Dedicated to

My Beloved Family

and

My Major Guide

Dinesh...

Gossypium sp. (Cotton)

INFLUENCE OF MODIFICATION OF MORPHOFRAME ON PHYSIOLOGY AND YIELD IN COTTON

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ABSTRACT

Gossypium sp. (Cotton)

INFLUENCE OF MODIFICATION OF MORPHOFRAME ON PHYSIOLOGY AND YIELD IN COTTON

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ABSTRACT

Since most plant growth and development processes are regulated by natural plant hormones, these processes may be manipulated either by altering the plant hormone level or by changing the capacity of the plant response to natural hormones. In recent years, plant growth regulators (PGRs), which are synthetic hormones, have been investigated for their ability to alter cotton growth and development in an attempt to improve production. Plant growth regulators have potential to promote square, flowers and boll retention, higher nutrient uptake and keeping vegetative and reproductive growth in harmony to improve yield and quality. As the present day cotton genotypes are photo insensitive, they initiate producing reproductive parts irrespective of the environmental and physical conditions by 40-45 days after sowing. Hence, sufficient morphoframe does not develop on the plant to hold the reproductive parts. *Bt* cotton by virtue of early switch over to reproductive phase, often do not express fully as far as vegetative growth in concerned. Further, late in the season, many *Bt* hybrids show excess vertical growth if first flushes are lost due to natural shedding because of aberrant weather condition under sufficient supply of nutrients and moisture both situations are not desirable. In

cotton, new squares are formed only on newly emerged sympodial branches but the promotion of vertical growth than horizontal growth under certain condition may lead to the loss of photosynthates during the vegetative phase and consequently small size bolls and ultimately result in low yield. Modification of morphoframe by Ethylene and Maleic hydrazide application could greatly help in dispensing away these limitations. This intervention may increase source size and then improve sink activity. Hence keeping these facts in mind, a field experiment were conducted at Main Cotton Research Station, Navsari Agricultural University, Surat during the *Kharif* 2011-12 and 2012-13 to study the Influence of Modification of Morphoframe on Physiology and Yield in Cotton. The experiments were laid out in Randomized Block Design (Factorial concept) with twelve treatments *viz.*, first factor (Growth regulators) (T_1) - Control (00 ppm), (T_2) - Ethylene 45 ppm at squaring stage, (T_3) - MH 500 ppm at 85 DAS and (T_4) - Ethylene + MH and second factor (Cotton hybrids) (V_1) - RCH 2 (BG-II), (V_2) - Vikram 5 (BG-II), (V_3) - G.Cot Hy-12 and replicated three times.

The results indicated that application of growth regulators significantly affect the physiological, morphological, biochemical, phenological characters, yield and yield attributing characters and economics of the hybrids over their untreated control. Single application of Ethylene and MH was found significantly effective in enhancing most of the parameters over control. Ethylene application recorded significantly greater plant height, LAI, RGR, reducing sugars, yield, seed index and lint index besides that it reduced days to 50 per cent boll bursting, maturity, took lesser growing degree days and heliothermal units compared to the control. Application of MH at 85 DAS significantly increased chlorophyll content and required more days to 50 per cent boll bursting, maturity, took more growing degree days and heliothermal units with lower seed and lint index besides usual increase in physiological parameters, growth and yield as compared to remaining treatments. In terms of net return and cost benefit ratio both Ethylene and MH were much advantageous over check.

Application of Ethylene (45 ppm) at squaring stage followed by MH (500 ppm) at 85 DAS recorded significantly higher LAI, LAD, CGR, RGR, NAR, dry matter, squares, flowers, green bolls, sympodia, mainstem nodes, chlorophyll content, GDD, HTU, number of bolls (at harvest), boll weight, biomass and yield, and brought about better net return and benefit cost ratio over control and over Ethylene and MH alone.

Amongst the three cotton hybrids, Vikram 5 (BG-II) recorded significantly higher LAI, LAD, CGR, RGR, NAR, dry matter accumulation, fruiting forms (square, flowers and bolls), sympodia, mainstem nodes, chlorophyll content, reducing sugars content, number of bolls, boll weight, biomass, seed cotton yield, seed and lint index than conventional hybrid G. Cot Hy-12. *Bt* hybrids, RCH 2 (BG-II) was observed significantly less days taken to 50 per cent boll bursting, maturity, growing degree days and heliothermal units compared to G. Cot.Hy-12.

On the basis of two years experimental results, it can be concluded that through modification of plant morphoframe by application of 45 ppm Ethylene at squaring stage or 500 ppm MH at 85 DAS, it is possible to improve various physiological, morphological, biochemical, morpho-phenological events in desired direction to harvest higher yield without impairing fibre quality. The two PGR's when used in succession offer additional advantage in yield of the hybrids whether *Bt* or non-*Bt* and can be utilized as a viable technology to enhance cotton yield.

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C E R T I F I C A T E

This is to certify that the thesis entitled **"INFLUENCE OF MODIFICATION OF MORPHOFRAME ON PHYSIOLOGY AND YIELD IN COTTON"** submitted by **Mr. DINESH PARASHRAM NAWALKAR** in partial fulfillment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY (AGRICULTURE)** in the subject of **Crop Physiology** of the **Navsari Agricultural University** is a record of bonafide research work carried out by him under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma or other similar title.

Place : Navsari
Date : / / 2014

(V. Kumar)
Major Advisor

D E C L A R A T I ON

This is to declare that the whole of the research work reported here in this thesis for the partial fulfillment of the requirements for the degree of **DOCTOR OF PHILOSOPHY (AGRICULTURE)** in **Crop Physiology** by the undersigned is the results of investigation carried out under the direct guidance and supervision of **Dr. V. Kumar,** Research Scientist (Cotton) Main Cotton Research Station, Navsari Agricultural University Surat - 395 007 and that no part of the work has been submitted for any other degree so far.

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I INTRODUCTION

Cotton (*Gossypium spp* L.) is one of the predominant fibre crops playing a pivotal role in agriculture, industrial development, employment generation and economy of India. It is also called as king of fibre due to higher economical value among all cash crops in India. Cotton is the most important cash and commercial crop contributing nearly 75 per cent of total raw material needs of textile industry in India. Textile industry is the number one export enterprise in the country earning revenue of over $ 8.5 billion. Hence, it is also called as 'White gold'.

Cotton belongs to the genus *Gossypium* under tribe Gossypiceae of Malvaceae family. There are four species of cotton under cultivation *i.e. Gossypium herbaceum* L., *G. arboreum* L., *G. hirsutum* L., and *G. barbadense* L. India is the only country where all four cultivated species of cotton are grown. Cotton is multipurpose crop that supplies basic products like fibre, oil, seed meal, oil cake, hulls and linters.

It is cultivated on about 33.0 million hectare across the world. India has the distinction of having the largest area under cotton cultivation in the world ranging between 11-12 million hectare. It accounts for about 33% of the global cotton area and contributes 21% (5.86 million tonnes) of the global cotton produce, currently ranking second after China. The yield per hectare is however the lowest *i.e.* 481 kg ha^{-1} against the world average 763 kg ha^{-1} and major cotton producing countries *viz.*, Brazil (1600 kg ha^{-1}), China (1311 kg ha^{-1}), USA (945 kg ha^{-1}), Uzbekistan (859 kg ha^{-1}) and Pakistan (684 kg ha^{-1}) (CICR, 2013).

In India, Gujarat is the largest producer of cotton having 2.6 million hectare under cotton cultivation producing 11.35 million bales and ranks first in production (CICR, 2013). Cotton provides employment and sustenance to a population of nearly 42 million people, who are involved directly or indirectly in cotton production, processing, textiles and related activities. It is estimated that more than 6.0 million farmers cultivate cotton in India and about 36 million persons are employed directly by the textile industry. There are more than 1.7 million registered looms, 1500 spinning units, and an estimated 280 composite mills. Therefore, cotton production in India is considered to have a wide reaching impact not only on the livelihood of farmers and economy of the country, but also on international trade.

Major losses in cotton production are due to its susceptibility to pests and diseases. Out of total insecticides used in the country which costs US $ 600 million, more than half are used on cotton. Realizing importance of severity of the loss of cotton crop due to insect pest, *Bt* cotton hybrids had been approved for commercial cultivation in India from 2002. *Bt* cotton is a genetically modified variety of cotton producing an insecticide. The gene coding for *Bt* (*Bacillus thuringiensis*) toxin has been inserted into cotton, causing cotton to produce this natural insecticide in its tissues. Which kill lepidopteron pest providing respite in pest control.

Due to population explosion and also the saturation in cotton area, new efforts should be initiated to enhance the productivity. Despite impressive growing in cotton production, India is 33rd rank in productivity amongst cotton growing countries of the world. Increasing population, growing demand and export potential all warned that new vistas must be exploited to increase the productivity through mainly by management.

There is wide possibility still to exploit full genetic potential of existing genotypes which is evident from stark difference in yield of same variety at different management levels. Physiological manipulation of crop growth and development, thereby enhancing the productivity per unit area, is one such approach, not many efforts were put in to understand the physiological factors for enhancing better yield through judicious use of land inputs, plant architecture and its mandeveur.

About 65 per cent cotton cultivation in India is under rainfed conditions. Cotton suffers from various biotic and abiotic stresses right from the germination to maturity. The growth during the seedling establishment phase plays an important role in yield realization. A good plant frame provides sufficient space for holding and catering the needs of the reproductive parts during the later part of growth. Under Indian conditions, the crop experiences initial water logging followed by sucking pests. Both these stresses cause considerable damage to the plant leading to stunted growth. As the present day cotton genotypes are photo-insensitive, they start producing reproductive parts irrespective of the environmental and physical conditions by 40-45 days after sowing. Hence, sufficient morphoframe does not develop on the plant to hold the reproductive parts. This is most so in *Bt* cotton where then is early shift to reproductive phase due to inbuilt protection from insect damage. This may lead the plants forced maturity or to reduction in boll setting. Whereas in irrigated and higher rainfall receiving areas, development of excessive vegetative growth leads to low reproductive load and fruit set thus by which the yield is reduced. Similarly physiological disorders like natural shedding of fruiting bodies, leaf reddening, bad opening of bolls contributes to low yield.

The cotton plant has perhaps the most complex structure of any major field crops. Its indeterminate growth and sympodial branch often defies analysis. Physiological efficiency of the plant holds the key for ideal performance of the crop in terms of growth, development and yield. However, efficiency is governed by many biotic and abiotic influences. Once an ideal genotype for a particular region is identified in terms of duration, productivity, growth habit and compatibility in the overall cropping system, the endeavour should optimize the yield realization through appropriate management methodologies including nutrient, moisture, insect pests, diseases and physiological maladies affecting the crop. Plant growth regulators have the potential to promote crop earliness, square and boll retention, higher nutrient uptake and keeping vegetative and reproductive growth in harmony to improve lint yield and quality (Kerby *et al*. 1993). Several naturally occurring hormones work in the cotton plant to adjust plant growth. When plant growth regulators are applied to the cotton plant, they work in much the same way as the natural regulators already present. In many ways, they supplement or destroy the natural hormone. They often work together in ratios and concentrations to regulate growth. Relatively little is known about hormonal control of cut-out but based on established effects of the hormones, it is thought that auxin, cytokinins and gibberellins promote growth and delay cut-out. Abscisic acid, on the other hand, promotes cut-out as it inhibits growth and prolongs bud dormancy. Ethylene increases boll abscission and may restrict growth, but may not induce dormancy. Various growth regulators have been applied in cotton in attempts to set more bolls, limit vegetative growth or terminate fruiting.

When boll load is limited by carbohydrate availability, exogenous modification of hormonal balance to increase boll set may be futile. More bolls may be set, but of smaller size and plant growth terminated prematurely. Therefore, a plant type with a good morphoframe would sustain more boll load with synchronous boll development and boll burst. This will help in enhancing the yield and effective harvesting in one or two picking. In *Bt* cotton, the plant morphoframe doesn't develop fully due to retention of plant tops. Chemical intervention may increase source size and then improve sink activity. Maleic hydrazide is a hormone like substance which has been found to have striking effects on plant growth, development and flowering. Presence of this growth substance results in inhibition in growth of one tissue or organ. Such inhibition is usually accompanied by rejuvenation and activation of tissues in some other part of the plant (Aubrey and Edwin, 1950).

Nearly 90 per cent cotton area in the country is under *Bt* cotton. *Bt* cotton by virtue of early switch over to reproductive phase, often do not express fully as far as vegetative growth in concerned. Further, late in the season, many *Bt* hybrids show excess vertical growth if first flushes are lost due to natural shedding because of aberrant weather condition under sufficient supply of nutrients and moisture. Both situations are not desirable. In cotton, new squares are formed only on newly emerged sympodial branches but the promotion of vertical growth than horizontal growth under certain condition may lead to the losses of photosynthates in vegetative growth and consequently small size bolls and poor yield. Modification of morphoframe by agrochemicals could greatly help in dispensing away these limitations. Keeping these facts in mind, the present investigation is proposed to investigate the influence of modification of morphoframe through growth retardants (Ethylene and Maleic hydrazide) on cotton with the following objectives.

1. To study the influence of modification of plant morphoframe on various physiological parameters, growth and yield of cotton.
2. To study the effect of modified morphoframe on economic characters and fibre quality.
3. To work out economics of different treatments.

REVIEW OF LITERATURE

Gossypium sp. (Cotton)

II REVIEW OF LITERATURE

Chemicals that are synthesized within the plant are called Phytohormones, while chemicals that are artificially synthesized but have similar functions are called plant growth regulators Kurt *et al.* (1994). Plant growth regulators that promote plant growth and development are widely used in a number of commercial crops, including cotton.

Climatic factors such as high temperature, length of daytime and relative humidity can have negative effects on the synthesis of some plant hormones (Abscisic acid, Gibberellic acid and Cytokinins). This directly affects physiological processes of the plant and, as a result, growth potential is limited. However, external application of synthetic plant growth regulators can have such similar functions and have effect as Phytohormones, thereby allow physiological processes to continue at their normal pace (Gulluoglu, 2004).

In recent years, Scientists have given attention to regulate plant growth by external application of growth regulators viz., Ethrel, Maleic hydrazide, Pix, Mepiquat chloride, NAA and CCC as third most important factor in improving the growth, yield and quality. With the application of plant growth substances in various ways it helps in efficient utilization of metabolites in certain physiological processes going in the cotton plant system.

The role of plant growth regulators (PGR's) on various physiological processes of plants is well known, which enables a rapid change in the phenotype of the plant within one season to achieve desirable results. Plant growth regulators are known to affect right from seed germination to senescence by enhancing the growth (growth promoters), reducing the plant height (growth retardants), altered flowering, fruit set, seed development, fruit ripening and yield. Cotton often produces more vegetative growth than is needed for maximum boll production and yield especially when climatic conditions favour vegetative growth, thereby directing the photo-assimilates towards the vegetative growth rather than reproductive growth. However, in the recent past, different workers have emphasized the use of various growth regulating chemicals for the control of vegetative growth in cotton. This chapter reviews same recent work on plant growth regulators in cotton and their effect on morpho-physiological parameters, yield and yield attributes.

Since most plant growth and development processes are regulated by natural plant hormones, these processes may be manipulated either by altering the plant hormone level or by changing the capacity of the plant to respond to its natural hormones. In recent years, plant growth regulators (PGRs), which are synthetic hormones, have been investigated for their ability to alter cotton growth and development in an attempt to improve production.

Ethylene is a gaseous molecule that causes leaf bending, acceleration of abscission, stem swelling, inhibition of stem and root growth, fruit ripening, dehiscence and leaf defoliation. In cotton, ethephon (Ethylene) has been used successfully and is widely accepted as a harvest aid to accelerate boll dehiscence prior to harvesting (Cathey *et al.*, 1982). Ethephon was also used to raise the node level of the first flower in cotton to higher position, thus potentially increasing the efficient, plant growth and development or lint yield. Husman *et al.* (1994).

Maleic Hydrazide is a hormone like substance which has been found to have striking effects on plant growth, development and flowering. Presence of this growth substance results in inhibition in growth of one tissue or organ. Such inhibition is usually accompanied by rejuvenation and activation of tissues in some other part of the plant Aubrey and Edwin, (1950).

Maleic Hydrazide (MH) had been reported to reduce the apical dominance in various crop plants (Singh and Jauhari, 1965). In many crop plants it is useful to increase the number of laterals, which resulted in higher flowering and fruiting and ultimately the yield.

Cotton plays a dominant role in the industrial and agricultural economy of the country. The productivity of cotton in India is low as compared to world average. Introduction of *Bt* cotton in India after 2002 proved to be a turning point for cotton production and productivity in country. More and more farmers are resorting to *Bt* cotton leaving behind traditional hybrids. *Bt* hybrids are expected to retain more bolls at early growth stage because of better insect control over their non-*Bt* counterparts. Developing bolls have a greater demand for photosynthesis and thus plants with higher boll load have greater inter-organ competition for photo-assimilates (Guinn, 1985). This higher fruit load appears to be a major factor which causes slow growth of flowering and decreased boll retention further Peterson *et al*. (1978). It is important in view of fact that in *Bt* cotton, the plant frame doesn't develop fully due to early switch over to reproductive phase. An attempt has been made to present a brief review of research work done in India and abroad on these aspects hereunder.

2.1 Effect of PGR on physiological characters

Pettigrew *et al.* (1993) observed that spraying of Ethephon 0.28 kg ha^{-1} resulted in significantly lower Crop Growth Rate (CGR), Relative Growth Rate (RGR) and Net Assimilation Rate (NAR) as compared to check plots in cotton genotypes. Hunnnur *et al.* (2011) reported increased in growth parameters like LAI, CGR and LAD with the application of growth retardant *i.e.* Mepiquat pentaborate @ 1000 ppm in cotton *cv.* JK-99.

Thakare *et al.* (2011) highlighted from an experiment that increased leaf area index (LAI) due to application of Ethylene (45 ppm) at square initiation stage in *Bt* cotton.

Koler *et al.* (2011) stated that the foliar spraying of Mepiquat chloride (50 ppm) at 90 DAS increased leaf area compared with cycocel and control in cotton. However, Prakash and Prasad (2000) showed that the growth retardant Chloromequat chloride @ 50 and 100 ppm reduced the LAI over control in cotton. Prasad and Prasad (1994) found that the leaf area was lowest when applied with Cycocel @ 50 ppm on cotton *cv.* Pusa 31.

Zhao and Oosterhuis (2000) indicated that the physiological processes like photosynthetic rate, stomatal conductance, transpiration rate and specific leaf weight increase with sprayed growth retardant Pix plus @ 293 ml ha^{-1} in cotton.

Kumar *et al.* (2001) found that photosynthesis rate, transpiration rate and stomatal conductance decreased when applied 50 mM with Ethrel at 60 days after sowing in cotton *cv.* H-777. The application of growth retardant Mepiquat chloride @ 50 ppm 90 DAS improved photosynthesis, transpiration, stomatal conductance and net assimilation rate

(NAR) compared with Chlormequat chloride in hybrid cotton *cv*. DHH-11 (Kumar *et al.*, 2005).

2.2 Effect of PGR on morphological characters

2.2.1 Effect on growth characters

Hall *et al.* (1957) noticed that intact cotton plants did not produce significant amounts of Ethylene until the initiation of reproductive stage indicating that squares and young fruits possibly produced significant amounts of ethylene.

De-Silva (1971) noticed decreased number of monopodial branches in cotton *cv*. Stato-65 when plants were treated with growth retardant CCC @ 125 or 250 ppm 38, 59 and 85 days after emergence.

Leonard and Pinkas (1972) stated that an application of 0.032 M Ethephon on American cotton plant *cv*. Pima S-4 raised the node level of the 1st flower to about 4th nodes in a green house experiment.

Rowland (1974) studied the effect of foliar application of growth retardants *viz*., MH, CCC, TIBA, NAA and Ethylene in cotton. In the investigation, MH and CCC were found more effective in decreasing plant height. Application of MH in various concentrations has been reported to reduce plant height in Okra (Verma and Singh 1978), Soybean (Mehetre and Lad 1995), Sunflower (Kulkarni *et al*. 1995), Rice (Manjula and Ibrahim 1999), Maize (Abramyan *et al*. 1972) and Pea (Rakava and Minor, 1970).

Anonymous (1977) found that foliar application of Ethephon @ 200, 400, 1000, or 2000 ppm caused shedding of young leaves, bolls and flower bud. However, bolls on treated plants increased to grow and matured rapidly compared to untreated control in cotton.

Abdallah and Mohmoud (1978) reported that application of growth retardant CCC @ 50, 100 and 200 ppm in cotton *cv*. Giza-75 decreased the internodal length and number of sympodial branches in cotton.

Reddy *et al*. (1990) reported that, application of Mepiquat chloride @ 49 g ha^{-1} reduced plant height, number of main stems, vegetative branches, fruiting branches and node formation in cotton.

Pettigrew *et al*. (1992) studied the effect of Ethephon on two genotypes (DLP-50 and MD-65-11) of cotton. The results indicated that Ethephon (2.8 kg ha^{-1}) application increase main stem nodes and decreased plant height over the control treatment.

Mahmaud *et al*. (1994) in a pot experiment on cotton sprayed with 100, 300, 500 ppm Ethrel and 1000, 3000, 5000 ppm Alar found decreased plant height at 80 or 94 days after sowing.

Another experiment conducted by Ahmed (1994) observed that there was increased in number of sympodia and number of flowers $plant^{-1}$ when plants were sprayed with CCC 100 ppm in cotton.

Prasad and Prasad (1994) indicated that plant height was lower with CCC at 50 ppm spray which differed significantly from other plant growth regulators and water spray on cotton *cv*. Pusa 31.

Singh and Brar (1999) observed higher leaf defoliation when applied with Ethrel and Thidiazuron @ 75 g ha^{-1} as compared to untreated control in cotton.

Zhao and Oosterhuis (2000) studied the effect of two growth retardants on physiological traits in cotton and found that the foliar spray of Pix Plus and Mepiquat chloride @ 293 ml ha^{-1} decrease plant height than untreated control in cotton *cv.* Suregrow 125.

Zulfiqar *et al.* (2003) found that plant height increased with Ethylene application (60 kg ha^{-1}) in cotton *cv.* BH-36. Kumar *et al.* (2005) recorded increased plant height and leaf area when applied with Mepiquat chloride @ 50 ppm at 90 DAS in cotton.

Buttar and Agarwal (2004) reported the reduction in vegetative growth such as plant height, leaf area, internodal distance due to application of growth retardants like Ethrel (Ethephon), Pix (Mepiquat chloride), Cycocel (Chlormequat chloride) and Alar (Daminozide) in cotton. Prakash and Prasad (2000) noticed that the foliar spray of Chloromequat chloride @ 50 and 100 ppm reduced the plant height significantly over the control in cotton.

Norton *et al.* (2005) reported that application of 20 gallons $acre^{-1}$ Pix to cotton plants provided balance between reproductive (Squares, flowers, bolls) and vegetative (leaves, stem, roots) components.

An experiment conducted by Gupta and Chauhan (2005) tested that foliar sprays with different concentrations of Ethrel delayed flowering when the application of 0.3 per cent Ethrel as chemical hybridizing agent for foliar spray on *Gossypium hirsutum* L. var. Pusa 846. However, all the treatments of 0.2 and 0.3 per cent ethrel exhibited significant increase in the number of flowers per plant in *G. hirsutum*. Similarly, Gupta and Chauhan (2006) observed that foliar application of 0.2 and 0.3 per cent Ethrel significantly increased the number of flowers per plant in *G. hirsutum* var. Pusa 846 when two varieties (*G. hirsutum* var. Pusa 846 and *G. arboreum* L. var RG 8) were tested. Pandey *et al.* (2003)

recorded that maximum number of flowers when the foliar application of Ethrel 5 µM at reproductive stage (55-60 days after sowing) in cotton *cv*. H-777.

Bardhan and Kumar (2010) studied the foliar application of Ethylene (30 and 45 ppm) at square initiation stage. The results indicated that application of 45 ppm ethylene significantly increase plant height as compared to control in cotton hybrids. Similarly, Thakare *et al*. (2011) observed that foliar application of Ethylene @ 45 ppm at square initiation stage resulted in increase in plant height as compared to control in *Bt* cotton hybrids. Kumari and George (2013) reported that increased plant height and number of sympodia per plant when sprayed with Ethrel 45 ppm at 35-45 DAS as compared to control in *Bt* hybrids.

A study was conducted on the effect of different plant growth regulator *viz*., Mepiquat pentaborate, Chloromequat chloride, Mepiquat chloride in *Bt* cotton *cv*. JK-99 by Hunnnur *et al*. (2011) which revealed that application of Mepiquat pentaborate at 1000 ppm significantly increased plant height compared with all other treatment in cotton.

2.2.2 Effect on fruiting forms

Pettigrew *et al*. (1992) in a study an effect of Ethephon on two cotton genotypes indicated that Ethephon (2.8 kg ha^{-1}) application increased main stem nodes as compared to control treatment in cotton.

El-Antably and El-Atta (1992) mentioned that the application of MH 100 ppm in 1990 and 50 ppm of the same substance in 1991 showed significantly increased number of fruiting branches and vegetative branches $plant^{-1}$ than other treatments and the control in Giza 75 cotton.

Henneberry *et al.* (1992) reported that number of the nodes of first fruiting branches with an open or green boll were higher in 1.12 kg ha^{-1} Ethephon treated plots as compared to control in cotton *cv.* Deltapine 61.

Zhao and Oosterhuis (2000) reported that foliar spray of Pix Plus and Mepiquat chloride at 293 ml ha^{-1} decreased main stem node than untreated control plant.

Buttar and Agarwal (2004) found increased number of sympodia plant^{-1} in cotton with the application of Ethrel, Pix, Cycocel and Alar.

Bardhan and Kumar (2010) observed the effect of foliar application of Ethylene (30 and 45 ppm) at square initiation stage and reported significantly increased number of main stem nodes, number of sympodia and number of fruiting forms with the application of Ethylene @ 45 ppm as compared to control and Ethylene @ 30 ppm irrespective of cotton hybrids. Similarly, Thakare *et al.* (2011) found that the foliar spraying of Ethylene @ 45 ppm at square initiation stage increased the number of fruiting forms and number of sympodia compared to control in *Bt* cotton *cv.* JKCH-99. Kumari and George (2010) noted that significantly higher number of sympodia plant^{-1} when foliar sprayed with 30 ppm Ethrel at square initiation stage, but it was at par with application of 45 ppm Ethrel in *Bt* cotton.

The foliar spraying of 500 ppm Maleic hydrazide at 85 DAS recorded significantly reduced plant height and increased number of sympodia as compared to control in cotton *cv.* Bunny *Bt* (Anonymous 2011[h]).

Hunnnur *et al.* (2011) found that, the number of sympodial branches, number of nodes and stem girth increase with Mepiquat pentaborate application (1000 ppm) in cotton.

Thakare and Kumar (2012) studied the effect of foliar application of Ethylene @ 45 ppm and found higher number of bolls in the first and second position of the fruiting branch in *Bt* hybrids as compared to non *Bt* hybrid. Similarly, Kumari *et al*. (2012) observed increased number of sympodial branches when applied with Ethrel 30 ppm at 35-45 days after sowing in cotton hybrids. Kumari and George (2013) showed that application of Ethrel 45 ppm at 35-45 DAS resulted in increased number of bolls per plant, seed cotton yield and dry matter production (kg ha^{-1}) DAS as compared to control in *Bt* hybrids.

Buttar and Singh (2013) also reported increase in number of sympodia with application of Ethrel 2500 ppm at 145 DAS in *Bt* cotton hybrid *cv*. RCH 134. Chaudhari *et al*. (2013) noted similar effect with 500 ppm Maleic hydrazide at 85 DAS in Bunny Bt.

2.3. Effect of PGR on biochemical parameters

Bhatt and Ramanujan (1970) reported that cotton leaves treated with 50 ppm cycocel increased chlorophyll content in cotton.

Pandey *et al*. (2003) reported that Ethrel @ 5 μM resulted increased chlorophyll content in cotton (*Gossypium hirsutum* L. *cv*. H-777). In contrast, Gethanjali *et al*., (2012) observed increased in chlorophyll content when applied with Ethrel 400 ppm at 25 and 45 days after sowing in groundnut.

Kumar *et al*. (2005) reported that foliar spraying of Mepiquat chloride @ 50 ppm 90 DAS improved chlorophyll content in hybrid cotton *cv*. DHH-11.

Norton *et al*. (2005) observed increased chlorophyll content and fruiting nodes with the application of Pix 20 gallons per acre in cotton.

Mohamed (2009) showed that increased reducing sugar when application of Ethrel 10 ppm compared to untreated control in two seasons in cotton *cv*. Brakat-90.

Nawalagatti *et al*. (2011) stated that chlorophyll content increased with application of growth retardant Mepiquat pentaborate at 1000 ppm in cotton *cv*. JK-99.

2.4. Effects of PGR on crop phenological characters

According to Lipe and Morgan (1973), Ethylene a gaseous hormone is the main cause of premature flower and fruit shedding in cotton.

Agakishiev and Pal'vanova (1976) reported that spraying of Ethrel 0.05% on cotton plant during flowering stage accelerated crop maturity in cotton.

Kandasamy (1980) indicated that spraying of Gramoxone 1.5 to 3.5 lit ha^{-1} as defoliant on cotton *cv*. MCU-9 had significantly advanced the harvesting and increased earliness index of cotton than control.

King *et al*. (1990) reported that Ethephon applied to prebloom cotton at rates of 0.34 and 0.68 kg ha^{-1} delayed flowering for approximately 3 week, after which rates of flowering were higher in ethephon treated as compared to untreated plots in cotton. Similarly, Henneberry *et al*. (1992) recorded delayed flowering due to application of Ethephon 1.12 kg ha^{-1} in cotton. Kennedy *et al*. (1991) observed that foliar spray of Ethephon (0.28 kg ha^{-1}) on super okra cotton removing early squares and resulted delayed the initiation of fruiting, which continued into a delayed crop maturity. Fruiting occurred more rapidly in square removal treatments than control. Leonard and Pinkas (1972) reported that applied the C_2H_2 producing chemical Ethephon either directly to square or over entire plant to abscise squares on lower fruiting branches and found that application of Ethephon promoted squares shedding and delayed floral initiation by approximately four main stem nodes in the most effective in cotton.

A study on the effect of different growth regulator and defoliant *viz.*, Cycocel, NAA, GA_3, Ethrel and Thidiazuron (0, 75, 150 and 225 g ha^{-1}) in cotton carried out by Singh and Brar (1999) at Ludhiana reported that application of Ethrel and Thidiazuron 75 g ha^{-1} significantly increase earliness index and crop maturity in cotton.

Brown *et al*. (1999) evaluated the effect of foliar application of Maleic hydrazide, Ethephon, Chlormequat (CCC) and Cyclanilide and observed that Ethephon at 0.2 lb $acre^{-1}$ and Cyclanilide at 0.1 lb $acre^{-1}$ was given significantly higher upper canopy fruit shedding percentage and boll weight than the control in cotton *cv*. NuCotn33B.

Mohamed (2009) revealed that application of Ethrel @ 5, 10 and 20 ppm increased number of flowers in two seasons in cotton *cv*. Brakat-90.

2.5. Effect of PGR on GDD and heliothermal units

Stringer *et al*. (1989) reported that after cut-out when crop received earlier than 750 or 850 degree-days, reduction in yields and micronaire values were observed with crop termination. The yield reduction averaged 14 per cent for each 100 degree day increment of earlier termination.

Bourland *et al*. (1997) suggested that defoliation with fewer than 850 degree-days may be advisable. However, premature crop termination may reduce lint yields and minimum heat-unit requirement for boll maturation and subsequent defoliation timing in cotton.

Gwathmey and Hayes (1996) reported that application of Ethephon required more than seven days (52 to 108 degree days) after treatment to significantly increase the boll opening of Deltapine 50 cotton, however, the boll opening response to Ethephon is highly correlated with degree days accumulation after Ethephon treatment (base 15.6^0C).

Gwathmey and Hayes (1997) showed that interactions between Ethephon and defoliants occurred under cool conditions that provided only 24 to 47 degree days after treatment to first harvest. Ethephon enhanced defoliation but did not increase boll opening under these conditions. Overall, the boll opening effects of Ethephon and defoliant mixtures tended to be more variable under cool conditions than under the more optimal temperature regimes.

Logan and Gwathmey (1998) suggested that boll opening was affected more with the application of Ethephon in cooler environments (but above the critical minimum of 60^0F or 15.6^0C) than in warmer environments where heat unit accumulation is more influential in cotton.

Lege *et al.* (1997) found that foliar application of Ethephon defoliated more effectively than a Tribufos and Finish mixture by seven days after treatment (DAT) under cool in wet conditions at South Eastern Coastal Plains.

Pearson (1985) proposed that counting degree-days from flowering until maturity of the last effective boll population as a defoliation timing in cotton.

2.6 Effect of PGR on yield contributing characters

Singh (1971) found that only H-14, out of three cottons H-14, F-320 and J-34 (G. *hirsutum* L.) was given significantly increase yield of *kapas* when treated with CCC after 80 days of sowing. However, Singh and Singh (1977) found that the foliar application of Ethrel at 500 ppm gave significantly increased number of bolls, boll weight and seed cotton yield compared to untreated control in cotton *cv*. H-14.

Kittock *et al*. (1973) observed that spraying on cotton plants with Ethephon at 1.12 kg ha^{-1} reduced the green immature bolls remaining after harvest by 98 per cent in cotton.

Agakishiev and Pal'Vanova (1976) found that the foliar application of Ethrel 0.05 per cent showed increase yield in 1st picking of cotton. However, seed cotton yield was not affected. Similarly, Scott (1990) noted that the foliar application of Ethephon increased seed cotton yield in the first harvest of cotton *cv*. DES 119 and DPL 20 and foliar application of Ethrel 3000 ppm at 145 days after sowing increased seed cotton yield in first picking and recorded highest earliness index as compared to control in cotton *cv*. Bunny *Bt* (Anonymous 2010[a]).

Singh and Tripathi (1977) noted increased bolls opening percentage, number of bolls and seed cotton yield with defoliants Ethrel 7.5 l ha^{-1} at 40 and 60 per cent boll opening in cotton *cv*. J-205. Singh and Tripathi (1976) studied the effect of spraying of chemical defoliants like Paraquat at 1 to 2 lit ha^{-1}, Ammonium thiocyanate at 8 to 10 kg ha^{-1} and boll eye at 1.5 to 3 lit ha^{-1} in cotton (var. J-205) and showed that spraying of Paraquat at 2.0 lit ha^{-1} significantly increased seed cotton yield, number of boll and opened bolls at 40 days after spray as well as enhanced the maturity as compared to control in cotton.

Oosterhuis (1977) found that cotton yield was slightly increased with Ethrel application (10 or 100 g ha^{-1}) as compared to control. In another experiment conducted by Anonymous (1977) noted that foliar application of Ethephon 200, 400, 1000, or 2000 ppm slightly improved matured bolls, bolls weight and fiber quality but bolls weight was decreased in immature bolls in cotton. Singh and Kumar (1978) observed that application of defoliants (Ethrel, Paraquat and Sodium Cacodylate) increased the yield in cotton *cv.* LSS, J 205, BN and Hybrid 4 compared to their respective control.

Weir and Gaggero (1982) reported increase in yield of cotton *cv.* Acala SJ-2 when the crop was treated with 200 ppm Ethephon compared to control. Similarly, Prokofex and Rasulov (1979) mentioned that spraying of cotton plants with Ethephon 0.04, 0.2 and 0.4 per cent after 19 to 21 bolls per plant were formed, enhanced boll ripening and increased seed cotton yield specially with low rate of Ethephon.

Thakral *et al.* (1991) noted increased seed cotton yield with defoliant treatments *i.e.* Ethrel and Drop compared to control at 40 and 60 per cent of boll opening in cotton. Similarly, Sawan *et al.* (1984) noted that spraying of Ethrel (at 5 and 10 ppm) after 90 days from planting led to increased the number of open bolls, lint percentage, boll weight and seed cotton yield $plant^{-1}$ in Giza 66 and Giza 70 cotton varieties.

Phillip *et al.* (2000) reported increase seed cotton yield due to mepiquat products in cotton. Similarly, Sawan *et al.* (2001) also found that foliar application of growth retardants (Pix, cycocel and Alar at 300 ppm) resulted in increased cotton seed yield, seed index and seed oil.

Smith *et al.* (1986) recorded reduced seed cotton yield when treated cotton with Ethephon 1.12 kg ha^{-1} at 48 to 62 per cent opened bolls in first year. However, in next year when Ethephon applied to cotton at 12 to 25 per cent opened bolls it did not reduce seed cotton yields relative to application with 48 to 72 per cent opened bolls in cotton *cv.* Stoneville. Donald *et al.* (2001) reported that the application of plant growth regulators in cotton caused significant increase in lint yield and fibre yield in cotton. Owen and Craig (2003) observed that mepiquat chloride significantly hastened the progress of flowering, increased fruit harvest percentage relative to untreated cotton.

Abdel *et al.* (1987) observed that when cotton plants *cv.* Giza 81 were treated with Ethrel (40 ppm) at the beginning of flowering it showed increased seed cotton yield from 25.01 g to 37.6 to 42.0 g $plant^{-1}$.

Kennedy *et al.* (1991) determined efficiency of Ethephon (0.28 kg ha^{-1}) on removing early squares and found lower average yield due to square removal as compared to control in super okra leaf cotton.

According to Pettigrew *et al.* (1992) foliar application of Ethephon (2.8 kg ha^{-1}) decrease seed cotton yield and boll weight as compared to control in two cotton genotypes (DLP-50 and MD-65-11). However, leaf area index and vegetative dry weight was not affected by the spray.

El-Antably and El-Atta (1992) revealed that applied with 50 ppm MH (Maleic hydrazide) on cotton showed increased number of bolls per plant in both 1990 and 1991 season. However, changeable results were obtained for the final yield of seed cotton in Giza 75 cotton.

Mehetre *et al*. (1993) reported that application of 5000 ppm Ethephon at 40 per cent boll bursting stage gave highest mean seed cotton yield of 1.27 t/ha in cotton *cv*. Kop-498. Similarly, Wankhade *et al*. (1994) observed that Ethephon application significantly increased seed cotton yield compared with control in cotton *cv*. AHH-468.

Prasad and Prasad (1994) reported that the number of bolls per plant were lowest with 50 ppm CCC which differed significantly from other PGR's treatment and water spray in cotton *cv*. Pusa 31. While, Pawar and Giri (1976) reported that the application of CCC at 40 and 80 ppm increased the number of bolls per plant significantly over control in cotton *cv*. CJ-73.

Snipes and Baskin (1994) tested the different defoliators *viz*., Tribufos 1.26, Thidiazuron 0.2 and Ethephon 2.24 kg ha^{-1} and reported that the foliar application of Ethephon increased seed cotton yield and lint yield as compared to Tribufos, Thidiazuron and untreated control in cotton *cv*. DES 119. Ahmed (1994) observed increased number of bolls per plant by using growth retardants like CCC, Pix and Alar at different concentrations in cotton.

Babu *et al*. (1995) reported that the application of defoliants (Ethephon 4000 ppm and 200 g Thidiazuron ha^{-1}) significantly increase seed cotton yield in cotton *cv*. AH 107. Tan-Qiling *et al*. (1995) reported that boll weight was slightly improved due to Ethephon application (200-2000 ppm) compared to control in cotton.

Singh and Brar (1999) stated that application of Ethrel and Thidiazuron 75 g ha^{-1} increases bolls opening percentage, number of bolls and seed cotton yield in cotton *cv*. F-846. Similarly, Prasad *et al*. (1997) found that Ethrel 2.0 kg ha^{-1} when sprayed at 60 per cent boll bursting recorded significantly higher boll opening percentage, boll weight, seed cotton yield and highest earliness index obtained in *G. hirsutum* variety RST-9.

Brown *et al*. (1999) tested Maleic hydrazide at 2 lb $acre^{-1}$ and Ethephon 0.2 lb $acre^{-1}$ and found increase seed cotton yield and average boll weight as compared to Chlormequat in cotton *cv*. Deltapine 20B.

Zhao and Oosterhuis (2000) noted that foliar spray of Pix plus at 293 ml ha^{-1} increased total dry matter, boll weight and lint yield compared to control.

An effect of Mepiquat chloride (Pix), Benzyl adenine (BA), Ethephon (Prep) and their combinations on the growth and yield of cotton *cv*. Giza 83 was determined in a field experiment by Abed (2001). All the treatments increased the number of bolls, average boll weight, yield of seed cotton, lint yield per plant and 100 seed weight while reducing the number of bad bolls in cotton.

Zulfiqar *et al*. (2003) noted that number of bolls $plant^{-1}$ increased with Ethylene application (60 kg ha^{-1}) in Cotton *cv*. BH-36. Buttar and Agarwal (2004) found that Ethrel, Pix, Cycocel, and Alar increased number of bolls per plant, boll weight, boll opening percentage and seed cotton yield.

Gupta and Chauhan (2006) observed that one spraying 0.1 per cent Ethephon or Ethrel before floral bud initiation significantly increased boll weight, numbers of seed per boll, 100 seed weight and lint weight in *G. hirsutum* var. Pusa 846 and *G. arboreum* var. RG 8. At the same time, Gupta and Chauhan (2005) tested that efficacy of Ethrel (2-Chloroethyl phosphonic acid) and Benzotriazole (1, 2, 3-benzotriazole) as chemical hybridizing agents on *Gossypium hirsutum* var. Pusa 846. The result indicated that the boll weight and 100 seed weight was slightly enhanced by single spray of 0.1% Ethrel in cotton. Thus, ethrel could be used as a potential hybridizing agent for *Gossypium hirsutum*.

Mohamed (2009) showed that application of Ethrel 10 ppm increased number of bolls per plant, seed cotton yield and earliness in two seasons in cotton *cv*. Brakat-90.

Bardhan and Kumar (2010) evaluated the foliar application of Ethylene at square initiation stage and observed that application of Ethylene at 45 ppm significantly increased number of bolls plant^{-1} and seed cotton yield up to 25 per cent as compared to control and Ethylene at 30 ppm in irrespective of hybrid type. However, Kumari and George (2010) reported that 30 ppm Ethrel significantly gave higher number of bolls plant^{-1}and seed cotton yield, but it was at par with 45 ppm Ethrel at square initiation stage in *Bt* cotton hybrids.

Sarlach *et al*. (2010) studied the effect of Ethrel (defoliant) on a late maturing *Bt* cotton hybrid var. RCH 134 *Bt* and reported that application of 800 ppm Ethrel at 145 days after sowing increased number of picked bolls, seed cotton yield, lint yield with maximum boll opening percentage as compared with control.

An experiment conducted at ANGRAU, Guntur showed that 5.7 or 8.56 mM Ethrel application significantly improved yield attributing characters like number of sympodia, number of fruiting parts, seed cotton yield and leaf area compared to control in *Bt* cotton hybrids (Anonymous, 2010[d]).

The application of 5.7 mM Ethrel at square initiation recorded significantly increased yield attributing characters like number of fruiting parts and seed cotton yield as compared to control in Bunny *Bt* and Bunny non-*Bt* genotypes in cotton (Anonymous, 2010[b]).

The application of Maleic hydrazide 500 ppm at 85 DAS recorded significantly lower plant height and significantly higher seed cotton yield over control in *Bt* cotton hybrids when tested at ARS, Guntur. Similarly, significant variation was noticed among the treatments for plant height, number of monopodia per plant, number of sympodia per plant, number of nodes per plant, number of squares per plant, number of flowers per plant and boll weight (Anonymous, 2010[e]). The application of MH 500 ppm at 85 DAS maximum number of bolls per plant, boll weight and more seed cotton yield than control treatment in cotton hybrids tested at Dharwad (Anonymous, 2010[f]).

Maleic hydrazide 500 ppm at 85 DAS recorded significantly increased number of bolls per plant, boll weight, biomass, harvest index and seed cotton yield as compared to untreated control in cotton *cv.* Bunny *Bt* at MCRS, Surat (Anonymous 2011[h]). And the another results showed by foliar spraying of Maleic hydrazide at 500 ppm changed the plant morphology with reduced internodal elongation and improve Leaf area index (LAI) with Leaf area duration (LAD) and seed cotton yield as compared to control in cotton genotypes (Anonymous, 2010[g]).

Koler *et al.* (2011) studied the effect of plant growth regulators *viz.*, Cycocel and Mepiquat chloride in cotton *cv.*

DHB-290 and reported that the spraying of Mepiquat chloride 50 ppm at 90 DAS increased number of bolls per plant, boll weight, seed cotton yield, harvest index and total dry weight compared with Cycocel and control in cotton. Similarly Kumar *et al*. (2005) reported that application of Mepiquat chloride 50 ppm at 90 DAS improved boll weight, seed cotton yield and total dry matter in cotton *cv*. DHH-11. Kerby *et al*. (1986) observed that the application of mepiquat chloride at 49 g ha^{-1} significantly increased the number of bolls per plant and number of nodes per plant.

Thakare *et al*. (2011) reported that foliar application of Ethylene at 45 ppm at square initiation stage increased boll weight, seed cotton yield and biomass as compared to control and 30 ppm Ethylene in *Bt* cotton *cv*. JKCH-99. Similar concentration recorded highest number of bolls per plant, boll weight and seed cotton yield irrespective of the *Bt* cotton hybrids (Anonymous 2011[j]).

Rajni *et al*. (2011) reported that defoliation with Ethrel 1.5 l ha^{-1} at 60 bolls opening percentage (BOP) gave higher number of picked bolls per plant and boll opening percentage as compared to control in *Bt* cotton hybrid *cv*.RCH 134. However, maximum boll weight and seed cotton yield was obtained in treatment Ethrel at 1.0 lit ha^{-1}, followed by Thidiazuron 100 g lit ha^{-1} applied at 60 BOP.

Hunnnur *et al*. (2011) revealed that application of Mepiquat pentaborate at 1000 ppm increased total dry matter content and seed cotton yield as compared to all other treatment in cotton. Nawalagatti *et al*. (2011) also observed that Mepiquat pentaborate at 1000 ppm gave significantly higher dry matter, number of bolls per plant, boll weight, seed cotton yield and harvest index over control in cotton var. JK-99.

Kumari and George (2012) showed that foliar application of Maleic hydrazide at 500 ppm at 85 days after sowing recorded increased number of bolls per plant, seed cotton yield, boll weight and dry matter production as compared to control in cotton hybrids *cv*. Kashinath *Bt* and Bunny Non *Bt*.

Thakare and Kumar (2012) found increased number of bolls per plant and seed cotton yield in *Bt* cotton hybrids when the foliage were sprayed with Ethylene 45 ppm at square initiation stage in cotton hybrids. Kumari *et al*. (2012) recorded significantly higher number of bolls per plant, seed cotton yield and dry matter production with 30 ppm Ethrel in cotton hybrids.

Buttar and Singh (2013) stated that the foliar application of Ethrel 2500 ppm at 145 DAS in *Bt* cotton hybrid *cv*. RCH 134 increased number of bolls per plant and seed cotton yield as compared to control. The higher seed cotton yields at all the levels of Ethrel were obtained when defoliant was applied at 145 as compared to 130 days after sowing in cotton. Kumari *et al*. (2013) got similar result with Ethrel 3000 ppm at 145 DAS in Bunny BG-I cotton. However, foliar sprayed of Ethrel 1500 and 2000 ppm at 130 DAS increased boll weight in cotton.

Chaudhari *et al*. (2013) reported that foliar application of MH 500 ppm at 85 DAS significantly increased number of bolls per plant, boll weight and seed cotton yield as compared to control in cotton *cv*. Bunny *Bt*. Similar results were obtained CICR Nagpur (Anonymous, 2010[i]).

2.7 Effect of PGR on economical characters

Bangarwa *et al.* (1981) evaluated the application of various growth retardants *viz.*, Ethephon, Paraquat and Bolls eye and reported that Ethephon at 2 to 3 lit ha^{-1}+ Paraquat 2.5 to 3.5 lit ha^{-1} increased oil content and seed index in first picking and ginning per cent in second picking in cotton *cv.* H.14. Mavarkar *et al.* (1992) noted lower seed index and oil percentage when sprayed with defoliant treatments *i.e.* Ethrel and Drop at 30 and 60 per cent of boll opening in cotton. However, Sawan *et al.* (1993) reported that application of Cycocel or Alar with different concentration increased oil content, seed index and seed cotton yield compared to control in Egyptian cotton *cv.* Giza-75. Prasad and Prasad (1994) showed that spraying of 50 ppm Cycocel increased lint index significantly over water spray in cotton *cv.* Pusa-31.

Buttar and Agarwal (2004) exhibited that foliage sprayed with Ethrel, Pix, Cycocel and Alar increased ginning percentage, seed oil, lint index and 100 seed weight in cotton.

Mohamed (2009) concluded that lint percentage was highest in plants treated with Ethrel 10 and 20 ppm at start of flowering and also showed that weight of 100 seeds at the stage of maximum flowering in cotton *cv.* Brakat-90.

Sarlach *et al.* (2010) reported that yield component traits like boll weight, seed index, lint index and ginning out turn did not exhibit any impact with the application of Ethrel in cotton *cv.* RCH 134 *Bt*.

Kumari and George (2012) found increased ginning percentage, lint index and seed index in cotton hybrids *cv.* Kashinath Bunny *Bt* and Non *Bt* when applied with Maleic hydrazide 500 ppm at 85 days after sowing in cotton.

Singh and Singh (1977) observed increase in ginning out turn and fibre strength when cotton plant sprayed with Ethrel at 500 ppm.

Kumari and George (2013) showed that increased harvest index, seed index (g), lint index (g) and ginning outturn when application of Ethrel 45 ppm was given at 35 to 45 DAS which was comparable with control in *Bt* hybrids.

2.8 Effect of PGR on fibre quality parameters

Smith *et al*. (1986) reported that application of Ethephon at 1.12 kg ha^{-1} did not have any adverse effect on fibre properties in cotton *cv*. Stoneville. Thakral *et al*. (1991) stated that there were no significant differences in fibre quality parameters due to defoliant treatment (Ethrel and Drop treatment) at 40 and 60 percentage of boll openings in cotton while Snipes and Baskin (1994) noted that foliar application of Ethephon 2.24 kg ha^{-1} increased strength (g tex^{-1}) compared to Tribufos, Thidiazuron and untreated control in cotton *cv*. DES 119.

Pettigrew *et al*. (1992) found that the foliar spraying of Ethephon 2.8 kg ha^{-1} decreased fibre quality parameters as compared to control in two cotton genotypes (DLP-50 and MD-65-11).

Prasad *et al*. (1997) revealed that none of the fibre properties were significantly affected when cotton variety RST-9 was treated with 2.0 kg ha^{-1} Ethrel (Ethephon-39). Also similar results obtained by Prasad and Prasad (1994) also indicated that none of the plant growth regulators showed any significant change in fibre quality parameters in cotton *cv*. Pusa-31.

Tan-Qiling *et al*. (1995) found increase and slightly improved fibre quality compared to control in cotton with the foliar application of Ethephon (200-2000 ppm).

Singh and Brar (1999) observed that the foliar spraying of Ethrel and thidiazuron 75 g ha^{-1} as a defoliant had non-significant effect on fibre properties (span length, bundle strength and maturity coefficient) in cotton *cv*. F-846.

Mohamed (2009) showed that lower concentration of Ethrel (5, 10 ppm) increased micronaire value when applied at start and maximum flowering. While higher concentration (20 ppm) decreased micronaire value at both stages in cotton *cv*. Brakat-90.

Bardhan and Kumar (2010) found that no adverse effect on fiber quality parameters of hybrid cotton when application of 30 and 45 ppm Ethylene at square initiation stage.

Sarlach *et al*. (2010) reported that higher concentration of Ethrel (800 ppm) application did not show any adverse effect on fiber quality in cotton hybrids.

Highest seed cotton yield, seed index, lint index and ginning percentage was obtained in 8.56 mM Ethylene at square initiation compared to control in cotton *cv*., RCH-2 *Bt* at ANGRAU, Guntur (Anonymous, 2010[c]).

Kumari *et al*. (2013) found no adverse effect on fiber quality parameters when cotton was treated with Ethrel 3000 ppm at 145 DAS and Ethrel 30 ppm at square initiation stage, similar results observed by Kumari *et al*. (2012).

2.9 Effect of PGR on economics

Singh and Singh (1977) reported that application of 500 ppm Ethrel was found to be highly profitable (net profit) compared to untreated control in cotton.

Prasad *et al*. (1997) observed higher net return and benefit cost ratio when the application of Ethrel at 2.0 kg ha^{-1} as compared to water spray in cotton *cv*. RST-9.

Anonymous (2011[j]) showed that application of 45 ppm Ethylene at square initiation indicated that enhanced net return, benefit cost ratio and gross returns compared to untreated control in *Bt* hybrids.

Rajni *et al*. (2011) reported that highest net return and benefit cost ration was obtained when *Bt* cotton hybrid *cv*.RCH 134 treated with Ethrel 1.5 l ha^{-1} as compared to untreated control.

Chaudhari *et al*. (2013) found that benefit cost ratio was superior with the application of Maleic hydrazide 500 ppm at 85 DAS compared to untreated control in cotton. Similar observations were made at Surat.

Gobi and Vaiyapuri (2013) studied that effect of plant growth regulator (40 ppm NAA at 45 and 60 DAS) on economics of cotton *cv*., LRA-5166 recorded highest net return and return rupee compared to untreated control.

MATERIALS AND METHODS

Gossypium sp. (Cotton)

III MATERIALS AND METHODS

Growth regulators have become tools in the hands of agricultural scientists in recent years, as they are capable of altering the canopy structure and redistribution of photosynthesis into various organs of the plant. To achieve optimum vegetative growth and to have better translocation of photosynthates into reproductive parts, use of synthetic growth regulators appears to be an effective approach. Hence, field experiments were conducted to study the "influence of modification of morphoframe on physiology and yield in cotton" during 2011-12 and 2012-13. The details of materials used and methods adopted during the course of investigation are embodied in this chapter.

3.1 General

3.1.1 Experimental site

The field experiment was conducted at Main Cotton Research Station, Navsari Agricultural University, Surat during *Kharif* 2011-12 and 2012-13.

The Main Cotton Research Station, Surat is situated in South Gujarat at a cross point of 20^{0}-12' N latitude and 72^{0}-52' E longitude at elevation of 11.34 meters above the mean sea level and is about 18 Km away from the Arabian seashore.

3.1.2 Climate and weather conditions

The climate of South Gujarat is typically tropical, characterized by fairly hot summer, moderately cool winter and more humid and warm monsoon with heavy rainfall. In general, monsoon commences from the second fortnight of

June and ceases in the second fortnight of September. Pre-monsoon rains in the first week of June and post monsoon rains in the months of October-November are not common. The rain is received mainly from the South West monsoon concentrating in the months of July and August. The winter sets in the end of mid-November and lasts up to February. The temperature starts decreasing from the end of November. However, December and January are the coldest months of season. The summer season commences from the end of February and prolongs up to first week of June. April and May are the hottest months during summer.

The mean meteorological data on maximum and minimum temperature, relative humidity, rainfall and sunshine hours during the course of investigation recorded at the meteorological observatory, Main Cotton Research Station, Navsari Agricultural University, Surat are presented in Appendix-I and II and graphically depicted in **Figure-1&2**.

It could be observed from the data presented in Appendix I and II that the mean maximum temperature ranged between 37.5 to 28.4^{o}C and 36.0 to 30.0 during 2011-12 and 2012-13, respectively. While the mean minimum temperature ranged between 28.8 to 13.2^{o}C and 27.8 to 14.6^{o}C during 2011-12 and 2012-13, respectively. During 2011-12 and 2012-2013, the mean morning relatively humidity ranged between 91.0 to 58.0 and 92.9 to 58.0 per cent, respectively, whereas, the evening humidity from 85.0 to 23.1 per cent and 89.0 to 23.7 per cent, respectively.

The total rainfall recorded during 2011-2012 and 2012-2013 amounted to 1142.0 mm in 52 total rainy days and 781 mm in 45 total rainy days during the crop growth period, respectively.

Fig.1: Meteorological data during the experimental period (2011-12) at Main Cotton Research Station, NAU, Surat

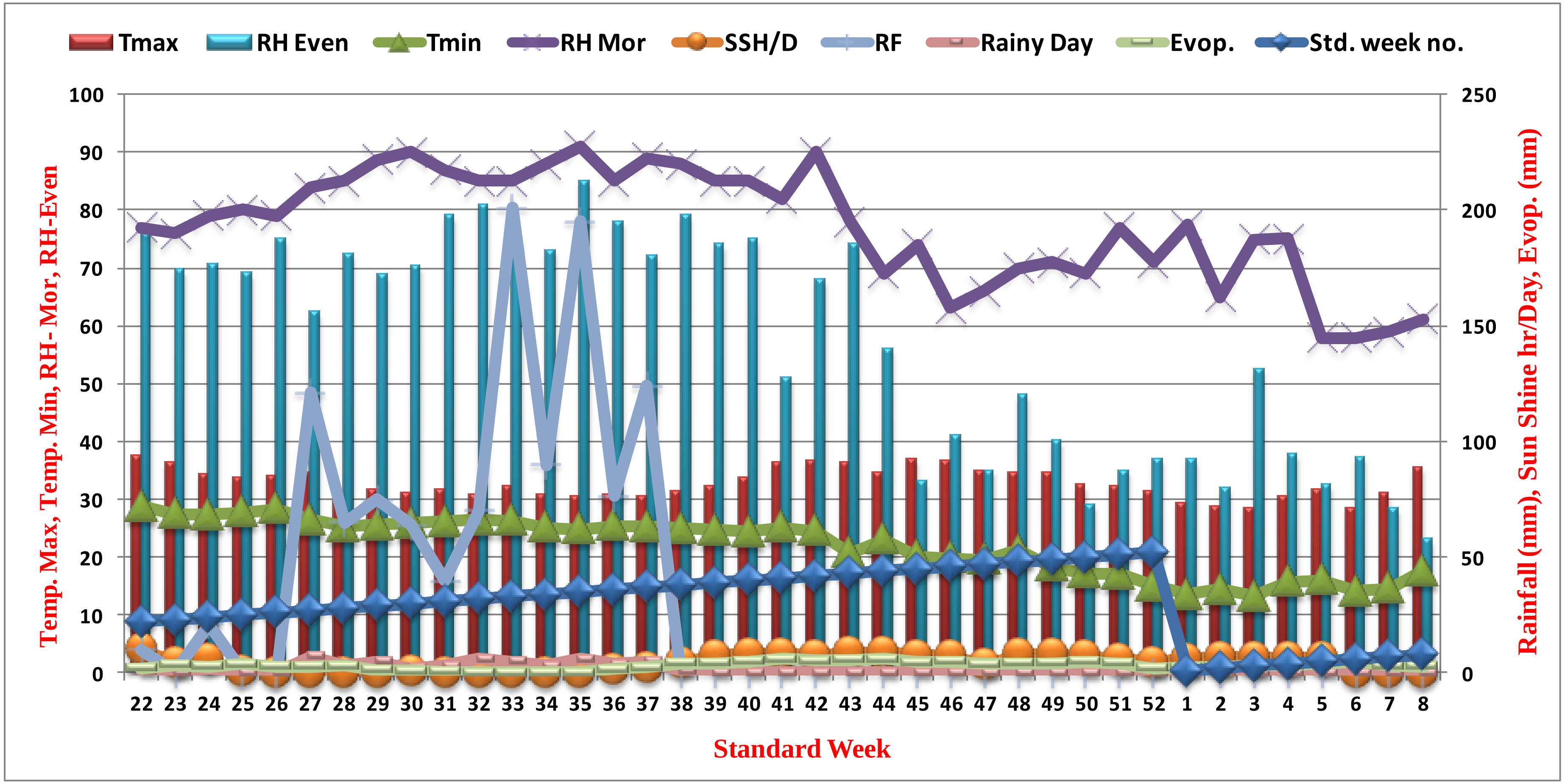
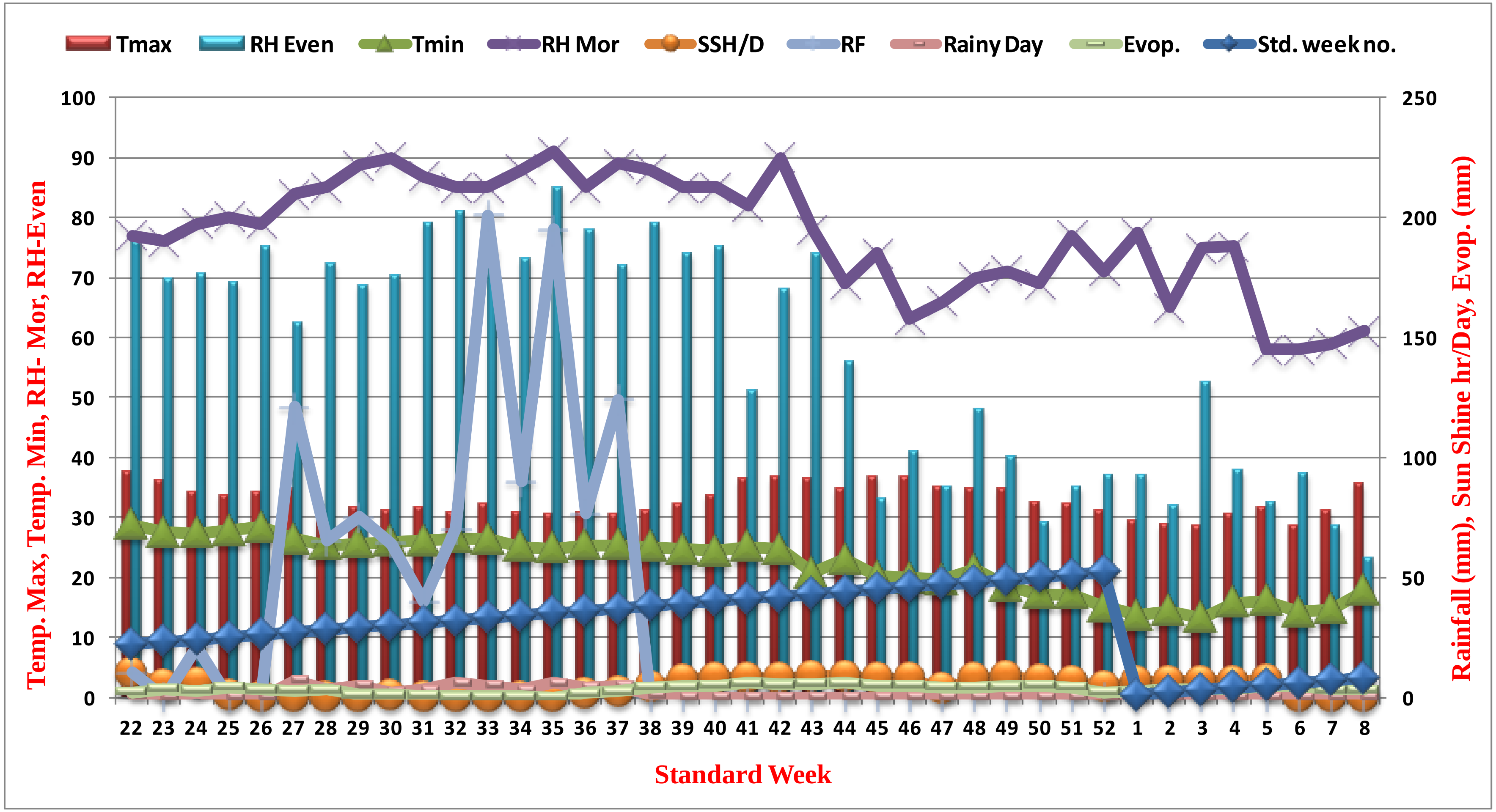


Fig.2: Meteorological data during the experimental period (2012-13) at Main Cotton Research Station, NAU, Surat



3.1.3 Soil characteristics

The experimental site contains derained clayey soils which represent the typical black cotton soil of South Gujarat having predominant montmorillonite clay minerals by its origin and is medium in fertility. These soils crack vertically upon drying up to a depth of 80 to 120 cm the details of soil physico-chemical properties and methods adopted for analysis are presented in **Table 3.1**

Table 3.1: Physico-chemical properties of experimental site

Sr. No.	Particulars		Analytical methods adopted
A)	**Mechanical composition**		
1.	Sand (%)	22.15	Bouyoucos hydrometer method (Piper, 1966)
2.	Silt (%)	17.50	
3.	Clay (%)	60.35	
4.	Texture	Clayey	
B)	**Physical Composition**		
1.	Bulk density (Mg m^{-3})	1.375	Clod method (Piper, 1966)
C)	**Chemical composition**		
1.	Organic carbon (%)	0.465	Walkley and Black's rapid titration method (1934)
2.	Soil pH (1:2.5 soil : water ratio)	8.15	Glass electrode pH meter (Jackson, 1967)
3.	Electrical conductivity (dSm^{-1}) at 25 ^{0}C	0.37	Conductivity meter (Jackson, 1967)
4.	Available Nitrogen (kg ha^{-1})	250.53	Alkaline permanganate method (Subbiah and Asija, 1956)
5.	Available P_2O_5 (kg ha^{-1})	40.97	Olsen's method (Olsen and Sommers,1982)
6.	Available K_2O (kg ha^{-1})	368.40	Flame emission spectrophotometer (Knudsen and Peterson, 1982)

With a view to determine the physico-chemical properties of experimental field, the respective soil samples were drawn from 0 to 22.5 cm and 22.5 to 45.0 cm depths randomly covering the entire experimental area before the layout of the experiment. A composite sample was prepared for both the soil depths and analyzed for various Physico-chemical properties and the average values obtained are presented in **Table-3.1**

3.2 Experimental details

I	Experimental design	:	Randomized Block Design (Factorial)
II	Crop	:	Cotton
III	Replications	:	Three
IV	Spacing	:	120 x 45 cm
V	No. of rows/plot	:	5
VI	No. of plants/row	:	16
VII	No. of plots	:	36
VIII	Plot size	:	Gross plot : 6.0 x 7.2 (43.2) Net plot : 3.6 x 6.3 (22.68)
IX	Treatments	:	12 (Twelve)
A.	**Factor - A** (Growth regulators)	:	$\mathbf{T_1}$ = Control (00 ppm) $\mathbf{T_2}$ = Ethylene 45 ppm (at squaring stage) $\mathbf{T_3}$ = Maleic Hydrazide 500 ppm (at 85 DAS) $\mathbf{T_4}$ = T_2 + T_3
B.	**Factor - B** (G. *hirsutum* hybrids)	:	$\mathbf{V_1}$ = RCH-2 (BG-II) $\mathbf{V_2}$ = Vikram-5 (BG-II) $\mathbf{V_3}$ = G.Cot.Hy-12

3.3 Field operations

3.3.1 Preparation of land

The field was ploughed with tractor drawn plough and was brought to fine tilth by following successive harrowing. The residue of previous crop was collected and destroyed as well as field was leveled with tractor drawn planker. The field was laid out as per plan of layout.

Table 3.2: Schedule of cultural operations

Sr. No.	Field operations	2011-12		2012-13	
		Freq.	Date	Freq.	Date
A.	**Preparatory tillage**				
1	Ploughing with tractor	1	10-5-11	1	08-5-12
	Application of FYM	1	20-5-11	1	15-5-12
2	Harrowing and panking	1	22-5-11	1	21-5-12
3	Field layout and preparation of plots, bunds and irrigation channels	1	23-6-11	1	27-6-12
B.	**Sowing and post-sowing operations**				
1	Sowing (Dibbling)	1	06-07-11	1	07-07-12
2	Gap filling	1	15-07-11	1	14-07-12
3	Thinning	1	23-07-11	1	25-07-12
C.	**Weeding**				
1	First Weeding	1	19-07-11	1	17-07-12
2	Second Weeding	1	14-08-11	1	12-08-12
3	Third Weeding	1	13-10-11	1	03-10-12
D.	**Intercultural operation**				
1	First Hoeing	1	16-07-11	1	15-07-12
2	Second Hoeing	1	12-08-11	1	17-08-12
3	Third Hoeing	1	01-09-11	1	05-09-12
E.	**Fertilizer application**	1	30-07-11	1	01-08-12
		1	26-08-11	1	29-08-12
		1	24-09-11	1	25-09-12
F.	**Irrigation**				
1	First irrigation	1	09-10-11	1	14-10-12
2	Second irrigation	1	05-11-11	1	14-11-12
G.	**Spraying schedule**				
1	Imidacloprid 200 SL @ 0.70%	1	16-08-11	1	22-08-12
2	Fipronil 5 % SC	1	27-09-11	1	20-09-12
3	Quinolphos 25% EC @ 0.05%	1	15-10-11	1	23-10-12
4	Acephate 75 % SP	1	04-11-11	1	09-11-12
H.	**Harvesting**				
1	Pickings of seed cotton	1	24-11-11	1	25-11-12
		1	09-12-11	1	10-12-12
		1	24-12-11	1	25-12-12
2	Removal of cotton stalks	1	03-03-12	1	25-02-13

3.3.2 Cultural practices

The calendar of cultural operations carried out for the cultivation of the experimental crop is presented in **Table 3.2.** The details of the operations are as under.

3.3.3 Layout

The experiment was laid out in randomized block design (factorial) with three replications. The plan of layout and allotment of treatment combinations to different plots is depicted in **figure-3** other experimental details are as follows.

3.3.4 Seed and Sowing

In the present investigation, G. *Hirsutum* cotton hybrids RCH-2 *Bt* (BG-II), Vikram-5 *Bt* (BG-II) and G.Cot.Hy-12 were studied for their response to growth modifiers. The seed of RCH-2 *Bt* (BG-II) was obtained from Rasi Seeds (Pvt.) Ltd., Salem District, Tamilnadu, Vikram-5 *Bt* (BG-II) from Vikram Seeds Ltd. Navragpura, Ahmadabad, Gujarat and G. Cot.Hy-12 from the Main Cotton Research Station, N.A.U., Surat.

The ridges were made 120 cm apart by using a tractor drawn ridge maker and dibbling was done at 45 cm spacing within row at 3 to 4 cm depth with two seeds per hill.

3.3.5 Thinning and gap filling

The seedling emerged out completely within 7 to 8 days after sowing and the optimum plant population was maintained by gap filling and subsequently by thinning keeping one plant per hill at 10 to 15 DAS.

3.3.6 Fertilizer application

The experimental soil was fertilized @ 10 tonnes FYM ha^{-1} uniformly at the time of land preparation. The chemical fertilizers were applied NPK @ 240:40:00 kg ha^{-1} in the form of urea at 25 to 30 days interval starting from 20 DAS and SSP as basal.

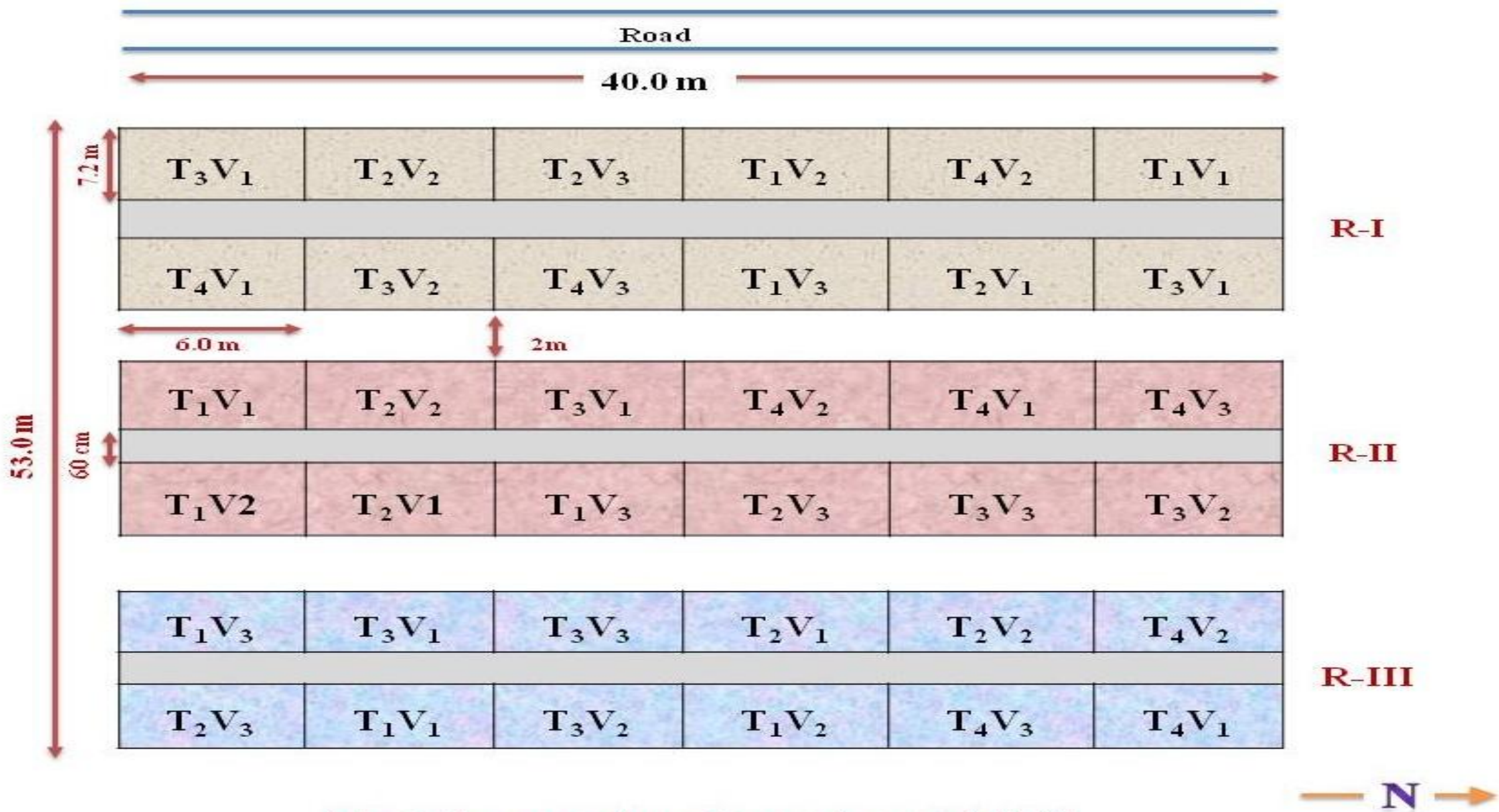


Fig-3: Layout plan of experimental field

3.3.7 Weeding and intercultural operations

Attempts were made to keep experimental field weed free throughout the crop season. Three hand weeding and two intercultural operations were done during the two years of experimentations.

3.3.8 Growth regulators

Plant growth regulators *i.e.*, Ethylene required for the investigation was obtained from market which is available in trade name Ethephon (39% SL Krishi Rasayan Export Pvt. Ltd.) and Maleic hydrazide (98% G Loba Chem). According to the percentage of active ingredient in the commercial product, doses were calculated and used in present study.

3.3.9 Irrigation

Crop was irrigated twice after the withdrawal of monsoon as per requirement during the two years through canal irrigation water.

3.3.10 Plant protection measures

For the control of insect pest and diseases, all the necessary plant protection measures were taken as and when required. In general, the field was free from any serious pests and diseases. Various plant protection measures undertaken during the two years along with their frequencies and dates are given in **Table 3.2**

3.3.11 Picking

Picking of cotton from border rows was done and kept aside Seed cotton from five randomly selected plants and net plot was picked and weighed separately for each treatment. The weight of seed cotton of five selected plants was added to the net plot seed cotton weight. Three pickings were done in both the years. Total weight of the three pickings along with that of five plants was used to compute seed cotton yield per hectare and analysis.

3.4. Sampling technique and details of biometric observations

The experimental plots were sown at 120 x 45 cm spacing constituting 5 rows. The outer most 1^{st} row on either side as well as one plant on either end of net plot rows was kept as border row to eliminate the border effect and to separate the net plot. In order to record the various biometric observations, five plants were selected randomly from each net plot area, labeled and observations were recorded on them at periodic intervals. The details of observations recorded during 2011-12 and 2012-13 and are given in **Table 3.3** and methods followed for recording each parameter are described below.

Table 3.3: Particulars of biometric observations recorded during 2011-12 and 2012-13 at different growth stages with their frequency

Sr.No	Particulars	Freq	Days after sowing (DAS)
A	**Morpho-physiological parameters**		
1	Leaf area index (LAI)	5	45,70,95,120 and 145 DAS
2	Leaf area duration (LAD)	4	45,70,95,120 and 145 DAS
3	Crop growth rate (CGR) (gm^{-2} day^{-1})	4	45-70,71-95,96-120 and 121-145 DAS
4	Relative growth rate (RGR) (g $g^{-1}day^{-1}plant^{-1}$)	4	45-70,71-95,96-120 and 121-145 DAS
5	Net assimilation rate (NAR) (mg cm^{-2} day^{-1})	4	45-70,71-95,96-120 and 121-145 DAS
6	Dry matter accumulation (g $plant^{-1}$)	5	45,70,95,120 and 145 DAS
B	**Growth and Morpho-physiological characters**		
1	Plant height (cm)	6	45,70,95,120,145DAS and at harvest
2	No. of main stem nodes	6	45,70,95,120,145DAS and at harvest
3	No. of monopodia $plant^{-1}$	-	At harvest
4	No. of sympodia $plant^{-1}$	-	At harvest
5	Height to node ratio	6	45,70,95,120,145DAS and at harvest

Tables 3.3 *Continue…..*

Sr. No	Particulars	Freq	Days after sowing (DAS)
C	**Fruit production**		
1	No. of squares plant^{-1}	5	45,70,95,120 and 145 DAS
2	No. of flowers plant^{-1}	5	45,70,95,120 and 145 DAS
3	No. of bolls plant^{-1}	5	45,70,95,120 and 145 DAS
D	**Biochemical studies**		
1	Chlorophyll content	4	60,90,120 and 150DAS
2	Reducing sugars	4	60,90,120 and 150DAS
E	**Crop phenological characters**		
1	Days to 50% squaring	1	--
2	Days to 50% flowering	1	--
3	Days to 50% boll bursting	1	--
F	**Morpho-phenological events** (Based on Growing degree days and Heliothermal units)	1	From emergence to 50 % squaring.
		1	From emergence to 50 % flowering.
		1	From emergence to 50 % boll busting.
		1	From emergence to maturity.
G	**Yield and yield contributing characters**		
1	No. of picked bolls plant^{-1}	1	At harvest
2	Boll weight (g)	1	At harvest
3	Seed cotton yield (g plant^{-1})	3	At 140, 155 and 170 days
4	Seed cotton yield (kg ha^{-1})	1	At harvest
4	Biomass (g)	1	At harvest
5	Partitioning efficiency(HI)	1	At harvest
H	**Economic characters**		
1	Ginning percentage	1	After harvest
2	Seed index (g)	1	After harvest
3	Lint index (g)	1	After harvest
4	Oil content (%)	1	After harvest
I	**Fibre quality parameters**		
1	2.5% span length (mm)	1	After harvest
2	Fibre fineness (10^{-6}g inch^{-1})	1	After harvest
3	Uniformity ratio (%)		After harvest
4	Maturity ratio	1	After harvest
5	Fibre strength (g tex^{-1})	1	After harvest
6	Fibre elongation (%)	1	After harvest
7	Short fibre index (mm)	1	After harvest
J	**Economics of the treatments**		
1.	Gross return Rs.ha^{-1}	1	After harvest
2.	Net return Rs.ha^{-1}	1	After harvest
3.	Benefit cost ratio (BCR)	1	After harvest

3.4.1 Morpho-physiological parameters

3.4.1.1 Leaf area index (LAI)

It is the ratio of leaf area per plant to the land area expressed in the same unit. The leaf area index for each treatment was worked out by using the following formula as proposed by Watson (1952).

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

3.4.1.2 Leaf area duration (LAD)

Leaf area duration or the persistence of the assimilatory surface was determined by the following formula (Power et al. 1967) and expressed as days.

$$LAD = \frac{L_1 + L_2}{2} \times (t_2 - t_1)$$

Where,

L_1 and L_2 are leaf area indices of time t_1 and t_2, respectively

3.4.1.3 Crop growth rate (CGR)

Crop growth rate is the rate of dry matter production per unit ground area per unit time (Watson, 1952). It was calculated by using the following formula and expressed as gm^{-2} day^{-1}.

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{P}$$

Where,

W_1 - Dry weight of the plant (g) at time t_1

W_2 - Dry weight of the plant (g) at time t_2

t_2-t_1 - Time interval in days

P - Unit land area

3.4.1.4 Relative growth rate (RGR)

Blackman (1919) pointed out that an increase in dry matter of plant is a process of continuous compound interest wherein the increment in any interval adds to the "Capital" for subsequent growth. This rate of increment is called as relative growth rate (RGR), which was worked out as per formula given by Fisher (1921) and expressed in g g^{-1} day^{-1} $plant^{-1}$

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

Where,

W_1 and W_2 - The initial and final plant dry weight (g)

t_1 and t_2 - The initial and final day of observation *i.e.* Time intervals in days

Log_e - Natural logarithm to the base e (e = 2.3026)

3.4.1.5 Net assimilation rate (NAR)

Net assimilation rate is the rate of dry weight increased per unit leaf area per unit time. It was calculated by following the formula of Radford (1967) and expressed as mg cm^{-2} day^{-1}.

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{\log_e A_2 - \log_e A_1}{(A_2 - A_1)}$$

Where,

A_1 and W_1 - Leaf area (cm^2) and total dry weight of plant (g) respective at time t_1

A_2 and W_2 - Leaf area (cm^2) and total dry weight of plant (g) respective at time t_2

t_2-t_1 - Time interval in days

Log_e - Natural logarithm to the base e (e = 2.3026)

3.4.1.6 Dry matter accumulation (g/plant)

Randomly selected plant from each plot was used for this study. After removing the roots, plants were air dried in sun first and later on dried in hot air oven at $65+2^{0}$C until constant weight was obtained.

3.4.2 Biometric observations

3.4.2.1 Plant height (cm)

The periodical plant height of tagged plants were measured in cm from the base of the plant (ground level) to the tip of main shoot and the average values were recorded at 45, 70, 95, 120, 145 DAS and at harvest.

3.4.2.2 Numbers of nodes on main stem

The number of nodes on main stem was counted from five sample plants and average values were recorded for each treatment.

3.4.2.3 Number of monopodia per plant

The total number of monopodial (vegetative) branches of five observational plants from each net plot was counted at harvest and mean was worked out.

3.4.2.4 Number of sympodia per plant

The total numbers of sympodial (fruiting) branches were recorded from the five selected plants at harvest and average numbers of sympodial branches per plant were worked out by dividing the total number by five.

3.4.2.5 Height to node ratio

The height to node ratio for each treatment was worked out by using the following formula.

$$\text{Height to node ratio} = \frac{\text{Plant height}}{\text{Numbers of nodes on main stem}}$$

3.4.2.6 Leaf area per plant (dm^2)

Leaf area was measured by using leaf area meter (LI-COR USA, Model LI- 3000) and expressed in dm^2 plant^{-1}.

3.4.3 Fruit production

3.4.3.1 Number of squares per plant

The number of squares of previously tagged five plants from each plot was counted and the average square number of plant^{-1} was recorded separately from each plot.

3.4.3.2 Number of flowers per plant

The number of flowers of previously tagged five plants from each plot was counted and the average number flower of plant^{-1} was recorded separately from each plot.

3.4.3.3 Number of green bolls per plant

The number of green bolls of previously tagged five plants from each plot was counted and the average number of green bolls plant^{-1} was recorded separately from each plot.

3.4.4 Biochemical studies

3.4.4.1 Estimation of chlorophyll content of leaf

For uniformity in sampling, 3rd leaf from the top of the plant was utilized for chlorophyll estimation. Extraction was done in DMSO (Dimethyl sulphoxide) according to Hiscox and Israelstam (1979).

Leaf sample weighing 50 mg was put into 10 ml of the extractant and was held for 2 hrs at 60 ^{0}C. The supernatant was used for estimation of chlorophyll. Absorbance was recorded at 652 nm on ‘spectrophotometer’. The amount of chlorophyll content was calculated by using formula.

$$\text{Chlorophyll (mg g}^{-1}\text{)} = \frac{\text{(O.D. at 652 nm) x 1000}}{34.5} \text{ X } \frac{V}{1000 \text{ x } W}$$

Where,

V - Final volume of DMSO
W - Fresh weight of sample (g)
O.D - Optical density

3.4.4.2 Estimation of reducing sugars (µ/g g fresh wt)

The reducing sugar was estimated using the leaf as method described by Nelson-Somogyi's method (Nelson, 1944)

Reagents:

A. Alkaline copper reagent

Solution A:

25 g Anhydrous sodium carbonate, 25 g Sodium potassium tartarate, 20 g of Sodium bicarbonate and 20 g of Sodium sulphate was dissolved in about 800 ml of distilled water and diluted to 1 litre.

Solution B:

15 g of copper sulphate was dissolved in distilled water to this, one or two drops of concentrated sulphuric acid was added and made up to 100 ml with distilled water. Solutions A and B were mixed in 24:1 (v/v) proportion just before use.

B. Arsenomolybdate reagent

25 g of ammonium molybdate was dissolved in 450 ml of distilled water, to this 21 ml of concentrated sulphuric acid was added and mixed well. In another vessel 3 g of sodium orthoarsenate was dissolved in 25 ml water. Both the solutions were mixed with stirring and placed in an incubator at 37°C for 24-48 hrs. The reagent was stored in brown bottle.

C. Stock standard solution

100 mg of D-glucose was dissolved in distilled water in a 100 ml volumetric flask. This solution contains 1mg of glucose per ml.

D. Working standard solution

10 ml of stock standard solution was diluted to 100 ml with distilled water in volumetric flask. This solution contains 100 µ g of glucose per ml.

Procedure:

Aliquot of working standard (10-100 µg) was pipette out in a series of labelled test tubes and made up to 1 ml with distilled water along with reagent blank with 1 ml distilled water.

1 ml freshly prepared alkaline copper reagent was added to all the tubes including reagent blank and the tubes placed in boiling water bath for exactly 20 min, after this the tubes were kept in ice for cooling without shaking and added with 1 ml of arsenomolybdate reagent followed by thorough mixing till effervescence die.

Made up the volume to 20 ml with distilled water and read the % thorough of standard and the sample against reagent blank at 510 nm.

Reducing sugar content was calculated by using glucose standard curve and expressed in µ/g g fresh wt.

3.4.5 Crop phenological characters

3.4.5.1 Days to 50 per cent squaring

Total number of days from the date of sowing to the date on 50 per cent squaring in a plot was recorded.

3.4.5.2 Days to 50 per cent flowering

The days required for flowering of 50% plants in the two rows in each plot was considered as days to 50% flowering of the plot. Two rows were selected from each plot and all the plants were monitored daily and the day on which half of total plants showed first flower was considered as days to 50 % flowering.

3.4.5.3 Days to 50 per cent boll bursting

The days required for boll opening of 50% plants of the two rows in each plot was considered as days to 50% boll bursting of the plot. Two rows were selected from each plot and days required for first boll bursting in 50% plants of the rows were monitored by daily observation.

3.4.4 Morpho-phenological events

Five plants per net plot free of mechanical or terminal damage with obvious defects and with plants on either side within the row were individually selected for recording data during the season. The following Morpho-phenological events were recorded and expressed based on degree days and heliothermal units.

Morpho-phenological events

1) Days from emergence to squaring

2) Days from emergence to 50 % flowering

3) Days from emergence to 50 % boll bursting

4) Days from emergence to maturity

3.4.4.1 Growing degree days (GDD) were calculated by formula developed by Jones and Wells (1998)

$$\text{GDD } (^0\text{C day}) = \sum_{a}^{b} \left[(T_{\max} + T_{\min}) / 2 \right] - T_b$$

Where,

T_{max} - Daily maximum temperature (^{0}C)

T_{min} - Daily minimum temperature (^{0}C)

T_b - Base temperature as 15.5 ^{0}C for cotton crop (Singh *et al.*, 2007)

a - Starting date of phenophase

b - Ending date of that phenophase

3.4.4.2 Heliothermal units (HTU)

Heliothermal unit make use of actual number of bright sunshine hours instead of day length used in calculating photo thermal units.

Daily sunshine hour's data during crop growth period were obtained from the metrological observatory. Mean sunshine hours per day between two stages of crop growth were calculated by formula described by Khichar and Niwas, 2007.

$$\text{HTU } (^0\text{C day hour}) = \sum_{a}^{b} \left(^0C\ day \times BSH \right)$$

Where,

BSH - Bright sunshine hours

^{0}C - day's hour

a - Starting date of phenophase

b - Ending date of that phenophase

3.4.7 Yield and yield contributing characters

For the entire yield attributes studied during the course of investigation, previously selected five tagged plants from each net plot were used. The observations were recorded from these plants and mean value was worked out and recorded for each plot.

3.4.7.1 Number of picked bolls per plant

Number of picked bolls per plant was counted at each picking and recorded. The total number of picked bolls per plant during crop duration was worked out by addition of the total number of bolls picked per plant at each picking successively.

3.4.7.2 Boll weight (g)

The seed cotton weight of five selected plants in each plot was recorded. Finally the average boll weight was worked out by dividing the total weight of seed cotton with number of picked bolls.

3.4.7.3 Seed cotton yield (g) per plant

The weight of seed cotton picked out from five plants was weighed separately and average seed cotton yield per plant was worked out by dividing the total weight of seed cotton with number of plants.

3.4.7.4 Seed cotton yield (kg/ha)

Seed cotton from each net plot was picked and weighted separately as per treatments at each picking. The total yield per net plot (kg) was worked out by adding together the quantities of seed cotton obtained from all pickings inclusive of the yield of five tagged plants from each corresponding treatments. The net plot yield (kg) was then converted into seed cotton yield kg ha^{-1} basis.

3.4.7.5 Biomass (g/plant)

Five selected plants used for recording yield per plant were pulled out from each plot after completion of picking and dried up till constant weight and averaged.

3.4.7.6 Partitioning efficiency (%)

The partitioning efficiency refers to the efficiency of translocation of dry matter into economic parts. It is defined as the percentage of economic yield to biological yield (Jain, 1972).

$$\text{Partitioning efficiency} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.4.7.7 Synchrony studies

The weight of seed cotton picked out from five plants was weighed separately at 140, 155 and 170 DAS seed cotton yield per plant was worked out to know the earliness in bolls bursting.

3.4.8 Economical character

3.4.8.1 Ginning percentage

Laboratory model gin was used for ginning the seed cotton samples for estimation of ginning percentage. Then hundred gram seed cotton from bulk produce of each plot was ginned. The lint was weighed and ginning percentage calculated by using the following formula.

$$\text{Ginning (\%)} = \frac{\text{Weight of lint (g)}}{\text{Weight of seed cotton}} \times 100$$

3.4.8.2 Seed index (g)

From the seed cotton samples taken to determine ginning percentage, 100 seeds from each individual sample were picked up randomly and weighted in gram and expressed as seed index.

3.4.8.3 Lint index (g)

The lint index represents the absolute weight of lint produced by 100 seed in grams. It was computed using the formula of Hutchison and Ramiah (1938).

$$\text{Lint index (g)} = \frac{\text{Seed index (g)} \times \text{Ginning percentage}}{100 - \text{Ginning percentage}}$$

3.4.8.4 Oil content (%)

Oil content was determined by Near Infrared Reflectance (NIR-Model No. Insta Lab - 600 Dickey John Corp) and expressed in percentage.

3.4.9 Fibre quality parameters

The Fibre quality was evaluated in the Central Institute for Research on Cotton Technology (CIRCOT) regional station, Surat using fully automatic HVI machine (Premier Evolvics Pvt. Ltd. Coimbatore) at R.H. 65 ± 2 and Temp. 27.2^{0}C in ICE mode.

3.4.9.1 2.5 per cent Span length (mm)

It can be defined as the distance spanned by a specified percentage of fibres in the specimen being tested when the fibres are parallelized and randomly distributed. The most commonly used measure in India is 2.5% span length.

3.4.9.2 Fibre fineness (mv)

The micronaire value indicates the extent of resistance of air flow fibre plugs. It is expressed as micrograms inch^{-1} (10^{-6} g inch^{-1}). The higher value of micronaire (above 4.5 mv) indicates coarseness of fibre while lower value (below 4.5 mv) indicates finer fibres.

3.4.9.3 Uniformity ratio (%)

It is obtained from the high volume instrument readings. It is the ratio of 50 % span length to 2.5 % span length and expressed as percentage.

$$\text{Uniformity ratio (\%)} = \frac{\text{50 \% span length}}{\text{2.5 \% span length}} \times 100$$

3.4.9.4 Maturity ratio

It is a unit of expression signifying the multiple character of fibre maturity usually represented by the percentage of mature and immature fibres.

3.4.9.5 Fibre strength (g tex^{-1})

The maximum load which material can take, when stretched in one direction, before its breaks is termed as tensile strength.

3.4.9.6 Elongation (%)

Cotton fibre elongation is the extensibility at breaking load measured with High Volume Instrument (HVI) and expressed in percentage.

3.4.9.7 Short fibre index

This value is the percentage by weight of fibres in a sample which are shorter than 12.7 mm.

3.4.10 Economics studies

3.4.10.1 Cost of cultivation

The input cost was worked out by considering the amount require for purchase of inputs like seeds, growth regulators, fertilizers and insecticides, etc. and amount spent on the labour charges for all the operations.

3.4.10.2 Gross monetary returns

The gross monetary returns (Rs ha^{-1}) were worked out by considering the seed cotton yield from different treatments and prevailing market prices in both the seasons.

3.4.10.3 Net monetary returns

The net monetary returns (Rs ha^{-1}) were worked out by subtracting the total cost of cultivation from the gross return of the corresponding treatments.

3.4.10.4 Benefit cost ratio

It is the ratio of gross monetary returns to the cost of cultivation, which can also be expressed as returns per rupee invested. The benefit cost ratio was worked out by considering the per hectare values of gross monetary returns and cost of cultivation.

3.5. Statistical analysis

Statistical analysis of the data of various growth and yield attributes studied in the present investigation were carried out through the statistical analysis of various techniques as described by Panse and Sukhatme (1967).

The method of analysis of variance for randomized block design with factorial concept was used and treatment effect on all the characters studied was further compared by employing 'F' test at five per cent level of significance of the results. The critical difference (CD) was calculated where the differences amongst the treatments were found significant.

EXPERIMENTAL RESULTS

Gossypium sp. (Cotton)

IV EXPERIMENTAL RESULTS

A field experiment was conducted during *Kharif* 2011-12 and 2012-13 to study the influence of modification of morphoframe by Ethylene and Maleic hydrazide on physiological traits, growth attributes, crop phenology, yield, yield components, fibre properties and some biochemical constituent of three cotton hybrids *viz.*, RCH 2 (BG-II), Vikram 5 (BG-II) and G.Cot Hy-12 at Main Cotton Research Station, N.A.U., Surat. The observations on important characters were recorded, tabulated and analyzed statistically. The result pertaining to each character has been explained in this chapter under different headings.

4.1. MORPHO-PHYSIOLOGICAL CHARACTERS

4.1.1 Leaf area index (LAI)

The data on leaf area index (LAI) as influenced by different treatments and varieties at various stages of crop growth are presented in **Table 4.1** and graphically depicted in Figure 4.1

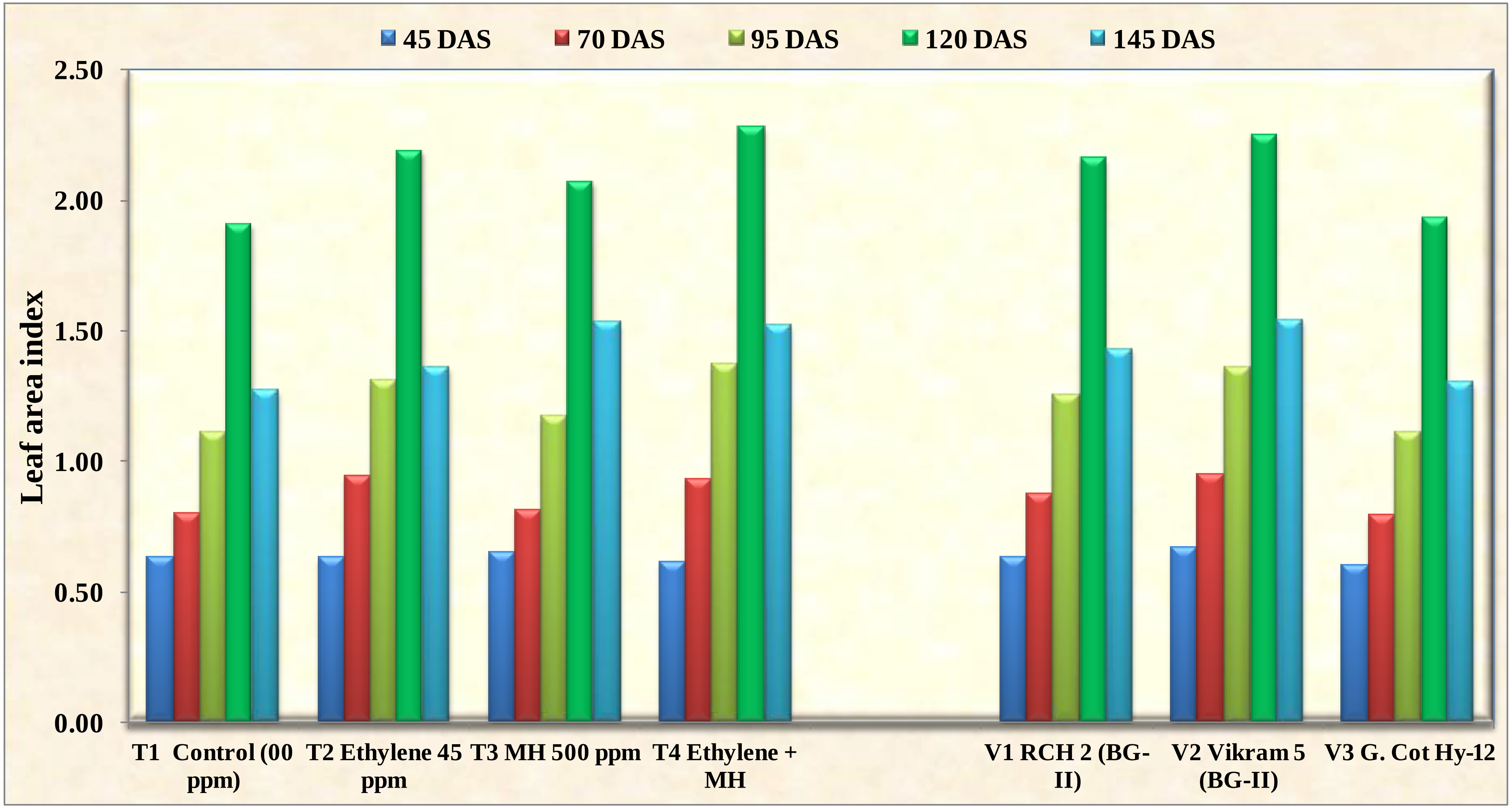
In general, leaf area index increased with the age of the crop till 120 days after sowing (DAS) and sharply decreased thereafter.

Leaf area index was significantly affected by foliar application of Ethylene 45 ppm at square initiation and MH 500 ppm at 85 DAS in individual years as well as in pooled at the all stages *viz.*, 70, 95, 120, and 145 DAS, barring 45 DAS. The data indicated **(Table 4.1)** that application of Ethylene (T_2) resulted in significantly higher LAI than untreated control at 70, 95 and 120 DAS. Application of MH at 85 DAS (T_3) also brought about significant increase in LAI at 120 and 145 DAS over control. Application of Ethylene + MH has

Table 4.1: Effect of Ethylene and Maleic hydrazide (MH) on Leaf area index at different growth stages in cotton hybrids

	45 DAS			70 DAS			95 DAS			120 DAS			145 DAS		
	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled
A. Treatments (T)															
T_1 - Control (00 ppm)	0.61	0.65	0.63	0.78	0.82	0.80	1.07	1.16	1.11	1.90	1.91	1.91	1.26	1.29	1.27
T_2 - Ethylene 45 ppm	0.63	0.64	0.63	0.91	0.96	0.94	1.30	1.32	1.31	2.14	2.25	2.19	1.35	1.36	1.36
T_3 - MH 500 ppm	0.64	0.65	0.65	0.80	0.81	0.81	1.14	1.20	1.17	2.04	2.10	2.07	1.47	1.59	1.53
T_4 - $T_2 + T_3$	0.58	0.64	0.61	0.92	0.94	0.93	1.36	1.39	1.37	2.20	2.36	2.28	1.47	1.57	1.52
S. Em. ±	0.02	0.02	0.02	0.03	0.04	0.02	0.06	0.04	0.04	0.07	0.08	0.05	0.06	0.07	0.05
C.D. at 5%	NS	NS	NS	0.08	0.11	0.07	0.18	0.13	0.11	0.22	0.24	0.15	0.17	0.21	0.13
B. Variety (V)															
V_1 - RCH 2 (BG-II)	0.60	0.65	0.63	0.86	0.89	0.87	1.24	1.25	1.25	2.10	2.21	2.16	1.40	1.45	1.43
V_2 - Vikram 5 (BG-II)	0.65	0.69	0.67	0.93	0.96	0.95	1.33	1.39	1.36	2.23	2.26	2.25	1.48	1.59	1.54
V_3 - G. Cot Hy-12	0.59	0.60	0.60	0.77	0.81	0.79	1.07	1.15	1.11	1.87	1.99	1.93	1.27	1.33	1.30
S. Em. ±	0.02	0.02	0.01	0.02	0.03	0.02	0.05	0.04	0.03	0.06	0.07	0.04	0.05	0.06	0.04
C.D. at 5%	0.05	0.06	0.04	0.07	0.09	0.06	0.16	0.11	0.10	0.19	0.21	0.13	0.15	0.18	0.11
C. Interaction															
V x T															
S. Em. ±	0.03	0.04	0.03	0.05	0.06	0.03	0.11	0.08	0.06	0.13	0.14	0.08	0.10	0.12	0.07
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y x T															
S. Em. ±			0.02			0.03			0.05			0.08			0.07
C.D. at 5%			NS			NS			NS			NS			NS
C.V.%	9.40	11.0	10.3	9.68	12.5	11.3	15.6	10.6	13.2	10.6	11.3	11.0	12.8	14.6	13.8

Fig. 4.1: Effect of Ethylene and MH on LAI at different growth stages in cotton hybrids



synergistic effect on LAI over Ethylene or MH application. LAI at 95 DAS in Ethylene + MH treatment (T_4) was 1.37 against 1.17 in MH alone (T_3) or 1.31 in Ethylene (T_2). The corresponding values were 2.28, 2.07 and 2.19 at 120 DAS.

The differences in LAI amongst the hybrids were significant in individual years as well as in pooled at all the stages. Vikram 5 (BG-II) recorded significantly higher LAI than RCH 2 (BG-II) and G.Cot Hy-12 at all the stages of crop growth *i.e.*, 45, 70, 95, 120, and 145 DAS. Only at 120 DAS it was at par with RCH 2 (BG-II). Lowest LAI was recorded in G.Cot Hy-12 all through. The interaction of hybrids and treatments was not significant implying that all the hybrids responded to treatments similarly. The interaction of treatment with year was also not significant indicating in response to the environment the effect of treatment remained that same. Other interactions were also not significant.

4.1.2 Leaf area duration (LAD)

The data pertaining to leaf area duration (LAD) as influenced by different growth modifiers and cotton hybrids are presented in **Table-4.2** and graphically depicted in Figure 4.2. The differences due to treatments and hybrids were significant in individual years as well as in pooled at all stages of the crop.

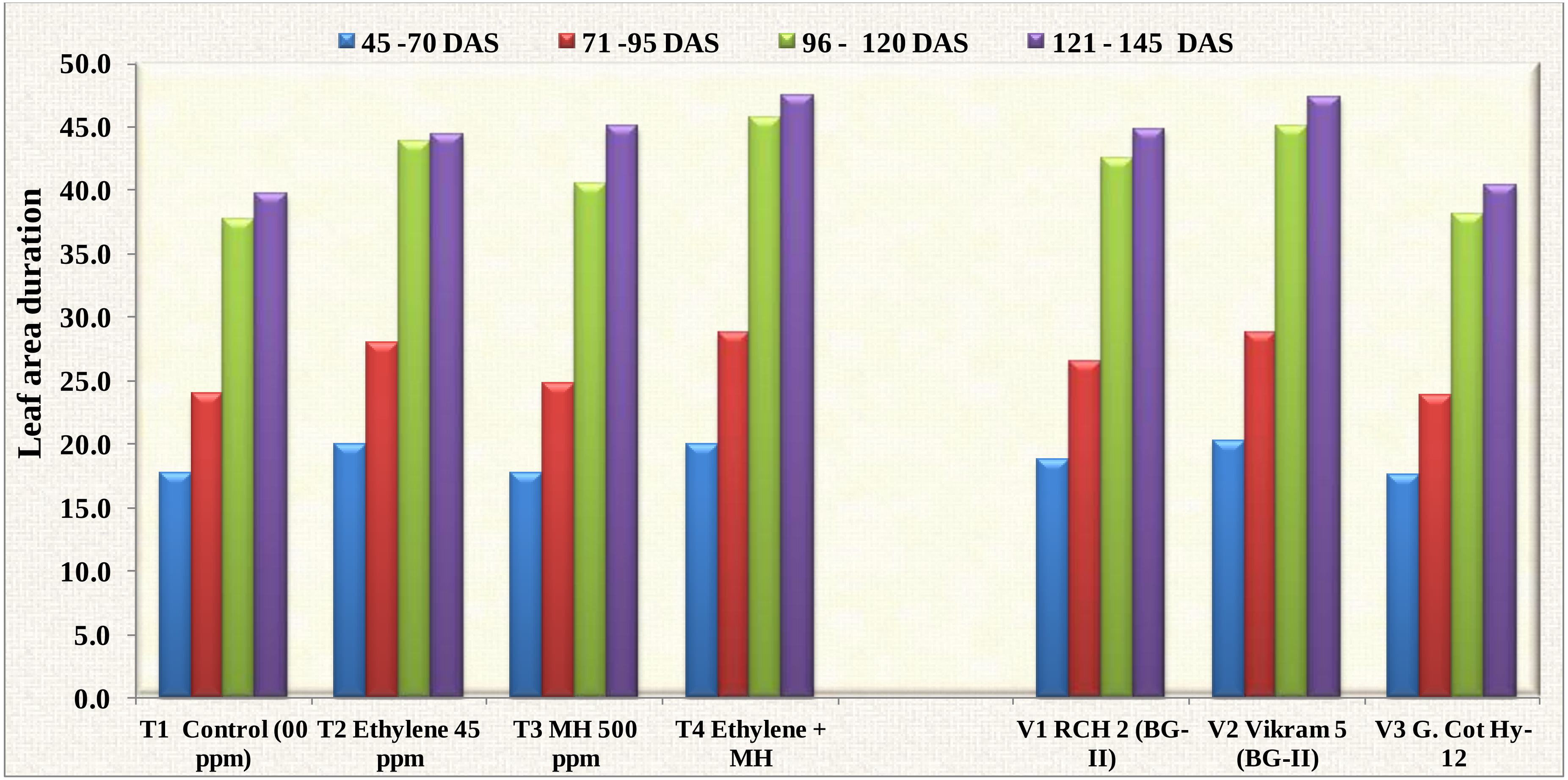
In general, LAD increased with the age of the crop till 145 days after sowing (DAS).

The data indicated that the application of Ethylene (T_2) at squaring stage significantly increased LAD over control at 45-70 DAS (19.9) which was maintained till 121-145 DAS. Application of MH at 85 DAS (T_3) also showed increasing effect on LAD at 95 to 145 DAS over control. Supplemental effect of MH with Ethylene (T_4) was observed

Table 4.2: Effect of Ethylene and MH on Leaf area duration (days) at different growth stages in cotton hybrids

	45 -70 DAS			71 -95 DAS			96-120 DAS			121 -145 DAS		
	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled
A. Treatments (T)												
T_1 - Control (00 ppm)	17.2	18.1	17.7	23.1	24.8	23.9	37.1	38.3	37.7	39.5	40.0	39.7
T_2 - Ethylene 45 ppm	19.4	20.4	19.9	27.5	28.5	28.0	43.0	44.5	43.8	43.6	45.1	44.4
T_3 - MH 500 ppm	17.5	18.0	17.7	24.2	25.2	24.7	39.8	41.3	40.5	43.9	46.1	45.0
T_4 - $T_2 + T_3$	19.8	20.1	19.9	28.5	29.1	28.8	44.5	46.9	45.7	45.8	49.1	47.5
S. Em. ±	0.60	0.65	0.43	0.79	0.72	0.52	1.58	1.32	0.99	1.30	1.47	0.96
C.D. at 5%	1.77	1.90	1.22	2.31	2.10	1.48	4.64	3.87	2.84	3.82	4.32	2.74
B. Variety (V)												
V_1 - RCH 2 (BG-II)	18.3	19.2	18.7	26.2	26.8	26.5	41.8	43.3	42.5	43.8	45.7	44.8
V_2 - Vikram 5 (BG-II)	19.7	20.6	20.2	28.2	29.4	28.8	44.6	45.7	45.1	46.5	48.2	47.3
V_3 - G. Cot Hy-12	17.4	17.6	17.5	23.1	24.5	23.8	36.9	39.3	38.1	39.3	41.5	40.4
S. Em. ±	0.52	0.56	0.38	0.68	0.62	0.45	1.37	1.14	0.89	1.13	1.27	0.83
C.D. at 5%	1.53	1.65	1.07	2.01	1.82	1.29	4.02	3.35	2.54	3.31	3.74	2.37
C. Interaction												
V x T												
S. Em. ±	1.05	1.12	0.74	1.37	1.24	0.87	2.74	2.28	1.68	2.26	2.55	1.60
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y x T												
S. Em. ±			0.63			0.75			1.46			1.39
C.D. at 5%			NS			NS			NS			NS
C.V.%	9.81	10.2	10.0	9.17	8.00	8.58	11.6	9.25	10.4	9.05	9.79	9.44

Fig. 4.2: Effect of Ethylene and MH on LAD at different growth stages in cotton hybrids



on LAD particularly 95 DAS. The LAD in this treatment (T_4) was 45.7 against 40.5 in MH and 43.8 in Ethylene. This trend was observed even in the later stage during 120-145 DAS.

The differences in LAD among the hybrids were found significant at all the stages of crop growth during both the years and in pooled. Vikram 5 (BG-II) recorded significantly higher value of LAD than remaining hybrids at all the phases of crop growth. At 121-145 DAS, the LAD in Vikram 5 (BG-II) reached to the highest (47.3) but it was at par with RCH 2 (BG-II) at 96-120 and 121-145 DAS. The minimum LAD was recorded in G.Cot Hy-12 at all the stages of crop growth.

The interaction effect between Ethylene and MH treatments with hybrids in relation to leaf area duration was found not significant at all the stages of crop growth during both the years and in pooled.

4.1.3 Crop growth rate (gm^{-2} days^{-1})

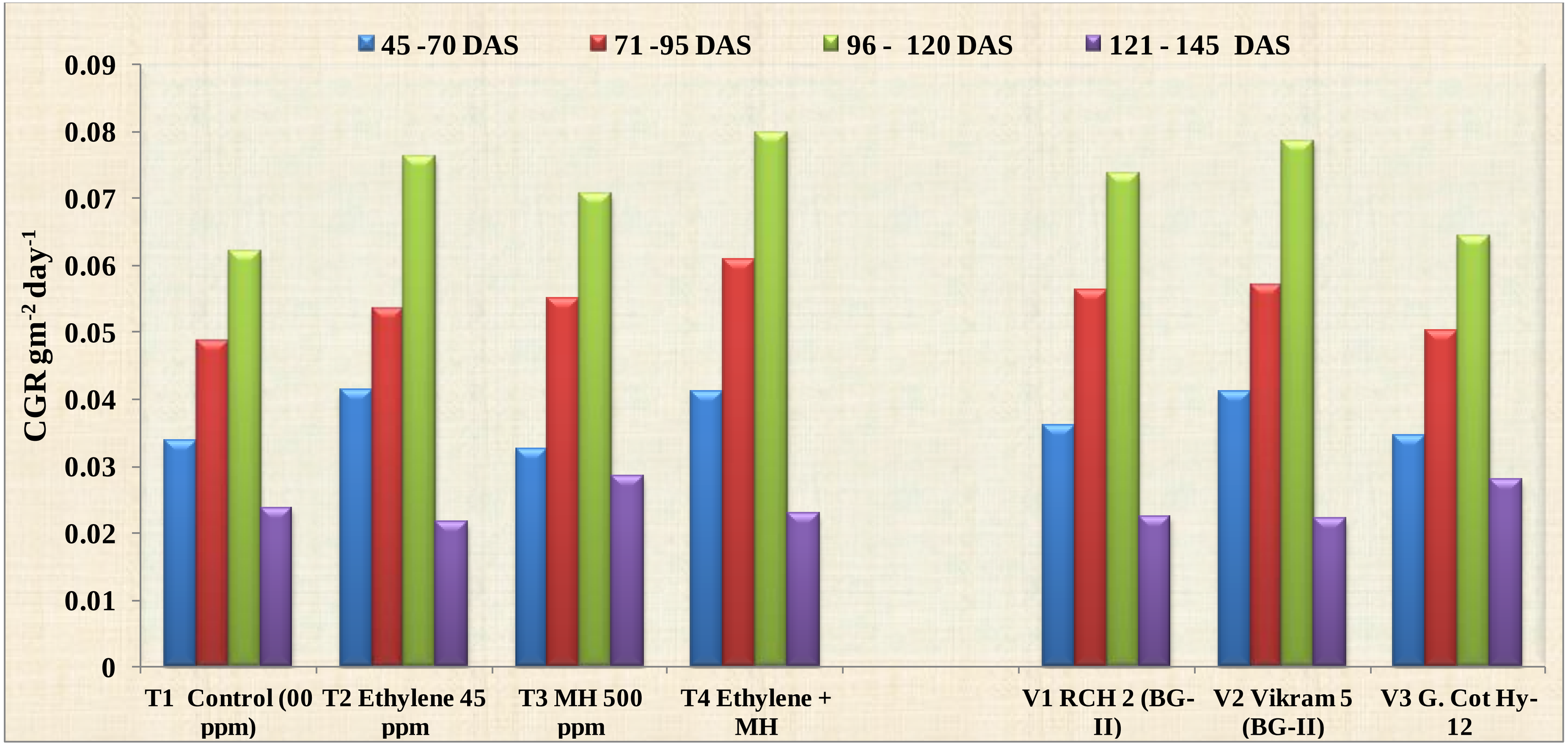
The data on crop growth rate (CGR) recorded at different growth stages as influenced by growth regulators and hybrids are presented in **Table-4.3** and graphically depicted in Figure 4.3

Growth regulators *i.e.*, Ethylene and MH application had the significant effect on CGR at all stages during both the years as well as in pooled. The data indicated that foliar applications of Ethylene (T_2) at square initiation significantly enhanced CGR (0.0413 gm^{-2} days^{-1}) over control (0.0338 gm^{-2} days^{-1}) at 45-70 DAS which was maintained until 120 DAS. MH application at 85 DAS (T_3) also had significant effect on CGR at 71-95 and 96-120 DAS over control. Application of Ethylene at squaring and MH at 85 DAS (T_4) had synergistic effect and significantly enhanced CGR at 71-95 (0.0607 gm^{-2}

Table 4.3: Effect of Ethylene and MH on Crop growth rate (gm^{-2} day^{-1}) at different growth stages in cotton hybrids

	45 -70 DAS			71 -95 DAS			96-120 DAS			121 -145 DAS		
	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled
A. Treatments (T)												
T_1 - Control (00 ppm)	0.0334	0.0343	0.0338	0.0490	0.0487	0.0488	0.0621	0.0619	0.0620	0.0248	0.0225	0.0237
T_2 - Ethylene 45 ppm	0.0427	0.0398	0.0413	0.0517	0.0556	0.0536	0.0791	0.0734	0.0762	0.0202	0.0227	0.0215
T_3 - MH 500 ppm	0.0311	0.0341	0.0326	0.0567	0.0535	0.0551	0.0686	0.0729	0.0707	0.0319	0.0251	0.0285
T_4 - $T_2 + T_3$	0.0419	0.0404	0.0411	0.0593	0.0621	0.0607	0.0780	0.0818	0.0799	0.0240	0.0217	0.0228
S. Em. ±	0.0024	0.0019	0.0015	0.0021	0.0026	0.0017	0.0043	0.0043	0.0031	0.0016	0.0008	0.0019
C.D. at 5%	0.0070	0.0056	0.0043	0.0062	0.0076	0.0048	0.0126	0.0126	0.0087	0.0047	0.0023	NS
B. Variety (V)												
V_1 - RCH 2 (BG-II)	0.0371	0.0350	0.0360	0.0552	0.0575	0.0563	0.0724	0.0749	0.0737	0.0234	0.0214	0.0224
V_2 - Vikram 5 (BG-II)	0.0415	0.0406	0.0410	0.0569	0.0573	0.0571	0.0788	0.0783	0.0786	0.0218	0.0222	0.0220
V_3 - G. Cot Hy-12	0.0333	0.0358	0.0345	0.0503	0.0501	0.0502	0.0646	0.0642	0.0644	0.0306	0.0253	0.0279
S. Em. ±	0.0020	0.0016	0.0013	0.0018	0.0023	0.0014	0.0037	0.0038	0.0026	0.0014	0.0007	0.0014
C.D. at 5%	0.0059	0.0047	0.0037	0.0053	0.0067	0.0041	0.0109	0.0111	0.0075	0.0041	0.0021	0.0019
C. Interaction												
V x T												
S. Em. ±	0.0041	0.0032	0.0025	0.0037	0.0045	0.0028	0.0075	0.0075	0.0035	0.0027	0.0014	0.0012
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y x T												
S. Em. ±			0.0021			0.0024			0.0043			0.0013
C.D. at 5%			NS			NS			NS			0.0036
C.V.%	19.0	14.9	17.1	11.8	14.3	13.1	18.0	17.9	18.0	18.7	10.7	15.6

Fig. 4.3: Effect of Ethylene and MH on CGR at different growth stages in cotton hybrids



days^{-1}) compared to Ethylene (0.0536 gm^{-2} days^{-1}) and MH (0.00551 gm^{-2} days^{-1}). A similar trend was observed at 96-120 DAS, although the differences over Ethylene were not significant. However year x treatment interaction was significant at 121-145 DAS.

The differences in CGR among the hybrids were found significant at all the stages. *Bt* hybrid Vikram 5 (BG-II) maintained highest crop growth rate until 120 DAS which was significantly higher than that in G.Cot Hy-12 and at par with that in RCH 2 (BG-II) except in the initial stage (45-70 DAS). It was in the late crop growth stage (121-145 DAS) that the CGR of conventional hybrid G.Cot Hy-12 (0.0279 gm^{-2} days^{-1}) significantly exceeded those of two *Bt* hybrids (0.0220 and 0.0224 gm^{-2} days^{-1}).

The interactive effect between growth regulators and hybrids on crop growth rate was found not significant at all stages during both years and in pooled.

4.1.4 Relative growth rate (g g^{-1} day^{-1} plant^{-1})

The data pertaining to relative growth rate (RGR) as influenced by different growth modifiers and hybrids at various stages are presented in **Table 4.4** and graphically depicted in Figure 4.4

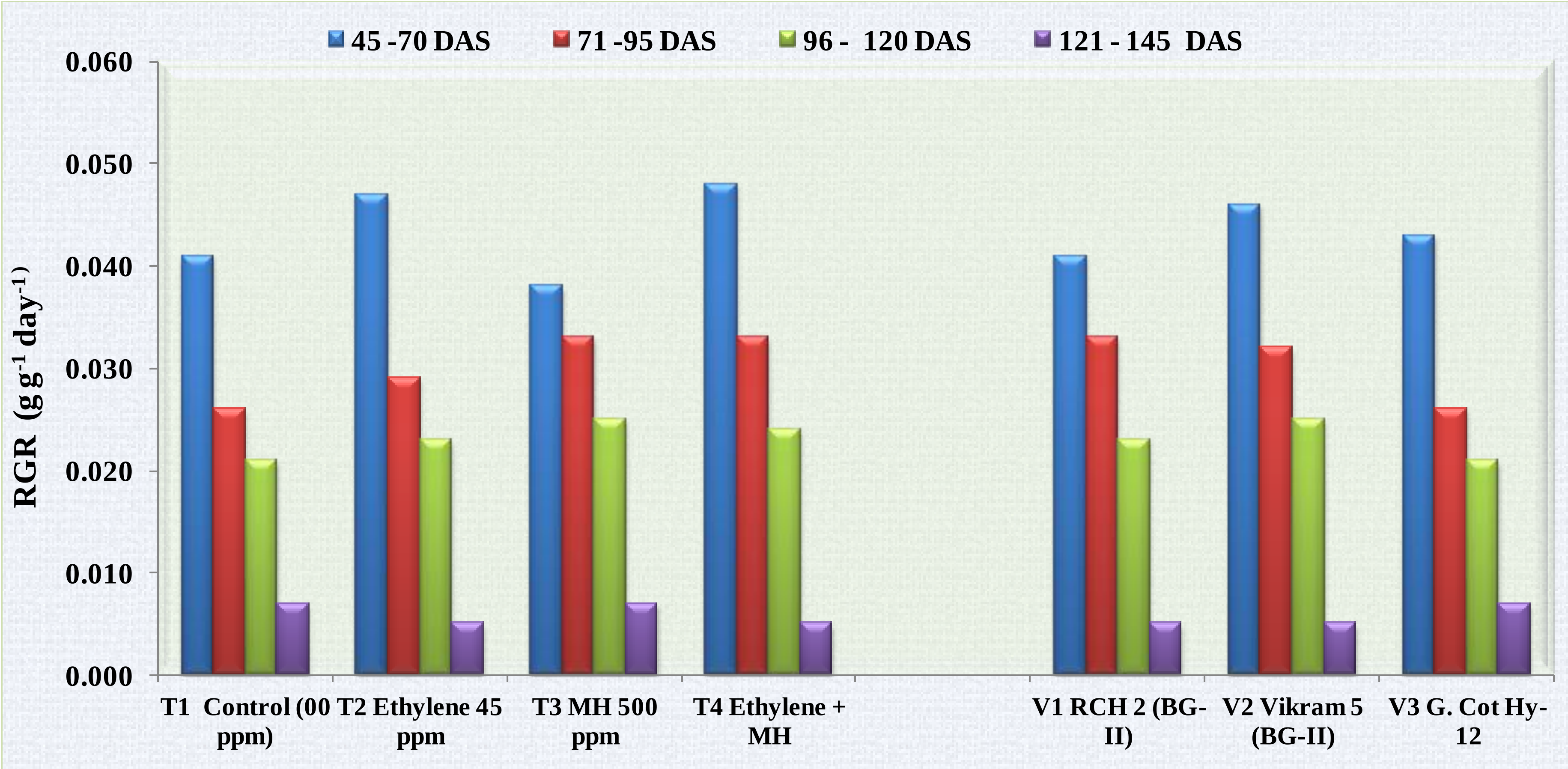
It was observed from the data that, rate of accumulation of dry matter per gram of existing dry matter was the highest between 45 to 70 DAS and tended to decrease subsequently as the cotton crop progressed toward maturity.

The data revealed that the application of growth regulators had significant influence on RGR in individual years as well as in pooled barring 121-145 DAS in 2012-13. Application of Ethylene (45 ppm) at squaring stage (T_2) was effective and significantly increased RGR (0.047 g g^{-1} day^{-1}

Table 4.4: Effect of Ethylene and MH on Relative growth rate (g g^{-1} day^{-1} $plant^{-1}$) at different growth stages in cotton hybrids

	45 -70 DAS			71 -95 DAS			96-120 DAS			121 -145 DAS		
	2011-12	**2012-13**	**Pooled**	**2011-12**	**2012-13**	**Pooled**	**2011-12**	**2012-13**	**Pooled**	**2011-12**	**2012-13**	**Pooled**
A. Treatments (T)												
T_1 - Control (00 ppm)	0.042	0.040	0.041	0.026	0.026	0.026	0.021	0.020	0.021	0.007	0.006	0.007
T_2 - Ethylene 45 ppm	0.049	0.044	0.047	0.030	0.028	0.029	0.024	0.021	0.023	0.005	0.005	0.005
T_3 - MH 500 ppm	0.039	0.038	0.038	0.036	0.031	0.033	0.025	0.026	0.025	0.008	0.006	0.007
T_4 - $T_2 + T_3$	0.049	0.047	0.048	0.032	0.035	0.033	0.024	0.024	0.024	0.005	0.005	0.005
S. Em. ±	0.003	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.0004	0.0004	0.0003
C.D. at 5%	0.008	0.007	0.005	0.007	0.005	0.004	0.002	0.004	0.002	0.0012	NS	0.0009
B. Variety (V)												
V_1 - RCH 2 (BG-II)	0.044	0.038	0.041	0.032	0.033	0.033	0.024	0.022	0.023	0.006	0.005	0.005
V_2 - Vikram 5 (BG-II)	0.049	0.043	0.046	0.035	0.029	0.032	0.025	0.026	0.025	0.005	0.005	0.005
V_3 - G. Cot Hy-12	0.041	0.045	0.043	0.026	0.027	0.026	0.022	0.021	0.021	0.008	0.007	0.007
S. Em. ±	0.002	0.002	0.001	0.002	0.002	0.001	0.001	0.001	0.001	0.0003	0.0004	0.0003
C.D. at 5%	0.007	0.006	0.004	0.006	0.004	0.003	0.002	0.003	0.002	0.0009	0.00012	0.0008
C. Interaction												
V x T												
S. Em. ±	0.004	0.004	0.002	0.004	0.003	0.002	0.001	0.002	0.001	0.0007	0.0008	0.0006
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y x T												
S. Em. ±			0.002			0.002			0.001			0.0004
C.D. at 5%			NS			NS			NS			NS
C.V.%	17.1	15.8	16.5	23.0	17.8	20.7	10.2	16.4	13.5	19.3	25.0	22.1

Fig. 4.4: Effect of Ethylene and MH on RGR at different growth stages in cotton hybrids



plant^{-1}) at 45-70 DAS over control (0.041 g g^{-1} day^{-1} plant^{-1}) which was maintained till 96-120 DAS. Application MH 500 ppm (T_3) at 85 DAS also significantly increased RGR during 71-95 (0.033 g g^{-1} day^{-1} plant^{-1}) and 96-120 (0.025 g g^{-1} day^{-1} plant^{-1}) DAS over control (0.026 and 0.021 g g^{-1} day^{-1} plant^{-1}, respectively). Supplementing 500 ppm MH spray on Ethylene treated plants (T_4) did not depict any significant advantage in RGR over Ethylene or MH at any of the stages but over control.

The data in **Table 4.4** revealed that the differences in relative growth rate amongst the hybrids were found to be significant at all the stages in both the years as well as in pooled. Vikram 5 (BG-II) showed significantly higher RGR (0.046 g g^{-1} day^{-1} plant^{-1}) at 45-70 and 96-120 DAS whereas, RCH 2 (BG-II) showed the highest RGR at 71-95 DAS. By and large, minimum RGR was recorded in G.Cot Hy-12 which showed an edge over *Bt* hybrids during late stage (121-145 DAS).

The interaction between growth regulators and hybrids on relative growth rate was found not significant at all stage of crop growth during both years and in pooled.

4.1.5 Net assimilation rate (mg cm^{-2} day^{-1})

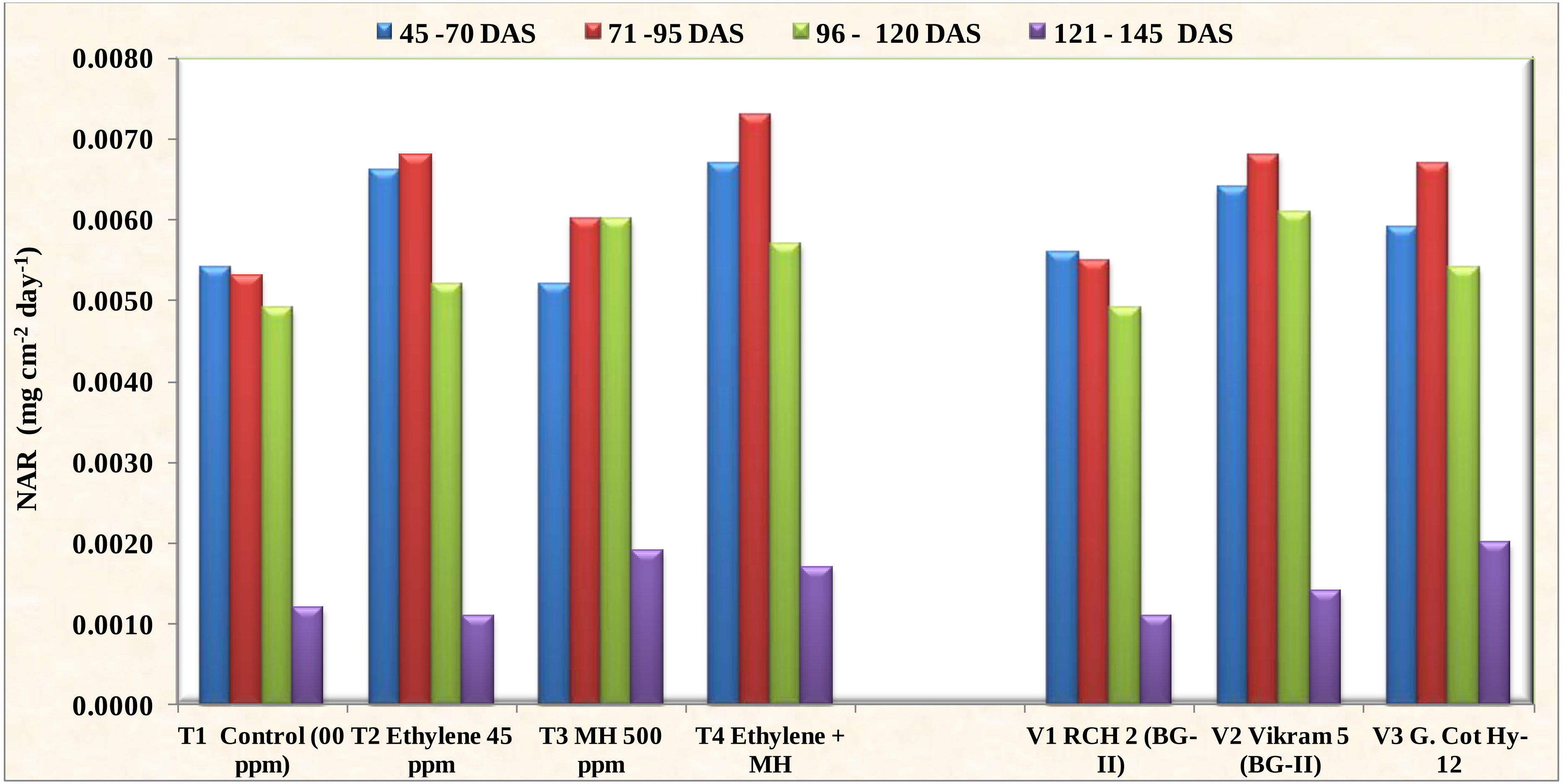
The data on the net assimilation rate (NAR) recorded at different growth stages as influenced by growth regulators and hybrids are presented in **Table 4.5** and graphically depicted in Figure 4.5

In general, cotton hybrids showed the highest mean net assimilation rate between 71 to 95 DAS and decreased thereafter as the crop progressed towards maturity during both the years.

Table 4.5: Effect of Ethylene and MH on Net assimilation rate (mg cm^{-2} day^{-1}) at different growth stages in cotton hybrids

	45 -70 DAS			71 -95 DAS			96-120 DAS			121 -145 DAS		
	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled
A. Treatments (T)												
T_1 - Control (00 ppm)	0.0057	0.0051	0.0054	0.0053	0.0054	0.0053	0.0051	0.0047	0.0049	0.0011	0.0012	0.0012
T_2 - Ethylene 45 ppm	0.0068	0.0064	0.0066	0.0064	0.0072	0.0068	0.0048	0.0057	0.0052	0.0013	0.0010	0.0011
T_3 - MH 500 ppm	0.0051	0.0054	0.0052	0.0065	0.0055	0.0060	0.0061	0.0060	0.0060	0.0017	0.0021	0.0019
T_4 - $T_2 + T_3$	0.0068	0.0067	0.0067	0.0075	0.0071	0.0073	0.0065	0.0049	0.0057	0.0019	0.0015	0.0017
S. Em. ±	0.0004	0.0004	0.0003	0.0005	0.0004	0.0003	0.0004	0.0003	0.0002	0.0001	0.0001	0.0002
C.D. at 5%	0.0013	0.0011	0.0008	0.0014	0.0012	0.0009	0.0012	0.0010	0.0007	0.0004	0.0004	0.0008
B. Variety (V)												
V_1 - RCH 2 (BG-II)	0.0062	0.0050	0.0056	0.0055	0.0055	0.0055	0.0048	0.0051	0.0049	0.0012	0.0009	0.0011
V_2 - Vikram 5 (BG-II)	0.0067	0.0061	0.0064	0.0065	0.0072	0.0068	0.0062	0.0063	0.0061	0.0013	0.0014	0.0014
V_3 - G. Cot Hy-12	0.0053	0.0066	0.0059	0.0073	0.0062	0.0067	0.0059	0.0046	0.0054	0.0020	0.0020	0.0020
S. Em. ±	0.0004	0.0003	0.0002	0.0004	0.0004	0.0003	0.0004	0.0003	0.0002	0.0001	0.0001	0.0001
C.D. at 5%	0.0011	0.0009	0.0006	0.0012	0.0010	0.0008	0.0010	0.0009	0.0007	0.0003	0.0004	0.0002
C. Interaction												
V x T												
S. Em. ±	0.0008	0.0006	0.0004	0.0008	0.0007	0.0005	0.0007	0.0006	0.0003	0.0002	0.0002	0.0001
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y x T												
S. Em. ±			0.0004			0.0005			0.0004			0.0001
C.D. at 5%			NS			NS			NS			NS
C.V.%	21.7	18.4	20.2	22.7	19.7	21.3	22.0	19.4	20.9	25.2	28.5	26.9

Fig. 4.5: Effect of Ethylene and MH on NAR (mg cm^{-2} day^{-1}) at different growth stages in cotton hybrids



Plant growth regulators significantly influenced net assimilation rate at all the stage in both the years and in pooled. The data indicated **(Table-4.5)** that applications of Ethylene (T_2) at squaring stage recorded significantly higher NAR (0.0066 mg cm^{-2} $days^{-1}$) over control and continued until 95 DAS. Application of MH at 85 DAS (T_3) enhanced NAR although the increase was significant only during 96-120 DAS. Application of MH after Ethylene (T_4) was found to show higher NAR (0.0073 mg cm^{-2} day^{-1}) at 71-95 DAS than rest of the treatments and significant over control during 96-120 DAS.

The differences in net assimilation rate amongst the hybrids were found significant at all the stages. Vikram 5 (BG-II) recorded significantly the highest net assimilation rate at all the stages except 121-145 DAS where highest NAR was recorded in G.Cot Hy-12. Minimum net assimilation rate was recorded in RCH 2 (BG-II) at all stages.

The interaction between growth regulators and hybrids on net assimilation rate (NAR) was found to be not significant at all the stages during both the years and in pooled.

4.1.6 Dry matter accumulation (g/plant)

The data on the dry matter accumulation (g/plant) recorded periodically are given in **Table 4.6.** Dry matter accumulation as influenced by varieties and treatments has also been illustrated in Figure 4.6.

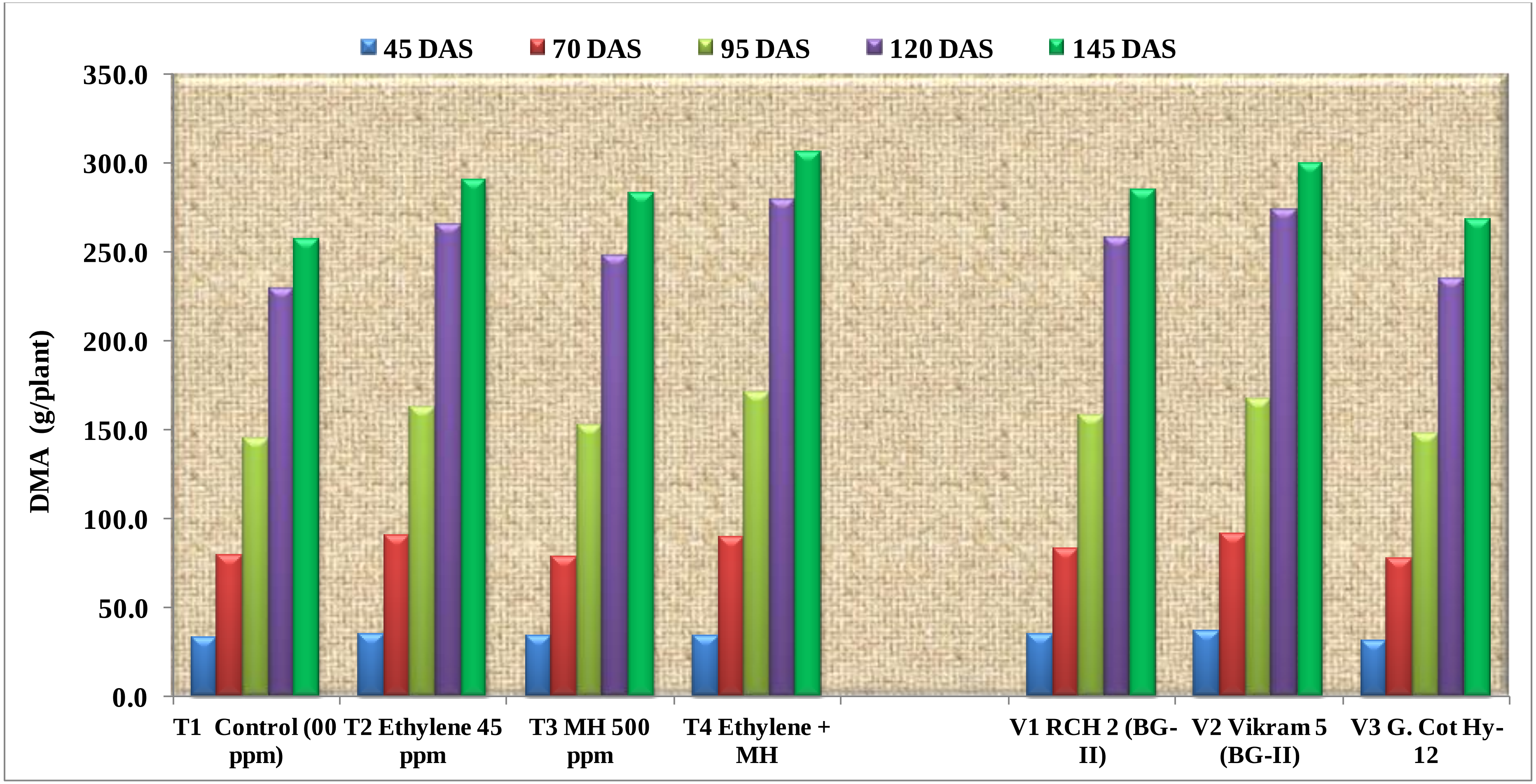
The dry matter accumulation $plant^{-1}$ increased progressively and reached to its maximum (284.5 g $plant^{-1}$) at 145 DAS.

The data indicated (**Table 4.6**) pronounced influence of growth regulators on dry matter accumulation and the

Table 4.6: Effect of Ethylene and MH on Dry matter accumulation (g/plant) at different growth stages in cotton hybrids

	45 DAS			70 DAS			95 DAS			120 DAS			145 DAS		
	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled
A. Treatments (T)															
T_1 - Control (00 ppm)	32.0	34.6	33.3	77.0	80.8	78.9	144.3	146.5	145.4	228.2	230.1	229.1	254.8	260.5	257.7
T_2 - Ethylene 45 ppm	32.2	37.6	34.9	89.9	91.2	90.6	158.4	166.3	162.3	265.1	265.4	265.2	285.6	296.0	290.8
T_3 - MH 500 ppm	32.6	35.6	34.1	74.6	81.7	78.1	151.1	153.9	152.5	243.6	252.3	248.0	279.9	286.1	283.0
T_4 - $T_2 + T_3$	31.4	35.8	33.6	87.9	90.4	89.2	167.9	174.3	171.1	273.2	284.7	278.9	298.8	313.9	306.4
S. Em. ±	1.28	2.02	1.19	3.64	3.12	2.34	4.73	6.18	3.78	9.09	8.95	6.21	8.05	8.57	5.71
C.D. at 5%	NS	NS	NS	10.7	9.14	6.66	13.9	18.1	10.8	26.7	26.2	17.7	23.6	25.1	16.3
B. Variety (V)															
V_1 - RCH 2 (BG-II)	31.9	36.9	34.4	82.0	84.1	83.0	155.6	161.3	158.4	253.3	262.4	257.9	278.1	291.3	284.7
V_2 - Vikram 5 (BG-II)	34.1	38.6	36.3	90.1	93.4	91.7	164.5	170.4	167.5	270.9	276.1	273.5	293.5	306.2	299.9
V_3 - G. Cot Hy-12	30.0	32.3	31.1	74.9	80.6	77.8	146.1	149.0	147.6	233.3	235.7	234.5	267.8	269.9	268.8
S. Em. ±	1.11	1.75	1.02	3.15	2.70	2.04	4.09	5.35	3.30	7.87	7.75	5.41	6.97	7.42	5.02
C.D. at 5%	3.25	5.12	2.91	9.25	7.92	5.81	12.0	15.7	9.40	23.1	22.7	15.4	20.5	21.8	14.3
C. Interaction															
V x T															
S. Em. ±	2.21	3.49	2.01	6.31	5.40	3.93	8.19	10.7	6.33	15.7	15.5	10.4	13.9	14.8	9.61
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y x T															
S. Em. ±			1.69			3.39			5.50			9.02			8.31
C.D. at 5%			NS			NS			NS			NS			NS
C.V.%	12.0	16.9	14.9	13.3	10.9	12.1	9.13	11.6	10.5	10.8	10.4	10.6	8.63	8.90	8.77

Fig. 4.6: Effect of Ethylene and MH on DMA (g/plant) at different growth stages in cotton hybrids



differences were statistically significant at all the stages, except initially at 45 DAS in both the years as well as in pooled. The pooled data revealed that application of Ethylene (T_2) at squaring stage significantly enhanced dry matter accumulation at 70 DAS which was maintained till 145 DAS over control. Application of MH (T_3) at 85 DAS also enhanced dry matter accumulation from 95 DAS till end. However, significant increase was discernible at 120 (248.0 g plant^{-1}) and145 DAS (283.0 g plant^{-1}). Supplemental effect of MH was seen in Ethylene treated plant (T_4). The dry matter accumulation at 95 DAS in this treatment was 171 g plant^{-1}, against 162 g plant^{-1} in Ethylene and 152 g plant^{-1} in MH. The corresponding values at 120 DAS were 279, 265 and 248 g plant^{-1}, respectively, while at 145 DAS these were 306, 291 and 283 g plant^{-1}, respectively.

Cotton hybrids under study showed significant differences in dry matter accumulation in individual years and in pooled mean. Vikram 5 (BG-II) accumulated significantly higher dry matter plant^{-1} than other hybrids almost throughout the growing period. Significantly low dry matter accumulation was recorded in conventional hybrids G.Cot Hy -12.

The interaction between treatments and cotton hybrids was found to be not significant, thereby meaning that hybrid's response to treatments was the same in terms of dry matter accumulation.

4.2 GROWTH AND MORPHOLOGICAL CHARACTERS

4.2.1 Plant height (cm)

The data on plant height (cm) recorded at various growth stages as influenced by growth regulators in different cotton hybrids is presented in **Table 4.7** and graphically depicted in Figure 4.7

In general, plant height increased with the age of the crop till harvest. The effect of growth regulators on morphoframe as reflected on plant height was found significant at 70, 95, 120, 145 DAS and at harvest in both the years as well as in pooled analysis. Foliar application of Ethylene (45 ppm) at squaring stage (T_2) resulted in significant increase in the plant height (79.3) over control (70.6 cm) at 70 DAS and this trend was maintained untill harvest. Application of MH at 85 DAS had a depressing effect on plant height. Significant reduction in plant height over control was observed at 120 DAS till harvest. Use of MH on previously Ethylene treated plant (T_4) reflected some interesting results. Ten days after application of MH *i.e.* 95 DAS, the plant height showed depressing effects *e.g.* against 105.7 cm in Ethylene alone, it was 101.4 cm in Ethylene + MH (T_4). This effect was more pronounced at 120 DAS where in the plant height in Ethylene (119.6 cm) was reduced to 107.7 cm in Ethylene + MH which was at par to untreated control (111.3 cm).

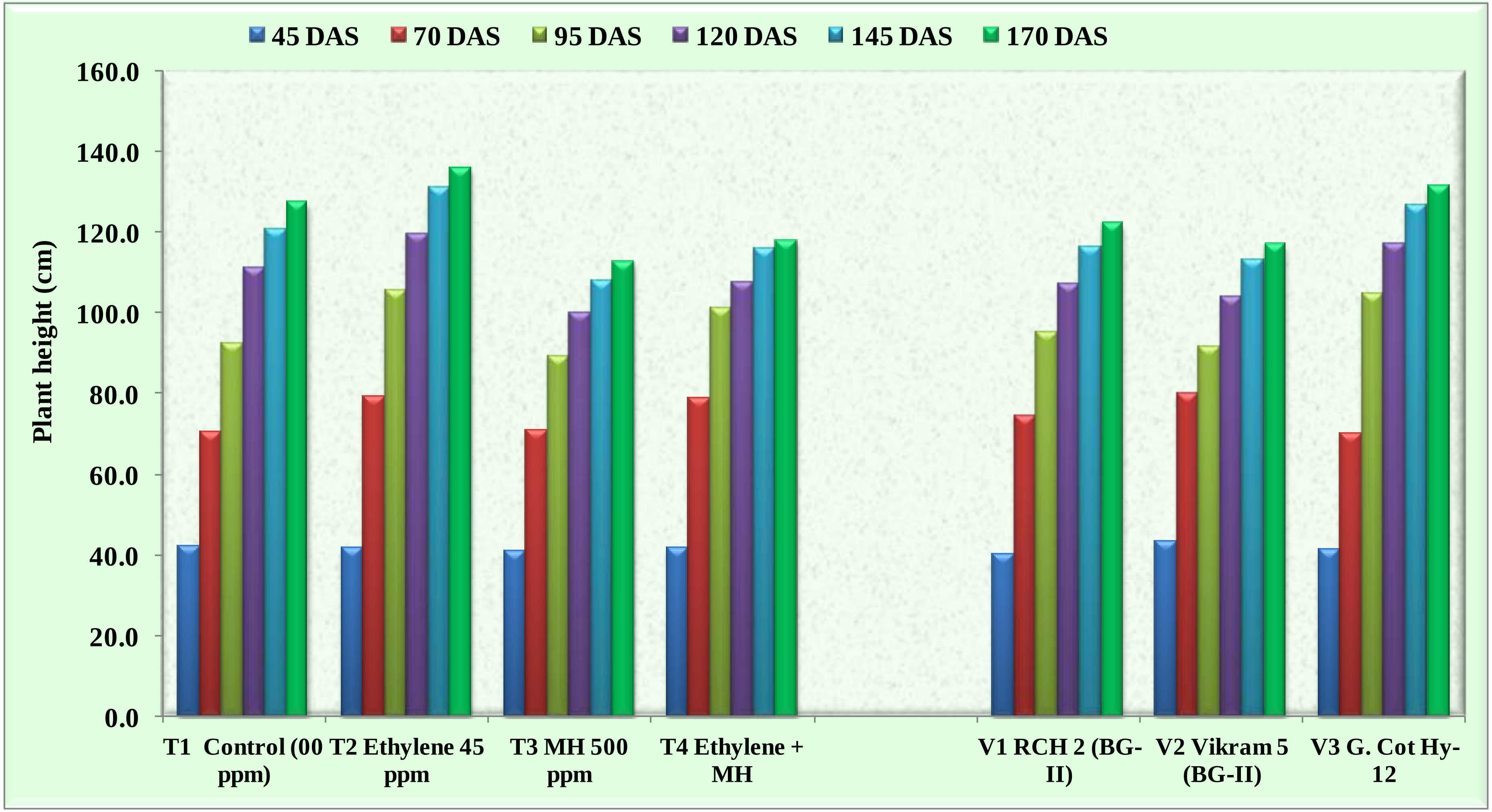
The plant height differed significantly amongst the hybrids at all the stages of growth, excluding at 45 DAS during both the years and in pooled. Initially (70 DAS), Vikram 5 (BG-II) showed significantly greater plant height (80.3 cm) than other hybrids but subsequently, G. Cot Hy-12 attained maximum plant height at 95 DAS (104.9 cm) and maintained till maturity and significantly more than RCH 2 (BG-II) and Vikram 5 (BG-II). Minimum plant height was recorded in Vikram 5 (BG-II).

The interaction effect between hybrids and growth modifier treatments on plant height at all growth stages was found to be not significant.

Table 4.7: Effect of Ethylene and MH on Plant height (cm) at different growth stages in cotton hybrids

	45 DAS			70 DAS			95 DAS			120 DAS			145 DAS			At harvest		
	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled
A. Treatments (T)																		
T_1 - Control (00 ppm)	40.3	44.1	42.2	69.3	71.9	70.6	89.3	96.1	92.7	107.4	115.2	111.3	118.5	123.1	120.8	126.3	128.3	127.3
T_2 - Ethylene 45 ppm	39.4	44.4	41.9	77.9	80.7	79.3	102.7	108.7	105.7	116.0	123.1	119.6	127.8	134.3	131.1	132.9	138.9	135.9
T_3 - MH 500 ppm	40.5	41.4	40.9	70.0	72.3	71.1	86.5	92.5	89.5	97.0	102.9	100.0	106.8	109.4	108.1	111.5	113.9	112.7
T_4 - $T_2 + T_3$	40.1	43.4	41.8	77.0	81.2	79.1	99.2	103.7	101.4	105.4	110.1	107.7	115.5	116.6	116.0	117.0	118.8	117.9
S. Em. ±	1.86	2.15	1.39	2.59	2.53	1.75	3.81	3.82	2.61	3.32	3.71	2.41	3.81	4.15	2.74	4.00	4.46	2.91
C.D. at 5%	NS	NS	NS	7.58	7.43	4.99	11.2	11.2	7.44	9.75	10.9	6.88	11.1	12.16	7.80	11.74	13.08	8.28
B. Variety (V)																		
V_1 - RCH 2 (BG-II)	38.9	41.3	40.1	73.7	75.7	74.7	92.9	97.9	95.4	104.5	110.5	107.5	114.9	118.4	116.6	120.6	123.7	122.2
V_2 - Vikram 5 (BG-II)	41.6	45.5	43.5	78.6	81.9	80.3	88.7	94.7	91.7	101.0	107.4	104.2	112.0	114.8	113.4	115.7	118.3	117.0
V_3 - G. Cot Hy-12	39.8	43.2	41.5	68.3	71.9	70.1	101.7	108.1	104.9	113.9	120.5	117.2	124.6	129.3	126.9	129.5	133.0	131.3
S. Em. ±	1.61	1.86	1.20	2.24	2.19	1.53	3.30	3.31	2.29	2.88	3.22	2.11	3.30	3.59	2.38	3.47	3.86	2.53
C.D. at 5%	NS	NS	NS	6.57	6.44	4.37	9.69	9.69	6.52	8.45	9.44	6.01	9.67	10.54	6.79	10.17	11.33	7.23
C. Interaction																		
V x T																		
S. Em. ±	3.22	3.73	2.47	4.48	4.39	2.99	6.60	6.61	4.39	5.76	6.43	4.10	6.60	7.18	4.62	6.93	7.73	4.92
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y x T																		
S. Em. ±			2.01			2.56			3.82			3.53			3.98			4.24
C.D. at 5%			NS			NS			NS			NS			NS			NS
C.V.%	13.9	14.9	14.5	10.6	9.94	10.2	12.1	11.4	11.8	9.40	9.88	9.65	9.75	10.3	10.0	9.85	10.7	10.3

Fig.4.7: Effect of Ethylene and MH on Plant height (cm) at different growth stages in cotton hybrids



4.2.2 Number of mainstem nodes per plant

The data on number of main stem nodes per plant recorded at periodical interval as influenced by foliar application of Ethylene 45 ppm at square initiation and MH 500 ppm at 85 DAS is presented in **Table-4.8.** The number of nodes increased with the age of the crop till harvest.

The data indicated that application of Ethylene (T_2) significantly enhanced number of main stem nodes (16.4) over control (13.9) at 70 DAS and this trend was seen till harvest. Foliar application of MH at 85 DAS (T_3) also had increasing effect on the mainstem nodes at 95 DAS onward, and significant increased over control was observed at 120, 145 DAS and at harvest. Application of Ethylene at squaring stage followed by MH at 85 DAS (T_4) exhibited the highest number of main stem nodes from 95 days onward. It was significantly higher than MH all through and over Ethylene at 145 DAS and at harvest.

The differences in number of main stem nodes per plant amongst the hybrids were found significant at 70, 95, 120, 145 DAS and at harvest. Vikram 5 (BG-II) recorded significantly higher number of main stem nodes at 70 (16.5), 95 (22.9), 120 (27.0), 145 (29.1) DAS and at harvest (30.1), but at par with RCH 2 (BG-II) at 120, 145 DAS and at harvest during both the years of experimentation. Minimum number of main stem nodes was observed in G. Cot Hy-12.

The interaction effects between growth modifier treatments and hybrids for number of main stem nodes were found not significant at all the growth stage.

Table 4.8: Effect of Ethylene and MH on Main stem nodes at different growth stages in cotton hybrids

	45 DAS			70 DAS			95 DAS			120 DAS			145 DAS			At harvest		
	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled
A. Treatments (T)																		
T_1 - Control (00 ppm)	11.0	11.7	11.3	12.9	14.9	13.9	18.9	19.6	19.2	21.2	23.3	22.3	23.0	25.1	24.1	23.9	25.5	24.7
T_2 - Ethylene 45 ppm	10.2	11.7	11.0	15.5	17.3	16.4	21.8	23.1	22.5	26.4	26.7	26.6	27.0	28.6	27.8	28.2	29.2	28.7
T_3 - MH 500 ppm	10.1	12.6	11.3	13.0	14.7	13.8	19.2	20.5	19.8	23.4	24.9	24.1	26.3	27.8	27.0	27.2	28.3	27.8
T_4 - $T_2 + T_3$	11.1	11.7	11.4	15.4	17.5	16.5	22.2	23.8	23.0	27.1	28.2	27.7	29.8	31.1	30.4	30.3	31.9	31.1
S. Em. ±	0.46	0.63	0.39	0.73	0.67	0.48	0.88	0.82	0.58	0.99	0.92	0.66	1.01	0.85	0.64	1.00	0.90	0.65
C.D. at 5%	NS	NS	NS	2.13	1.97	1.37	2.58	2.40	1.65	2.91	2.70	1.89	2.96	2.50	1.82	2.92	2.65	1.86
B. Variety (V)																		
V_1 - RCH 2 (BG-II)	10.4	12.4	11.4	14.2	16.0	15.1	20.2	21.3	20.7	24.6	25.7	25.1	26.5	28.3	27.4	27.4	28.9	28.1
V_2 - Vikram 5 (BG-II)	11.4	11.9	11.7	15.6	17.4	16.5	22.2	23.5	22.9	26.2	27.9	27.0	28.3	30.0	29.1	29.5	30.8	30.1
V_3 - G. Cot Hy-12	10.0	11.4	10.7	12.9	14.9	13.9	19.1	20.5	19.8	22.9	23.8	23.3	24.8	26.3	25.5	25.3	26.6	26.0
S. Em. ±	0.40	0.54	0.34	0.63	0.58	0.41	0.76	0.71	0.51	0.86	0.80	0.58	0.87	0.74	0.56	0.86	0.78	0.57
C.D. at 5%	1.17	NS	NS	1.85	1.70	1.19	2.23	2.08	1.44	2.52	2.34	1.64	2.56	2.17	1.59	2.53	2.29	1.62
C. Interaction																		
V x T																		
S. Em. ±	0.80	1.09	0.64	1.26	1.16	0.82	1.52	1.41	0.98	1.72	1.59	1.14	1.75	1.48	1.07	1.73	1.56	1.13
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y x T																		
S. Em. ±			0.55			0.70			0.85			0.96			0.93			0.95
C.D. at 5%			NS			NS			NS			NS			NS			NS
C.V.%	13.1	15.8	14.7	15.4	12.5	13.9	12.8	11.3	12.0	12.2	10.7	11.4	11.4	9.09	10.2	10.9	9.42	10.2

4.2.3 Number of monopodia per plant

The data on mean number of monopodia plant^{-1} recorded at harvest as influenced by plant growth regulators is presented in **Table-4.9**

The results on number of monopodia per plant due to different treatments were found to be significant. The data indicated that foliar application of Ethylene (3.28) and MH (3.06) recorded significantly higher number of monopodia per plant at harvest over control (2.64). Application of Ethylene + MH (T_4) recorded the highest number of monopodia per plant (3.57) which was at par with Ethylene (3.28) but significantly greater than MH (3.06).

The data presented in **Table-4.9** indicated significant differences in number of monopodia per plant amongst the hybrids. Vikram 5 (BG-II) recorded highest number of monopodia (3.50) which was significantly greater than that in RCH 2 (BG-II) and G. Cot Hy-12. Minimum number of monopodia was observed in G. Cot Hy-12 during both the years and in pooled.

The interaction effect between growth regulators and hybrids was found to be not significant.

4.2.4 Number of sympodia per plant

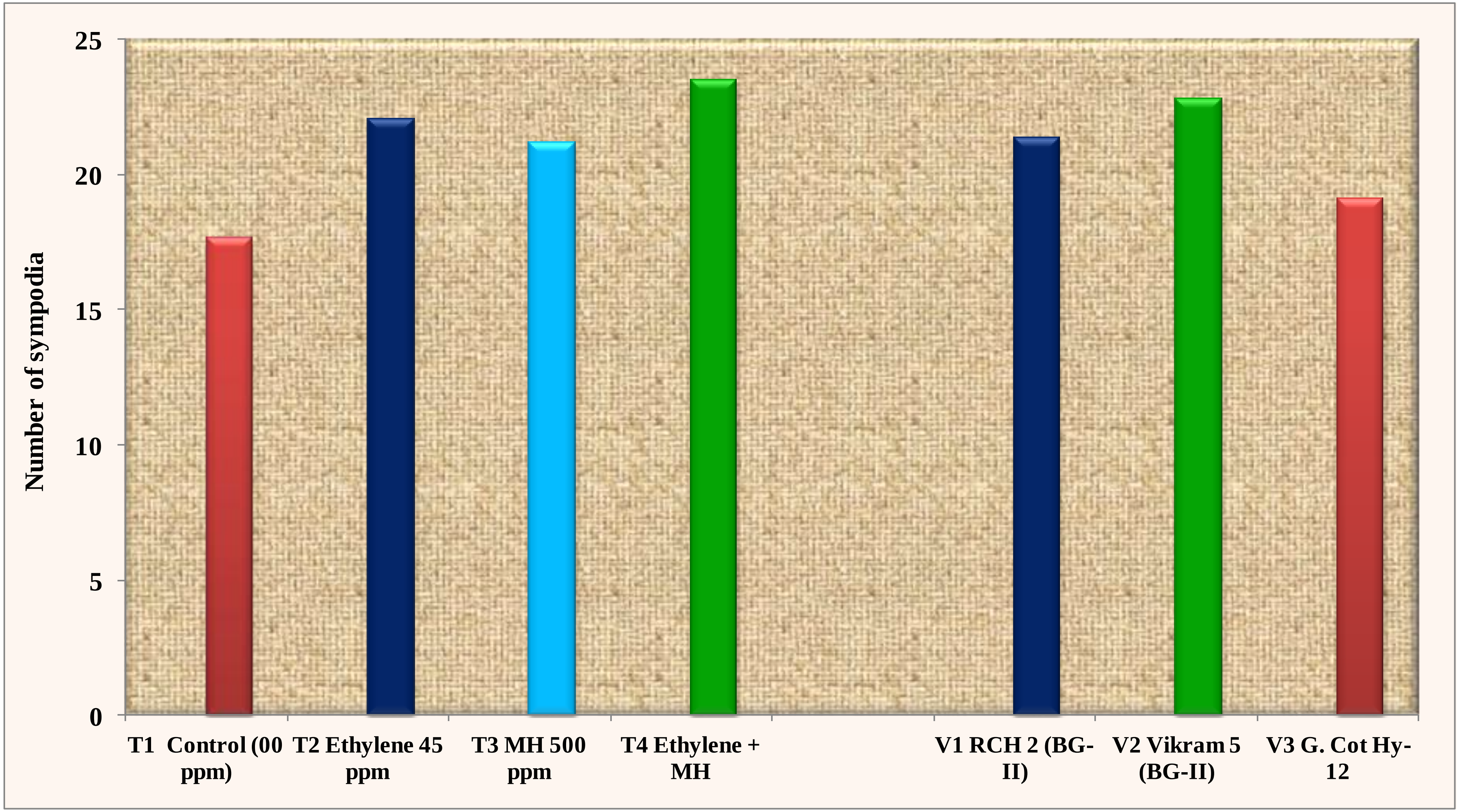
The data presented in **Table 4.9** showed that the mean number of sympodia per plant recorded at harvest as influenced due to foliar application of growth regulators and hybrids, graphically depicted in Figure 4.8.

The results on number of sympodia per plant due to different treatments were found to be significant. The data indicated that Ethylene application at squaring stage (T_2) and MH at 85 DAS (T_3) recorded significantly higher number of sympodia per plant over untreated control. Application of

Table 4.9: Effect of Ethylene and MH on Monopodia and Sympodia per plant at harvest in cotton hybrids

	No.of Monopodia			No. of Sympodia		
	2011-12	**2012-13**	**Pooled**	**2011-12**	**2012-13**	**Pooled**
A. Treatments (T)						
T_1 - Control (00 ppm)	2.27	3.01	2.64	17.3	18.1	17.7
T_2 - Ethylene 45 ppm	2.91	3.64	3.28	21.5	22.6	22.1
T_3 -MH 500 ppm	2.75	3.38	3.06	21.0	21.4	21.2
T_4 - T_2 + T_3	3.22	3.91	3.57	23.1	23.8	23.5
S. Em. ±	0.17	0.20	0.13	0.94	0.94	0.64
C.D. at 5%	0.49	0.58	0.37	2.77	2.74	1.83
B. Variety (V)						
V_1 - RCH 2 (BG-II)	2.89	3.48	3.18	21.1	21.8	21.4
V_2 - Vikram 5 (BG-II)	3.14	3.87	3.50	22.5	23.1	22.8
V_3 - G. Cot Hy-12	2.34	3.12	2.73	18.6	19.5	19.1
S. Em. ±	0.14	0.17	0.11	0.82	0.81	0.56
C.D. at 5%	0.42	0.51	0.32	2.40	2.37	1.60
C. Interaction						
V x T						
S. Em. ±	0.29	0.35	0.25	1.63	1.62	1.11
C.D. at 5%	NS	NS	NS	NS	NS	NS
Y x T						
S. Em. ±			0.25			0.93
C.D. at 5%			NS			NS
C.V.%	17.9	17.1	17.6	13.7	13.1	13.4

Fig. 4.8: Effect of Ethylene and MH on Number of sympodia at harvest in cotton hybrids



Ethylene at squaring stage followed by MH at 85 DAS (T_4) had supplemental effect on the number of sympodia which recorded greater number over Ethylene (T_2) and MH (T_3). This increase was however, significant over MH and at par with Ethylene.

Different cotton hybrids showed significant variation in number of sympodia at harvest in individual years as well as in pooled. The data revealed that Vikram 5 (BG-II) exhibited higher number of sympodia (22.8), which was significantly more than G. Cot Hy-12 and although RCH 2 (BG-II). Minimum and significantly lesser number of sympodia was recorded in G. Cot Hy-12 (19.1).

The interaction effect of growth regulators with varieties for number of sympodia was found to be not significant.

4.2.5 Height to node ratio

The data on height to node ratio are presented in **Table-4.10.** In general, height to node ratio showed significant variations due to growth regulators and hybrids in both the years and in pooled at all the stages except 45 DAS.

The data revealed that application of Ethylene at squaring stage (T_2) resulted in significant reduction in height to node ratio (4.68) over control (5.26) at 70 DAS and this trend was observed till harvest. Application of MH at 85 DAS (T_3) also had reducing effect on height to node ratio. Significant reduction in the ratio over control was observed at 95 DAS till harvest. Ten days after application of MH on Ethylene treated plant (T_4) at 95 DAS, the height to node ratio showed reducing effect, against 4.73 in Ethylene and 4.57 in MH it was 4.41 in Ethylene + MH (T_4). This effect was more pronounced at 120 DAS (4.00), 145 DAS (3.83) and

Table 4.10: Effect of Ethylene and MH on Height to node ratio at different growth stages in cotton hybrids

	45 DAS			70 DAS			95 DAS			120 DAS			145 DAS			At harvest		
	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled
A. Treatments (T)																		
T_1 - Control (00 ppm)	3.68	3.83	3.76	5.57	4.94	5.26	5.02	5.06	5.04	5.26	5.00	5.13	5.21	5.13	5.17	5.46	5.14	5.30
T_2 - Ethylene 45 ppm	3.92	3.84	3.88	4.88	4.49	4.68	4.70	4.76	4.73	4.44	4.68	4.56	4.53	4.26	4.39	4.73	4.81	4.77
T_3 - MH 500 ppm	4.08	3.35	3.72	5.62	5.36	5.49	4.55	4.58	4.57	4.17	4.16	4.16	3.98	4.18	4.08	4.14	4.06	4.10
T_4 - $T_2 + T_3$	3.64	3.76	3.70	4.95	4.54	4.74	4.49	4.34	4.41	3.99	4.01	4.00	3.78	3.88	3.83	3.99	3.74	3.86
S. Em. ±	0.20	0.25	0.16	0.20	0.15	0.12	0.14	0.15	0.10	0.24	0.19	0.15	0.17	0.17	0.12	0.24	0.17	0.14
C.D. at 5%	NS	NS	NS	0.57	0.44	0.34	0.40	0.45	0.29	0.71	0.56	0.43	0.49	0.48	0.34	0.70	0.50	0.41
B. Variety (V)																		
V_1 - RCH 2 (BG-II)	3.79	3.37	3.58	5.17	4.62	4.90	4.64	4.64	4.64	4.32	4.35	4.33	4.23	4.15	4.19	4.45	4.32	4.38
V_2 - Vikram 5 (BG-II)	3.66	3.88	3.77	4.91	4.56	4.74	4.00	4.05	4.02	3.92	3.90	3.91	3.88	3.80	3.84	4.01	3.88	3.95
V_3 - G. Cot Hy-12	4.04	3.83	3.93	5.68	5.31	5.49	5.44	5.36	5.40	5.15	5.14	5.15	5.01	5.14	5.07	5.28	5.11	5.20
S. Em. ±	0.17	0.22	0.14	0.17	0.13	0.10	0.12	0.13	0.09	0.21	0.17	0.13	0.15	0.14	0.10	0.21	0.15	0.12
C.D. at 5%	NS	NS	NS	0.50	0.38	0.29	0.34	0.39	0.25	0.62	0.49	0.38	0.43	0.42	0.29	0.61	0.43	0.35
C. Interaction																		
V x T																		
S. Em. ±	0.35	0.43	0.27	0.34	0.26	0.21	0.23	0.27	0.17	0.42	0.33	0.26	0.28	0.29	0.20	0.41	0.30	0.24
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y x T																		
S. Em. ±			0.23			0.17			0.15			0.22			0.17			0.21
C.D. at 5%			NS			NS			NS			NS			NS			NS
C.V.%	15.7	20.2	18.0	11.1	9.28	10.3	8.68	9.93	9.32	16.3	13.0	14.8	11.5	11.4	11.4	15.6	11.5	13.8

at harvest (3.86) wherein the ratio in untreated control was 5.13, 5.17 and 5.30, respectively.

The data on height to node ratio amongst the hybrids showed that Vikram 5 (BG-II) had significantly lower ratio than rest of the hybrids at all the stages during both the years and in pooled analysis. G. Cot Hy-12 exhibited the highest ratio at all the stages.

None of the interactions were found significant for height to node ratio at any of the crop growth stages during both the years.

4.3 FRUIT PRODUCTION

4.3.1 Number of Squares per plant

The data on number of squares plant^{-1} recorded at periodical interval as influenced by foliar application growth regulators is presented in **Table-4.11** and figure 4.9

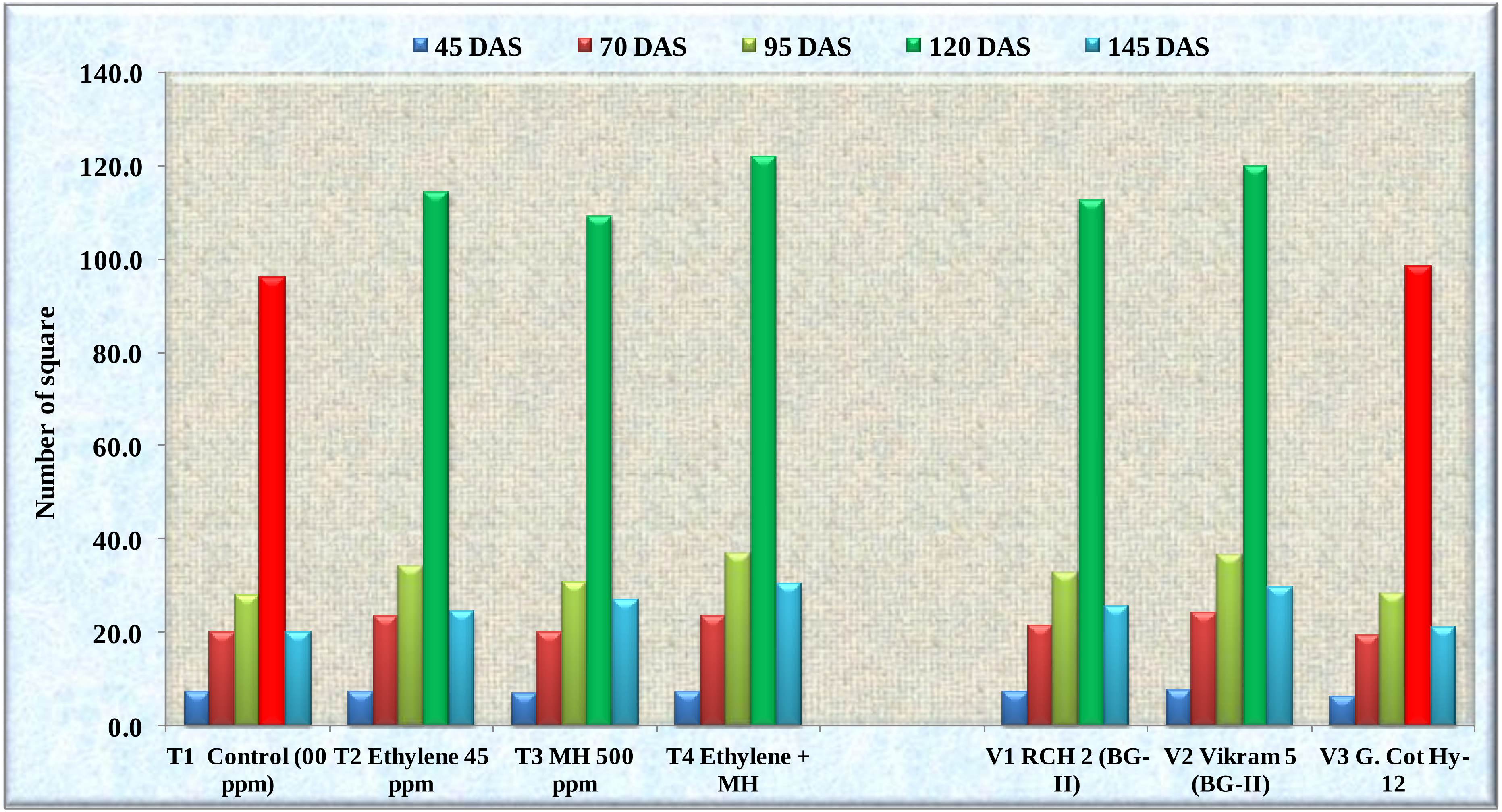
In general, number of squares increased up to 120 DAS and decreased afterwards during both the years and in pooled.

The data **(Table-4.11)** revealed that foliar application of Ethylene (45 ppm) at squaring stage (T_2) resulted in more number of squares plant^{-1} depicting significant increase (23.4) over untreated control (20.1) at 70 DAS and maintained similar trend till harvest. Application of 500 ppm MH (T_3) at 85 DAS also had increasing effect on number of squares at 120 (108.9) and 145 DAS (26.9) was significantly higher than control *i.e.* 96.0 and 20.2, respectively. Application of Ethylene at squaring stage followed by MH at 85 DAS (T_4) had supplemental effect on the production of squares which recorded greater number at 95 (37.0), 120 (121.7) and 145 DAS (30.3) over Ethylene and MH alone. This increase was however significant over MH and at par with Ethylene.

Table 4.11: Effect of Ethylene and MH on Number of squares at different growth stages in cotton hybrids

	45 DAS			70 DAS			95 DAS			120 DAS			145 DAS		
	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled
A. Treatments (T)															
T_1 - Control (00 ppm)	7.30	7.15	7.22	19.2	21.0	20.1	27.3	28.9	28.1	92.4	99.6	96.0	19.2	21.2	20.2
T_2 - Ethylene 45 ppm	7.04	7.37	7.21	21.9	24.8	23.4	33.4	35.4	34.4	111.6	117.3	114.4	24.3	24.7	24.5
T_3 - MH 500 ppm	7.08	6.81	6.95	18.7	21.2	20.0	30.5	30.8	30.7	105.8	112.0	108.9	24.9	28.8	26.9
T_4 - $T_2 + T_3$	7.33	6.96	7.15	22.2	24.7	23.5	35.4	38.7	37.0	118.9	124.4	121.7	28.4	32.3	30.3
S. Em. ±	0.35	0.44	0.28	0.89	1.03	0.66	1.37	1.43	0.97	3.80	4.10	2.70	1.43	1.16	0.92
C.D. at 5%	NS	NS	NS	2.60	3.03	1.88	4.01	4.19	2.76	11.16	12.01	7.70	4.18	3.41	2.62
B. Variety (V)															
V_1 - RCH 2 (BG-II)	8.08	6.67	7.38	20.7	22.5	21.6	32.2	33.3	32.7	108.6	116.3	112.4	24.4	26.5	25.5
V_2 - Vikram 5 (BG-II)	7.11	8.17	7.64	22.9	25.2	24.1	35.4	37.7	36.6	115.7	124.1	119.9	27.1	32.5	29.8
V_3 - G. Cot Hy-12	6.36	6.39	6.38	17.9	21.1	19.5	27.3	29.4	28.4	97.2	99.6	98.4	21.1	21.3	21.2
S. Em. ±	0.31	0.38	0.62	0.77	0.90	0.58	1.18	1.24	0.84	3.29	3.55	2.39	1.23	1.01	0.82
C.D. at 5%	0.90	1.12	NS	2.25	2.63	1.65	3.47	3.63	2.39	9.66	10.40	6.81	3.62	2.96	2.35
C. Interaction															
V x T															
S. Em. ±	0.61	0.76	0.48	1.53	1.79	1.13	2.37	2.47	1.63	6.59	7.09	4.68	2.47	2.02	1.58
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y x T															
S. Em. ±			0.40			0.96			1.40			3.95			1.30
C.D. at 5%			NS			NS			NS			NS			NS
C.V.%	14.7	18.7	16.8	13.0	13.5	13.3	13.0	12.8	12.9	10.7	10.8	10.7	17.7	13.1	15.3

Fig. 4.9: Effect of Ethylene and MH on Number of squares at different growth stages in cotton hybrids



The differences in number of squares amongst the hybrids were found significant at all the stages of crop growth during both the years and in pooled. Vikram 5 (BG-II) recorded the highest number of squares per plant however, which was significantly more than RCH 2 (BG-II) and G. Cot Hy-12. Minimum number of squares was recorded in G. Cot Hy-12 at all the stages of crop growth during the both year.

The interaction effect between growth regulators with hybrids on number of square at all growth stages were found not significant during both the years.

4.3.2 Number of flowers per plant

The data on number of flowers plant^{-1} recorded at periodical interval as influenced by growth modifiers and hybrids is presented in **Table- 4.12** and graphically depicted in Figure 4.10

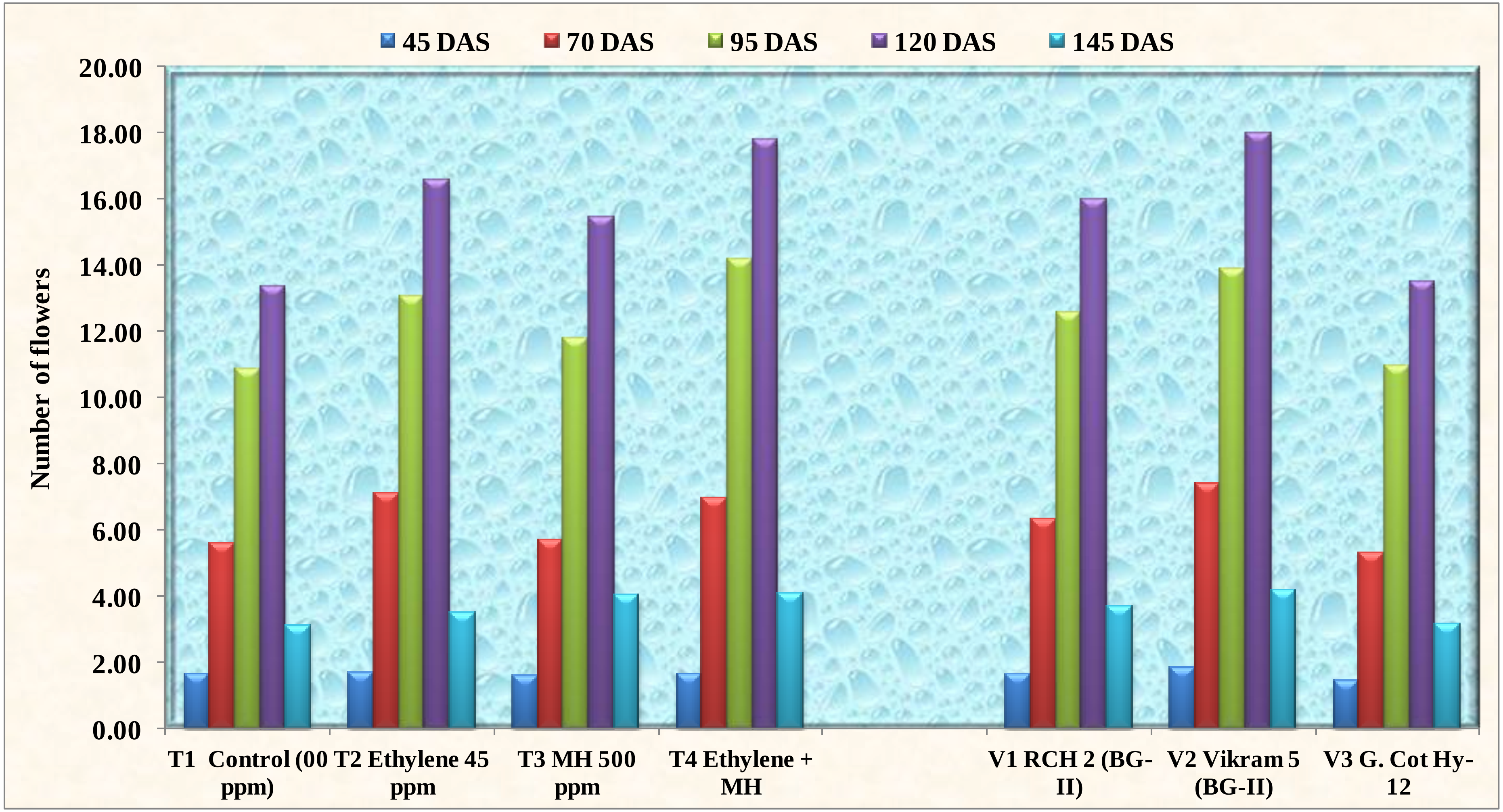
In general, numbers of flowers plant^{-1} increased up to 120 DAS and decreased thereafter during both the years.

The data **(Table-4.12)** indicated that foliar application of Ethylene (T_2) at squaring stage resulted in significantly greater number of flowers plant^{-1} (7.12) over control (5.61) at 70 DAS which was maintained till 145 DAS. Application of MH at 85 DAS (T_3) also resulted in significantly greater number of flowers plant^{-1} at 120 (15.5) and 145 DAS (4.06) over 13.4 and 3.13, respectively in the control. Application of Ethylene at squaring stage followed by MH at 85 DAS (T_4) had supplemental effect on number of flowers which showed the highest number of flowers at 95 DAS till end over Ethylene and MH alone. This increase was however significant over MH and at par with Ethylene at 95 and 120 DAS. After 120 DAS, a decline in number of flowers was observed at 145 DAS in both the years.

Table 4.12: Effect of Ethylene and MH on Number of flowers at different growth stages in cotton hybrids

	45 DAS			70 DAS			95 DAS			120 DAS			145 DAS		
	2011-12	**2012-13**	**Pooled**	**2011-12**	**2012-13**	**Pooled**	**2011-12**	**2012-13**	**Pooled**	**2011-12**	**2012-13**	**Pooled**	**2011-12**	**2012-13**	**Pooled**
A. Treatments (T)															
T_1 - Control (00 ppm)	1.67	1.66	1.67	5.00	6.22	5.61	10.1	11.6	10.9	13.1	13.6	13.4	3.19	3.07	3.13
T_2 - Ethylene 45 ppm	1.74	1.63	1.69	6.51	7.73	7.12	12.4	13.7	13.1	16.4	16.9	16.6	3.53	3.48	3.51
T_3 - MH 500 ppm	1.70	1.48	1.59	5.22	6.19	5.70	11.2	12.4	11.8	15.3	15.7	15.5	4.00	4.11	4.06
T_4 - $T_2 + T_3$	1.52	1.81	1.67	6.70	7.29	7.00	13.6	14.8	14.2	17.3	18.2	17.8	4.00	4.19	4.09
S. Em. ±	0.11	0.09	0.07	0.32	0.30	0.21	0.54	0.54	0.37	0.64	0.66	0.45	0.16	0.18	0.12
C.D. at 5%	NS	NS	NS	0.93	0.88	0.61	1.59	1.58	1.05	1.89	1.95	1.28	0.46	0.53	0.33
B. Variety (V)															
V_1 - RCH 2 (BG-II)	1.64	1.67	1.65	6.00	6.69	6.34	12.0	13.2	12.6	15.5	16.4	16.0	3.72	3.67	3.70
V_2 - Vikram 5 (BG-II)	1.89	1.83	1.86	6.55	8.25	7.40	13.2	14.6	13.9	17.8	18.2	18.0	4.10	4.31	4.20
V_3 - G. Cot Hy-12	1.45	1.44	1.44	5.03	5.64	5.33	10.4	11.6	11.0	13.2	13.8	13.5	3.22	3.16	3.19
S. Em. ±	0.10	0.08	0.06	0.27	0.26	0.19	0.47	0.47	0.32	0.56	0.58	0.39	0.14	0.16	0.10
C.D. at 5%	0.29	0.22	0.18	0.81	0.76	0.54	1.38	1.37	0.92	1.63	1.69	1.11	0.40	0.46	0.29
C. Interaction															
V x T															
S. Em. ±	0.20	0.15	0.12	0.55	0.52	0.37	0.94	0.93	0.63	1.11	1.15	0.75	0.27	0.31	0.21
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y x T															
S. Em. ±			0.10			0.31			0.54			0.65			0.17
C.D. at 5%			NS			NS			NS			NS			NS
C.V.%	20.4	15.9	18.4	16.2	13.1	14.5	13.8	12.4	13.0	12.4	12.3	12.4	12.8	14.6	13.7

Fig. 4.10: Effect of Ethylene and MH on Number of flowers at different growth stages in cotton hybrids



The differences in number of flowers $plant^{-1}$ amongst the hybrids were found significant at all the stages of crop growth in individual years as well as in pooled. The data revealed that Vikram 5 (BG-II) recorded the maximum number of flowers $plant^{-1}$ which was significantly more than G. Cot Hy-12 and RCH 2 (BG-II) at all the stages. G. Cot Hy-12 recorded minimum number of flowers $plant^{-1}$ at all the growth stages of crop.

None of the interactions of growth regulators with cotton hybrids were found significant at any of the growth stages of crop.

4.3.3 Number of green bolls per plant

The data on mean number of green bolls $plant^{-1}$ recorded at periodical interval as influenced by plant growth regulators and hybrids is presented in **Table 4.13** and graphically depicted in Figure 4.11

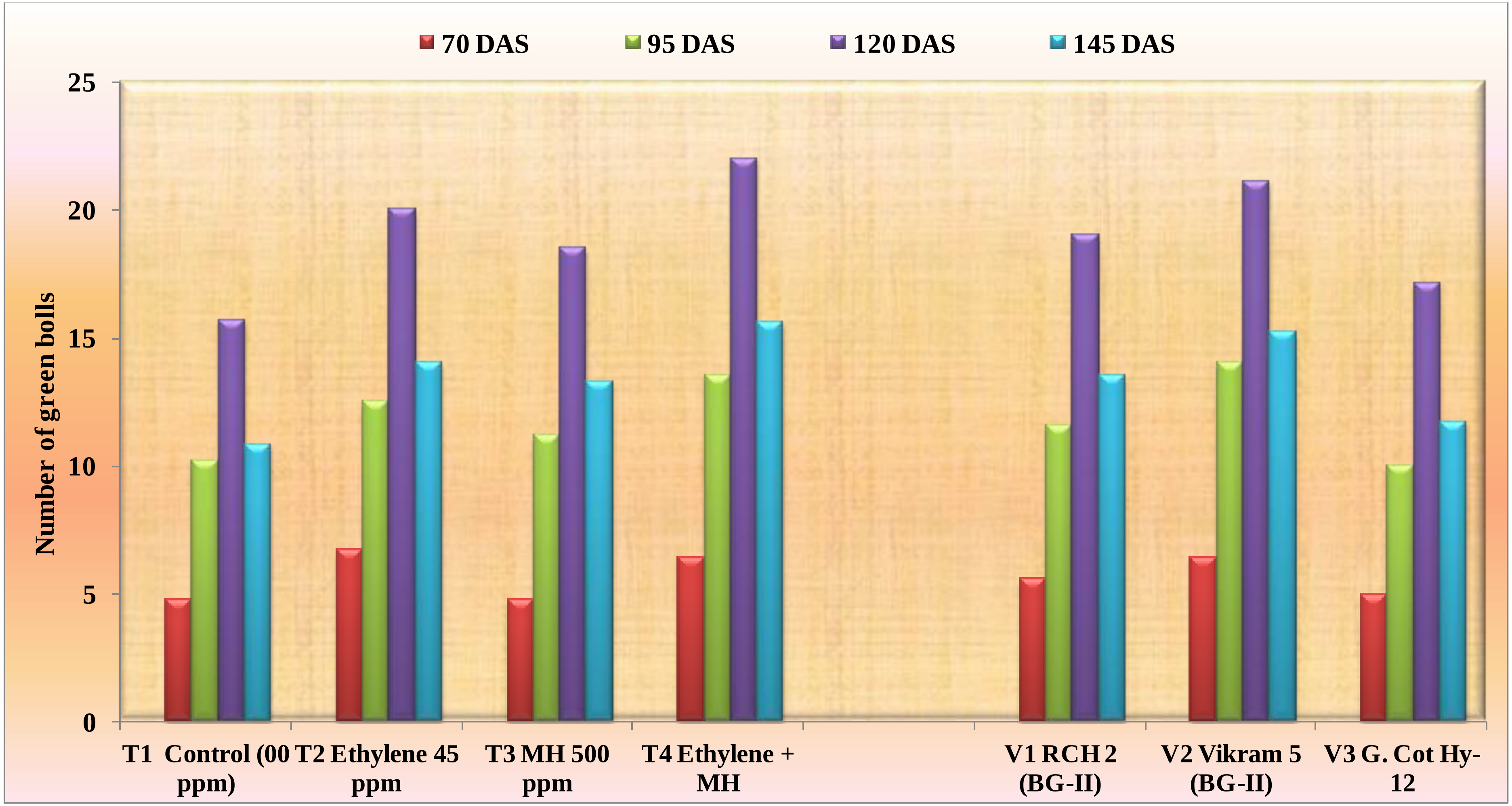
In general, the number of green bolls was increased from 70 to 120 DAS and decreased thereafter during both the years.

The differences in number of green bolls $plant^{-1}$ due to growth regulators were found significant in both the years as well as in pooled analysis. The data **(Table-4.13)** indicated that foliar application of Ethylene (T_2) at squaring stage recorded higher number of green bolls $plant^{-1}$ (6.70) at 70 DAS over control (4.72) and this trend was maintained till end. MH application (T_3) at 85 DAS also had positive effect on the number of green bolls at 95 (11.2), 120 (18.5) and 145 DAS (13.3) and recorded significantly more green bolls than those in untreated control (10.2, 15.7 and 10.8, respectively). Application of Ethylene at squaring stage followed by MH at 85 DAS (T_4) had synergetic effect on production of bolls

Table 4.13: Effect of Ethylene and MH on Number of green bolls at different growth stages in cotton hybrids

	70 DAS			95 DAS			120 DAS			145 DAS		
	2011-12	**2012-13**	**Pooled**	**2011-12**	**2012-13**	**Pooled**	**2011-12**	**2012-13**	**Pooled**	**2011-12**	**2012-13**	**Pooled**
A. Treatments (T)												
T_1 - Control (00 ppm)	4.48	4.96	4.72	9.78	10.6	10.2	14.8	16.7	15.7	10.1	11.6	10.8
T_2 - Ethylene 45 ppm	5.93	7.47	6.70	12.0	13.0	12.5	19.0	21.0	20.0	13.7	14.3	14.0
T_3 - MH 500 ppm	4.37	5.11	4.74	10.7	11.6	11.2	17.4	19.6	18.5	12.1	14.4	13.3
T_4 - $T_2 + T_3$	5.67	7.09	6.38	12.9	14.1	13.5	20.8	23.2	22.0	14.5	16.8	15.6
S. Em. ±	0.25	0.34	0.21	0.41	0.39	0.28	0.61	0.75	0.47	0.56	0.59	0.41
C.D. at 5%	0.74	0.99	0.60	1.20	1.17	0.80	1.80	2.20	1.33	1.65	1.73	1.15
B. Variety (V)												
V_1 - RCH 2 (BG-II)	4.97	6.13	5.55	10.9	12.2	11.6	17.7	20.3	19.0	12.6	14.4	13.5
V_2 - Vikram 5 (BG-II)	5.81	7.00	6.40	13.6	14.4	14.0	20.0	22.2	21.1	14.5	15.9	15.2
V_3 - G. Cot Hy-12	4.56	5.33	4.94	9.56	10.4	10.0	16.3	17.9	17.1	10.7	12.6	11.7
S. Em. ±	0.22	0.29	0.18	0.36	0.34	0.25	0.53	0.65	0.41	0.49	0.51	0.35
C.D. at 5%	0.64	0.85	0.52	1.04	1.02	0.70	1.56	1.91	1.18	1.42	1.50	0.98
C. Interaction												
V x T												
S. Em. ±	0.44	0.58	0.37	0.71	0.69	0.48	1.06	1.30	0.82	0.97	1.02	0.67
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y x T												
S. Em. ±			0.30			0.40			0.69			0.58
C.D. at 5%			NS			NS			NS			NS
C.V.%	14.9	16.4	15.9	10.9	9.57	10.3	10.2	11.2	10.8	13.4	12.4	12.9

Fig.4.11: Effect of Ethylene and MH on Number of green bolls at different growth stages in cotton hybrids



which recorded greater number of green bolls plant^{-1} at 95, 120 and 145 DAS. This was significant over Ethylene and MH.

The data indicated that differences in number of green bolls amongst the hybrids were found significant at all the stages of crop growth in individual years and in pooled. Vikram 5 (BG-II) exhibited more number of green bolls which was significantly higher than those in G. Cot Hy-12 at and RCH 2 (BG-II) at 70, 95, 120 and 145 DAS. G. Cot Hy-12 recorded minimum number of green bolls at all the stages of crop growth.

The interaction of growth regulators with hybrids for number of green bolls was found to be not significant at all the stages during both years and in pooled.

4.4 BIOCHEMICAL STUDIES

4.4.1 Chlorophyll content (mg g^{-1})

The data on chlorophyll content (mg g^{-1}) recorded periodically in different hybrids treated with growth regulators are presented in **Table 4.14** and graphically depicted in Figure 4.12

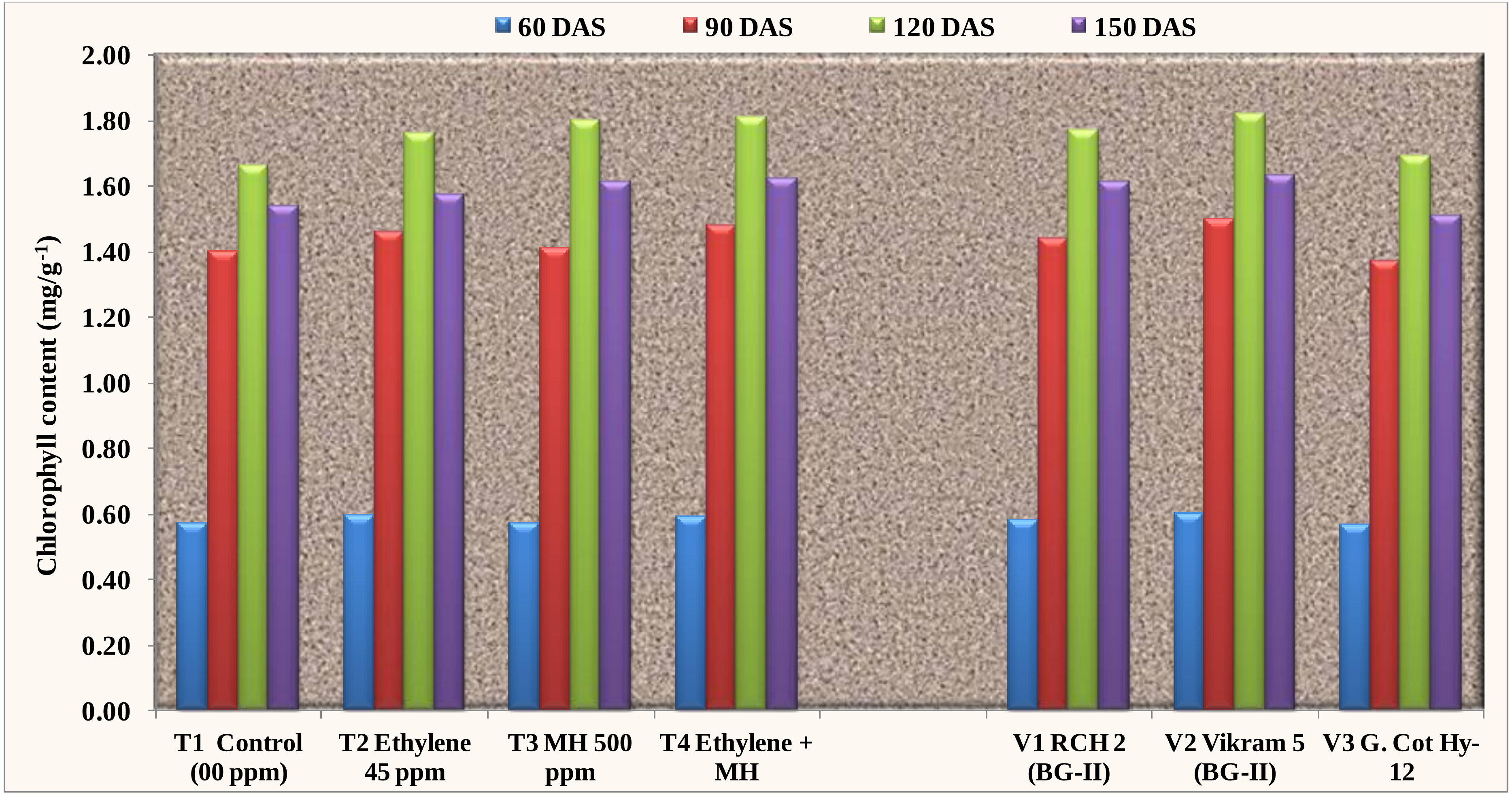
It appears from the data that, in general, the chlorophyll content increased from 0.579 at 60 DAS to 1.76 mg g^{-1} at 120 DAS and declined thereafter. The rate of increase was the highest from 60 DAS to 90 DAS during both the years.

Use of growth modifiers *i.e.*, Ethylene 45 ppm and MH 500 ppm significantly influenced chlorophyll content in both the years as well as in pooled. A perusal of the data indicated (**Table-4.14)** that foliar application of Ethylene at squaring stage (T_2) significantly increased chlorophyll content (0.594 mg g^{-1}) over control (0.567 mg g^{-1}) at 60 DAS and this

Table 4.14: Effect of Ethylene and MH on Chlorophyll content (mg/g^{-1}) at different growth stages in cotton hybrids

	60 DAS			90 DAS			120 DAS			150 DAS		
	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled
A. Treatments (T)												
T_1 - Control (00 ppm)	0.544	0.590	0.567	1.39	1.40	1.40	1.66	1.67	1.66	1.53	1.56	1.54
T_2 - Ethylene 45 ppm	0.573	0.614	0.594	1.44	1.48	1.46	1.76	1.77	1.76	1.56	1.57	1.57
T_3 - MH 500 ppm	0.553	0.582	0.567	1.40	1.43	1.41	1.79	1.82	1.80	1.60	1.62	1.61
T_4 - $T_2 + T_3$	0.561	0.619	0.590	1.46	1.50	1.48	1.79	1.84	1.81	1.61	1.62	1.62
S. Em. ±	0.007	0.008	0.005	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.01
C.D. at 5%	0.021	0.023	0.015	0.06	0.07	0.04	0.06	0.08	0.05	0.06	0.05	0.04
B. Variety (V)												
V_1- RCH 2 (BG-II)	0.560	0.597	0.579	1.41	1.46	1.44	1.76	1.78	1.77	1.58	1.63	1.61
V_2-Vikram 5 (BG-II)	0.570	0.624	0.597	1.48	1.52	1.50	1.80	1.85	1.82	1.62	1.65	1.63
V_3- G. Cot Hy-12	0.543	0.583	0.563	1.37	1.38	1.37	1.70	1.69	1.69	1.53	1.49	1.51
S. Em. ±	0.006	0.007	0.005	0.02	0.02	0.01	0.02	0.02	0.01	0.02	0.02	0.01
C.D. at 5%	0.018	0.020	0.013	0.05	0.06	0.04	0.05	0.07	0.04	0.05	0.05	0.03
C. Interaction												
V x T												
S. Em. ±	0.012	0.014	0.010	0.03	0.04	0.03	0.04	0.05	0.03	0.04	0.03	0.02
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y x T												
S. Em. ±			0.007			0.02			0.02			0.02
C.D. at 5%			NS			NS			NS			NS
C.V.%	3.79	3.96	3.88	3.98	5.11	4.59	3.51	4.43	4.01	4.00	3.42	3.72

Fig. 4.12: Effect of Ethylene and MH on Chlorophyll content (mg/g^{-1}) at different growth stages in cotton hybrids



trend was maintained at upto120 DAS after which the increase was not significant. Application of MH at 85 DAS (T_3) also reflected increased in chlorophyll content at 120 (1.80 mg g^{-1}) and 150 DAS (1.61 mg g^{-1}) over control (1.66 and 1.54 mg g^{-1}, respectively). Additive effect of MH with Ethylene (T_4) was observed on chlorophyll content particularly at 90 and 120 DAS. The chlorophyll content in this treatment was 1.48 and 1.81 mg g^{-1} against 1.41 and 1.80 mg g^{-1} in MH and 1.46 and 1.76 mg g^{-1} in Ethylene at 90 and 120 DAS, respectively. Effect of MH with or without Ethylene was more pronounced in later crop stage.

Differences in chlorophyll content amongst the hybrids were found significant at all the stages during both the years as well as in pooled. The data indicated (**Table 4.14)** that Vikram 5 (BG-II) recorded significantly the highest chlorophyll content at 60 (0.597 mg g^{-1}), 90 (1.50 mg g^{-1}) and 120 (1.82 mg g^{-1}) DAS followed by RCH 2 (BG-II). Lowest chlorophyll content was observed in G. Cot Hy-12 at all the stages of crop growth.

None of the interactive effect of growth regulators and cotton hybrids was found to be significant.

4.4.2 Reducing Sugars (µ/g g fresh wt)

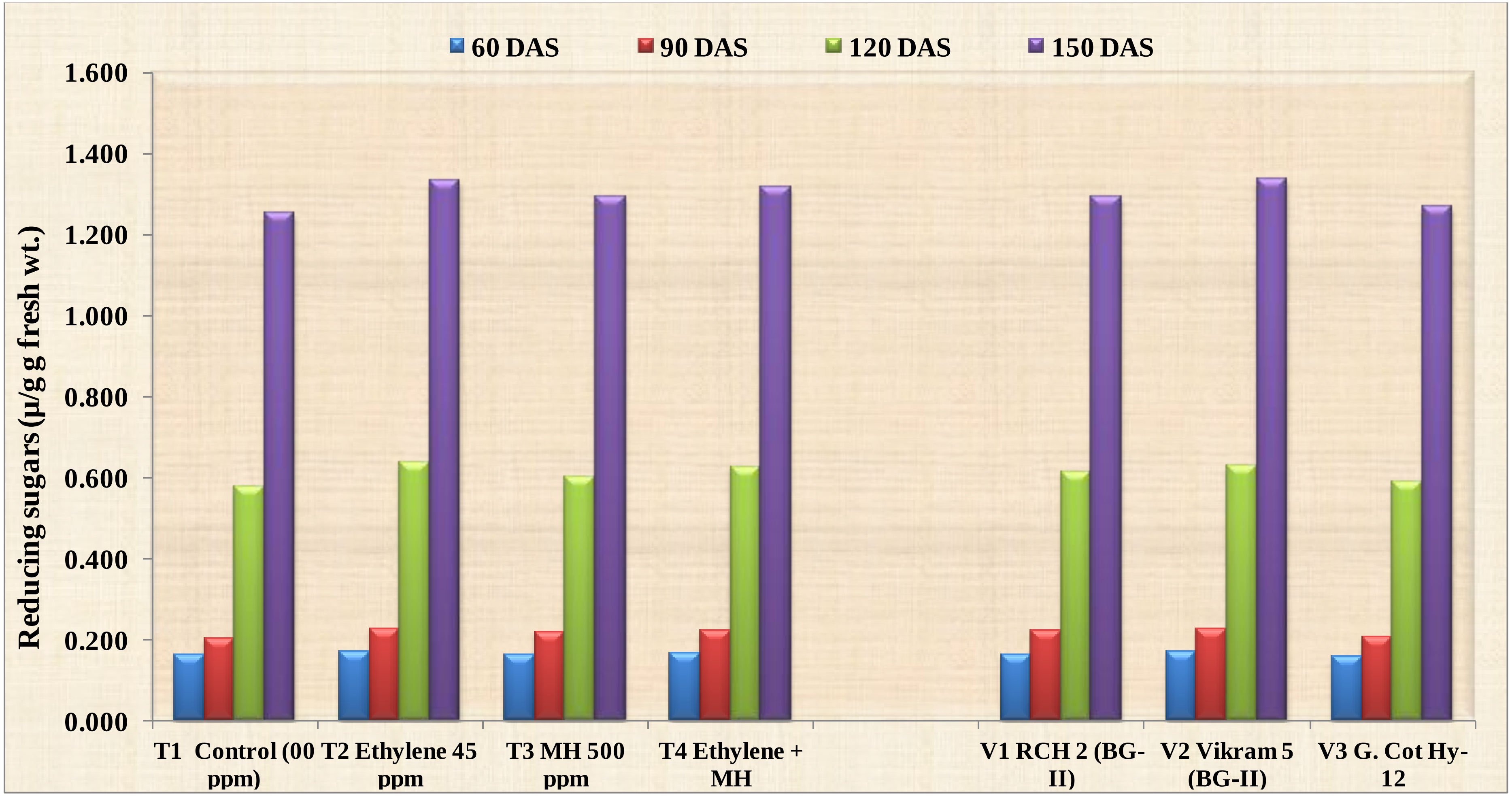
The reducing sugars content in the leaves registered significant changes due to growth regulators and hybrids in individual years as well as in pooled. The data is presented in **Table 4.15** and graphically depicted in figure 4.13 indicated that average reducing sugar content increased from 0.163 at 60 DAS to 1.298 µ/g g fresh wt. at 150 DAS.

The data indicated that foliar application of Ethylene (T_2) at squaring stage significantly increased reducing sugars content (0.168 µ/g g fresh wt.) over control (0.160 µ/g g fresh

Table 4.15: Effect of Ethylene and MH on Reducing sugar (µ/g g fresh wt.) at different growth stages in cotton hybrids

	60 DAS			90 DAS			120 DAS			150 DAS		
	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled
A. Treatments (T)												
T_1 - Control (00 ppm)	0.152	0.167	0.160	0.203	0.204	0.203	0.669	0.489	0.579	1.444	1.058	1.251
T_2 - Ethylene 45 ppm	0.159	0.177	0.168	0.229	0.225	0.227	0.738	0.539	0.638	1.519	1.147	1.333
T_3 - MH 500 ppm	0.154	0.166	0.160	0.214	0.219	0.217	0.696	0.507	0.602	1.481	1.104	1.293
T_4 - $T_2 + T_3$	0.158	0.174	0.166	0.224	0.222	0.223	0.721	0.525	0.623	1.498	1.139	1.315
S. Em. ±	0.002	0.003	0.002	0.004	0.005	0.003	0.007	0.008	0.006	0.016	0.018	0.012
C.D. at 5%	0.005	0.008	0.005	0.011	0.014	0.008	0.021	0.025	0.016	0.048	0.054	0.035
B. Variety (V)												
V_1- RCH 2 (BG-II)	0.155	0.170	0.162	0.218	0.224	0.221	0.711	0.519	0.615	1.472	1.111	1.292
V_2-Vikram 5 (BG-II)	0.160	0.178	0.169	0.226	0.222	0.224	0.718	0.539	0.628	1.520	1.151	1.335
V_3- G. Cot Hy-12	0.153	0.164	0.159	0.208	0.206	0.207	0.689	0.488	0.589	1.459	1.074	1.267
S. Em. ±	0.002	0.002	0.001	0.003	0.004	0.003	0.006	0.007	0.005	0.014	0.016	0.011
C.D. at 5%	0.004	0.007	0.004	0.009	0.012	0.007	0.018	0.021	0.014	0.042	0.047	0.030
C. Interaction												
V x T												
S. Em. ±	0.003	0.005	0.003	0.006	0.008	0.005	0.013	0.015	0.010	0.028	0.032	0.020
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y x T												
S. Em. ±			0.002			0.004			0.008			0.017
C.D. at 5%			NS			NS			NS			NS
C.V.%	3.25	4.71	4.11	4.93	6.31	5.65	3.06	4.91	3.84	3.29	4.94	4.00

Fig. 4.13: Effect of Ethylene and MH on reducing sugars (µ/g g fresh wt.) at different growth stages in cotton hybrids



wt.) at 60 DAS and this trend was continued untill 150 DAS. Application of MH at 85 DAS (T_3) also increased reducing sugars over control at 90 DAS and onward. Application of Ethylene at squaring stage followed by MH at 85 DAS (T_4) also showed enhanced reducing sugars content at 90 (0.223 µ/g g fresh wt.), 120 (0.623 µ/g g fresh wt.) and 150 DAS (1.315 µ/g g fresh wt.) over control however, the enhancement was not significant over Ethylene.

Amongst the hybrids, Vikram 5 (BG-II) recorded higher reducing sugars than RCH 2 (BG-II) and G. Cot Hy-12. Lowest reducing sugars content was recorded in G. Cot Hy-12 at all the growth stages.

The interaction between growth regulators treatment and hybrids was found not significant at all the stages of crop.

4.5 CROP PHENOLOGICAL CHARACTERS

4.5.1 Days to 50 per cent squaring

4.5.2 Days to 50 per cent flowering

4.5.3 Days to 50 per cent bolls bursting and maturity

The data on number of days to 50 per cent squaring, 50 per cent flowering, 50 per cent boll bursting and maturity are presented in **Table-4.16**

The data indicated that application of Ethylene at the time of square initiation and Maleic hydrazide at 85 DAS had no significant effect on 50 per cent squaring as well as 50 per cent flowering. Marginal effect on days to 50 per cent flowering was observed due to Ethylene application. Days required for 50 per cent boll bursting and maturity were significantly affected by both the chemicals. The days were significantly reduced by application of Ethylene (111,169

Table 4.16: Effect of Ethylene and MH on Crop phenological stages in cotton hybrids

	Days to 50 % Squaring			Days to 50 % Flowering			Days to 50 % Boll bursting			Maturity		
	2011-12	**2012-13**	**Pooled**	**2011-12**	**2012-13**	**Pooled**	**2011-12**	**2012-13**	**Pooled**	**2011-12**	**2012-13**	**Pooled**
A. Treatments (T)												
T_1 - Control (00 ppm)	47.7	48.0	47.8	74.4	74.2	74.3	120	119	119	176	172	174
T_2 - Ethylene 45 ppm	47.8	47.6	47.7	75.8	76.4	76.1	111	111	111	169	168	169
T_3 - MH 500 ppm	47.4	47.3	47.4	74.3	74.3	74.3	126	127	126	188	193	190
T_4 - $T_2 + T_3$	47.6	48.1	47.8	76.2	76.0	76.1	123	123	123	179	182	181
S. Em. ±	1.41	1.46	0.98	1.78	1.88	1.25	2.6	2.5	1.7	4.3	5.8	3.6
C.D. at 5%	NS	NS	NS	NS	NS	NS	7.6	7.2	4.9	12.7	17.0	10.3
B. Variety (V)												
V_1 - RCH 2 (BG-II)	46.8	47.6	47.2	73.4	74.1	73.8	115	116	115	172	171	172
V_2 - Vikram 5 (BG-II)	47.3	47.2	47.2	74.5	74.2	74.3	118	118	118	176	176	176
V_3 - G. Cot Hy-12	48.8	48.5	48.7	77.7	77.5	77.6	127	126	126	186	189	188
S. Em. ±	1.22	1.26	0.86	1.54	1.62	1.09	2.2	2.1	1.5	3.8	5.0	3.1
C.D. at 5%	NS	NS	NS	NS	NS	3.12	6.6	6.3	4.3	11.0	14.7	8.9
C. Interaction												
V x T												
S. Em. ±	2.44	2.53	1.64	3.08	3.25	2.11	4.5	4.3	2.9	7.5	10.0	5.8
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y x T												
S. Em. ±			1.43			1.83			2.5			5.11
C.D. at 5%			NS			NS			NS			NS
C.V.%	8.88	9.16	9.02	7.09	7.48	7.29	6.47	6.18	6.33	7.3	9.7	8.6

days) over control (119,174 days) whereas, MH significantly enhanced the same (126, 190 days), respectively.

The differences in average days to 50 per cent squaring of hybrids RCH 2 (BG-II), Vikram 5 (BG-II) and G. Cot Hy-12 were found not significant. Pooled results indicated that days required for 50 per cent flowering were significantly higher in not-*Bt* hybrids G. Cot Hy-12 versus *Bt* hybrids Vikram 5 (BG-II) and RCH 2 (BG-II), the latter two were statistically at par.

An identical trend was observed in days required for 50 per cent bolls bursting and maturity wherein G. Cot Hy-12 required significantly more days than the two *Bt* hybrids which were at par. Minimum days required for 50 per cent bolls bursting and maturity was required in RCH 2 (BG-II).

None of the interactions of plant growth regulators with hybrids was found to be significant during both the years and in pooled analysis with respect to days to 50 per cent squaring, 50 per cent flowering, 50 per cent boll bursting and maturity.

4.6 MORPHO-PHENOLOGAL EVENTS

4.6.1 Morpho-phenological events based on growing degree days (G.D.D^{o}C)

In the present study, the whole life cycle of cotton hybrids from sowing to physiological maturity was divided into four distinct phenological stages *viz.*, squaring, flowering, boll bursting and maturity. Agro-meteorological indices like growing degree days (GDD) and heliothermal unit (HTU) required for attainment of phenophases of cotton cultivars under variable weather conditions calculated are presented in **Table.4.17**

Effect of application of Ethylene at squaring stage and MH at 85 DAS had no significant bearing on growing degree days required for emergence to 50 per cent squaring and emergence to 50 per cent flowering in individual years as well as in pooled. However, G.D.D. required from emergence to 50 per cent boll bursting was significantly affected.

Ethylene application at squaring (T_2) required significantly less degree days for 50 per cent boll bursting (1417°C) and maturity (2019°C) than untreated control (1521 and 2126°C, respectively). MH application at 85 DAS (T_3) required significantly more degree days for 50 per cent boll bursting (1602°C) and maturity (2249°C). Application of Ethylene followed by MH (T_4) increased requirement of degree days for 50 per cent boll bursting (1563) and maturity (2150°C) over Ethylene but decreased over MH.

It is evident from the pooled data **(Table-4.17)**, that on an average the cotton hybrids required 575°C days for emergence to 50 per cent squaring, 926°C days for emergence to 50 per cent flowering, 1525°C days for emergence 50 per cent boll bursting and 2136°C days for emergence to maturity.

The pooled data indicated that growing degree days (GDD) required for morpho-phenological events differed significantly amongst cotton hybrids, except for emergence to 50 per cent squaring. RCH 2 (BG-II) and Vikram 5 (BG-II) required less degree days to attain a definite stage of growth and development, compared to G. Cot Hy-12 during both the years and in pooled. The later required 1601 and 2243°C days to attain 50 per cent boll bursting and maturity respectively, as compared to 1472 and 2055°C degree days of RCH 2(BG-II) for the similar events.

Table 4.17: Effect of Ethylene and MH on Growing degree days (GDD) at different stages in cotton hybrids

	Emergence to 50 % squaring			Emergence to 50 % flowering			Emergence to 50 % Boll bursting			Emergence to maturity		
	2011-12	**2012-13**	**Pooled**	**2011-12**	**2012-13**	**Pooled**	**2011-12**	**2012-13**	**Pooled**	**2011-12**	**2012-13**	**Pooled**
A. Treatments (T)												
T_1 - Control (00 ppm)	561	595	578	893	935	914	1517	1525	1521	2137	2115	2126
T_2 - Ethylene 45 ppm	562	589	576	911	965	938	1396	1438	1417	2005	2032	2019
T_3 - MH 500 ppm	558	586	572	892	937	914	1595	1609	1602	2264	2233	2249
T_4 - $T_2 + T_3$	558	596	577	916	959	937	1556	1571	1563	2167	2134	2150
S. Em. ±	17.5	19.7	12.8	22.6	24.6	16.2	34.1	26.6	21.6	59.9	46.8	36.9
C.D. at 5%	NS	NS	NS	NS	NS	NS	99.9	77.9	61.6	175.6	137.4	105.2
B. Variety (V)												
V_1 - RCH 2 (BG-II)	549	590	569	881	934	907	1452	1492	1472	2046	2063	2055
V_2 - Vikram 5 (BG-II)	555	584	569	894	934	914	1492	1518	1505	2127	2094	2111
V_3 - G. Cot Hy-12	575	602	588	934	978	956	1604	1597	1601	2257	2228	2243
S. Em. ±	15.2	17.1	11.2	19.5	21.3	14.2	29.5	23.0	18.5	51.8	40.6	32.3
C.D. at 5%	NS	NS	NS	NS	NS	40.3	86.6	67.4	52.6	152.1	119.0	92.1
C. Interaction												
V x T												
S. Em. ±	30.4	34.1	21.4	39.1	42.6	27.3	59.0	46.0	35.3	103.7	81.1	61.8
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y x T												
S. Em. ±			18.7			23.6			30.6			53.7
C.D. at 5%			NS			NS			NS			NS
C.V.%	9.40	9.99	9.72	7.49	7.79	7.65	6.74	5.19	6.01	8.38	6.60	7.55

The interaction effect between growth regulator treatments with hybrids was found not significant during both the years and pooled.

4.6.2 Morpho-phenological events based on heliothermal units (HTU^{o}C)

Data presented in **Table 4.18** revealed wide deviations in accumulation of heliothermal units (HTU) to reach a particular morpho-phenological stage between the two years. In general, the HTU accumulated during 2011-12 was more than three times those in 2012-13 due to long rainfall spell and over last skies during the latter.

The data revealed pronounced influence of growth regulators on heliothermal unit for boll bursting and maturity. The differences were significant during both the years and in pooled. Application of Ethylene (T_2) significantly required lowest heliothermal unit (HTU) for emergence to 50 per cent boll bursting (2954^{o}C) and emergence to maturity (6208^{o}C) over rest of the treatments whereas application of MH (T_3) required highest HTU *i.e.* 3732^{o}C day and 7297^{o}C for the same event to occur. Application of Ethylene + MH (T_4) recorded increased heliothermal unit for 50 per cent boll bursting and maturity over control and Ethylene.

Cotton hybrids differed significantly in accumulation of heliothermal units to attain a definite stage of growth and development during both the years as well as in pooled analysis. *Bt* hybrids RCH 2 (BG-II) and Vikram 5 (BG-II) recorded significantly lower heliothermal units for 50 per cent boll bursting (3170 and 3350^{o}C) and maturity (6353 to 6582^{o}C) compared to G. Cot Hy-12 (3783 to 7165^{o}C).

Different morpho-phenological events based on heliothermal units were not influenced significantly due to

Table 4.18: Effect of Ethylene and MH on Heliothermal unit (HTU) at different stages in cotton hybrids

	Emergence to 50 % Boll bursting			Emergence to maturity		
	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled
A. Treatments (T)						
T_1 - Control (00 ppm)	5236.4	1648.1	3442.3	9753.8	3228.79	6491.3
T_2 - Ethylene 45 ppm	4429.6	1478.6	2954.1	9376.6	3039.36	6208.0
T_3 - MH 500 ppm	5701.2	1761.8	3731.5	10188.3	4404.95	7296.6
T_4 - $T_2 + T_3$	5477.6	1741.8	3609.7	9840.5	3768.26	6804.4
S. Em. ±	313.3	57.8	159.3	190.8	318.39	185.6
C.D. at 5%	919.0	169.6	454.4	559.6	933.86	529.3
B. Variety (V)						
V_1 - RCH 2 (BG-II)	4765.6	1574.7	3170.2	9508.6	3197.65	6353.1
V_2 - Vikram 5 (BG-II)	5067.6	1632.4	3350.0	9732.7	3430.73	6581.7
V_3 - G. Cot Hy-12	5800.4	1765.7	3783.0	10128.2	4202.64	7165.4
S. Em. ±	271.3	50.1	138.0	165.2	275.73	160.7
C.D. at 5%	795.9	146.9	393.5	484.7	808.75	458.4
C. Interaction						
V x T						
S. Em. ±	542.7	100.2	215.2	330.5	551.47	239.9
C.D. at 5%	NS	NS	NS	NS	NS	NS
Y x T						
S. Em. ±			225.3			262.5
C.D. at 5%			NS			NS
C.V.%	14.0	12.5	13.3	12.4	11.0	11.8

interactions of growth regulators and hybrids during both the years and pooled.

4.7 YIELD AND YIELD CONTRIBUTING CHARACTERS

4.7.1 Number of bolls

The data on number of bolls plant^{-1}, boll weight (g), yield (g plant^{-1}), yield (kg ha^{-1}), biomass and partitioning efficiency (HI) as influenced by growth regulators was recorded at harvest and presented in **Table 4.19.**

The differences in number of bolls were found significant in both the years as well as in pooled. The data indicated that foliar application of Ethylene at squaring stage (T_2) and MH at 85 DAS (T_3) recorded significantly higher number of bolls plant^{-1} *i.e.*, 46.9 and 45.6, respectively than the untreated control (39.5) Application of both Ethylene at squaring and MH at 85 DAS (T_4) had supplemental effect on number of bolls which recorded the highest number of bolls (51.0 plant^{-1}) and significantly higher than MH, Ethylene as also the control.

The data on mean number of bolls harvested in the three hybrids during the two years and in pooled analysis is presented in **Table 4.19.** Vikram 5 (BG-II) recorded maximum (48.6) number of bolls which was at par with RCH 2 (BG-II) (47.0) but significantly higher than non-*Bt* G. Cot Hy-12 (41.6).

The interaction effect between growth regulators treatment and cotton hybrids for number of bolls was found not significant during both the years and in pooled.

4.7.2 Boll weight (g)

The data on mean boll weight (g) as influenced by growth regulators treatments is presented in **Table-4.19**

The data revealed that foliar application of Ethylene at squaring stage (T_2) and MH at 85 DAS (T_3) resulted in significantly higher boll weight (3.58 and 3.63g, respectively) than untreated control (3.29 g). Application of Ethylene at squaring stage followed by MH at 85 DAS (T_4) also resulted in higher boll weight (3.64 g) but without significant edge over Ethylene (T_2) or MH (T_3).

The differences in boll weight amongst the hybrids were found significant. Vikram 5 (BG-II) (3.64 g) recorded highest boll weight; RCH 2 (BG-II) was at par (3.61g) to it. Significantly low boll weight was observed in G. Cot Hy-12 (3.35 g).

None of the interaction between growth regulators and hybrids was found significant during both years and in pooled.

4.7.3 Yield per plant (g/plant)

The data on seed cotton yield (g plant^{-1}) as influenced by growth modifiers and hybrids is presented in **Table 4.19**.

The data revealed that growth regulator treatments on seed cotton yield were found to significantly influence yield plant^{-1} during both the years as well as in pooled. The data showed that application of Ethylene at squaring stage (T_2) and MH at 85 DAS (T_3) increased seed cotton yield by significant margin over control which was 167.4 g and 163.9 g, respectively, in the former two, against 131.7 g in the control. Application of Ethylene at squaring stage followed by MH at 85 DAS (T_4) further enhance seed cotton yield (183.5 g) over Ethylene or MH.

The differences in seed cotton yield in the three hybrids were found significant in individual years as well as in pooled. The data indicated that Vikram 5 (BG-II) recorded significantly highest seed cotton yield (175 g plant^{-1}) followed by RCH 2 (BG-II) (169 g plant^{-1}). Both were significantly higher than G. Cot Hy-12 (140.8 g plant^{-1}).

Interaction effect between growth regulators with hybrids was found not significant during both the years as well as in pooled.

4.7.4 Seed cotton yield (kg/ha)

The data on seed cotton yield (kg ha^{-1}) as influenced by plant growth regulators is presented in **Table 4.19**

The data indicated that foliar application of Ethylene and MH was found to significantly influence seed cotton yield during both the years and in pooled analysis. Application of Ethylene at squaring stage (T_2) and MH at 85 DAS (T_3) recorded significantly higher seed cotton yield of 2453 and 2400 kg ha^{-1}, respectively, over untreated control (2158 kg ha^{-1}). The former two were statistically at par. Application of Ethylene at squaring stage followed by MH at 85 DAS (T_4) had supplemental effect on seed cotton yield which was increased by significant margin (2645 kg ha^{-1}) over MH and Ethylene.

The differences in seed cotton yield amongst the hybrids were found significant in individual years as well as in pooled. Vikram 5 (BG-II) recorded the highest seed cotton yield (2645 kg ha^{-1}) which was significantly higher than RCH 2 (BG-II) (2482 kg ha^{-1}) as well as G. Cot Hy-12 (2115 kg). Thus lowest seed cotton yield was harvested in G. Cot Hy-12.

Interaction effects between growth regulators and hybrids was found not significant during both the years and in pooled.

4.7.5 Biomass (g/plant)

The data on mean biomass (g plant^{-1}) recorded at harvest as influenced growth regulators and hybrids is presented in **Table-4.19** and graphically depicted in Figure 4.14

The treatments receiving Ethylene and MH resulted in significant influence on mean biomass during both the years and in pooled. The data indicated that application of Ethylene (T_2), MH (T_3) and Ethylene + MH (T_4) significantly enhanced biomass production (301.1, 295.1 and 315.8 g plant^{-1}, respectively) over control (267.1g). Of the three treatments Ethylene at squaring stage + MH at 85 DAS recorded the highest biomass per plant which was significantly higher than MH and at par with Ethylene.

Amongst different hybrids, Vikram 5 (BG-II) recorded higher biomass (311.5 g plant^{-1}) which was significant over G. Cot Hy-12 (275.4g) and RCH 2 (BG-II) (297.5g).

The interaction between growth regulators and hybrids during both years and in pooled analysis was not significant.

4.7.6 Partitioning efficiency: Harvest index (%)

The data presented in **Table 4.19** indicated that application plant growth regulators did not exhibit significant effect on harvest index during individual years but in pooled analysis. Pooled results indicated that application of Ethylene at squaring stage (T_2), MH at 85 DAS (T_3) and Ethylene + MH (T_4) resulted in higher translocation *i.e.*, harvest index (35.7, 35.6 and 36.6, respectively) over untreated control (33.0). Highest harvest index was observed in Ethylene + MH treatment but was at par to Ethylene and MH.

Table 4.19: Effect of Ethylene and MH on Yield and Yield contributing characters in cotton hybrids

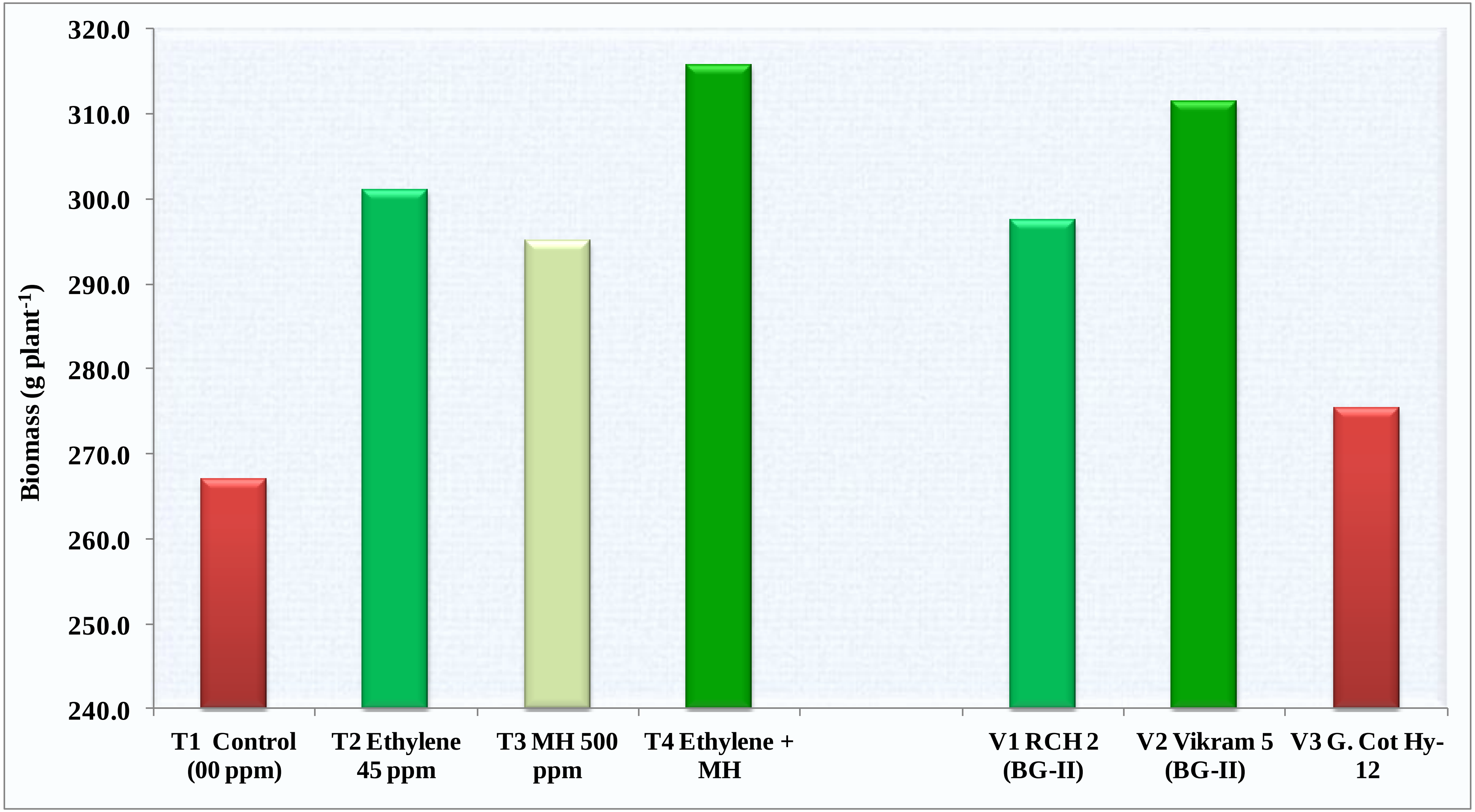
	Number of bolls plant^{-1}			Boll weight (g)			Yield g plant^{-1}		
	2011-12	**2012-13**	**Pooled**	**2011-12**	**2012-13**	**Pooled**	**2011-12**	**2012-13**	**Pooled**
A. Treatments (T)									
T_1 - Control (00 ppm)	36.8	42.1	39.5	3.38	3.19	3.29	129.9	133.5	131.7
T_2 - Ethylene 45 ppm	44.7	49.1	46.9	3.62	3.55	3.58	162.2	172.6	167.4
T_3 - MH 500 ppm	43.5	47.7	45.6	3.66	3.61	3.63	157.1	170.7	163.9
T_4 - T_2 + T_3	48.9	53.1	51.0	3.67	3.60	3.64	177.6	189.3	183.5
S. Em. ±	1.72	1.72	1.17	0.08	0.11	0.07	6.98	6.74	4.72
C.D. at 5%	5.03	5.06	3.35	0.22	0.33	0.20	20.5	19.8	13.5
B. Variety (V)									
V_1 - RCH 2 (BG-II)	44.8	49.3	47.0	3.64	3.58	3.61	163.6	174.5	169.0
V_2 -Vikram 5 (BG-II)	46.6	50.6	48.6	3.68	3.61	3.64	170.9	179.1	175.0
V_3 - G. Cot Hy-12	39.2	44.1	41.6	3.43	3.28	3.35	135.6	145.9	140.8
S. Em. ±	1.49	1.49	1.03	0.07	0.10	0.06	6.05	5.84	4.11
C.D. at 5%	4.36	4.38	2.93	0.19	0.29	0.17	17.7	17.1	11.7
C. Interaction									
V x T									
S. Em. ±	2.97	2.99	2.02	0.13	0.20	0.11	12.1	11.7	8.01
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y x T									
S. Em. ±			1.72			0.10			6.87
C.D. at 5%			NS			NS			NS
C.V.%	11.8	10.8	11.3	6.45	9.77	8.23	13.4	12.2	12.8

Table 4.19 *Conti...*

Table 4.19... ***Conti.....***

	Seed cotton yield (kg ha^{-1})			Biomass (g) plant^{-1}			Harvest Index (%)		
	2011-12	**2012-13**	**Pooled**	**2011-12**	**2012-13**	**Pooled**	**2011-12**	**2012-13**	**Pooled**
A. Treatments (T)									
T_1 - Control (00 ppm)	2110	2206	2158	264.2	270.1	267.1	32.9	33.1	33.0
T_2 - Ethylene 45 ppm	2352	2553	2453	295.4	306.9	301.1	35.4	36.0	35.7
T_3 - MH 500 ppm	2301	2499	2400	290.7	299.4	295.1	35.0	36.2	35.6
T_4 - T_2 + T_3	2588	2701	2645	309.1	322.6	315.8	36.4	36.9	36.6
S. Em. ±	73.1	80.1	52.9	8.40	8.57	5.81	1.17	1.29	0.84
C.D. at 5%	214.4	235.0	150.7	24.6	25.1	16.5	NS	NS	2.40
B. Variety (V)									
V_1 - RCH 2 (BG-II)	2420	2545	2482	291.2	303.8	297.5	35.8	36.4	36.1
V_2 - Vikram 5 (BG-II)	2590	2700	2645	308.9	314.0	311.5	35.6	36.1	35.9
V_3 - G. Cot Hy-12	2004	2226	2115	269.3	281.5	275.4	33.4	34.1	33.7
S. Em. ±	63.3	69.4	46.3	7.27	7.42	5.10	1.02	1.11	0.75
C.D. at 5%	185.7	203.5	132.0	21.3	21.8	14.5	NS	NS	NS
C. Interaction									
V x T									
S. Em. ±	127	139	89.4	14.5	14.8	9.76	2.03	2.23	1.42
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y x T									
S. Em. ±			76.7			8.48			1.23
C.D. at 5%			NS			NS			NS
C.V.%	9.38	9.65	9.53	8.69	8.58	8.63	10.1	10.9	10.5

Fig. 4.14: Effect of Ethylene and MH on Biomass (g/plant) in cotton hybrids



The data presented in **Table 4.19** revealed that cotton hybrids did not show any significant differences in harvest index in individual years as well as in pooled analysis. Lowest harvest index was recorded in G. Cot Hy-12 (33.7%), whereas highest in RCH 2 (BG-II) (36.1 %).

None of the interactions of growth modifier treatments and hybrids was found significant.

4.7.7 Seed cotton yield per plant at 140, 155 and 170 days

The data on seed cotton yield recorded at different intervals as influenced by growth regulators and hybrids are presented in **Table 4.20**

The data revealed that growth regulator were found to significantly influence yield plant^{-1} at 140, 155 and 170 DAS during both the years as well as in pooled. The data indicated that application of Ethylene (T_2) recorded significantly higher (109 g plant^{-1}) seed cotton yield over MH and control at 140 DAS. Application of Ethylene + MH (T_4) recorded significantly higher seed cotton yield (101.6) over control (82.5 g plant^{-1}) and remained at par with MH (T_3) (93.7 g plant^{-1}).

Application of MH recorded significantly higher seed cotton yield at 155 and 170 DAS over Ethylene (T_2) and control whereas application of both Ethylene and MH (T_4) recorded significantly higher yield over all other treatments. More or less, a similar trend was observed at 170 DAS thus Ethylene resulted in earliness whereas MH caused delay in harvesting but in both cases it brought advantage in yield.

The differences in seed cotton yield in the three hybrids were found significant in individual years as well as in pooled. The data indicated that at 140 DAS, RCH 2 (BG-II) recorded significantly higher seed cotton yield (107 g plant^{-1})

Table 4.20: Effect of Ethylene and MH on Seed cotton yield per plant at different interval in cotton hybrids

	140 days (g $plant^{-1}$)			155 days (g $plant^{-1}$)			170 days (g $plant^{-1}$)		
	2011-12	**2012-13**	**Pooled**	**2011-12**	**2012-13**	**Pooled**	**2011-12**	**2012-13**	**Pooled**
A. Treatments (T)									
T_1 - Control (00 ppm)	81.9	83.2	82.5	29.7	32.6	31.1	18.3	19.9	19.1
T_2 – Ethylene 45 ppm	106.6	111.3	109.0	32.9	36.8	34.9	22.3	24.2	23.2
T_3 - MH 500 ppm	89.5	97.8	93.7	40.7	42.0	41.3	26.9	29.2	28.1
T_4 - T_2 + T_3	99.1	104.1	101.6	46.6	51.1	48.8	31.6	32.3	32.0
S. Em. ±	4.60	5.60	3.62	2.09	1.86	1.40	1.52	1.74	1.16
C.D. at 5%	13.5	16.4	10.3	6.12	5.47	3.99	4.47	5.11	3.30
B. Variety (V)									
V_1 - RCH 2 (BG-II)	103.8	110.2	107.0	33.0	38.8	35.9	26.8	25.1	26.0
V_2 - Vikram 5 (BG-II)	86.6	93.7	90.2	50.7	50.7	50.7	33.3	34.7	34.0
V_3 - G. Cot Hy-12	92.5	93.4	92.9	28.7	32.3	30.5	14.2	19.5	16.8
S. Em. ±	3.99	4.85	3.14	1.81	1.61	1.21	1.32	1.51	1.00
C.D. at 5%	11.7	14.2	8.95	5.30	4.74	3.46	3.87	4.42	2.86
C. Interaction									
V x T									
S. Em. ±	7.98	9.69	3.82	3.62	3.23	2.93	2.64	3.02	1.03
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y x T									
S. Em. ±			5.12			1.98			1.64
C.D. at 5%			NS			NS			NS
C.V.%	14.7	16.9	15.9	16.7	13.8	15.2	18.5	19.8	19.2

than G. Cot Hy-12 (92.9 g) and Vikram 5 (BG-II) (90.2 g/plant) whereas at 155 and 170 DAS, Vikram 5 (BG-II) recorded significantly higher seed cotton yield (50.7 and 34 g $plant^{-1}$) than RCH 2 (BG-II) (35.9 and 26 g). Both were significantly higher than G. Cot Hy-12 in the last two picking at 155 and 170 DAS.

Interaction effect between growth regulators with hybrids was found not significant.

4.8 ECONOMICAL CHARACTERS

4.8.1 Ginning percentage

The data pertaining to ginning percentage as influenced by growth modifiers and hybrids is presented in **Table 4.21**

The data indicated that ginning percentage was not significantly affected by Ethylene (T_2), MH (T_3) and Ethylene + MH (T_4) in both the years and in pooled.

In respect of hybrids, no significant differences were observed in ginning percentage. Nonetheless, RCH 2 (BG-II) recorded highest ginning percentage (33.8) and Vikram 5 (BG-II) lowest ginning percentage (32.1).

The interaction of growth regulators with cotton hybrids was found not significant during both years and in pooled.

4.8.2 Seed index (g)

The data pertaining to seed index as influenced by growth regulators and hybrids is presented in **Table 4.21**

The data indicated significant differences due to growth regulators during the two years and in pooled. It revealed that application of MH at 85 DAS (T_3) significantly lowered seed index (9.54 g) compared to Ethylene (T_2), Ethylene + MH (T_4) and the control (10.5g). Ethylene tended to increase seed index (10.8g) compared to control.

The pooled data showed that Vikram 5 (BG-II) recorded higher seed index (11.9 g) which was significant over G. Cot Hy-12 (9.61 g) and RCH 2 (BG-II) (9.28 g). The later two were statistically at par.

The interaction of year with variety was significant which indicated that contrary to pooled results, G. Cot Hy-12 registered significantly higher seed index than RCH 2 (BG-II) in 2012-13.

The interaction between growth regulators and cotton hybrids for seed index was found not significant.

4.8.3 Lint index (g)

The data pertaining to lint index (g) as influenced by Ethylene and MH as well as hybrids is presented in **Table 4.21**

The results indicated that Ethylene and MH had significant effect on lint index during both the years and in pooled. The data revealed that application of Ethylene at squaring stage (T_2) significantly increased lint index (5.53g) whereas that of MH at 85 DAS (T_3) decreased the same (4.70) over control (5.09). Detrimental effect of MH on lint index was moderated in previously Ethylene treated plants 5.00 g (T_4).

Cotton hybrids showed significant differences in lint index during both the years and in pooled mean. Hybrid Vikram 5 (BG-II) recorded the highest lint index (5.61 g) which was significant over RCH 2 (BG-II) (4.74 g) and G. Cot Hy-12 (4.88 g).

The interaction between growth regulators and cotton hybrids was found to be not significant.

Table 4.21: Effect of Ethylene and MH on Economical characters in cotton hybrids

	Ginning percentage (%)			Seed index (g)			Lint Index (g)			Oil content (%)		
	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2011-12	Pooled	2011-12	2012-13	Pooled
A. Treatments (T)												
T_1 - Control (00 ppm)	31.9	33.1	32.5	9.88	11.1	10.5	4.68	5.51	5.09	17.9	17.5	17.7
T_2 - Ethylene 45 ppm	32.7	33.3	33.0	10.0	11.6	10.8	4.86	6.19	5.53	18.2	18.2	18.2
T_3 - MH 500 ppm	33.1	33.9	33.5	8.63	10.5	9.54	4.24	5.15	4.70	17.2	17.0	17.1
T_4 - $T_2 + T_3$	33.1	33.6	33.4	9.64	10.7	10.2	4.79	5.21	5.00	17.9	17.5	17.7
S. Em. ±	1.14	1.26	0.82	0.35	0.29	0.23	0.16	0.19	0.13	0.55	0.51	0.37
C.D. at 5%	NS	NS	NS	1.02	0.86	0.65	0.46	0.57	0.36	NS	NS	NS
B. Variety (V)												
V_1 - RCH 2 (BG-II)	33.0	34.6	33.8	9.08	9.48	9.28	4.46	5.02	4.74	17.5	17.2	17.4
V_2 - Vikram 5 (BG-II)	32.1	32.2	32.1	11.0	12.8	11.9	5.18	6.05	5.61	18.0	18.1	18.0
V_3 - G. Cot Hy-12	33.0	33.7	33.3	8.54	10.7	9.61	4.29	5.47	4.88	17.8	17.4	17.6
S. Em. ±	0.99	1.09	0.73	0.30	0.26	0.19	0.14	0.17	0.11	0.47	0.44	0.32
C.D. at 5%	NS	NS	NS	0.88	0.75	0.61	0.40	0.49	0.32	NS	NS	NS
C. Interaction												
V x T												
S. Em. ±	1.97	2.18	1.39	0.60	0.51	0.44	0.27	0.34	0.23	0.95	0.89	0.67
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y x T												
S. Em. ±			1.20			0.32			0.18			0.53
C.D. at 5%			NS			NS			NS			NS
C.V.%	10.5	11.3	10.9	10.9	8.05	9.42	10.2	10.6	10.5	9.24	8.73	8.99

4.8.4 Oil content (%)

The data oil content as influenced by plant growth regulators and hybrids is presented in **Table 4.21**

The data indicated that growth regulators did not have any significant impact on oil content in individual years as well as in pooled. Numerically, Ethylene (T_2) recorded the highest oil content (18.2%) and MH lowest oil content (17.1%).

Cotton hybrids did not reveal any significant differences in oil content during the two years and in pooled. Nonetheless, Vikram 5 (BG-II) showed higher oil content (18.0%) whereas, RCH 2 (BG-II) lower oil content (17.4%).

The interaction of growth regulators and hybrids was found not significant in both the years as well as in pooled.

4.9 FIBRE QUALITY PARAMETERS

4.9.1 2.5 per cent Span length (mm)

The data on 2.5 per cent span length (mm) as influenced by growth regulators and hybrids is presented in **Table 4.22.** The data indicated that Ethylene and MH had no significant influence on 2.5 per cent span length and the fibre belonged to long staple category (*i.e.*, more than 27.5mm). Application of Ethylene at squaring stage followed by MH at 85 DAS (T_4) yielded slightly longer fibre (30.2 mm) over rest of the treatments.

The data presented in **Table 4.22** indicated that differences in 2.5 per cent span length (mm) amongst the hybrids were significant during both the years and in pooled. Vikram 5 (BG-II) yielded longer fibre (31.2 mm) which were significantly better than G. Cot Hy-12 (28.4) and RCH 2 (BG-II) (30.5).

The interaction between growth regulators and cotton hybrids was found to be not significant during both the years and in pooled.

4.9.2 Fibre fineness (µg inch^{-1})

The data on fibre fineness (micronaire) is presented in **Table 4.22.** It indicated that growth regulator treatments did not have any significant effect on the micronaire value during both the years and in pooled analysis. Untreated control recorded minimum fibre fineness. All the treatments displayed average fibre fineness.

The cotton hybrid revealed significant differences in fineness during 2012-13 and in pooled analysis. The pooled results showed that fibres of G. Cot Hy-12 were less finer (4.70 µg inch^{-1}) than RCH 2 (BG-II) (4.43) although all the three hybrids were average in fibre fineness.

Interaction between growth regulators and hybrids was found not significant in individual years and in pooled.

4.9.3 Uniformity ratio (%)

Data pertaining to uniformity ratio (%) presented in **Table 4.22**. indicated that growth regulator treatments did not significantly affect uniformity ratio (%) in individual years or in pooled. However, untreated control recorded better uniformity ratio (47.4%) than in Ethylene (T_2) (46.4) which showed lower uniformity ratio. The uniformity ratio was comparatively higher during 2012-13 than 2011-12.

The cotton hybrids revealed significant difference in uniformity ratio (%) in individual years as also in pooled. The hybrid G. Cot Hy-12 exhibited excellent uniformity ratio (48.5%) which was significantly over Vikram 5 (BG-II) and RCH 2 (BG-II) which exhibited good (46.8) and average (45.8) fibre uniformity ratio, respectively.

The interaction between growth regulators and cotton hybrids was found not significant.

4.9.4 Maturity ratio

The data for maturity ratio of cotton is presented in **Table 4.22.** It revealed that application of plant growth regulators did not cause any significant changes in maturity during the two years of experimentation. Good mature fibres were produced in all the treatments and in untreated control (0.851).

The data indicated that (**Table 4.22)** hybrids showed significant differences in fibre maturity ratio during the two years of experimentation and in pooled. G. Cot Hy-12 recorded higher maturity ratio (0.857) than that in Vikram 5 (BG-II) and RCH 2 (BG-II). Significantly lower maturity ratio (0.841) was recorded in RCH 2 (BG-II) although fibre of all the hybrids fell in good maturity category.

The interaction between growth modifiers and cotton hybrids was found to be not significant in individual years as well as in pooled.

4.9.5 Fibre strength (g tex^{-1})

Mean fibre strength (g tex^{-1}) as influenced by growth regulators is presented in **Table 4.22.** The data indicated that application of Ethylene at square initiation and MH at 85 DAS significantly affected fibre strength during both the years and in pooled analysis. Ethylene (T_2) significantly improved strength of the fibre (23.7) whereas MH had slightly detrimental effect on the same (22.7) compared to control (22.9). Therefore the fibre strength in Ethylene treatment was significantly better than that in MH. Application of Ethylene + MH (T_4) recorded significant higher fibre strength (23.3 g tex^{-1}) than MH and at par to the Ethylene and control.

The data indicated that **(Table 4.22)** fibre strength of cotton hybrids significantly differed during both the years but pooled results it did not depict significance. Yet cotton hybrid G. Cot Hy-12 showed better fibre strength (23.9 g tex^{-1}) than the other two. The interaction of year with variety was significant which indicated that during 2011-12, RCH 2 (BG-II) yielded fibre with significantly low strength (21.2 g tex^{-1}) vis-a-vis Vikram 5 (BG-II) (23.2) and G. Cot Hy-12 (23.1) whereas in 2012-13, G.Cot Hy-12 yielded fibres with significantly higher strength (24.8) vis-a-vis RCH 2 (BG-II) (23.3 g tex^{-1}) and Vikram 5 (BG-II) (23.4g tex^{-1}).

Interaction between plant growth regulators and cotton hybrids was found not significant.

4.9.6 Fibre elongation (%)

The data for fibre elongation (%) presented in **Table 4.22.** indicated that growth modifiers did not show any significant influence on fibre elongation during the two years and in pooled.

The data further revealed that (**Table 4.22)** differences in fibre elongation of the cotton hybrids were found significant during 2011-12 and in pooled. The pooled result indicated that hybrids Vikram 5 (BG-II) and RCH 2 (BG-II) recorded greater fibre elongation (6.25 and 6.21%) which was significant over G. Cot Hy-12 (6.00).

The interaction between growth regulators and cotton hybrids was not significant.

4.9.7 Short fibre index (SFI)

The data for short fibre index (SFI) presented in **Table 4.22** indicated that growth regulators did not show any significant effect on short fibre index during both the years and in pooled. Application of Ethylene at squaring stage (T_2)

Table 4.22: Effect of Ethylene and MH on Fibre quality traits in cotton hybrids

	2.5 % Span length (mm)			Fibre fineness (µg inch^{-1})			Uniformity ratio (%)			Maturity ratio		
	2011-12	**2012-13**	**Pooled**	**2011-12**	**2012-13**	**Pooled**	**2011-12**	**2012-13**	**Pooled**	**2011-12**	**2012-13**	**Pooled**
A. Treatments (T)												
T_1 - Control (00 ppm)	28.6	31.3	29.9	4.67	4.63	4.65	44.7	50.1	47.4	0.849	0.853	0.851
T_2 - Ethylene 45 ppm	28.7	31.2	30.0	4.57	4.36	4.46	43.4	49.4	46.4	0.848	0.850	0.849
T_3 - MH 500 ppm	29.0	31.1	30.0	4.58	4.68	4.63	44.0	50.1	47.1	0.844	0.852	0.848
T_4 - $T_2 + T_3$	29.1	31.3	30.2	4.62	4.52	4.57	44.1	50.2	47.2	0.848	0.852	0.850
S. Em. ±	0.33	0.31	0.23	0.09	0.09	0.06	0.39	0.54	0.33	0.003	0.002	0.002
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
B. Variety (V)												
V_1 - RCH 2 (BG-II)	29.4	31.5	30.5	4.54	4.31	4.43	42.8	48.9	45.8	0.839	0.843	0.841
V_2 - Vikram 5 (BG-II)	30.0	32.4	31.2	4.60	4.63	4.61	43.8	49.7	46.8	0.850	0.851	0.850
V_3 - G. Cot Hy-12	27.1	29.8	28.4	4.68	4.71	4.70	45.6	51.3	48.5	0.853	0.862	0.857
S. Em. ±	0.29	0.27	0.20	0.07	0.08	0.05	0.34	0.47	0.29	0.003	0.002	0.002
C.D. at 5%	0.84	0.79	0.56	NS	0.22	0.15	1.00	1.37	0.81	0.007	0.006	0.005
C. Interaction												
V x T												
S. Em. ±	0.57	0.54	0.38	0.15	0.15	0.11	0.68	0.93	0.61	0.005	0.004	0.005
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y x T												
S. Em. ±			0.32			0.09			0.47			0.003
C.D. at 5%			NS			NS			NS			NS
C.V.%	3.44	3.00	3.21	5.63	5.76	5.69	2.68	3.23	3.01	1.04	2.06	0.91

Table 4.22: ***continues ….***

Table 4.22: ***continues ….***									
	Fibre strength (g/tex)			**Fibre elongation (%)**			**Short Fibre Index (SFI)**		
	2011-12	**2012-13**	**Pooled**	**2011-12**	**2012-13**	**Pooled**	**2011-12**	**2012-13**	**Pooled**
A. Treatments (T)									
T_1 - Control (00 ppm)	22.1	23.8	22.9	5.96	6.37	6.16	11.9	5.53	8.74
T_2 - Ethylene 45 ppm	23.1	24.2	23.7	5.96	6.49	6.22	12.5	6.03	9.26
T_3 - MH 500 ppm	22.1	23.3	22.7	5.94	6.27	6.11	12.0	5.86	8.91
T_4 - $T_2 + T_3$	22.7	24.0	23.3	5.90	6.34	6.12	11.6	5.39	8.48
S. Em. ±	0.24	0.20	0.16	0.07	0.06	0.05	0.49	0.33	0.30
C.D. at 5%	0.69	0.60	0.44	NS	NS	NS	NS	NS	NS
B. Variety (V)									
V_1 - RCH 2 (BG-II)	21.2	23.3	22.3	5.97	6.46	6.21	12.4	6.04	9.20
V_2 -Vikram 5 (BG-II)	23.2	23.4	23.3	6.11	6.38	6.25	10.7	4.81	7.75
V_3 - G. Cot Hy-12	23.1	24.8	23.9	5.74	6.26	6.00	12.9	6.26	9.59
S. Em. ±	0.20	0.18	0.48	0.06	0.06	0.04	0.43	0.29	0.26
C.D. at 5%	0.60	0.52	NS	0.19	NS	0.12	1.26	0.84	0.73
C. Interaction									
V x T									
S. Em. ±	0.41	0.35	0.32	0.13	0.11	0.08	0.86	0.57	0.37
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Y x T									
S. Em. ±			0.22			0.07			0.42
C.D. at 5%			NS			NS			NS
C.V.%	3.14	2.57	2.86	3.75	3.05	3.40	12.4	17.4	14.3

resulted in greater SFI (9.26) while that of Ethylene at squaring stage and MH at 85 DAS (T_4) resulted in minimum short fibre index (8.48) over untreated control (8.74).

The differences in SFI of the three hybrids were found significant. G. Cot Hy-12 showed significantly high SFI (9.59) compared to Vikram 5 (BG-II) which recorded lowest SFI (7.75). The SFI in RCH 2 (BG-II) (9.20) was statistically at par to that in G. Cot Hy-12.

The interaction between plant growth regulators and hybrids was found not significant during both the years and in pooled.

4.10 Economics Studies

The data on economics of the use of growth regulators in cotton hybrids in presented in **Table-4.23**

Data pertaining to gross monetary returns (GMR) revealed that application of Ethylene at squaring stage followed by MH at 85 DAS (T_4) resulted in the highest gross monetary returns (Rs 1,16, 493 ha^{-1}) vis-a-vis application of Ethylene at squaring stage (T_2) (Rs 1,08,119 ha^{-1}) and MH at 85 DAS (T_3) (Rs 1,05,798 ha^{-1}) and untreated control (Rs 95,041ha^{-1}).

Amongst the hybrids, Vikram 5 (BG-II) gave GMR (Rs 1, 16,480 ha^{-1}) followed by RCH 2 (BG-II) (Rs 1, 09,335 ha^{-1}). Minimum GMR was in conventional hybrid G. Cot Hy-12 (Rs 93, 273 ha^{-1}).

In terms net returns, a similar picture emerged and highest net return in the growth regulators was with Ethylene + MH (Rs 66,449 ha^{-1}). Minimum net returns were observed in untreated control (Rs. 48,338 ha^{-1}) which were much lower than Ethylene (Rs 59,335 ha^{-1}) and MH (Rs 57, 375 ha^{-1}) alone.

Amongst the hybrids, Vikram 5 (BG-II) recorded highest net monetary returns of Rs 66,226 ha^{-1} whereas G. Cot Hy-12 the lowest (Rs 47,554 ha^{-1}).

The data on benefit cost ration (BCR) revealed that it was influenced by plant growth regulators. Application of Ethylene + MH (T_4) recorded higher BCR (2.32) compared to Ethylene (2.21) and MH alone (2.18) and over untreated control (2.03).

Amongst the hybrids, Vikram 5 (BG-II) recorded higher benefit cost ratio (2.31) *vis-a-vis* G. Cot Hy-12 (2.03) and RCH 2 (BG-II) (2.21).

Since the interaction of hybrids with growth regulators for most the traits studied were found not significant it in assumed that *Bt* hybrids or conventional hybrid both responded to the growth regulators same way and benefits of use of growth regulators can be accrued in all type cotton hybrids.

Table 4.23: Economics of modification of morphoframe in cotton hybrids (Average of 2011-12 and 2012-13)

	Seed cotton yield kg/ha	Stalk yield (Rs ha^{-1})	Total cost of production	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	B. C. Ratio
A. Treatments (T)						
T_1 - Control (00 ppm)	2158	4316	46653	95041	48388	2.03
T_2 - Ethylene 45 ppm	2453	4905	48764	108119	59355	2.21
T_3 - MH 500 ppm	2400	4800	48423	105798	57375	2.18
T_4 - T2 + T3	2645	5290	50045	116493	66449	2.32
B. Variety (V)						
V_1 - RCH 2 (BG-II)	2483	4964	49441	109335	59895	2.21
V_2 - Vikram 5 (BG-II)	2645	5289	50254	116480	66226	2.31
V_3 - G. Cot Hy-12	2115	4230	45719	93273	47554	2.03

DISCUSSION

Gossypium sp. (Cotton)

V DISCUSSION

Cotton hybrids generally have robust architecture, greater horizontal (particularly 1st internode of sympodia) and vigorous growth with more plant height which leads to more vegetative growth and mutual shading resulting in shedding of reproductive parts. There are several other problems associated with the growth and development limiting the yield. Abscission of leaves and reproductive parts is one of the major problems in irrigated and heavy rainfall areas. Excessive vegetative growth also reduces yield. Plant growth regulators are known to modify the source to sink relationship and increase the translocation and photosynthetic efficiency resulting in increased square and boll retention and boll setting per cent (Kumar, 2001).

Cotton is a perennial plant with an indeterminate growth habit with both vegetative and reproductive growth occurring simultaneously. While vegetative growth is necessary to support reproductive growth, excessive vegetative growth can be detrimental. Under excessive vegetative growth, fruit abscission may increase; crop maturity may be delayed and reduce the harvest. Growth habits of cotton genotypes are inconsistent, ranging from well balanced growth to aggressive vegetative growth. The growth habit of these varieties combined with high availability of nutrients, timely rainfall or irrigation and delayed fruit retention can encourage excessive vegetative growth. Cotton plants produce several natural growth regulators or plant hormones which modify plant growth and divert energy allocation within the plant. Regulators are being applied to the foliage in an effort to maintain a balance between vegetative and reproductive phase. One of the most commonly used growth regulator is Maleic hydrazide which decreases the vegetative growth by interfering in the biosynthetic path way of gibberellins. Understanding the physiology of excessive vegetative growth for the use of Maleic hydrazide based regulators is essential for satisfactory management of vegetative growth. Benefits from the use of such a chemical depend on the concentration, time of application, varietal behaviour and environmental conditions.

Plant growth and development is a complex process and two classes of mechanisms that influence and regulate the developmental pattern of a plant have been recognized. The first is a system of endogenous chemical messengers, called hormones that co-ordinate the development of individual organs as well as the plant as a whole. The second class of mechanism comprises of extrinsic factors such as light, water, temperature and gravity which originate outside the organism and convey the information about the environment. Thus, the final pattern of development and behaviour of each individual plant is the result of complex interplay between genetic, hormonal and environmental factors. Application of growth retardants will reduce yield due to altered source sink relationship, reduced plant height and canopy size. But, optimum concentration and single application of retardants at appropriate stage will increase the yield by optimizing source sink relationship. Multiple application and higher concentration will reduce yield by altering enzyme/hormonal concentration through protein synthesis along with secondary messengers. Regulating substances both the natural and synthetic hormones operate by inducing such changes in the activity of enzymes directly or indirectly. Changes in plant growth and development are brought about by changing enzyme pattern in the plant cells. Curtailing excessive plant growth in *Bt* cotton hybrids by use of growth regulators could prove to be useful strategy to augment cotton production to meet the ever growing demand of burgeoning population in the country.

With this view, an experiment entitled “Influence of modification of morphoframe on physiology and yield in cotton” was undertaken at Main Cotton Research Station, NAU, Surat during *kharif* 2011-12 and 2012-13 to study the effect of foliar application of Ethylene and Maleic hydrazide on various Morpho-physiological traits on yield and quality parameters of cotton hybrids.

In the present investigation two *Bt* and one non-*Bt* hybrids of cotton were subjected to foliar application of Ethylene and Maleic hydrazide and monitored for growth, yield and quality characters. The weather conditions prevailed during the entire crop growth period are represented in Appendix-I and II. Further, the treatments variations which were found significant have been discussed to establish the cause and effect relationship with existing evidence and literature. The results obtained from the investigation are discussed in this chapter.

5.1 MORPHO-PHYSIOLOGICAL CHARACTERS

Growth parameters like LAI, LAD, CGR, RGR and NAR have been extensively used for past several years for better understanding of physiological basis of yield variation in crop plants. Increase in yield is not associated with increase in photosynthetic rate alone there are many more which govern the plant output in terms of yield and it is difficult to find out clear cut answer for improving the yield potential. An attempt has been made in the following pages to find an answer or at least to justify. The yield in the light of different physiological and growth parameters used in this study:

5.1.1 Leaf area index (LAI)

Dry matter accumulation and supply of required photosynthates for the developing bolls largely depend on leaf area index. The photosynthetic efficiency of crop plants as measured by net assimilation rate is dependent upon photosynthetic capacity expressed as leaf area index (Watson, 1952). Under field conditions, an increase in LAI may therefore improve the yield, provided such an increase is commensurate with an increased rate of dry matter accumulation in reproductive parts. Leaf area over unit ground area gives a fairly good idea of the photosynthetic surface. In the present study, leaf area index increased with the age of the crop till 120 days after sowing (DAS) and decreased thereafter which was due to ageing and senescence of leaves.

Leaf area index was significantly enhanced by the application of Ethylene at squaring stage over control untill 120 DAS. Ethylene resulted in shedding of square and the sink demand for photosynthates decreased and photosynthates were translocated to vegetative parts resulting in greater LAI. These findings were similar to the findings of Mcarthur *et al*. (1975) and Thakare *et al*. (2012).

Application of MH at 85 DAS also brought about significant increase in LAI over control. LAI was further enhanced by the application of MH in Ethylene treated plant especially at 95 DAS untill 145 DAS. It was more like a complimentary effect of the two chemicals. A relatively higher LAI was maintained in MH treatments vis-a-vis Ethylene other than control during maturation phase *i.e.* beyond 120 DAS. This indicated that photosynthetic system remained active for a longer time resulting in greater assimilation and the yield. Increase in LAI by MH spray was because of horizontal growth putting in more leaf area, sympodial branches subsequently greater LAI. MH induced increased in LAI has been reported earlier (Anonymous 2010[g]).

The higher LAI recorded in Vikram 5 (BG-II) and RCH 2 (BG-II) was observed than in G.Cot Hy-12. Such variations in growth habit of hybrids are common due to their different genetic background (Hebbar *et al.*, 2007).

Higher LAI maintained up to peak flowering in present study indicated higher photosynthetic surface area resulting in better plant growth. Higher LAI at flower initiation and peak flowering are desirable for higher seed cotton yield because such a situation would not lead to competition for photo-assimilates. Similar results were reported by Ashley *et al.* (1965) and Janagoudar (1980).

5.1.2 Leaf area duration (LAD)

LAD is a useful concept not only in depicting efficiency of photosynthetic system but also to represent the linear relationship with dry matter accumulation. LAD was significantly increased by the application of Ethylene at all the stages over control. Similar increase was observed due to MH application at 85 DAS over control. The results also revealed that MH further enhanced the LAD which was already increased by Ethylene. The entire pattern of LAD had corollary with LAI. Persistence in leaf area *i.e.,* LAD with the application of Ethylene can be ascribed to better vegetative growth due to shedding of early squares. In case of MH, the vertical growth was arrested followed by horizontal growth in terms of branching, leaf area and chlorophyll content hence the LAD. Leaf area retention period due to application of Ethylene was observed by Thakare *et al.* (2012) and also MH was showed by (Anonymous 2010[g]).

Amongst the hybrids, Vikram 5 (BG-II) and RCH 2 (BG-II) recorded higher LAD than G.Cot Hy-12 (non-*Bt*) at all stages of crop growth corroborating LAI.

5.1.3 Crop growth rate (gm^{-2} days^{-1})

A significantly high CGR was observed with the application of Ethylene at square initiation over control and maintained untill 120 DAS. Application of MH at 85 DAS also enhanced CGR in subsequent stages. Application of both Ethylene and MH at respective stages had synergistic effect and higher CGR over Ethylene and MH alone was observed during 71-95 and 96-120 DAS. A higher LAI in these treatments could be possible account for the enhanced CGR.

5.1.4 Relative growth rate (g g^{-1} day^{-1} plant^{-1})

The relative growth rate (RGR) was more during early stage and gradually decreased thereafter. This indicates that RGR in cotton is more closely associated with vegetative growth than seed cotton yield (Coy, 1976).

An increased RGR due to Ethylene application over control was observed till 120 DAS. Similarly MH Application also increased RGR during subsequent stages at 71-120 DAS. Supplementing MH spray on Ethylene treated plants did not depict any significant advantage in RGR over Ethylene or MH but over control. This increased RGR by the application of growth regulators could be attributed to increased photosynthetic efficiency as a result of increased leaf area index and higher chlorophyll content. Joseph and Johnson (2006) also observed increased RGR in cotton in response to PGR application.

The results **(Table-4.4)** showed that Vikram 5 (BG-II) and RCH 2 (BG-II) showed significantly higher RGR than G.Cot Hy-12 at all the stages and their response to growth regulators was same as evident from not significant interaction.

5.1.5 Net assimilation rate (mg cm^{-2} day^{-1})

Net assimilation rate (NAR) expressed as the rate of dry weight increase at any instant per unit per unit leaf area and leaf representing an estimate of the size of the assimilatory surface area. The NAR decreased continuously from 96 in all the treatments. Ethylene spray caused greater net assimilation rate which was primarily due to enhanced LAI.

Application of MH also enhanced NAR at stages later than that *i.e.*, 96 DAS. Greater leaf area index coupled with photosynthetic pigments could explain the enhanced NAR due to MH. Application of MH after Ethylene was found to further increase NAR especially at 71-95 DAS than Ethylene and MH alone.

The result indicated that Vikram 5 (BG-II) recorded significantly higher NAR at all the stages except 121-145 DAS where in the conventional hybrid G.Cot Hy-12 recorded higher NAR due to higher RGR in this hybrid in the later stages.

5.1.6 Dry matter accumulation (g/plant)

Cotton is basically an indeterminate crop where the vegetative and reproductive phases overlap resulting in intra-plant competition for photosynthates between the developing bolls and vegetative parts (mainly stem, lateral branches and leaves). As such the dry matter accumulation went on increasing with crop age but the rate of dry matter accumulation decreased as the crop growth advanced.

The results indicated that (**Table 4.6**) Ethylene significantly enhanced dry matter accumulation at 70 DAS untill maturity. This higher dry matter accumulation was basically due to curtailment of initial reproductive phase, greater LAD, NAR, RGR and promotion of vegetative development. Similar results were reported by Kumari and George (2013).

MH applications also increased dry matter accumulation. This increased dry matter accumulation was due to increased leaf area, growth rate and profuse reproductive growth occurred after MH sprayed at 85 DAS. Kumari and George (2012) also reported similar findings.

Supplemental effect of MH on dry matter accumulation was seen in Ethylene treated plant compared to MH and Ethylene alone which was substantiated by greater LAI and RGR.

It was observed that Vikram 5 (BG-II) accumulated significantly higher dry matter throughout the growing period compared to remaining hybrids which was evident from its higher LAI, RGR and overall growth.

5.2 GROWTH AND MORPHOLOGICAL CHARACTERS

The effect of foliar application of plant growth regulators on various morphological characters such as plant height, number of node, number of sympodial and monopodial branches has been discussed here under.

5.2.1 Plant height (cm)

Plant height (cm) is an important morphological character in cotton which provides sites for nodes and internodes from which sympodial branches emerge and thus plays an important role in determining the morphological frame work relating to productivity (Patil, 1989). Several studies have indicated that the plant height is affected by the application of plant growth regulators *i.e.*, Ethylene, Maleic hydrazide, Pix, Mepiquat chloride, GA_3, Chloromequat chloride and NAA. Pettigrew *et al.* (1992), Mahmaud *et al.* (1994), Zhao and Oosterhuis (2000), Zulfiqar *et al.* (2003), Buttar and Agarwal (2004), Kumar *et al.* (2005), Bardhan and Kumar (2010) and Thakare *et al.* (2011). In the present investigation, significant differences in plant height were noticed due to growth regulator treatments.

Effect of square shedding by Ethylene was seen on plant height later than 40 DAS which is quite obvious since the treatments were sprayed 40 days after sowing. There after Ethylene significantly increased plant height over untreated control. Increased plant height due to early square removal by Ethylene was because of partitioning of assimilates in favour of vegetative structures due to early reproductive sink losses. It indicates that fruit loss changes partitioning of plant resources in favour of vegetative growth. This shift in partitioning increases the ability of the plant to acquire more photosynthates towards vegetative structures. These results are similar to those of Kennedy *et al.* (1986), Sadras (1995), Kumari and George (2010), Thakare *et al.* (2011) and Kumari and George (2013).

Application of MH at 85 DAS reduced plant height than the control at subsequent stages. The Maleic hydrazide (MH) is known as growth retardant. In cotton, Maleic hydrazide acts as a growth inhibitory substance and imparts its inhibitory effect in the biosynthesis of GA_3 thus causing shortening of plant height. Nooden (1969), Rowland (1974) and Buwa *et al.* (2007). Copur *et al.* (2010) and Thorat *et al.* (2012) opined similar mode of action for MH in crops plants. Anonymous, (2010[e]) and Kumari and George (2012) reported MH induced reduction in plant height of cotton.

The result indicated **(Table-4.7)** that at early stage Vikram 5 (BG-II) recorded greater plant height while at later stages, G. Cot Hy-12 a non-*Bt* hybrid attained much greater plant height at 95 DAS till harvest. It would be due to the fact that this hybrid had limited sink due to entomological shedding and partitioned of more of its photosynthates to the vegetative parts resulting in greater height. Thakare *et al.* (2011) and Sarlach and Sharma (2012) reported similar findings.

5.2.2 Numbers of main stem nodes per plant

Number of nodes on the mainstem is an important morphological character which is directly related to yield. Significant differences were noticed among the treatments. Application of Ethylene showed significant increase in main stem node over untreated control which might have been due to the increased vegetative growth as evident by LAI and plant height caused by early square removal with the application of Ethylene. Pettigrew *et al.* (1992), Kumari and

George (2010) and Thakare *et al*. (2012) also reported similar findings. Application of MH recorded significant increase in number of mainstem nodes over control. This result is in conformity with the finding of Anonymous, (2010[e]).

Application of Ethylene at squaring stage followed by MH at 85 DAS recorded highest number of main stem nodes over Ethylene and MH and coincided with plant height.

5.2.3 Number monopodia per plant

The number of monopodia per plant **(Table-4.9)** was significantly affected by the application of Ethylene at squaring stage (T_2), MH at 85 DAS (T_3) as well as the two together (T_4) over untreated control. The increase in the number of branches with application of MH might be due to suppression of apical dominance which initiates functioning of several meristems at a time leading to more number of branches which is in agreement with the findings of Verma and Singh (1978) and Anonymous (2010[e]). As for the effect of Ethylene is concerned, an explanation similar to sympodia can justify the increased number of monopodia due to Ethylene.

Number of monopodia significantly varied amongst the hybrid. Such variations in the number of monopodia are common and have been reported by Khadi *et al*. (2008).

5.2.4 Number of sympodia per plant

Sympodial branches form the principal segment of super structures of cotton plants on which the fruiting bodies develop. Present investigation confirmed that higher number of sympodia resulted in the formation more fruiting bodies.

Application of Ethylene at squaring stage promoted formation of fruiting branches. At early stage first stimulated vegetative growth by arresting reproductive growth and subsequently branching on the mainstem, hence increased sympodial branches. Similar results were observed by Kennedy *et al*. (1986), Kumari and George (2010), Thakare *et al*. (2011) and Kumari and George (2013).

Application of MH also had positive effect on number of sympodia which was increased over control. The MH inhibited vertical plant growth and subsequently promoted lateral growth including branching. These results are in conformity with the findings of El-Antably and El-Atta (1992), Anonymous (2010[e]) and Kumari and George (2012).

In treatment receiving Ethylene at squaring stage and MH at 85 DAS had supplemental effect on number of sympodia over Ethylene and MH alone. The increase in number of sympodia may be due to increased number of nodes and plant height.

Branching is a genetically governed trait untill and unless there are abrupt changes in the environment. So whatever's difference in the hybrids are seen basically due to their height and number of nodes. These results are in accordance with the results of Khargade and Ekbote (1980), Patil *et al*. (2009) and Sarlach and Sharma (2012).

5.2.5 Height to node ratio

The effect of Ethylene and MH recorded on the plant height and main stem nodes and reported earlier ought to reflect on height to nodes ratio. Accordingly, the highest height to node ratio was recorded in the untreated control and lowest with application of Ethylene plus MH. This indicated that depressed plant height was mainly due to shorter internodal length. This happened because of modification of morphoframe by Ethylene and MH individually as well as together.

Higher height to node ratio was recorded in conventional hybrid G. Cot Hy-12 compared to *Bt* hybrids RCH 2 (BG-II) and Vikram 5 (BG-II).

5.3 FRUIT PRODUCTION

Numbers of squares, flowers and green bolls/plant

Application of Ethylene at squaring stage resulted in greater number of squares per plant depicting significant increase over untreated control. Similar findings were reported by Pettigrew *et al.* (1992), Thakare *et al.* (2011) and Kumari and George (2012).

Application of MH (500 ppm) at 85 DAS also had increasing effect on number of squares over control. Similar results were observed by Anonymous (2010[e]) and Kumari and George (2012).

Application of Ethylene at square initiation followed by MH at 85 DAS had supplemental effect on the production of squares which were recorded in greater number than Ethylene and MH alone. It indicates that profuse vegetative growth, more sympodia provided better room for more fruiting forms.

The result indicated that Vikram 5 (BG-II) recorded higher number of squares at all stages of crop growth than RCH 2 (BG-II) and G. Cot Hy-12 which might be due to greater LAI and sympodial branches. A comparable variation amongst different hybrids in fruiting capacity was observed by Hebbar *et al.* (2007).

As far as number of flowers is concerned significantly higher number was recorded due application of Ethylene and MH as well as Ethylene plus MH (T_4). Increased number of sympodia and squares resulted in increased in flowers per plant due to Ethylene and MH and reported earlier by Gupta and Chauhan (2006), Mohamed (2009) and Thakare *et al*. (2012).

Similarly, Ethylene and MH increased number of green bolls per plant over untreated control. This may be because of the fact that modification of morphoframe by these chemicals lead to increased squares and flowers production leading to more bolls. Putting the two growth regulators in the same plots (T_4) showed synergistic effect and the green bolls were significantly more than those in Ethylene or MH alone. Results are in conformity with the findings of Kittock *et al*. (1973), Mohamed (2009), Thakare *et al*. (2012), Kumari and George (2012) and Kumari and George (2013).

The data clearly indicated greater number of green bolls in *Bt* hybrids than in non-*Bt* hybrid. This can be ascribed to the increased number of squares and flowers in the former by virtue of protection from entomological shedding. Patil *et al*. (2009), Thakare *et al*. (2012) and Sarlach and Sharma (2012) also reported higher fruiting bodies in *Bt* hybrids compared to conventional hybrid.

5.4 BIOCHEMICAL STUDIES

5.4.1 Chlorophyll content (mg g^{-1})

According to Bhatt and Ramanujam (1971), photosynthetic pigments are capable of absorbing light energy for the synthesis of carbohydrates. Chlorophyll content determines the photosynthetic capacity of the cotton genotypes and influences the rate of photosynthesis, dry matter production and the yield (Krasichkova *et al.,* 1989).

Foliar application of Ethylene, MH and Ethylene + MH showed increased chlorophyll content over control. This variation in chlorophyll content due to growth regulators may be attributed to decreased chlorophyll degradation and increased chlorophyll synthesis especially the MH which is known to give dark green colour to foliage. Similar findings were reported by Bhatt and Ramanujam (1971) and Reddy *et al*. (1996).

The results showed that Vikram 5 (BG-II) had highest chlorophyll content whereas G. Cot Hy-12 lowest chlorophyll content. It indicates that *Bt* hybrids retained more chlorophyll content than non-*Bt*. Sarlach and Sharma (2012) also found higher chlorophyll content in *Bt* hybrids than non-*Bt*.

5.4.2 Reducing Sugars (µ/g g fresh wt)

The results revealed significant increase in reducing sugars content due to the application of Ethylene at squaring stage. It was the consequence of Ethylene application which enhanced and stimulated the chlorophyll content, photosynthetic activity and increased metabolites required for more carbohydrate biosynthesis. This also may be due to indirect effect of Ethylene on enzyme activity. Similar inference was drawn by Mohamed (2009).

MH application also increased reducing sugar content over control at 90 DAS onward which can be ascribed to increased chlorophyll content, photosynthates and growth rates. It is usual that with advancement in the crop growth, metabolic activity of the plant is increased to support the reproductive growth.

The results showed that Vikram 5 (BG-II) recorded significantly higher reducing sugars compared to remaining hybrids *i.e.*, RCH 2 (BG-II) and G. Cot Hy-12.

5.5 MORPHO PHENOLOGICAL EVENTS

5.5.1 Days to 50 per cent squaring, 50 per cent flowering, 50 per cent boll bursting and maturity

Development pattern in cotton is an important aspect as the phenological characters are varied and distinct. Seed cotton yield is dependent on many factors, of which the rates of flowering, length of flowering period, the percentage of bolls setting are important. This was known to be influenced by environmental conditions such as growing season, PGRs' fertilizer application, irrigation etc. Earliness of crop maturity in cotton may be defined as the extent to which square initiation, flower occurrence, complete boll bursting and maturity occur in relation to the time of planting.

The results indicated that application of Ethylene at the time of square initiation and Maleic hydrazide at 85 DAS had no significant effect on 50 per cent squaring. Marginal effect on days to 50 per cent flowering was observed due to Ethylene which might be the result of reduced availability of endogenous gibberellins. (King *et al*. 1990). The findings are in agreement with those of Dubey and Singh (1967), Henneberry *et al*. (1992) and Gupta and Chauhan (2005).

Ethylene application however, significantly enhanced bolls bursting and reduced maturity over control and required lesser days for these event. Ethylene known as ripening hormone was boosted up in the bolls due to external application leading to weakening and dissolving of cell walls and build up of internal pressure causing carpels to split apart and allowing the bolls to open naturally early. Weir and Gaggero (1982) and Rajni *et al*, (2011) also observed similar results and accounted for it to increased level of Ethylene in bolls. On the other hand, application of MH at 85 DAS showed significantly delayed boll bursting and maturity over control as well as over Ethylene. MH is a known growth inhibitors and an anti-gibberellin which delayed senescence and retained greenness through greater chlorophyll content, LAI and LAD which resulted into delayed boll bursting and maturity.

The results indicated that days required for 50 per cent flowering were significantly higher in non-*Bt* hybrid G. Cot Hy-12 versus *Bt* hybrids, Vikram 5 (BG-II) and RCH 2 (BG-II). This could be understood in the light of the fact that in *Bt* hybrids, earliest squares turned into flowers by virtue of inbuilt protection due to *Bt* toxin which was not there in conventional hybrid G. Cot Hy-12. Moreover, early setting of most squares also imparted determinateness in *Bt* hybrids and matured earlier compared to non-*Bt* hybrid. An identical trend was observed in days required for bolls bursting and maturity wherein G. Cot Hy-12 required significantly more days than the two *Bt* hybrids. In general, it was observed that as *Bt* hybrids were early when compared with conventional cotton, as a consequence they are early in peak squaring, flowering, boll bursting and maturity. The present findings are in line with the results of Villareal (1991).

5.5.2 Growing degree days and Heliothermal unit

Application of growth regulators had no significant bearing on growing degree days (GDD) required form emergence to 50 per cent squaring and emergence to 50 per cent flowering **(Table-4.18)**. However, Ethylene application resulted in significantly less degree days for 50 per cent boll bursting and maturity than untreated control whereas, MH application resulted in significantly more degree days for these morpho-phenological events. These are in tune with morpho-phenological events discussed earlier. Treatment with both Ethylene and MH required significantly more degree days than Ethylene but less than MH for 50 per cent boll bursting and maturity. Similar results was obtained by Gwathmey and Hayes (1996) who reported that application of Ethephon significantly increased the boll opening of cotton, however, the boll opening response to Ethephon was highly correlated with degree days accumulation.

The results indicated that the *Bt* hybrids RCH 2 (BG-II) and Vikram 5 (BG-II) required significantly less degree days to attain 50 per cent boll bursting and maturity than non-*Bt* G. Cot Hy-12 which matches with the days required for 50 per cent boll bursting by these hybrids.

Heliothermal unit (HTU) for morpho-phenological events differed significantly **(Table-4.19)** due to growth regulators. Lower HTU due to Ethylene application and higher HTU due to MH application were required the highest for 50 per cent boll bursting and maturity. Application of Ethylene + MH recorded increased heliothermal unit for 50 per cent boll bursting and maturity over control and Ethylene but less than MH application singly for the same events to occur. Logan and Gwathmey (1998) suggested that boll opening was affected more when application with Ethephon in cooler environments than in warmer environments where heliothermal unit (heat unit) accumulation is more influential in cotton.

Bt hybrids required significantly less HTU to attain 50 per cent boll bursting and maturity compared to non-*Bt* hybrid G. Cot Hy-12. Morpho-phenological events in these hybrids corroborated with their heliothermal units consumed.

5.7. YIELD CONTRIBUTING CHARACTERS

Yield is the final product of all the physiological and growth process that the plant went through. In cotton the yield is the product of number of bolls per plant and boll weight. Both these are the result of percentage of biomass translocated to reproductive parts (H.I.). Therefore it will be pertinent to discuss each of these in the light of foregoing discussion.

5.7.1 Number of bolls

The number of bolls that a cotton hybrids bears at harvest or maturity is an important yield component having the greatest direct effect on yield. This character is greatly influenced both by physiological process and environmental factors. Application of Ethylene at squaring stage induced higher photosynthetic efficiency as indicated by greater leaf area, growth rate, NAR, RGR, higher biomass production, higher sympodia per plant and providing better room for more fruiting forms which in turn increased the number of bolls. Sawan *et al.* (2006), Zulfiqar *et al.* (2006), Thakare *et al.* (2011) and Kumari and George (2013) also reported higher bolls due to Ethylene.

Application of MH also increased number of bolls when compared with the control. Increased number of bolls due to growth inhibitor were basically due to increased leaf area, growth rate and biomass production during active reproductive phase. These results are in harmony with the finding of El-Antably and El-Atta (1992) and Anonymous (2011[h]). Kumari and George (2012) also observed higher bolls per plant due to MH application in cotton.

Ethylene (45 ppm) and MH (500 ppm) applied at squaring stage and 85 DAS, respectively showed amazing effect on number of bolls, which was significantly more than that recorded due to application of these chemicals singly. The physiological advantage of each of these chemicals proved complimentary in combined application. This can be substantiated by higher growth rate, canopy, photosynthetic pigments, plant stature and biomass observed in this treatment over the two chemicals used alone which was enough to sustain increased number of bolls.

More bolls in *Bt* hybrids compared to conventional hybrid G. Cot Hy-12 were because of increased number of squares and flowers in the former. Patil *et al.* (2009), Thakare *et al.* (2011) and Sarlach and Sharma (2012) also reported similar results.

5.7.2 Boll weight (g)

Boll weight is relatively less affected by growing conditions than boll number. It is strongly genetically governed and small changes in environment, cultural manoeuvres do not affect boll weight unless a change at cell/molecular level or an abrupt change in environment takes place. Ethylene a naturally occurring plant hormone is known for varied effect on plant system *viz*., plant height, sympodia and biomass. Singh and Singh (1977), Sawan *et al.* (1984), Tan-Qiling *et al.* (1995) and Brown *et al.* (1999). In the present study Ethylene application resulted significant enhancement in boll weight. Increased source size (LAI), subsequent growth and biomass production could well explain increased sink number and size (boll weight) due to Ethylene. Thakare *et al.* (2011) also reported similar results.

Maleic hydrazide a growth retardant also increased boll weight which can be ascribe to increased canopy development, chlorophyll content, growth rate, biomass accumulation subsequent to MH spray. Such reports by Anonymous (2010[f]) and Kumari and George (2012) support the present findings.

Application of Ethylene followed by MH also exhibited significantly higher boll weight over untreated control. This might be the result of increased photosynthetic activity which can be viewed in the light of foregoing discussion but unlike number of boll, it was not as advantageous over the two chemicals used alone.

Vikram 5 (BG-II) recorded higher boll weight than RCH 2 (BG-II) and G. Cot Hy-12. The variations in boll weight amongst genotypes are commonly known. Khan *et al*. (2009) and Patil *et al*. (2009) reported higher boll weight in *Bt* cotton compared to non *Bt* counterpart.

5.7.3 Seed cotton yield

The seed cotton yield per plant as well as per hectare was significantly enhanced due to one spray of Ethylene (45ppm) at squaring stage or/and one spray of MH (500ppm) 85 DAS. This could simply be explained as a product of number of bolls and/or boll weight which the present finding fully substantiate. Both Ethylene and MH triggered/enhanced physiological reactions and a series of growth processes leading to greater biomass production in their own way as explained earlier. Efficient translocations of biomass to fruiting bodies by these chemicals lead to higher yield. Literature abounds with several reports on the beneficial effect of Ethylene on cotton yield. Similarly, there are report where in MH has been reported to enhance seed cotton yield. Singh and Singh (1977), Singh and Tripathi (1977), Prokofex and Rasulov (1979), Weir and Gaggero (1982), Sawan *et al*. (1984), Scott (1990), Thakral *et al*. (1991), Prasad *et al*.

(1997), Mohamed (2009), Anonymous (2010[a]), Thakare *et al*. (2011) and Buttar and Singh (2013). (Anonymous 2010[f], Anonymous, 2010[g] and Kumari and George, 2012).

A complimentary effect of Ethylene and MH on seed cotton yield was observed where both were applied at appropriate stage. Higher yield in this treatment was in tune with higher growth rates and biomass recorded in this treatment.

Bt hybrids Vikram 5 (BG-II) and RCH 2 (BG-II) were significantly superior to G. Cot Hy-12, which may be because of increase in number of sympodia, squares, flowers and bolls due to inbuilt protection from entomological damage and retention of more energy was utilized in reproductive development in the *Bt* cotton rather than vegetative development in non-*Bt* cotton. Patil *et al*. (2009), Sarlach and Sharma (2012) and Kumari and George (2012) also reported higher yield in *Bt* cotton than conventional cotton.

5.7.4 Biomass (g/plant)

The results reveal that Ethylene application at squaring stage recorded enhanced biomass over untreated control, this increased biomass was due to increase in plant height, sympodia, nodes and number of bolls, preceding series physiological processes as evident by LAI, NAR and RGR. Thakare *et al*. (2011) also observed increased biomass due to Ethylene application in cotton hybrids.

Application of MH at 85 DAS increased biomass (g/plant) over untreated control which might be due to increased reproductive growth occurred after MH spray accompanied by higher chlorophyll content, better canopy development (LAI), its retention (LAD), subsequent growth leading to biomass production. The findings are in conformity with those of Kumari and George (2012).

Supplemental effect of MH application on biomass was seen in Ethylene treated plant compared to MH and Ethylene individually which was substantiated by greater LAI, LAD, NAR, growth rates and plant stature. Higher biomass in this treatment was retained with higher sympodia and fruiting bodies.

The results indicate that Vikram 5 (BG-II) and RCH 2 (BG-II) recorded higher biomass (g/plant) compared to G. Cot Hy-12, which may be partly due to higher LAI, LAD and partly due to retention of fruiting sites.

5.7.5 Partitioning efficiency (%) (Harvest index)

Harvest index indicates the translocation efficiency of plants and is measured in terms of per cent of dry matter utilized for the production of economic yield.

Single application of Ethylene and/or MH increased harvest index of cotton. Better sink development both in terms of number and size as well as source *i.e.* LAI and its photosynthetic efficiency as indicated by NAR, RGR and CGR lead to efficient translocation due to these chemicals.

The hybrids did not show significant differences in harvest index. Relatively low H.I was observed in conventional hybrid G. Cot Hy-12 than *Bt* hybrids which is quite obvious *Bt* hybrids possessed higher H.I. values compared to their non-*Bt* counterparts is well documented (Patil *et al.* 2009 and Hebbar *et al.* 2007).

5.7.6 Seed cotton yield/plant at 140, 155 and 170 days

The results clearly indicated (**Table 4.21**) that the Ethylene not only results in higher yield but also brought in earliness. Similar results were observed by Agakishiev and

Pal'Vanova (1976), Scott (1990) and Mohamed (2009) who reported increased seed cotton yield in first picking due to Ethylene application. Whereas MH causes delay in harvesting by virtue to greenness and LAI development of late stage but ultimately higher yield, there are similar report where in MH has been reported to enhance seed cotton yield. (Anonymous, 2010[f], Anonymous, 2010[g] and Kumari and George, 2012).

5.8. ECONOMICAL CHARACTERS

5.8.1 Ginning percentage

It was observed **(Table-4.22)** that ginning per cent did not significantly differ either due to the growth regulator treatments or hybrids.

5.8.2 Seed index (g)

The present results indicated that Ethylene tended to increase seed index over control. This might be due to increased photosynthetic activity and dry matter accumulation resulting in to sustained supply and formation of fully matured seeds and thereby increased seed weight. Analogous results were reported by Bangarwa *et al*. (1981), Sawan *et al*. (1993), Mohamed (2009) and Anonymous (2010[c]).

On the other hand, applications of MH recorded a significant reduction in seed index. Similar results for Maleic hydrazide were obtained by Kumari and George (2012).

The result showed significant variation in seed index of hybrids. Seed index is a genetically governed character therefore such differences do occur amongst *Bt* hybrids. Better reproductive growth and biomass in *Bt* hybrids probably is responsible for the higher seed index which Kumari and George (2012) and Patil *et al*. (2009) also reported in *Bt* hybrids compared to their non-*Bt* version.

5.8.3 Lint index (g)

The result showed that Ethylene significantly increased lint index (g) whereas MH decreased the same over control. Buttar and Agarwal, (2004) also reported higher seed index due to Ethylene. A lower seed index due to MH has been reported earlier (Anonymous, 2010[c]).

The lint index (g) significantly differed amongst the cotton hybrids due to their different genetic background.

5.8.4 Oil content (%)

The results indicated that **(Table-4.22)** growth regulators did have any significant bearing on oil content. Ethylene application resulted in slightly higher oil content which could be the results of its higher seed weight. Similar result was observed by Bangarwa *et al*. (1981). On the other hand, lower seed index in MH treated plants might be the possible cause of lower oil content. The hybrids did not differ in oil content.

5.9 FIBRE QUALITY PARAMETERS

Growth regulators treatment **(Table-4.23)** had no significant bearing on span length and fineness of the fibre. Fibres in all treatments including control were long (27.5-32.5 mm) and average in fibre fineness (4.0-4.9 µg $inch^{-1}$) very good to excellent in uniformity ratio (47%- above) and excellent in maturity ratio (0.81-0.90).

It indicated that quality of the fibre decreased with the application of growth regulators but uniformity ratio, fibre fineness, maturity ratio and elongation did not show any significant difference amongst the treatments. This is in agreement with Boman and Westerman (1994) and Mondino *et al, (*2004).

Application of Ethylene significantly improved strength over MH alone. Similar, results were reported by Kerby (1985), Mehetre *et al.* (1990), Reddy *et al.* (1990), Snipes and Baskin (1994) and Kumari and George (2013). On the other hand application of MH at 85 DAS recorded significantly detrimental effect on fibre strength over control was also reported similar results by Kumari and George (2012). Application of Ethylene + MH significantly increased value of fibre strength than MH and at par to the Ethylene.

Fibre quality parameters as delineated in **Table 4.23** showed that all the hybrids fell in long staple category (27.5-32.5mm) with good maturity ratio (0.81-0.90). However, uniformity ratio was excellent in G. Cot Hy-12, Vikram 5 (BG-II) and good in RCH 2 (BG-II). In term of fibre fineness, G. Cot Hy-12 and Vikram 5 (BG-II) yielded fine fibre (4.0-4.9 µg $inch^{-1}$) whereas RCH 2 (BG-II) was average in fibre fineness whereas all hybrids were average in fibre strength (21-24 g tax^{-1}).

5.10 ECONOMICS STUDIES

The data on economics of the use of growth regulators is presented in **Table-4.24.** Individual application of Ethylene at squaring stage and MH at 85 DAS increased gross monetary returns (GMR), net monetary returns (NMR) and benefit cost ratio (BCR) over untreated control. Similar results were reported by Singh and Singh (1977), Prasad *et al.* (1997), Anonymous (2011j) and Chaudhari *et al.* (2013).

Application of Ethylene followed by MH resulted in highest gross monetary returns (GMR), net monetary returns (NMR) and benefit cost ratio (BCR) over MH and Ethylene alone. This was associated primarily to higher seed cotton yield in these treatments. Hence application of 45 ppm

Ethylene at squaring initiation stage followed by application of 500 ppm MH at 85 DAS was found to be most cost effective and economically viable technology.

Amongst the hybrids, Vikram 5 (BG-II) gave highest GMR, NMR and BCR followed by RCH 2 (BG-II). Minimum GMR, NMR and BCR were in conventional hybrid G. Cot Hy-12. However, the technology was found equally effective for *Bt* cotton hybrids as well as conventional cotton hybrid.

SUMMARY AND CONCLUSION

Gossypium sp. (Cotton)

VI SUMMARY AND CONCLUSION

A field experiment was conducted on black cotton soil at Main Cotton Research Station, N.A.U., Surat during *kharif* 2011-12 to 2012-13 to study the influence of modification of morphoframe on physiology and yield in cotton. The experiment was conducted in Randomized Block Design with factorial concept (FRBD) having three replications. Observations on various parameters pertaining to physiological traits, growth attributes, biochemical constituent, crop phenology, morpho-phenological event, yield and yield components were taken at different time intervals and their inter-relationships were worked out. The results obtained from the present investigations are summarized below.

1. The LAI and LAD increased continuously with the age of crop until 120 and 145 DAS, respectively and decreased thereafter during both the years as well as in pooled. Individual application of Ethylene at squaring stage and MH at 85 DAS recorded increased LAI and LAD over control. Supplemental effect of MH on Ethylene treated plant was observed on LAI and LAD which was higher than that in MH and Ethylene alone, particularly 95 DAS onward.

Application of Ethylene and MH increased CGR, RGR as well as NAR over control. Application of Ethylene and MH both had synergistic effect and significantly enhanced CGR and NAR over rest of the treatments. However did not depict any significant advantage on RGR.

2. Ethylene and MH exhibited significantly enhanced dry matter accumulation over untreated control. Supplemental effect of MH on Ethylene treated plant was observed as higher dry matter accumulated in this treatment against MH and Ethylene alone.

3. Ethylene application exhibited significantly greater plant height over rest of treatments. Conversely, MH application had depressing effect on plant height over control.

Ethylene significantly enhanced the numbers of sympodia, monopodia, squares, flowers and green bolls over control. MH application also displayed significant effect on these characters over control especially at 120 DAS. Application of both Ethylene and MH had supplemental effect on the number of sympodia, mainstem nodes, squares, flowers and green bolls over MH and Ethylene alone.

4. Chlorophyll content showed significant increased due to Ethylene and MH over untreated control. Application of Ethylene + MH resulted in further increase in chlorophyll content over Ethylene.

Ethylene as well as MH application all along significantly increased reducing sugars content.

5. Days required for 50 per cent squaring and flowering were not influenced by Ethylene application. However, days to 50 per cent boll bursting and maturity were significantly reduced. MH, contrary to it, increased days required for 50 per cent boll bursting and maturity. Application of Ethylene required significantly less degree days and heliothermal units for emergence to 50 per cent boll bursting and maturity compared to other treatments whereas, MH application required significantly more degree days and heliothermal units for the same events. Application of Ethylene + MH recorded higher degree days and heliothermal units over

Ethylene and lower GDD and HTU over MH for the same events.

6. Both the growth regulators Ethylene and MH showed increment in yield over untreated control during both the years and in pooled, duly substantiated by number of bolls, boll weight, biomass and harvest index. Application of both Ethylene + MH showed further enhancement in yield attributing and yield over Ethylene and MH used individually.

7. Significantly higher seed index and lint index (g) were obtained with the application of Ethylene over untreated control. Whereas MH significantly lowered seed index and lint index. Detrimental effect of MH on lint index was moderated in previously Ethylene treated plant. Ginning percentage and oil content were not significantly influenced by growth regulators.

8. Fibre quality parameters like 2.5 per cent span length, fibre fineness, uniformity ratio, maturity ratio, fibre elongation and short fibre index did not show any differences due to Ethylene or MH. However, Ethylene significantly improved strength of the fibre whereas MH had slightly detrimental effect on the same over control.

9. Ethylene and MH application brought about substantial increase in gross return, net returns and benefit cost ratio than untreated control. Application of Ethylene followed by MH resulted in highest gross return, net returns and benefit cost ratio compared to Ethylene and MH alone.

10. Amongst the three hybrids Vikram 5 (BG-II) followed by RCH 2 (BG-II) was superior than non-*Bt* G. Cot Hy-12 with respect to various growth, morphological characters, biochemical characters, economical characters like seed index, lint index, oil content, 2.5 per cent span length and fibre elongation except some fibre quality parameters *i.e.*, fibre fineness, uniformity ratio, maturity ratio, fibre strength, short fibre index where higher in G. Cot Hy-12.

The *Bt* hybrids RCH 2 (BG-II) and Vikram 5 (BG-II) were early in terms of days to 50 per cent boll bursting and maturity required less degree days and heliothermal unit to attain a particular growth and reproductive stage and final maturity compared to G.Cot Hy-12.

Vikram 5 (BG-II) and RCH 2 (BG-II) gave higher yield due to greater LAI, LAD, CGR, RGR as well as NAR, more number of fruiting forms and sympodia contributing to higher yield *vis-a-vis* G.Cot Hy-12.

11. The interactions of hybrids with growth regulators for most of the important parameters were found not significant implying that the response of *Bt* and non-*Bt* hybrids to chemical growth modifiers was the same and that use of 45 ppm Ethylene at squaring stage followed by application of 500 ppm MH at 85 DAS significantly increased seed cotton yield bringing in higher net return in cotton.

CONCLUSION

Influence of modification of morphoframe through application of Ethylene (45 ppm) at square initiation followed by application of MH (500 ppm) at 85 DAS resulted in higher leaf area index, better assimilation of photosynthates, improved fruiting bodies, number of sympodia, number of bolls, chlorophyll content, boll weight, biomass and seed cotton yield ultimately better net returns and benefit without affecting the quality of the produce. As such this treatment was beneficial in term of earliness, maturity compared to the control.

Amongst the three hybrids tested Vikram 5 (BG-II) was highest yielding duly substantiated by greater physiological parameters, number of fruiting forms, chlorophyll content, reducing sugars, fruiting branches and biomass. Non-*Bt* G. Cot Hy-12 was lowest yielder as was evident from relatively low values for all the above characters. The three hybrids responded to chemical modification of morphoframe in similar manner.

FUTURE LINE OF WORK

1. The two PGRs tested in the present study need to be demonstrated on larger scale and in other agroecological situations.

2. A few more *Bt* and non-*Bt* cotton hybrids should be evaluated to confirm the technology so that it could make a recommendation for farmers.

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*Original not seen

APPENDICES

Gossypium sp. (Cotton)

Appendix-I: Meteorological data during the experimental period (2011-12) at Main Cotton Research Station, NAU, Surat

Sr. No	Month	Std. week no.	Temp.		RH (%)		Sun shine hrs/day	Rainfall (mm)	Rainy days	Evap. (mm)
			Max. (^{0}C)	Min. (^{0}C)	Mor	Even				
1	June - 2011	22	37.5	28.8	77	76	10.19	10.0	1	2.1
		23	36.2	27.5	76.0	69.6	4.70	0.0	0.0	3.4
		24	34.2	27.3	79.0	70.7	5.64	21.0	2	2.6
		25	33.7	27.8	80.1	69.1	0.50	0.0	0.0	4.0
		26	34.1	28.3	79.0	75.0	0.0	0.0	0.0	2.9
2	July - 2011	27	34.7	26.4	83.9	62.3	0.0	121.0	7	2.8
		28	30.6	25.3	85.0	72.3	0.0	65.0	3	3.2
		29	31.6	25.6	88.7	68.7	0.0	75.0	5	1.1
		30	31.1	25.9	90.0	70.3	0.86	64.0	2	1.0
3	Aug - 2011	31	31.5	26.1	86.9	79.0	0.0	39.6	3	0.6
		32	30.9	26.5	85.0	81.0	0.0	70.0	6	0.3
		33	32.1	26.3	85.0	75.0	0.0	201.0	5	0.1
		34	30.7	25.1	88.0	73.0	0.0	90.0	3	0.3
		35	30.6	24.8	91.0	85.0	0.0	195.0	6	-
4	Sept-2011	36	30.7	25.4	85.0	78.0	1.63	76.4	4	1.5
		37	30.4	25.3	89.0	72.0	2.31	124.0	5	2.3
		38	31.2	25.0	88.0	79.0	4.19	0.0	1	4.1
		39	32.3	24.7	85.0	74.0	7.41	0.0	0.0	4.3
5	Oct - 2011	40	33.7	24.4	85.0	75.0	8.11	0.0	0.0	4.9
		41	36.3	25.1	82.0	51.0	8.07	0.0	0.0	6.0
		42	36.6	24.6	90.0	68.0	7.64	0.0	0.0	5.3
		43	36.4	20.7	78.0	74.0	8.57	0.0	0.0	5.7
		44	34.7	23.0	69.0	56.0	8.79	0.0	0.0	5.9
6	Nov-2011	45	36.8	20.2	74.0	33.0	7.57	0.0	0.0	4.7
		46	36.6	19.9	63.0	41.0	7.57	0.0	0.0	4.9
		47	35.0	19.6	66.0	35.0	3.57	0.0	0.0	4.0
		48	34.7	21.2	70.0	48.0	7.71	0.0	0.0	4.1
7	Dec-2011	49	34.6	18.4	71.0	40.0	8.41	0.0	0.0	4.3
		50	32.4	17.2	69.0	29.0	7.29	0.0	0.0	5.0
		51	32.3	17.1	77.0	35.0	6.21	0.0	0.0	4.1
		52	31.2	15.0	71.0	37.0	4.44	0.0	0.0	2.0
8	Jan-2012	1	29.3	13.6	77.4	36.9	6.1	0.0	0.0	2.3
		2	28.7	14.4	65.0	31.9	6.6	0.0	0.0	2.9
		3	28.4	13.2	74.9	52.4	6.7	0.0	0.0	3.0
		4	30.5	15.8	75.1	37.7	6.5	0.0	0.0	3.1
9	Feb-2012	5	31.6	16.1	58.0	32.4	6.9	0.0	0.0	4.3
		6	28.4	14.2	58.0	37.3	0.0	0.0	0.0	5.0
		7	31.0	14.6	58.9	28.4	0.0	0.0	0.0	3.1
		8	35.5	17.7	61.1	23.1	0.0	0.0	0.0	2.9
Total								1142.0	52	

Appendix-II: Meteorological data during the experimental period (2012-13) at Main Cotton Research Station, NAU, Surat

Sr. No	Month	Std. week no.	Temp. Max. (^{0}C)	Temp. Min. (^{0}C)	RH (%) Mor	RH (%) Even	Sun shine hrs/day	Rainfall (mm)	Rainy days	Evap. (mm)
1	June - 2012	22	35.0	27.8	75.4	56.9	7.7	0.0	0. 0	3.9
		23	34.8	27.8	73.3	58.9	5.2	60.0	3	2.1
		24	35.5	26.9	79.4	58.7	5.1	26.0	5	2.0
		25	35.0	27.5	80.9	58.9	7.4	0.0	0.0	2.6
		26	34.5	27.6	76.1	60.1	9.3	0.0	0.0	3.6
2	July - 2012	27	30.0	26.6	82.1	69.1	5.4	106.0	4	1.1
		28	33.9	26.5	81.4	69.1	3.8	57.8	4	1.1
		29	32.7	27.3	87.6	71.6	0.0	60.0	1	1.7
		30	31.9	27.6	92.3	86.0	0.0	2.6	2	2.1
3	Aug - 2012	31	31.2	26.5	91.4	88.7	0.0	8.0	5	2.1
		32	31.9	26.6	81.0	79.1	0.0	66.0	5	0.7
		33	31.3	25.6	80.3	70.9	0.0	18.0	2	3.4
		34	31.9	25.7	86.6	76.6	0.0	29.4	2	2.4
		35	32.5	25.9	82.9	77.0	0.0	55.8	1	1.7
4	Sept-2012	36	30.6	25.6	92.9	87.4	0.0	218.2	5	0.1
		37	30.3	25.0	91.9	86.7	0.0	77.8	5	0.4
		38	31.9	25.9	82.0	61.3	0.0	0.0	0.0	4.1
		39	33.1	24.9	83.4	55.4	0.0	30.6	3	4.3
5	Oct - 2012	40	34.4	26.1	84.7	63.6	0.2	13.6	2	3.4
		41	35.4	22.6	82.4	45.7	3.3	0.0	0.0	5.0
		42	36.0	21.4	70.6	33.3	7.2	0.0	0.0	6.4
		43	36.0	20.4	68.0	36.0	5.3	0.0	0.0	7.4
		44	34.9	18.9	58.0	37.3	2.2	0.0	0.0	4.0
6	Nov-2012	45	33.2	18.7	69.0	47.7	0.0	0.0	0.0	6.9
		46	31.6	18.5	79.3	44.0	0.0	0.0	0.0	4.1
		47	33.9	16.7	69.0	23.7	0.0	0.0	0.0	3.9
		48	33.2	16.7	74.3	30.9	2.0	0.0	0.0	4.9
7	Dec-2012	49	33.5	21.3	67.0	32.0	5.7	0.0	0.0	5.6
		50	31.7	17.4	85.6	37.0	5.0	0.0	0.0	4.9
		51	32.7	20.7	62.9	30.6	5.3	0.0	0.0	4.9
		52	32.9	17.1	64.8	28.4	6.0	0.0	0.0	4.4
8	Jan-2013	1	30.0	14.6	64.3	80.6	7.2	0.0	0.0	4.0
		2	30.9	16.9	87.6	84.7	9.0	0.0	0.0	4.7
		3	31.1	16.7	82.7	79.1	7.6	0.0	0.0	5.9
		4	31.1	17.4	92.6	89.0	8.3	0.0	0.0	6.9
9	Feb-2013	5	33.1	18.3	92.1	77.7	9.4	0.0	0.0	7.2
		6	32.0	18.8	64.4	30.4	8.9	0.0	0.0	7.9
		7	33.1	20.5	65.7	33.4	7.0	0.0	0.0	7.3
		8	34.8	20.8	75.4	59.6	8.8	0.0	0.0	7.5
Total								781.00	45	

Appendix- III: Particulars of expenditure and income

	Particulars	Amount (Rs ha^{-1})	
		2011-12	2012-13
A) Fixed cost:			
1.	Land preparation (9 hrs ploughing + 3 hrs harrowing + 2 hrs planking)	4150	4150
2.	FYM @ 10 tonne ha^{-1} + application (2 labours)	7740	10240
3.	Lay out and preparation of plots, bunds and irrigation channels (8 labours)	960	960
4.	Sowing and fertilizer application (8 labours)	960	960
5.	Cost of fertilizer (240:40:0 kg NPK ha^{-1}) (15 labour)	5019	5335
6.	Thinning and gap filling (5 labours)	600	600
7.	Weeding 3 (15 labours)	1800	1800
8.	Interculturing (3 hoeing 6 hrs)	840	840
9.	Irrigation (2 irrigation + 2 labours)	940	940
10.	Plant protection (4 spraying + 8 labours)	2171	2310
11.	Stalk uprooting (6) and Stalk collection (5)	1320	1320
12.	Land revenue Rs 50/ha/annum (7 month)	29	29
13.	Total working capital	26529	29484
14.	Interest on working capital @ 12% (7 month)	3183	3538
15.	Supervision charges @ 10% of total working capital (7 month)	2653	2948
	Fixed cost (A)	32365	35970
B) Variable cost			
1.	**Growth regulators**		
	T_1- Control (00 ppm)	00	00
	T_2- Ethylene 45 ppm (2 labours)	585	689
	T_3- Maleic hydrazide 500 ppm (2 labours)	526	592
	T_4- Ethylene 45 ppm + MH 500 ppm (2 labours)	871	1041
2.	**Seed**		
	V_1- RCH-2 (BG –II) (1125 gm ha^{-1})	2325	2325
	V_2- Vikram- 5 Bt (BG –II) (1125 gm ha^{-1})	2325	2325
	V_3- G.Cot Hy- 12 (1125 gm ha^{-1})	439	439
C) Rates used for cultivation and inputs			
1.	Tractor cultivation (Rs hr^{-1})	350	350
2.	Tractor planking (Rs hr^{-1})	200	200
3.	Irrigation charges (Rs. $Irrigation^{-1}$)	350	350
4.	Harrowing charges (Rs. hr^{-1})	200	200
5.	Hoeing (Rs. hr^{-1})	200	200
6.	Labour charges (Rs. day^{-1})	120	120
D) Selling rate of produce			
1.	Seed cotton (Rs. kg^{-1})	40	44
2.	Cotton stalk (Rs. kg^{-1})	1.00	1.00
3.	Picking cost Rs kg^{-1}	5.00	5.00

Appendix- III: ***contd…***

Price rates				
A	Inputs		Cost	
			2011-12	2012-13
	1.	**Growth regulators**		
		Ethylene	Rs. 100/100ml.	Rs. 130/100ml.
		Maleic hydrazide	Rs. 447/250g	Rs.550/250g
	2.	**Seed**		
		RCH- 2 (BG –II)	Rs. 930/450g	Rs. 930/450g
		Vikram- 5 (BG –II)	Rs. 930/450g	Rs. 930/450g
		G.Cot Hy- 12	Rs. 390/Kg	Rs. 390/Kg
	3.	**Fertilizers**		
		2011-12 / **2012-13**		
		Urea — Rs 292/50kg — (Rs. 305/50 kg)	Rs. 11.68	Rs. 12.26
		SSP — Rs 260/50 kg — (Rs. 370/50 kg)	Rs. 10.40	Rs. 14.80
		FYM — (Rs. 0.75/kg) — (Rs. 1.00/kg)	Rs. 0.75	Rs. 1.00
	4.	**Pesticides**		
		Imidacloprid 200 SL @ 0.70%	650/250ml	750/250ml
		Fipronil 5 % SC	1070/lit	1100/lit
		Quinolphos 25% EC @ 0.05%	300/lit	400/lit
		Acephate 75 % SP	430/kg	500/kg

Appendix- IV: Economics (Average 2011-12 and 2012-13)

Treatments	Common cost (a)	Treatment cost (b)	Total (c = a+b)
Growth regulators			
T_1 - Control (00 ppm)	34168	1696	35864
T_2 - Ethylene 45 ppm	34168	2333	36501
T_3 - MH 500 ppm	34168	2255	36423
T_4 - $T_2 + T_3$	34168	2652	36820
Hybrids			
V_1 - RCH 2 Bt (BG-II)	34168	2863	37031
V_2 - Vikram 5 Bt (BG-II)	34168	2863	37031
V_3 - G. Cot Hy-12	34168	977	35145

Appendix- IV: *Cont…*

Treatments	Common cost (a)	Treatment cost (b)	Total (c = a+b)
T_1V_1	34168	2325	36493
T_1V_2	34168	2325	36493
T_1V_3	34168	439	34607
T_2V_1	34168	2962	37130
T_2V_2	34168	2962	37130
T_2V_3	34168	1076	35244
T_3V_1	34168	2884	37052
T_3V_2	34168	2884	37052
T_3V_3	34168	998	35166
T_4V_1	34168	3281	37449
T_4V_2	34168	3281	37449
T_4V_3	34168	1395	35563

C E R T I F I C A T E

This is to certify that I have no objection for supplying to any scientist only one copy or any part of this thesis at a time through reprographic process, if necessary for rendering references service in a library or documentation center.

Place: Navsari

Date: / / 2014 **(Dinesh P. Nawalkar)**