduced vegetative growth, early flowering onset and shorten effective flowering period in transgenic cotton. Similar results were noted by Butter *et al.* (2007) and Breznev *et al.* (2011).

4.2.2 Days to 50% boll bursting

Data on the days to 50% boll bursting presented in table 4.6 and depicted by fig.7.

Table 4.6: Phenological observations of different Bt (BG II) Cotton hybrids.

Bt (BG II) Hybrids	Days to 50% flowering	Days to 50% Boll bursting	Days to maturity
Bunny Bt	84.00	118.00	164.25
MRC 7301 Bt	82.00	115.50	156.00
Brahma Bt	80.75	117.25	159.75
Super Maruti Bt	78.00	113.00	154.00
Akka Bt	80.25	116.50	158.00
Mean	81	116.05	158.4
SE(m)±	1.16	1.05	1.68
CD at 5%	3.59	3.25	5.17

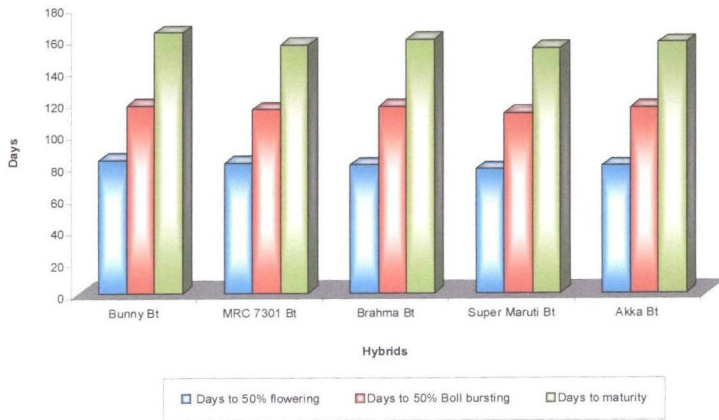


Fig.7.Phenological observations of different Bt (BG II) Cotton hybrids

All hybrids statistically differ significantly with respect to each other for 50% boll bursting. The maximum number of days required to the hybrid Bunny BG II (118 days) and it was at par with Brahma BG II (117.25 days), Akka BG II (116.5 days) and MRC 7301 BG II (115.5 days). The lowest days required for the treatment Super Maruti BG II (113 days) which lead in earliness.

The percent of boll setting was higher from the flowers produced in the earlier part of flowering period but later decreased gradually Ahlawat (1979). Hebbar *et al.* (2007) reported that Bt had earlier formed boll on the lower canopy which contributes to higher biomass and seed cotton yield, similar results was found by Butter *et al.* (2007).

4.2.3 Days to maturity

The data on days to maturity presented in table 4.6 and depicted by fig.7. All the treatments differ significantly among each other. The maximum day taken by the hybrid Bunny BG II (164.25 days) and it was at par with hybrid Brahma BG II i.e. 159.75 days for maturity. The lowest days required for maturity by the hybrid Super Maruti BG II i.e. 154 days.

Patil (1993) suggested that days to 50 per cent flowering and boll opening were the reliable method of finding out earliness in cotton, while time of appearance of fruiting nodes on first sympodial branch and mean dates of maturity were the next best method in its reliability. Mayee *et al.* (2004) revealed that all the Bt hybrids tested were exhibited 20 – 30 days early maturity over their non Bt counterparts. The earliness and dwarfness might have resulted due to utilization of more nutrients energy in the nourishment of maximum numbers of bolls which were saved from boll damage. Similar result was also illustrated by Butter *et al.* (2007).

4.3 Physiological Observations

4.3.1 Relative water content (%)

Data on relative water content showed in table 4.7 and depicted in fig.8. The statistical difference among the Bt hybrids at 30 DAS found non significant, whereas at subsequent growth stages it remained statistically significant.

At 60 DAS the maximum RWC found in Akka BG II (91%) which was at par with the Bunny BG II (87.5%) and Super Maruti BG II (88 %).

At 90 DAS the highest RWC was maintained in Akka BG II (79%) which was at par with Super Maruti BG II (78.02 %) and MRC 7301 BG II (77.77 %). The lowest RWC was found in Brahma BG II (75.67 %).

Table 4. 7: Relative water content (%) at various growth stages of different Bt (BG II) Cotton hybrids.

Bt (BG II) Hybrids	30 DAS	60 DAS	90 DAS	120 DAS
Bunny Bt	86.60	87.5	76.12	74.39
MRC 7301 Bt	85.48	89	77.77	72.92
Brahma Bt	85.53	86.5	75.67	72.82
Super Maruti Bt	83.68	88	78.02	73.26
Akka Bt	85.31	91	79.00	74.81
Mean	85.32	88.4	77.31	73.64
SE(m)±	0.93	0.79	0.62	0.44
CD at 5%	-	2.44	1.91	1.37

At 120 DAS, the RWC was decreased. The maximum RWC found in Akka BG II (74.81%). The lowest RWC found in Braham BG II (72.82 %). The Akka BG II remained at par with the Bunny BG II (74.39 %) at this stage of plant growth.

Ratna Kumari *et al.* (2012) reported that Bt cotton genotypes possessing higher RWC under rainfed condition. Araujo *et al.* (2003) water deficits, show reduction in yield of up to 50% if compared to that have been irrigated especially when the stress factor was imposed during the period between flowering and fruitification.

4.3.2 Chlorophyll content index

Data on chlorophyll content index in leaves at different growth stages were presented in table 4.8 and depicted in fig.9

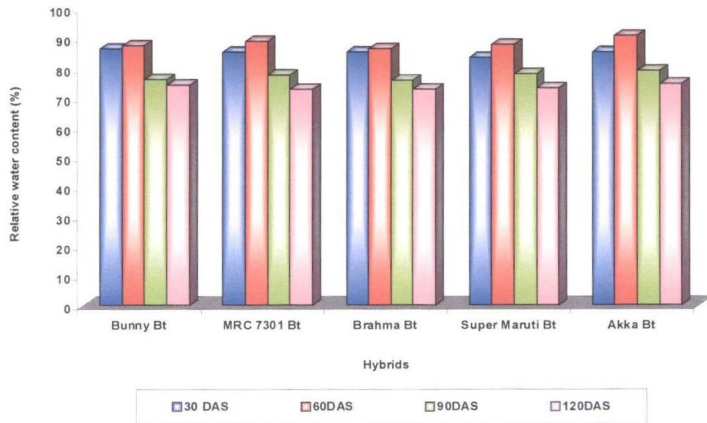


Fig.8. Relative water content (%) at various growth stages of different Bt (BG II) Cotton hybrids

The statistical difference among the Bt hybrids at 30 DAS found non significant, whereas at subsequent growth stages it remained statistically significant.

At 60 DAS the higher CCI was recorded in Akka BG II i.e. 18.43. The lowest CCI was found in Bunny BG II (16.98).

Table 4.8: Chlorophyll content index at various growth stages of different Bt (BG II) Cotton hybrids.

Bt (BG II) Hybrids	30 DAS	60 DAS	90 DAS	120 DAS
Bunny Bt	16.89	16.98	18.70	17.13
MRC 7301 Bt	16.68	17.41	17.68	16.03
Brahma Bt	16.94	17.28	17.23	15.62
Super Maruti Bt	16.83	17.84	18.23	17.01
Akka Bt	16.32	18.43	18.99	18.94
Mean	16.73	17.58	18.16	16.94
SE(m)±	0.30	0.18	0.21	0.71
CD at 5%	-	0.57	0.65	2.18

At 90 DAS the maximum CCI was found in Akka BG II (18.99) and It was remained at par with Bunny BG II i.e. 18.70. The lowest CCI was found in Brahma BG II (17.23) at this stage.

At 120 DAS significantly the higher CCI was found in Akka BG II i.e. 18.94. Akka BG II was at par with Bunny BG II (17.13) and Super Maruti BG II (17.01). The lowest CCI found in Brahma BG II (15.62).

The increase in chlorophyll was an indicator of the primary reactions of photosynthesis (Zhu *et al.* 2005).

4.3.3 Photosynthetic efficiency:

The data on photosynthetic efficiency was showed in table 4.9 and depicted by fig.10. The value of photosynthesis efficiency was the value obtained from Fv/Fm in chlorofluorometer.

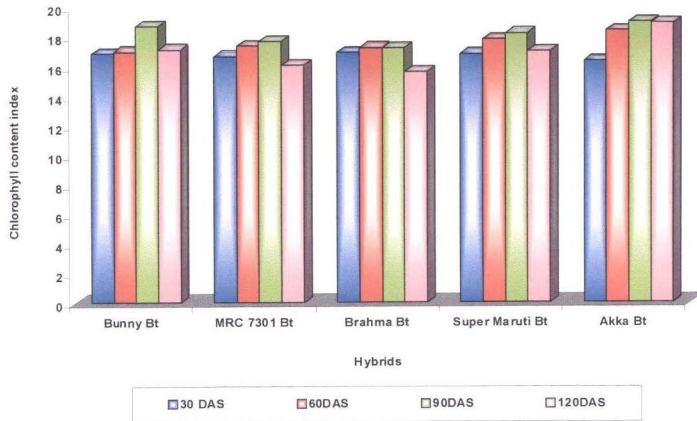


Fig.9. Chlorophyll content index at various growth stages of different Bt (BG II) Cotton hybrids

The statistical difference among the Bt hybrids at 60 DAS found non significant, whereas at subsequent growth stages it remained statistically significant for different for different phynological stages.

At 30 DAS the photosynthetic efficiency was maximum in Akka BG II (0.742). The Akka BG II remained at par with Super Maruti BG II (0.739) and MRC 7301BG II (0.738). The statistically lowest photosynthetic efficiency was found in Brahma BG II (0.703).

Table 4.9:-Photosynthetic efficiency at various growth stages of different Bt (BG II) Cotton hybrids.

Bt (BG II) Hybrids	30 DAS	60 DAS	90 DAS	120 DAS
Bunny Bt	0.707	0.724	0.712	0.728
MRC 7301 Bt	0.738	0.723	0.686	0.718
Brahma Bt	0.703	0.719	0.708	0.709
Super Maruti Bt	0.739	0.728	0.695	0.738
Akka Bt	0.742	0.746	0.732	0.748
Mean	0.725	0.728	0.706	0.728
SE(m)±	0.009	0.010	0.005	0.008
CD at 5%	0.028	-	0.015	0.026

At 90 DAS the hybrid Akka BG II showed maximum photosynthetic efficiency (0.732), which was at par with Bunny BG II (0.712) and Brahma BG II (0.708). The lowest photosynthesis efficiency was found in MRC 7301 BG II (0.686) at this stage.

At 120 DAS, the photosynthetic efficiency was found increased due to influence of environments and want of more assimilate. The Akka BG II had maximum photosynthetic efficiency i.e. 0.748. The Akka BG II was remained at par with Super Maruti BG II (0.738) and Bunny BG II (0.728).

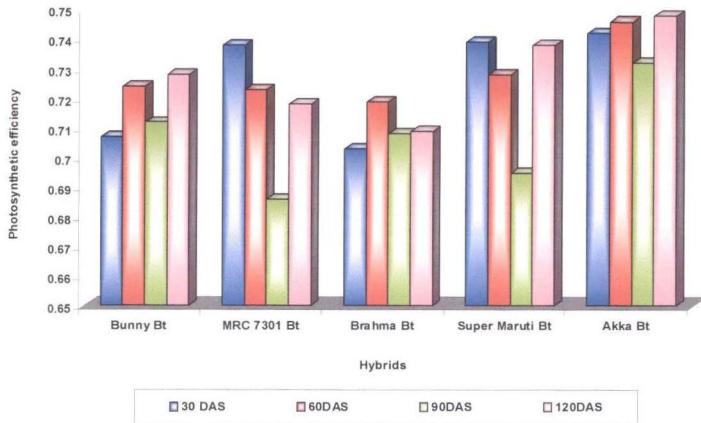


Fig.10. Photosynthetic efficiency at various growth stages of different Bt (BG II) Cotton hybrids

Scott (1920), observed increase in seed cotton yield which was basically because of more and bigger bolls. These in turn were affected by greater LAI and increase photosynthetic efficiency resulting in higher biomass. Liu *et al.* (2008) observed under drought during the flowering and boll setting periods, photosynthetic efficiency was decreased. Similar result was also illustrated by Dongxizo *et al.* (2012).

4.4 Computation of growth parameters

4.4.1 Crop growth rate (g / day)

Crop growth rate (CGR) was increased from day by day. The data obtained at various growth stages was given in table 4.10 and depicted by fig. 11. The crop growth rate at various stages from 30 – 60 DAS, 60-90DAS, 90 – 120 DAS and 120 – 150 DAS differed significantly. The crop growth rate increased from 30 DAS to 150 DAS.

At 30 – 60 DAS the significantly maximum crop growth rate was found in hybrid Akka BG II (0.96 g/ day) and it was remained at par with Super Maruti BG II (0.94 g/ day) and MRC 7301 BG II (0.75 g/ day). The lowest crop growth rate at this stage found in hybrid Banny BG II (0.44 g/ day).

Table 4.10:- Crop growth rate (g /day) at various growth stages of different Bt (BG II) Cotton hybrids.

Bt (BG II) Hybrids	30-60 DAS	60-90DAS	90-120DAS	120-150DAS
Bunny Bt	0.44	1.27	2.96	0.72
MRC 7301 Bt	0.75	1.27	2.44	0.85
Brahma Bt	0.62	1.44	2.88	0.31
Super Maruti Bt	0.94	1.52	3.43	0.86
Akka Bt	0.96	2.40	4.10	1.28
Mean	0.74	1.58	3.16	0.80
SE(m)±	0.09	0.16	0.17	0.087
CD at 5%	0.29	0.49	0.55	0.27

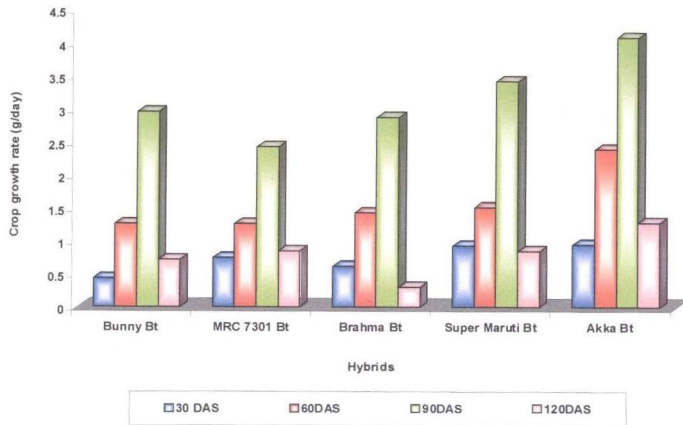


Fig.11.Crop growth rate (g /day) at various growth stages of different Bt (BG II) Cotton hybrids

At 60 – 90 DAS the maximum CGR was found in Akka BG II (2.40 g/ day). The lowest CGR was found in both Bunny BG II and MRC 7301 BG II (i.e. 1.27 g/ day). At 90 – 120 DAS the highest CGR was maintained by Akka BG II (4.10 g/ day). At 120 – 150 DAS the hybrid AKKA BG II had maximum CGR i.e. 1.28 g/day and the hybrid Brahma BG II had lowest CGR i.e. 0.31g/day. At this stage the CGR was decreased than earlier stage.

Godoy *et al.* (2000) reported that transgenic cultivars showed significant increase in biomass (crop growth rate) during 84 – 105 days after sowing.

4.4.2 Relative growth rate (g /g /day)

RGR was increased in plant material per unit time. Data obtained at various growth stages was given in table 4.11 and depicted by fig. 12. The RGR was maximum at 30 – 60 DAS, and then it was decreased. Similar result was also reported by Patil *et al.* (2002).

The RGR at various stages from 30 – 60 DAS, 60-90DAS, and 120 – 150 DAS differed significantly. At 30 – 60 DAS the hybrid Akka BG II was maintained statistically higher RGR i.e. 0.091 g/g/day and lowest RGR was found in hybrid Bunny BG II (0.061 g/g/day). The hybrid Akka BG II found at par with Super Maruti BG II, MRC 7301 BG II, Brahma BG II i.e. 0.086 , 0.085 , 0.082 g/g/day respectively.

Table 4. 11: Relative growth rate (g/g/day) at various growth stages of different Bt (BG II) Cotton hybrids.

Bt (BG II) Hybrids	30-60 DAS	60-90DAS	90-120DAS	120-150DAS
Bunny Bt	0.061	0.041	0.033	0.0047
MRC 7301 Bt	0.085	0.032	0.025	0.0058
Brahma Bt	0.082	0.039	0.023	0.0021
Super Maruti Bt	0.086	0.031	0.029	0.0045
Akka Bt	0.091	0.042	0.026	0.0053
Mean	0.081	0.037	0.028	0.0044
SE(m)±	0.005	0.002	0.001	0.0005
CD at 5%	0.017	0.008	-	0.0015

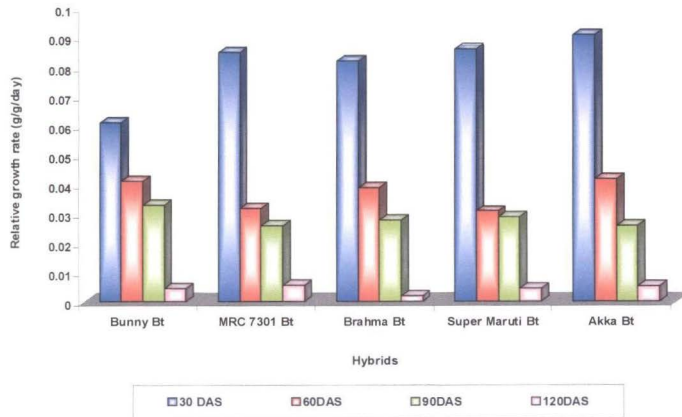


Fig.12. Relative growth rate (g/g/day) at various growth stages of different Bt (BG II) Cotton hybrids

At 60 – 90 DAS the higher RGR was found in hybrid Akka BG II (0.042 g/g/day) which was at par with Bunny BG II (0.041 g/g/day) and Brahma BG II (0.039 g/g/day). The lowest RGR was found in hybrid Super Maruti BG II (0.031g/g/day).

At 120 -150 DAS the highest RGR found in hybrid MRC 7301 BG II (0.0058 g/g/day). The lowest RGR was found in hybrid Brahma BG II (0.0021g/g/day)

The RGR was maximum at 30 – 60 DAS, and then it was found decreased. These results are associated with the findings of Patil *et al* (2002) in cotton.

Patil and Patil (1982) reported that the RGR was highest at 40 DAS there after gradually decreased up to 100 DAS and sharply up to 130 DAS.

Channaveeraiah (1983) assessed the performance of cotton (*G. Hirsutum* L.) genotypes under rainfed condition and found that high yielding cotton genotypes had moderate value of RGR.

4.4.3 Net assimilation rate (g/dm²/day)

Net assimilation rate (NAR) is a measure of photosynthetic capacity of plant. Data on NAR was presented in table 4.12 and depicted by fig. 13.

The NAR at various stages from i.e 30 – 60 DAS, 90 – 120 DAS and 120 – 150 DAS differed significantly. The NAR was maximum at 30 – 60 DAS while decreased up to 150 DAS. At 30-60 DAS hybrid Super Maruti BG II showed maximum NAR 0.091 g/dm²/day which were at par with Akka BG II (0.087 g/dm²/day).

At 90 – 120 DAS the highest NAR was found in Akka BG II (0.026 g/dm²/day), Akka BG II remained at par with Bunny BG II (0.024 g/dm²/day) and MRC 7301 BG II (0.023 g/dm²/day).

Table 4.12: Net assimilation rate (g/dm²/day) at various growth stages of different Bt (BG II) Cotton hybrids.

Bt (BG II) Hybrids	30-60 DAS	60-90DAS	90-120DAS	120-150DAS
Bunny Bt	0.053	0.023	0.024	0.005
MRC 7301 Bt	0.078	0.024	0.023	0.008
Brahma Bt	0.069	0.023	0.022	0.003
Super Maruti Bt	0.091	0.019	0.023	0.006
Akka Bt	0.087	0.025	0.026	0.008
Mean	0.075	0.022	0.023	0.006
SE(m)±	0.008	0.002	0.0009	0.0006
CD at 5%	0.025	-	0.002	0.002

At 120 – 150 DAS the NAR was statistically highest in Akka BG II and MRC 7301 BG II (0.008 g/dm²/day) and lowest was found in Brahma BG II (0.003 g/dm²/day).

The NAR was found highest during 40 – 70 DAS (Patil and Patil 1982). Cotton genotypes with high NAR and LAI resulted in higher dry matter per plant as reported by Patil and Patil (1983). The greater LAI of hybrids resulted from greater value of NAR and stimulate growth (wells and Meredith 1986). The increase in NAR trend was up to 60 to 90 days after sowing as illustrated earlier by Patil *et al.* (2002).

4.4.4 Specific leaf weight (mg/cm²)

Specific leaf weight is the integral structure of the leaf and known to have correlation with photosynthetic rate. The data on specific leaf weight were recorded at different growth stages of cotton crop was presented in table 4.13 and depicted by fig 14.

The statistical difference among the Bt hybrids at 30 DAS found non significant, whereas at subsequent growth stages it remained statistically significant. At 60 DAS the significantly highest specific leaf weight found in Akka BG II i.e. 5.43 mg/cm² which were at par with Super

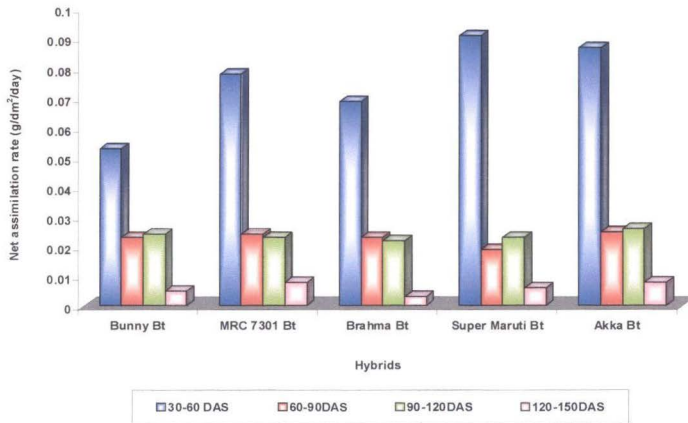


Fig.13. Net assimilation rate (g/dm²/day) at various growth stages of different Bt (BG II) Cotton hybrids

Maruti BG II (5.27 mg/cm²): The lowest specific leaf weight found in MRC 7301 BG II i.e. 4.78 mg/cm² than other hybrids.

Table 4. 13: Specific leaf weight (mg/cm²) at various growth stages of different Bt (BG II) Cotton hybrids.

Bt (BG II) Hybrids	30 DAS	60DAS	90DAS	120DAS
Bunny Bt	3.58	4.92	7.41	8.00
MRC 7301 Bt	3.75	4.78	7.25	7.82
Brahma Bt	3.36	4.82	6.73	7.61
Super Maruti Bt	4.09	5.27	8.01	8.26
Akka Bt	4.62	5.43	8.18	8.59
Mean	3.88	5.04	7.15	8.05
SE(m)±	0.33	0.14	0.27	0.13
CD at 5%	-	0.44	0.84	0.40

At 90 DAS the highest specific leaf weight found in Akka BG II i.e. 8.18 mg/cm² which was at par with Super Maruti BG II (8.01 mg/cm²) and Bunny BG II (7.41 mg/cm²). The lowest SLW was noted in Brahma BG II (6.73 mg/dm²).

At 120 DAS the specific leaf weight found gradually increased. The Akka BG II was found maximum SLW i.e. 8.5 mg/cm² which were at par with Super Maruti BG II (8.26 mg/cm²).

The SLW decreased at relatively higher leaf area (Gitte and Khandagle 1994). SLW increased at 120 DAS and decreased at harvest as reported by Adarsha *et al* (2004). The increase in yield due to increase in SLW under rainfed condition was noted by Ratnakumari *et al*. (2012). Similar result found by Bharadwaj and Singh (1988)

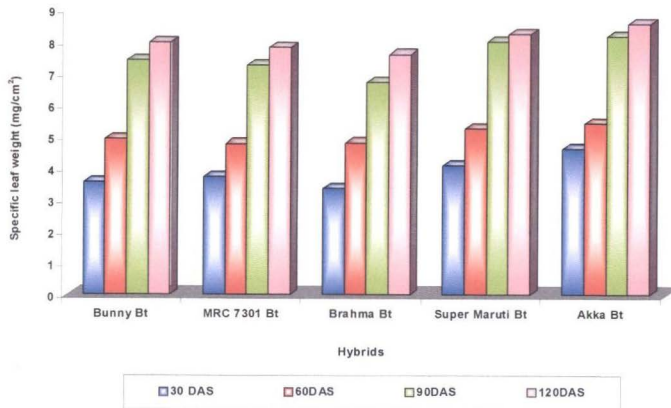


Fig.14. Specific leaf weight (mg/cm²) at various growth stages of different Bt (BG II) Cotton hybrids

4.5 Seed cotton yield and Yield attributes

4.5.1 Number of bolls per plant

The data on number of bolls per plant was presented in table 4.14 and depicted in fig.15. The difference between numbers of bolls per plant was found statistically significant. The significantly more number of bolls were found in Akka BG II i.e. 22.40 followed by the Super Maruti BG II (19.65), MRC 7301 BG II (19.05), Bunny BG II (16.70) and Brahma BG II (14.72). The Akka BG II was at par with Super Maruti BG II and MRC 7301 BG II in respect of bolls/plant.

Table 4.14: Seed cotton yield and yield attributes in different Bt (BG II) Cotton hybrids.

Bt (BG II) Hybrids	No. of bolls per plant	Boll Weight (g)	Seed cotton yield (g/plant)	Harvest index (%)
Bunny Bt	16.70	3.35	54.97	25.95
MRC 7301 Bt	19.05	3.31	62.50	28.09
Brahma Bt	14.72	3.24	47.04	30.46
Super Maruti Bt	19.65	3.38	63.56	29.43
Akka Bt	22.40	3.79	83.74	32.19
Mean	18.50	3.41	62.36	29.22
SE(m)±	1.31	0.09	3.55	1.09
CD at 5%	4.04	0.28	10.95	3.36

Singh *et al.* (1983) reported that the number of bolls per plant is major yield determinants in *G. hirsutum* cotton under rainfed condition. Similar results were found by Jatav *et al.* (2011) and Sudha *et al.* (2011). Also (2011) reported that the green bolls per plant were significantly more in Bt, apparently better retention of early formed fruiting parts in Bt has lead to more efficient translocation of photosynthates into the reproductive sink component and consequently the overall growth attainment.

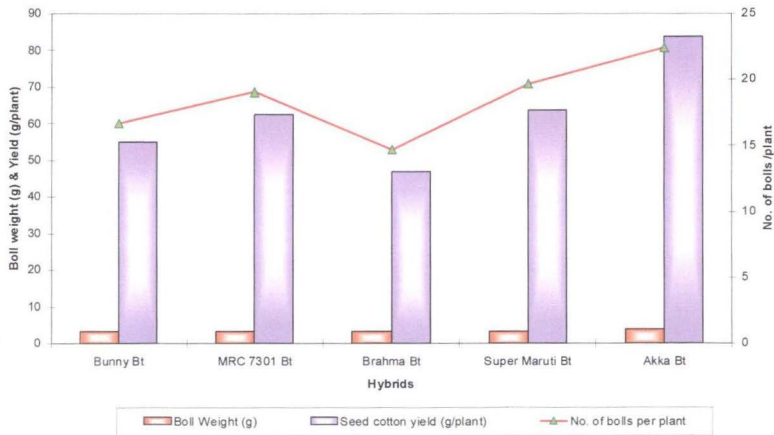


Fig.15.Yield and yield attributes in different Bt (BG II) Cotton hybrids

4.5.2 Boll weight (g)

The data on single boll weight (g) was presented in table 4.14 and depicted by fig.15. The boll weight was found statistically significant among all hybrids. The Akka BG II showed highest boll weight (3.79 g) the lowest boll weight found in Brahma BG II (3.24 g).

Sing et. al. (1983) reported that the boll weight was major yield components in *G. Hirsutum* cotton under rainfed condition. Similar results found by Nehra *et al.* (2004), Shrinivasan (2006), Rao *et al.* (2009), Sarang *et al.* (2011) and Thakare *et al.* (2011). The increase in lint yield because of increase in boll weight which clearly indicated that Bt gene offers protection against boll worm damage and which in turn contributes to the development of a number of healthy bolls (Khadi *et al.* 2008).

4.5.3 Seed cotton yield per plant (g/plant)

The data on seed cotton yield per plant (g/plant) was presented in table 4.14 and depicted in fig.15. The difference between seed cotton yield per plant found statistically significant. The Akka BG II (83.74 g/plant) showed statistically superior than all the remaining hybrids. The lowest seed cotton yield was recorded by the Brahma BG II (47.04 g/plant).

The seed cotton yield of all treatments were related to higher fruiting co-efficient, medium leaf area, optimum amount of dry matter, low to medium photosynthetic rate and high to medium boll number and boll weight as per Bharadwaj *et al.* (1971). The increase in seed cotton yield per plant increases the seed cotton yield per ha in Bt cotton as per Singh (2007). Similar result was also found by Joshi *et al.* (2011).

4.5.4 Harvest index (%)

Data on harvest index presented in table 4.14. All treatments found statistically significant in this respect. The maximum harvest index was found in Akka BG II (32.19%). The Akka BG II was at par with Brahma BG II (30.46%) and Super Maruti BG II (29.43%). The statistically lowest harvest index was maintained by Bunny BG II (25.95%).

All treatments found statistically significant. Singh (2006) found that the Bt hybrid had high potential i.e. harvest index. Higher harvest index and more bolls numbers, these attributes formed the physiological



**Plate 1. Plant of
Bunny Bt (BGII)
hybrid (T₁)**



**Plate 2. Plant of
MRC 7301 Bt (BGII)
hybrid (T₂)**



Plate 3. Plant of Brahma Bt (BGII) hybrid (T₃)



**Plate 4. Plant of Super Maruti
Bt (BGII) hybrid (T₄)**



**Plate 5. Plant of Akka Bt (BGII)
hybrid (T₅)**

basis for higher productivity in *hirsutum* cotton under rainfed condition (Kudachikar *et al.* 1999).

4.6 Fiber Properties

Increase in yield alone could not benefit the cotton growers as quality of cotton fiber is the primary concern for fetching higher price (Sreenivasan, 2004)

4.6.1 Span length (mm.)

All treatment differ significantly with each other (table 4.15). The staple length of the Akka BG II was maximum i.e. 33.30 mm, which was at par with the Bunny BG II (33.10mm). The lowest staple length was found in Super Maruti BG II i.e. 27.95 mm.

Table 4.15: Fibre properties in different Bt (BG II) cotton hybrids.

Bt (BG II) Hybrids	Span length(mm) at 2.5 %	Fibre strength(g/tex)	Fibre fineness (Micronaire value)	Ginning percentage (%)
Bunny Bt	33.10	24.56	3.8	38.95
MRC 7301 Bt	31.80	24.60	3.6	31.45
Brahma Bt	32.00	24.16	4.1	36.57
Super Maruti Bt	27.95	23.93	3.4	37.82
Akka Bt	33.30	25.67	3.6	37.70
Mean	31.63	24.58	3.7	36.49
SE(m)±	0.13	0.33	0.09	1.92
CD at 5%	0.42	1.04	0.28	-

Mayee *et al.* (2004) reported in Bt hybrids exhibited slightly lesser 2.5% span length than their non Bt hybrids. This might be due to the earliness of Bt cotton hybrids which provide lesser period for fibre elongation. Sudha *et al.* (2011) found that Bt cotton genotypes recorded significantly higher 2.5% span length. Breznev *et al.* (2011) reported increase in stable length in Bt genotypes.



**Plate 6. Bolls of Bunny Bt (BGII)
hybrid (T1)**



**Plate 7. Bolls of MRC 7301
Bt (BGII) hybrid (T2)**



**Plate 8. Bolls of Brahma
Bt (BGII) hybrid (T3)**



**Plate 9. Bolls of Super Maruti
Bt (BGII) hybrid (T4)**



**Plate 10. Bolls of Akka
Bt (BGII) hybrid (T5)**

4.6.2 Fiber strength (g/tex)

The data on the fibre strength recorded in terms of (g/tex) presented in table 4.15. Regarding fibre strength, all the treatments differ significantly with each other. The fibre strength is indicator for spinning ability of yarn. The Akka BG II had significantly higher fibre strength i.e. 25.67 g/tex. The lowest fibre strength was found in Super Maruti BG II (23.93 g/tex) among all Bt hybrids tested.

4.6.3 Fibre fineness

The fibre fineness indicates the softness of the cotton fibre. All treatments differ significantly with each other for this trait. The Brahma BG II found more fibre fineness i.e. 4.1, which was at par with Bunny BG II (3.8). The lowest value obtained in the Super Maruti BG II (3.4) for this trait.

4.6.4 Ginning percentage (%)

The ginning percentage of the all hybrids recorded in table 4.15. The Bt hybrids not differed significantly with each other for this character. The MRC 7301 BG II had lowest value 31.45 %. The highest value found in Bunny BG II i.e. 38.95%, which was at par with Super Maruti BG II, Akka BG II, Brahma BG II (37.82, 37.70, 36.57 %) respectively.

Mayee *et al.* (2004), noted that Bt hybrids exhibited higher ginning percentage. Khadi *et al.* (2008), recorded increases in ginning out turn in Bt genotypes.

4.7 To study the morphophysiological traits associated with yield in BG II cotton hybrids (correlation).

Seed cotton yield per plant is a complex phenomenon and was governed by several morpho-physiological characters in order to identify important yield contributing characters, simple correlations were worked out and given in table 4.16.

From table, observed that the seed cotton yield was significantly and positively associated with number of bolls ($r=0.852$), dry matter ($r=0.822$) CCI ($r=0.759$) Leaf area ($r=0.681$), leaf area index ($r=0.681$), sympodia ($r=0.670$), harvest index ($r=0.630$), plant height ($r=0.619$), monopodia ($r=0.597$), photosynthetic efficiency ($r=0.580$), boll

weight ($r=0.488$), net assimilation rate ($r=0.477$), similar result was found by Ansari *et al.* (1989), Arshad *et al.* (1993), Bharadwaj *et al.* (1971), Singh and Bharadwaj (1983), Basu and Bhatt (1987), Gite *et al.* (2006), Tayade *et al.* (2011), Anapurve *et al.* (2007), Girase *et al.* (2007) in cotton hybrids.

Harvest index was significantly and positively associated with LA and LAI ($r=0.628$) followed by plant height, dry matter, monopodia, net assimilation rate, relative growth rate and number of bolls in present investigation. Similar result was found to Basu and Bhatt, 1987 with number of bolls.

Boll weight was significantly associated with dry matter ($r=0.695$), sympodial branches ($r=0.593$), leaf area ($r=0.549$), leaf area index (0.549) and plant height ($r=0.496$), chlorophyll content index ($r=0.483$)

Number of bolls was significantly and positively associated with monopodia (0.663), dry matter ($r=0.647$) followed by CCI ($r=0.645$), NAR (0.637), photosynthetic efficiency ($r=0.553$), leaf area ($r=0.498$), leaf area index ($r=0.498$) and RGR ($r=0.483$). Similarly result was found to the Bharadwaj (1988).

Photosynthetic efficiency was significantly and positively associated with dry matter ($r=0.650$), monopodial branches ($r=0.588$) followed by leaf area ($r=0.521$), leaf area index (0.521), sympodia ($r=0.470$) Chlorophyll content index was significantly and positively associated with sympodial braches ($r=0.698$) followed by monopodia ($r=0.555$), dry matter ($r=0.553$) and plant height ($r=0.499$). Relative growth rate was significantly and positively associated with net assimilation rate ($r=0.807$). Net assimilation rate was significantly and positively associated with monopodial branches ($r=0.573$).

Dry matter production plant was highly significant and positively associated with leaf area ($r=0.980$) and leaf area index (0.910) followed by sympodial branches ($r=0.692$), monopodial branches ($r=0.643$) and plant height ($r=0.605$).

Sympodial braches was significantly and positively associated with leaf area (0.665) and leaf area index ($r=0.662$) followed by plant height

($r=0.577$) and monophodial branches ($r=0.531$). Monophodial branches was significantly and positively associated with leaf area and leaf area index ($r=0.532$). LAI was highly and significantly and positively associated with leaf area ($r=0.984$) and followed by plant height ($r=0.533$). Leaf area significantly and positively associated with plant height ($r=0.533$). However, present findings needs further confirmation on multilocation basis.



Table 4.16: To study the morphophysiological traits associated with yield in BG II Cotton hybrids

characters	Plant ht. At harvest	LA at 120DAS	LAI at 120 DAS	Monopodia per plant.	Sympodia per plant.	DM at harvest	NAR at 30-60 DAS	RGR at 30-60DAS	CCI at 120 DAS	P. E. at 120 DAS	No. Of bolls per plant.	Boll Wt. (g)	HI %	S C Y (g/plant)
Plant ht. at harvest	1.000	0.533*	0.533*	0.438	0.577**	0.605**	0.266	0.235	0.499*	0.034	0.386	0.496*	0.585**	0.619**
LA at 120DAS		1.000	0.984**	0.532*	0.662**	0.910**	0.194	0.270	0.429	0.521*	0.498*	0.549*	0.628**	0.681**
LAI at 120 DAS			1.000	0.532*	0.662**	0.910**	0.194	0.270	0.429	0.521*	0.498*	0.549*	0.628**	0.681**
Monopodia per plant				1.000	0.531*	0.643**	0.573**	0.403	0.555*	0.588**	0.663**	0.249	0.448*	0.597**
Sympodia per plant.					1.000	0.692**	0.209	0.072	0.698**	0.470*	0.517*	0.593**	0.412	0.670**
DM at harvest						1.000	0.359	0.411	0.533*	0.650**	0.647**	0.695**	0.544*	0.822**
NAR at 30-60							1.000	0.807**	0.275	0.316	0.637**	0.053	0.496*	0.477*
RGR at 30-60								1.000	0.146	0.151	0.483*	0.202	0.467*	0.396
CCI at 120 DAS.									1.000	0.362	0.645**	0.483*	0.431	0.759**
P. E. at 120 DAS										1.000	0.553*	0.345	0.165	0.580**
No. Ofbolls / plant.											1.000	0.299	0.503*	0.852**
Boll Wt. (g)												1.000	0.138	0.488*
HI %													1.000	0.630**
SCY(g/plant)														1.000

*Significant at 5%

**Significant at 1%.

CHAPTER V

SUMMARY AND CONCLUSIONS

The present investigation on "Evaluation of different Bt Cotton (BG II) hybrids for morphological traits under rainfed condition" was undertaken with the specific objectives (i) to study the morphophysiological traits associated with seed cotton yield in BG II cotton hybrids and (ii) to study the fibre properties of BG II Bt cotton hybrids. The research work was carried out at the experimental field, Department of Agricultural Botany, Post Graduate Institute, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *kharif* season 2012 – 2013. The experiment laid out in Randomised block design, with four replications and five hybrids.

The observations were recorded on various parameters, i.e. Morphophysiological parameters (plant height, leaf area per plant, leaf area index per plant, number of monopodia, number of sympodia, dry matter production per plant). Phenological observations (days to 50% flowering, days to 50% boll bursting and days to maturity). Physiological observations (relative water content, chlorophyll content index, photosynthetic efficiency). Computation of growth parameters (crop growth rate, relative growth rate, net assimilation rate and specific leaf weight). Yield and yield attributes (Number of bolls per plant, Boll weight, seed cotton yield per plant and harvest index). Fibre properties (span length, fibre strength, fibre fineness and ginning percentage). The results obtained are summarized hereunder :-

In respect of morphological parameters, it was revealed that the Bt cotton hybrid Akka BGII recorded maximum plant height (106.93 cm) and hybrid Bunny Bt recorded lowest plant height (97.25 cm) at harvest. Akka BG II was found tall where as Bunny remained dwarf. The hybrid Akka BGII showed significantly higher leaf area (68.52 dm²), while hybrid MRC 7301 BGII (37.12 dm²) showed lower leaf area at 120 DAS. The hybrid Akka BGII showed higher leaf area index, while hybrid MRC 7301 BGII showed least leaf area index among all the hybrids tested.

The number of monopodia and sympodia was counted at harvest. The hybrid Akka BGII showed significantly higher number of

monopodia and sympodia i.e. 3.40 and 27.42 respectively. Due to this higher number of monopodia and sympodia it produced higher seed cotton yield as compared to other hybrids under rainfed condition. While, hybrids MRC 7301 BGII, Bunny BGII, Brahma BGII recorded low monopodia and sympodia which resulted in lower yield as compared to Bt hybrid Akka BGII. The data on dry matter production revealed that the hybrid Akka BGII (269.16 g/plant), Super Maruti BGII (209.37g/plant), had maximum dry matter production. Due to higher dry matter it gives good seed cotton yield under rainfed condition, due to optimum translocation of their food material from source to sink. Thus these hybrids seem to be more efficient as compared to other hybrids.

In respect of phenological parameters i.e. 50% flowering revealed that, the higher number of days required for hybrid Bunny BGII 84 and MRC 7301 BGII was 82 days. The minimum days required for flowering was 78 days for Super Maruti BGII which is early. Data on 50% boll bursting is an important yield attributing characters, maximum days required for 50% boll bursting was in hybrid Bunny BGII 118 days followed by hybrid Brahma BGII (117.25), Akka BGII (116.5) and minimum days to 50% boll bursting required to hybrid Super Maruti BGII 113 days. The maximum days taken for maturity were by the hybrid Bunny BGII (164.25 days) followed by Brahma BGII (159.75 days) which remained late matured.

The RWC is an important yield attributing character in cotton hybrids. It was ranged between 76.55% to 79% at 90 DAS. The highest RWC was maintained by Akka BGII (79% and 74.81) at 90 and 120 DAS respectively which resulted in higher yield in rainfed condition. CCI indicated highest value at 90 to 120 DAS. The hybrid Bunny BGII, Akka BGII has maximum CCI. The lowest CCI found in Brahma BGII and MRC 7301 BGII. In case of photosynthetic efficiency the hybrid Akka BGII showed maximum photosynthetic efficiency i.e. 0.748 fv/fm at 120 DAS, where as hybrid MRC 7301 BGII and Brahma BGII showed lower photosynthetic efficiency i.e. 0.718 and 0.709 fv/fm respectively at this stage.

From the study of plant growth parameters, the crop growth rate was lowest at initial stages. The crop growth rate was higher from 30-60 DAS to 90-120 DAS and then decreased at 120-150 DAS among all the hybrid. In general the crop growth rate was highest in hybrid Akka BGII. At peak period i.e. 90 – 120 DAS the crop growth rate was significantly maximum in hybrid Akka BGII (4.10 g/day). In case of Relative growth rate it was highest at initial stage. The hybrid Akka BGII showed higher RGR i.e. 0.091g/g/day at 30-60 DAS while, hybrid Bunny BGII (0.61 g/g/day) showed lowest at this stage. In case of Net assimilation rate it was highest at initial stage and then on later it declined. The highest NAR was found in Super Maruti BGII (0.091g/dm²/day) & Akka BGII (0.087 g/dm²/day) at 30-60 DAS. In case of specific leaf weight, it was lowest at initial stage and increased in later subsequent growth stages. From the table 4.13 it appears highest in hybrids Akka BGII (8.59 mg/cm²), Super Maruti BGII (8.26 mg/ cm²), Bunny BGII (8 mg/ cm²), MRC 7301 BGII (7.82 mg/ cm²) & lowest in Brahma BGII (7.61 mg/ cm²) at 120 DAS, respectively.

Seed cotton yield and its attributing characters revealed that number of bolls were ranged in between 14.72 to 22.4. The hybrid Akka BGII recorded higher numbers of bolls i.e. 22.4. Due to higher number of bolls it gives higher seed cotton yield under rainfed condition. While the hybrid Super Maruti BGII, MRC 7301 BGII, Bunny BGII, Brahma BGII recorded 19.65, 19.05, 16.70, 14.72 number of bolls respectively. In case of boll weight, the boll weight ranged from 3.24 to 3.79 g in different hybrid. Highest boll weight recorded in Akka BGII i.e. 3.79 g. Seed cotton yield per plant varies from 47.04 g/ plant to 83.74 g/plant. The maximum seed cotton yield was recorded by Akka BGII 83.74 g/plant followed by hybrids Super Maruti BGII (63.56 g/plant). This increase in yield was attributed to the favorable increase in the characters viz. number of sympodia, monopodia, number of bolls per plant and harvest index etc. The harvest index was ranged in between 25.95% to 32.19% statistically higher harvest index found in Akka BGII 32.19%, followed by hybrid Brahma BGII (30.46 %), Super Maruti BGII (29.43 %), the lowest harvest index found in Bunny BG II (25.95 %).

at early growth stage and then increased in later stage of growth. The RGR, NAR was maximum at initial stage and then declined in later stages. While specific leaf weight recorded lowest at initial stage but it was highest at 120 DAS in all the hybrids tested.

6. The Akka BGII recorded significantly maximum seed cotton yield (83.74 g/plant) higher number of bolls (22.40/plant), boll weight (3.79 g), sympodia (27.42/plant) and harvest index (32.19). Therefore, the hybrid Akka BG II had resulted in higher yield under rainfed condition.
7. In correlation studies, the characters like number of bolls ($r=0.82$), dry matter ($r=0.822$), leaf area ($r=0.681$), chlorophyll content index ($r=0.759$), leaf area index ($r=0.681$), sympodia ($r=0.670$), harvest index ($r=0.630$), plant height ($r=0.619$), monopodia ($r=0.597$), photosynthetic efficiency ($r=0.580$), Boll weight ($r=0.488$), net assimilation rate ($r=0.477$) showed significant and positive correlation with seed cotton yield in Bt (BG II) hybrids tested.
8. The hybrid Akka BG II showed higher staple length i.e. 33.3 mm and higher staple strength i.e. 25.69 g/tex. The micronaire value in hybrid Akka BG II was moderate and ginning percentage was also moderate in Akka BG II i.e. 37.70%.
9. From this study it indicated that, the Akka BGII showed higher yield under rainfed condition than other hybrids. This hybrid grown very well and showed good morphological, physiological, phenological, growth parameters, yield attributing characters and fibre qualities under rainfed condition. However present investigation needs further confirmation on multilocation basis.

CHAPTER VI

IMPLICATIONS

The investigation on "Evaluation of different Bt cotton (BG II) hybrids for morphophysiological traits under rainfed condition" have useful information for discovering new cotton hybrids under rainfed condition. The morphophysiological traits can be used for breeding of high yielding cotton hybrids. This study needs multiseasonal and multilocal trials for the confirmation of this investigation.

CHAPTER VII

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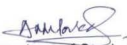
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APPENDIX I

Weekly weather Data for the Year 2012 recorded at Agromet. Observatory, Dr. PDKV, Akola

Weeks	Dates	T MAX (°C)		T MIN (°C)		BSH (hrs)		WS (km/hr)		RH I (%)		RH II (%)		Evap (mm)		RF (mm)		CRF (mm)	Rainy Days	
		N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A		N	A
26	25-1 Jul	33.8	37.71	24.3	26.44	4.8	6.6	12.8	12.35	80	71.28	55	36.85	7.4	12.51	43.4	20.6	20.6	2.2	1.0
27	2-8	33.2	30.71	24.0	23.91	4.8	2.2	12.0	5.81	81	90	58	72.28	6.5	4.05	39.4	101	121.6	2.2	5.0
28	9-15	32.3	31.84	23.8	24.6	3.8	3.95	11.2	7.44	83	86.57	60	57	5.5	5.31	42.8	20.3	141.9	2.5	3.0
29	16-22	31.9	33.08	23.6	24.95	4.0	2.62	10.4	8.85	84	80.85	63	58.28	5.2	5.77	52.8	46.1	188	2.4	4.0
30	23-29	31.3	26.71	23.3	23.18	4.0	0.0	10.8	9.12	86	87	64	82.85	4.8	2.55	43.4	91.1	279.1	2.6	5.0
31	30-5 Aug	30.9	28.04	23.3	23.01	3.5	0.15	10.6	8.04	86	84.4	67	77	4.6	2.97	49.6	30.1	308.1	2.4	4.0
32	6-12	29.9	28.12	23.0	23.35	3.2	1.02	10.9	9.32	88	89.85	70	80	4.1	4.05	61.0	15.9	324	2.8	2.0
33	13-19	30.4	28.67	23.0	23	4.0	1.15	12.4	5.6	87	90.14	67	75.85	4.5	3.64	35.9	18.4	342.4	2.0	2.0
34	20-26	30.4	29.12	22.8	23.02	4.1	3.35	11.9	4.91	87	93.85	67	71.57	4.3	3.91	42.5	25.8	368.2	1.9	3.0
35	27-2 Sep	30.5	30.9	22.7	23.61	4.2	3.52	9.3	2.08	87	94.14	66	68.71	4.6	3.88	42.4	44.9	413	2.1	3.0
36	3-9	31.0	30.07	22.5	23.44	5.3	4.28	8.6	5.5	87	88.57	62	67.71	5.3	4.47	33.6	93.8	506.9	1.5	5.0
37	10-16	32.1	30.22	22.4	22.92	6.6	5.0	8.0	4.24	85	84.71	57	61	5.1	3.91	22.0	10.4	517.3	1.1	2.0
38	17-23	32.9	31.67	22.4	23.02	6.8	4.98	6.4	2.5	84	86.42	55	54.28	5.2	4.21	23.7	23.8	541.1	1.4	1.0
39	24-30	33.5	32.5	22.1	22.6	7.3	7.05	5.1	1.18	84	84.85	50	45.42	5.0	4.05	24.4	9.3	550.4	1.4	2.0
40	1-7 Oct	33.7	33.05	21.2	22.54	7.6	7.65	4.8	2.6	82	87.71	47	48.27	5.4	5.07	23.4	40.9	591.3	1.1	2.0
41	8-14	34.0	33.57	19.8	16.2	8.1	7.65	4.5	0.3	78	84.57	40	32.57	5.3	4.71	13.1	1.5	592.8	0.7	0.0
42	15-21	33.7	34.05	18.3	17.62	8.2	7.07	4.6	1.22	76	78.42	37	24.14	5.3	5.57	6.1	0.0	592.8	0.4	0.0
43	22-28	33.1	32.95	16.8	18.58	8.3	4.78	4.4	1.02	74	76.14	34	28.28	5.3	5.57	7.6	0.0	592.8	0.4	0.0
44	29-4 Nov	32.7	31.38	16.0	14.37	8.4	4.97	4.1	1.72	73	75.42	32	35.42	5.3	5.07	2.3	0.0	592.8	0.2	0.0
45	5-11	32.3	32.05	15.2	14.82	8.4	7.65	3.9	1.28	71	72.42	32	23.14	5.1	5.21	3.0	0.0	592.8	0.2	0.0
46	12-18	31.6	31.02	14.6	11.94	8.3	7.57	3.9	1.18	73	73	32	21.14	4.8	4.5	5.3	0.0	592.8	0.2	0.0
47	19-25	31.0	30.65	13.3	13.02	8.4	7.58	3.7	1.25	72	72.85	30	26.25	4.6	3.97	7.7	0.0	592.8	0.3	0.0
48	26-2 Dec	30.5	31.82	12.8	15.52	8.4	6.95	3.6	1.24	71	74	32	28	4.4	3.94	5.5	0.0	592.8	0.3	0.0
49	3-9	30.0	31.11	11.9	15.08	8.4	7.54	3.8	1.22	71	64.57	30	21.42	4.3	4.54	1.0	0.0	592.8	0.1	0.0
50	10-16	29.6	31.42	10.9	15.08	8.4	7.47	3.6	0.8	71	75.85	28	26	4.2	3.72	0.8	0.0	592.8	0.1	0.0
51	17-23	29.5	29.24	10.8	11.88	8.5	7.07	3.8	1.02	70	78.71	29	27.14	4.1	4.14	0.9	0.0	592.8	0.1	0.0
52	24-31	29.1	28.12	10.65	12.17	8.3	8.23	4.5	0.81	71	71.87	30	27.25	4.2	3.97	2.6	0.0	592.8	0.2	0.0
										Total RF June to Dec						636.2	592.8	592.8	34.2	44

