STUDIES ON SOURCE SINK RELATIONSHIP FOR REALIZATION OF HIGHER PRODUCTIVITY IN *BT* COTTON (*Gossypium hirsutum* L.)

Dissertation

Submitted to the Punjab Agricultural University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY
in
AGRONOMY
(Minor Subject: Soil Science)

By

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(L-2009-A-1-D)

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LUDHIANA-141 004

2013

CERTIFICATE – I

This is to certify that the thesis entitled, "**Studies on source sink relationship for realization of higher productivity in *Bt* cotton (*Gossypium hirsutum* L.)**" submitted for the degree of Ph.D., in the subject of **Agronomy** (Minor subject: **Soil Science**) of Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Mr. Amit Kaul (L-2009-A-01-D)** under my supervision and that no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

Major Advisor
(Dr. J.S. Deol)
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CERTIFICATE – II

This is to certify that the thesis entitled, "Studies on source sink relationship for realization of higher productivity in *Bt* cotton (*Gossypium hirsutum* L.)" submitted by Mr. Amit Kaul (L-2009-A-01-D) to the Punjab Agricultural University, Ludhiana, in partial fulfilment of the requirements for the degree of P.hD., in the subject of Agronomy (Minor subject: Soil Science) has been approved by the Student's Advisory Committee after an oral examination on the same.

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Dean, Post-Graduate Studies
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(Amit Kaul)

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ABSTRACT

The present investigation entitled "Studies on source sink relationship for realization of higher productivity in *Bt* cotton (G*ossypium hirsutum* L)"comprising of three experiments (two field and one pot experiment) were carried out at the Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana, during *kharif* seasons of 2011 and 2012. All the three experiments were laid out in split plot design with four replications. Three *Bt* cotton hybrids i.e. MRC 7017, MRC 7031 and RCH 314 were kept in main plots. The sub plot treatments in Experiment I consisted of 0 % (No square removal), 25 % removal (25 % squares removed for a period of month at pin head stage), 50 % removal (50 % squares removed for a period of month at pin head stage), P1 (fruits retained at first position), P2 (fruits retained at second position) and P1, 2 (fruits retained at first and second position). The Experiment II was a pot experiment comprising similar treatments as in Experiment I. The sub plot treatments in Experiment III consisted of control, detopping (removal of 5 to 7 cm apical portion of the main stem), MC application @ 300 ppm, TIBA @ 100 ppm and MH @ 250 ppm. Growth retardants and detopping treatments were applied at maximum vegetative growth stage i.e. 80 days after sowing (DAS).

The hybrid MRC 7017 attained maximum plant height and higher dry matter accumulation at all the growth stages than MRC 7031 and RCH 314 during both the years. The total number of main stem internodes plant^{-1}, height : node, SPAD value and monopodial branches plant^{-1} did not differ significantly among the three hybrids. Hybrid MRC 7017 produced significantly higher seed cotton yield by 15.0 to 19.1 per cent than hybrid RCH 314 whereas, it was statistically at par with hybrid MRC 7031 during both the years. Higher total seed cotton yield in MRC 7017 was attributed to the maximum number of sympodial branches plant^{-1}, total number of flowers, bolls and picked bolls plant^{-1}.

Fruiting form removal treatments had a significant influence on plant height and LAI at all the growth stages except at 60 DAS during both the years. A significant increase in plant height and LAI was observed in 50 % square removal treatment at 90 DAS. While, at 120 DAS to maturity, P2 attained more plant height and LAI as compared to other fruiting form removal treatments. Accumulation of dry matter in vegetative parts was significantly higher in P2 while, dry matter accumulated in fruiting bodies was significantly higher in 0 and 25 % square removal treatments at 120 and 150 DAS during both the years. The treatment where 0 and 25 % squares were removed recorded higher number of flowers, total bolls and picked bolls plant^{-1} as compared to all other fruiting form removal treatments. The higher setting percentage in first fruit position (P1) resulted in significantly higher number of total bolls and picked bolls plant^{-1} than second fruit position i.e. P2 which eventually helped in producing significantly higher seed cotton yield than P2. Fruiting form removal delayed boll open initiation and 50 % boll opening by 4-11 days than 0 % square removal treatment. Boll weight in P1 improved by 5.6 to 11.8 per cent over control and all the fruiting form removal treatments helped in improving the boll weight as compared to control during both the years. Total seed cotton yield was maximum in 0 % square removal treatments as compared to all other fruiting form removal treatments.

Application of MC (300 ppm), TIBA (100 ppm) and MH (250 ppm) significant reduced plant height, LAI and total dry matter accumulation than control. Detopping treatment significantly reduced plant height than control but attained more plant height than all the PGRs. Application of PGRs resulted in significantly higher dry matter allocation towards fruiting bodies and less towards the vegetative plant organs which improved setting percentage of bolls but did not regulate the CGR and RGR during different periods of crop growth. Different PGR treatments failed to influence the number of monopodial branches plant^{-1} while the number of sympodial branches plant^{-1} was highest with application of MC @ 300 ppm followed by TIBA (100 ppm) and MH (250 ppm) but significantly higher than control. The application of MC @ 300 ppm significantly influenced the total number of flowers produced plant^{-1} while, rest of the PGRs did not show any significant improvement in total number of flowers plant^{-1} over control. Application of MC (300 ppm), TIBA (100 ppm) and MH (250 ppm) improved the total number of bolls, picked bolls plant^{-1} and boll weight. MC (300 ppm) increased the total seed cotton yield (22.79 and 31.62 q ha^{-1} in 2011 and 2012, respectively) as well as that obtained from first, second and third pick. TIBA (100 ppm) and MH (250 ppm) showed statistical similar results with MC (300 ppm) for the seed cotton yield obtained in all the pickings as well as in total seed cotton yield. Detopping failed to influence the seed cotton yield during both the years. Different quality parameters such as seed index, lint index and ginning out-turn were not significantly influenced by application of various PGR treatments.

Keywords: *Bt* cotton hybrids, fruiting form removal, plant growth regulators, mepiquat chloride, 2,3,5-triiodo benzoic acid, maleic hydrazide, seed cotton yield

Signature of Major Advisor

Signature of the Student

ਖੋਜ ਪ੍ਰਬੰਧ ਦਾ ਸਿਰਲੇਖ	:	ਬੀ.ਟੀ. ਨਰਮਾ (*ਗੋਸੀਪੀਅਮ ਹਿਰਸੁਟਮ* ਐਲ.) ਦੀ ਵਧੇਰੇ ਪੈਦਾਵਾਰ ਉਪਰ ਸਰੋਤ-ਸਿੰਕ ਦੇ ਆਪਸੀ ਸਬੰਧ ਦਾ ਅਧਿਐਨ।
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ਸ਼ਾਰ ਅੰਸ਼

ਮੌਜੂਦਾ ਖੋਜ ''ਬੀ.ਟੀ. ਨਰਮੇ (*ਗੋਸੀਪੀਅਮ ਹਿਰਸੁਟਮ* ਐਲ.) ਦੀ ਵਧੇਰੇ ਪੈਦਾਵਾਰ ਉਪਰ ਸਰੋਤ-ਸਿੰਕ ਦੇ ਆਪਸੀ ਸਬੰਧ ਦਾ ਅਧਿਐਨ'' ਸਿਰਲੇਖ ਅਧੀਨ ਪੰਜਾਬ ਖੇਤੀਬਾੜੀ ਯੂਨੀਵਰਸਿਟੀ ਦੇ ਫ਼ਸਲ ਵਿਗਿਆਨ ਵਿਭਾਗ ਵਿਖੇ ਸਾਉਣੀ 2011 ਅਤੇ 2012 ਦੌਰਾਨ ਕੀਤੀ ਗਈ। ਅਧਿਐਨ ਦੌਰਾਨ ਤਿੰਨ ਤਜ਼ਰਬੇ (ਦੋ ਖੇਤ ਅਤੇ ਇੱਕ ਗਮਲਿਆਂ ਵਿੱਚ) ਕੀਤੇ ਗਏ। ਤਿੰਨੇ ਤਜ਼ਰਬੇ ਸਪਲਿਟ ਪਲਾਟ ਡਿਜ਼ਾਇਨ ਵਿਧੀ ਤਹਿਤ ਚਾਰ ਵਾਰ ਦੁਹਰਾਏ ਗਏ। ਬੀ.ਟੀ. ਨਰਮੇ ਦੀਆਂ ਤਿੰਨ ਕਿਸਮਾਂ ਐਮ.ਆਰ.ਸੀ. 7017, ਐਮ.ਆਰ.ਸੀ. 7031 ਅਤੇ ਆਰ.ਸੀ.ਐਚ. 314 ਪ੍ਰਮੁੱਖ ਪਲਾਟ ਵਿੱਚ ਰੱਖੀਆਂ ਗਈਆਂ। ਪਹਿਲੇ ਤਜ਼ਰਬੇ ਦੌਰਾਨ ਉਪ-ਪਲਾਟਾਂ ਵਿੱਚ 0% (ਕੋਈ ਫੁੱਲ ਨਹੀਂ ਤੋੜਿਆ), 25% (ਇੱਕ ਮਹੀਨੇ ਵਿੱਚ 25% ਫੁੱਲ ਤੋੜੇ), 50% (ਇੱਕ ਮਹੀਨੇ ਵਿੱਚ 50% ਫੁੱਲ ਤੋੜੇ), ਪੀ-1 (ਪਹਿਲੀ ਥਾਂ ਤੇ ਫ਼ਲਾਂ ਦਾ ਬਰਕਰਾਰ ਰਹਿਣਾ), ਪੀ-2 (ਦੂਜੀ ਥਾਂ ਤੇ ਫ਼ਲਾਂ ਦਾ ਬਰਕਰਾਰ ਰਹਿਣਾ) ਅਤੇ ਪੀ-1,2 (ਪਹਿਲੀ ਅਤੇ ਦੂਜੀ ਥਾਂ ਤੇ ਫ਼ਲਾਂ ਦਾ ਬਰਕਰਾਰ ਰਹਿਣਾ) ਤਜ਼ਰਬੇ ਕੀਤੇ ਗਏ। ਦੂਜਾ ਤਜ਼ਰਬਾ ਗਮਲਿਆਂ ਵਿੱਚ ਕੀਤਾ ਗਿਆ ਅਤੇ ਇਸ ਦੌਰਾਨ ਪਹਿਲੇ ਤਜ਼ਰਬੇ ਵਾਲੇ ਉਪਚਾਰ ਦੁਹਰਾਏ ਗਏ। ਤੀਜੇ ਤਜ਼ਰਬੇ ਦੌਰਾਨ ਉਪ-ਪਲਾਟਾਂ ਵਿੱਚਲੇ ਪੌਦਿਆਂ ਦੀ ਡੀ-ਟੋਪਿੰਗ ਕੀਤੀ ਗਈ ਭਾਵ ਪ੍ਰਮੁੱਖ ਟਾਹਣੀ ਦੇ ਐਪੀਕਲ ਭਾਗ ਨੂੰ 5-7 ਸੈ.ਮੀ. ਤੱਕ ਕੱਟਿਆ ਗਿਆ ਅਤੇ ਐਮ.ਸੀ. 300 ਪੀ.ਪੀ.ਐਮ., ਟੀ.ਆਈ.ਬੀ.ਏ. 100 ਪੀ.ਪੀ.ਐਮ. ਅਤੇ ਐਮ.ਐਚ. 250 ਪੀ.ਪੀ.ਐਮ. ਦਾ ਛਿੜਕਾਅ ਕੀਤਾ ਗਿਆ। ਬਿਜਾਈ ਤੋਂ 80 ਦਿਨਾਂ ਮਗਰੋਂ ਜਦੋਂ ਪੌਦੇ ਦਾ ਬਨਸਪਤਕ ਵਾਧ ਆਪਣੇ ਸਿਖਰ ਤੇ ਸੀ ਉਸ ਸਮੇਂ ਪੌਦੇ ਦੀ ਡੀ-ਟੋਪਿੰਗ ਕੀਤੀ ਗਈ ਅਤੇ ਪੌਦੇ ਦੇ ਵਿਕਾਸ ਨੂੰ ਰੋਕਣ ਵਾਲੇ ਸਾਧਨਾਂ ਦੀ ਵਰਤੋਂ ਕੀਤੀ ਗਈ।

ਦੋਨਾਂ ਸਾਲਾਂ ਦੌਰਾਨ, ਐਮ.ਆਰ.ਸੀ. 7031 ਅਤੇ ਆਰ.ਸੀ.ਐਚ. 314 ਕਿਸਮਾਂ ਦੇ ਮੁਕਾਬਲੇ ਐਮ.ਆਰ.ਸੀ. 7017 ਕਿਸਮ ਵਿੱਚ ਵਿਕਾਸ ਦੇ ਸਾਰੇ ਪੜਾਵਾਂ ਉਪਰ ਪੌਦੇ ਦੀ ਉਚਾਈ ਅਤੇ ਸੁੱਕੇ ਮਾਦੇ ਨੂੰ ਸਮਾ ਸਕਣ ਦੀ ਸਮਰੱਥਾ ਵਧੇਰੇ ਪਾਈ ਗਈ। ਤਿੰਨੇ ਕਿਸਮਾਂ ਵਿੱਚ ਪ੍ਰਤੀ ਪੌਦਾ ਪ੍ਰਮੁੱਖ ਟਾਹਣੀਆਂ ਵਿਚਲੀਆਂ ਗੰਢਾਂ, ਉਚਾਈ: ਗੰਢ ਦਾ ਅਨੁਪਾਤ, ਐਸ.ਪੀ.ਏ.ਡੀ. ਮਿਕਦਾਰ ਅਤੇ ਪ੍ਰਤੀ ਪੌਦਾ ਮੋਨੋਪੋਡੀਅਲ ਸ਼ਾਖਾਵਾਂ ਵਿੱਚ ਕੋਈ ਅਰਥਪੂਰਨ ਅੰਤਰ ਨਹੀਂ ਪਾਇਆ ਗਿਆ। ਦੋਨਾਂ ਸਾਲਾਂ ਦੌਰਾਨ ਆਰ.ਸੀ.ਐਚ. 314 ਦੇ ਮੁਕਾਬਲੇ ਐਮ.ਆਰ.ਸੀ. 7017 ਕਿਸਮ ਤੋਂ ਸਭ ਤੋਂ ਵਧੇਰੇ ਝਾੜ ਪ੍ਰਾਪਤ ਹੋਇਆ (15.0 ਅਤੇ 19.1%) ਜੋ ਕਿ ਐਮ.ਆਰ.ਸੀ. 7031 ਦੇ ਨਾਲ ਤੁਲਨਾਤਮਕ ਸੀ। ਸਭ ਤੋਂ ਵਧੇਰੇ ਪ੍ਰਤੀ ਪੌਦਾ ਸਿੰਪੋਡੀਅਲ ਸ਼ਾਖਾਵਾਂ, ਕੁੱਲ ਫੁੱਲਾਂ ਦੀ ਸੰਖਿਆ, ਟੀਂਡਿਆਂ ਅਤੇ ਪ੍ਰਤੀ ਪੌਦਾ ਚੁਗੇ ਗਏ ਟੀਂਡਿਆਂ ਦੀ ਗਿਣਤੀ ਕਾਰਨ ਐਮ.ਆਰ.ਸੀ. 7017 ਤੋਂ ਸਭ ਤੋਂ ਵਧੇਰੇ ਦਾ ਝਾੜ ਮਿਲਿਆ।

ਦੋਨਾਂ ਸਾਲਾਂ ਦੌਰਾਨ ਵਾਧੇ ਦੇ ਸਾਰੇ ਪੜਾਵਾਂ ਉਪਰ (ਸਿਵਾਏ ਬਿਜਾਈ ਦੇ 60 ਦਿਨਾਂ ਮਗਰੋਂ) ਫ਼ਲਾਂ ਦੀ ਤੁੜਾਈ ਦਾ ਪੌਦੇ ਦੀ ਉਚਾਈ ਅਤੇ ਐਲ.ਏ.ਆਈ. ਉਪਰ ਅਰਥਪੂਰਨ ਪ੍ਰਭਾਵ ਪਿਆ। ਬਿਜਾਈ ਦੇ 90 ਦਿਨਾਂ ਮਗਰੋਂ 50% ਤੁੜਾਈ ਨਾਲ ਪੌਦੇ ਦੀ ਉਚਾਈ ਅਤੇ ਐਲ.ਏ.ਆਈ. ਵਿੱਚ ਅਰਥਪੂਰਨ ਵਾਧਾ ਹੋਇਆ। ਜਦੋਂ ਕਿ ਬਿਜਾਈ ਦੇ 120 ਦਿਨਾਂ ਤੋਂ ਫ਼ਸਲ ਦੇ ਪੂਰੇ ਪੱਕਣ ਤੱਕ, ਪੀ-2 ਪੌਦਿਆਂ ਨੇ ਦੂਜੇ ਪੌਦਿਆਂ ਦੇ ਮੁਕਾਬਲੇ ਸਭ ਤੋਂ ਵਧੇਰੇ ਉਚਾਈ ਅਤੇ ਐਲ.ਏ.ਆਈ. ਪ੍ਰਾਪਤ ਕੀਤੀ। ਖੋਜ ਦੇ ਦੋਨਾਂ ਸਾਲਾਂ ਦੌਰਾਨ ਬਿਜਾਈ ਦੇ 120 ਅਤੇ 150 ਦਿਨਾਂ ਮਗਰੋਂ ਪੀ-2 ਪੌਦਿਆਂ ਦੇ ਬਨਸਪਤਕ ਹਿੱਸਿਆਂ ਨੇ ਸੁੱਕੇ ਮਾਦੇ ਨੂੰ ਅਰਥਪੂਰਨ ਤੌਰ ਤੇ ਸਭ ਤੋਂ ਵਧੇਰੇ ਜਜ਼ਬ ਕੀਤਾ, ਜਦੋਂਕਿ 0 ਅਤੇ 25% ਤੁੜਾਈ ਵਾਲੇ ਪੌਦਿਆਂ ਦੇ ਫ਼ਲਾਂ ਭਾਵ ਟੀਂਡਿਆਂ ਵਿੱਚ ਸੁੱਕੇ ਮਾਦੇ ਨੂੰ ਜਜ਼ਬ ਕਰਨ ਦੀ ਸਮਰੱਥਾ ਵਧੇਰੇ ਦੇਖੀ ਗਈ। ਬਾਕੀ ਸਾਰੇ ਉਪਚਾਰਾਂ ਦੇ ਮੁਕਾਬਲੇ 0 ਅਤੇ 25% ਤੁੜਾਈ ਵਾਲੇ ਉਪਚਾਰ ਵਾਲੇ ਪੌਦਿਆਂ ਵਿੱਚ ਫ਼ੁੱਲਾਂ ਦੀ ਸੰਖਿਆ, ਕੁੱਲ ਟੀਡਿਆਂ ਦੀ ਅਤੇ ਪ੍ਰਤੀ ਪੌਦਾ ਚੁਗੇ ਗਏ ਟੀਂਡਿਆਂ ਦੀ ਸੰਖਿਆ ਸਭ ਤੋਂ ਵਧੇਰੇ ਸੀ। ਜਮਾਅ ਪ੍ਰਤੀਸ਼ਤਤਾ ਦੇ ਲਿਹਾਜ਼ ਨਾਲ ਪੀ-2 ਉਪਚਾਰ ਦੇ ਮੁਕਾਬਲੇ ਪੀ-1 ਉਪਚਾਰ ਨਾਲ ਕੁੱਲ ਟੀਂਡਿਆਂ ਦੀ ਸੰਖਿਆ ਅਤੇ ਪ੍ਰਤੀ ਪੌਦਾ ਚੁਗੇ ਗਏ ਟੀਂਡਿਆਂ ਦੀ ਸੰਖਿਆ ਅਰਥਪੂਰਨ ਤੌਰ ਤੇ ਵਧੇਰੇ ਪਾਈ ਗਈ ਜਿਸ ਨਾਲ ਪੀ-2 ਦੇ ਮੁਕਾਬਲੇ ਪੀ-1 ਪੌਦਿਆਂ ਤੋਂ ਵਧੇਰੇ ਝਾੜ ਪ੍ਰਾਪਤ ਹੋਇਆ। ਤਜ਼ਰਬੇ ਦੌਰਾਨ ਦੇਖਿਆ ਗਿਆ ਕਿ ਫੁੱਲਾਂ ਦੇ ਝਾੜਨ ਨਾਲ, ਪੌਦੇ ਵਿੱਚਲੇ ਟੀਂਡਿਆਂ ਦੇ ਖੁੱਲਣ ਦੀ ਪ੍ਰਕਿਰਿਆ ਵਿੱਚ 4-11 ਦਿਨਾਂ ਦੀ ਦੇਰੀ ਆਉਂਦੀ ਹੈ।ਪੀ-1 ਉਪਚਾਰ ਨਾਲ ਟੀਂਡਿਆਂ ਦੇ ਭਾਰ ਵਿੱਚ 5.6 ਤੋਂ 11.8 ਪ੍ਰਤੀਸ਼ਤ ਦਾ ਸੁਧਾਰ ਹੋਇਆ ਅਤੇ ਦੋਨਾਂ ਸਾਲਾਂ ਦੌਰਾਨ ਕੰਟਰੋਲ ਦੇ ਮੁਕਾਬਲੇ ਫ਼ਲਾਂ ਨੂੰ ਹਟਾਉਣਾ ਦੀ ਪ੍ਰਕਿਰਿਆ ਨਾਲ ਟੀਂਡਿਆਂ ਦੇ ਭਾਰ ਵਿੱਚ ਸੁਧਾਰ ਵੇਖਿਆ ਗਿਆ। ਬਾਕੀ ਸਾਰੇ ਉਪਚਾਰਾਂ ਦੇ ਮੁਕਾਬਲੇ ਬਿਨਾਂ ਤਬਦੀਲੀ ਵਾਲੇ (0%) ਪੌਦਿਆਂ ਨੇ ਸਭ ਤੋਂ ਵਧੇਰੇ ਝਾੜ ਦਿੱਤਾ।

ਕੰਟਰੋਲ ਦੇ ਮੁਕਾਬਲੇ ਐਮ.ਸੀ. (300 ਪੀ.ਪੀ.ਐਮ.), ਟੀ.ਆਈ.ਬੀ.ਏ. (100 ਪੀ.ਪੀ.ਐਮ.) ਅਤੇ ਐਮ.ਐਚ. (250 ਪੀ.ਪੀ.ਐਮ.) ਦੇ ਉਪਚਾਰ ਨਾਲ ਪੌਦੇ ਦੀ ਉਚਾਈ, ਪੱਤਾ ਖੇਤਰਫਲ ਅੰਕ ਅਤੇ ਸੁੱਕੇ ਮਾਦੇ ਨੂੰ ਸਮਾ ਸਕਣ ਦੀ ਸਮਰੱਥਾ ਵਿੱਚ ਅਰਥਪੂਰਨ ਕਮੀ ਆਈ। ਕੰਟਰੋਲ ਦੇ ਮੁਕਾਬਲੇ ਡੀ-ਟੋਪਿੰਗ ਨਾਲ ਪੌਦੇ ਦੀ ਉਚਾਈ ਵਿੱਚ ਅਰਥਪੂਰਨ ਕਮੀ ਆਈ ਹਾਲਾਂਕਿ ਸਾਰੇ ਪੀ.ਜੀ.ਆਰ. ਦੇ ਮੁਕਾਬਲੇ ਇਹ ਉਚਾਈ ਵਧੇਰੇ ਸੀ। ਫ਼ਸਲ ਦੇ ਵਾਧੇ ਦੇ ਵੱਖੋ-ਵੱਖਰੇ ਪੜਾਵਾਂ ਦੌਰਾਨ ਪੀ.ਜੀ.ਆਰ. ਦੇ ਛਿੜਕਾਅ ਕਾਰਨ ਬਨਸਪਤਕ ਹਿੱਸਿਆਂ ਦੇ ਮੁਕਾਬਲੇ ਫ਼ਲਾਂ ਵਿੱਚ ਸੁੱਕੇ ਮਾਦੇ ਦਾ ਵਹਾਅ ਵਧੇਰੇ ਸੀ ਜਿਸ ਨਾਲ ਟੀਂਡਿਆਂ ਦੀ ਪ੍ਰਤੀਸ਼ਤਤਾ ਵਿੱਚ ਸੁਧਾਰ ਹੋਇਆ ਪਰ ਇਸ ਨਾਲ ਸੀ.ਜੀ.ਆਰ. ਅਤੇ ਆਰ.ਜੀ.ਆਰ. ਉਪਰ ਕੋਈ ਪ੍ਰਭਾਵ ਵੇਖਣ ਨੂੰ ਨਹੀਂ ਮਿਲਿਆ। ਵੱਖੋ-ਵੱਖਰੇ ਪੀ.ਜੀ.ਆਰ. ਦੇ ਉਪਚਾਰ ਨਾਲ ਪ੍ਰਤੀ ਪੌਦਾ ਮੋਨੋਪੋਡੀਅਲ ਸ਼ਾਖਾਵਾਂ ਦੀ ਸੰਖਿਆ ਉਪਰ ਕੋਈ ਪ੍ਰਭਾਵ ਨਹੀਂ ਪਿਆ ਜਦੋਂਕਿ ਪ੍ਰਤੀ ਪੌਦਾ ਸਿੰਪੋਡੀਅਲ ਸ਼ਾਖਾਵਾਂ ਦੀ ਗਿਣਤੀ ਕ੍ਰਮਵਾਰ ਐਮ.ਸੀ. (300 ਪੀ.ਪੀ.ਐਮ.), ਟੀ.ਆਈ.ਬੀ.ਟੀ. (100 ਪੀ.ਪੀ.ਐਮ.) ਅਤੇ ਐਮ.ਐਚ. (250 ਪੀ.ਪੀ.ਐਮ.) ਦੇ ਉਪਚਾਰ ਨਾਲ ਵਧੇਰੇ ਪਾਈ ਗਈ ਜੋਕਿ ਕੰਟਰੋਲ ਦੇ ਮੁਕਾਬਲੇ ਅਰਥਪੂਰਨ ਤੌਰ ਤੇ ਵਧੇਰੇ ਸੀ। ਐਮ.ਸੀ. (300 ਪੀ.ਪੀ.ਐਮ.) ਦੀ ਵਰਤੋਂ ਦਾ ਪ੍ਰਤੀ ਪੌਦਾ ਕੁੱਲ ਫੁੱਲਾਂ ਦੀ ਸੰਖਿਆ ਉਪਰ ਅਰਥਪੂਰਨ ਪ੍ਰਭਾਵ ਪਿਆ ਜਦੋਂ ਕਿ ਬਾਕੀ ਦੇ ਪੀ.ਜੀ.ਆਰ. ਦਾ ਵਰਤੋਂ ਨਾਲ, ਕੰਟਰੋਲ ਦੇ ਮੁਕਾਬਲੇ ਪ੍ਰਤੀ ਪੌਦਾ ਕੁੱਲ ਫੁੱਲਾਂ ਦੀ ਸੰਖਿਆ ਉਪਰ ਕੋਈ ਅਰਥਪੂਰਨ ਸੁਧਾਰ ਵੇਖਣ ਨੂੰ ਨਹੀਂ ਮਿਲਿਆ। ਐਮ.ਸੀ. (300 ਪੀ.ਪੀ.ਐਮ.), ਟੀ.ਆਈ.ਬੀ.ਏ. (100 ਪੀ.ਪੀ.ਐਮ.) ਅਤੇ ਐਮ.ਐਚ. (250 ਪੀ.ਪੀ.ਐਮ.) ਦੀ ਵਰਤੋਂ ਨਾਲ ਟੀਂਡਿਆਂ ਦੀ ਕੁੱਲ ਸੰਖਿਆ, ਪ੍ਰਤੀ ਪੌਦਾ ਟੀਂਡਿਆਂ ਦੀ ਚੁਗਾਈ ਅਤੇ ਟੀਂਡਿਆਂ ਦੇ ਭਾਰ ਵਿੱਚ ਸੁਧਾਰ ਹੋਇਆ। ਐਮ.ਸੀ. (300 ਪੀ.ਪੀ.ਐਮ.) ਦੀ ਵਤਰੋਂ ਨਾਲ ਪਹਿਲੀ, ਦੂਜੀ ਅਤੇ ਤਿਜੀ ਤੁੜਾਈ ਦੇ ਨਾਲ-ਨਾਲ ਕੁੱਲ ਪੈਦਾਵਾਰ (ਸਾਲ 2011 ਅਤੇ 2012 ਦੌਰਾਨ ਕ੍ਰਮਵਾਰ 22.79 ਅਤੇ 31.62 ਕੁਇੰਟਲ ਪ੍ਰਤੀ ਹੈਕਟੇਅਰ) ਵਿੱਚ ਵਾਧਾ ਹੋਇਆ। ਸਾਰੀਆਂ ਤੁੜਾਈਆਂ ਦੌਰਾਨ ਅਤੇ ਕੁੱਲ ਪ੍ਰਾਪਤ ਝਾੜ ਦੇ ਲਿਹਾਜ਼ ਨਾਲ ਟੀ.ਆਈ.ਬੀ.ਏ. (100 ਪੀ.ਪੀ.ਐਮ.) ਅਤੇ ਐਮ.ਐਚ. (250 ਪੀ.ਪੀ.ਐਮ.) ਤੋਂ ਪ੍ਰਾਪਤ ਨਤੀਜੇ ਐਮ.ਸੀ. (300 ਪੀ.ਪੀ.ਐਮ.) ਨਾਲ ਮੇਲ ਖਾਂਦੇ ਸਨ। ਦੋਨਾਂ ਸਾਲਾਂ ਦੌਰਾਨ ਡੀ-ਟੋਪਿੰਗ ਦਾ ਝਾੜ ਉਪਰ ਕੋਈ ਪ੍ਰਭਾਵ ਨਹੀਂ ਪਿਆ। ਵਰਤੇ ਗਏ ਵੱਖੋ-ਵੱਖਰੇ ਪੀ.ਜੀ.ਆਰ. ਉਪਚਾਰਾਂ ਨਾਲ ਗੁਣਵਤਾ ਦੇ ਵੱਖੋ-ਵੱਖਰਾ ਮਾਪਦੰਡਾਂ ਜਿਵੇਂ ਕਿ ਬੀਜ ਦੇ ਤਤਕਰੇ, ਪੌਦੇ ਦਾ ਤਤਕਰਾ ਅਤੇ ਰੂੰ ਦਾ ਵਲੇਵਾਂ ਆਦਿ ਦਾ ਕੋਈ ਅਰਥਪੂਰਨ ਸਬੰਧ ਦੇਖਣ ਨੂੰ ਨਹੀਂ ਮਿਲਿਆ।

ਮੁੱਖ ਸ਼ਬਦ: ਬੀ.ਟੀ. ਨਰਮੇ ਦੀਆਂ ਕਿਸਮਾਂ, ਫ਼ਲਾਂ ਨੂੰ ਉਤਾਰਨਾ, ਪੌਦੇ ਦੀ ਪੈਦਾਵਾਰ ਨੂੰ ਵਧਾਉਣ ਵਾਲੇ ਸਾਧਨ, ਝਾੜ, ਮੈਪੀਕਿਉਟ ਕਲੋਰਾਈਡ, 2,3,5-ਟ੍ਰਾਈ-ਆਇਡੋ-ਬੈਂਜ਼ੋਇਕ ਐਸਿਡ, ਮੈਲਿਕ ਹਾਈਡਰਜ਼ਾਇਡ

ਪ੍ਰਮੁੱਖ ਸਲਾਹਕਾਰ ਦੇ ਹਸਤਾਖਰ

ਵਿਦਿਆਰਥੀ ਦੇ ਹਸਤਾਖਰ

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CHAPTER I

INTRODUCTION

Cotton (*Gossypium hirsutum* L.), also known as "white gold" is an immensely important cash crop for sustaining agrarian economy and livelihood of the Indian farming community. It is mainly grown for textile fibre, feed, fuel and edible oil. Cotton continues to occupy a place of prime importance in the textile industry despite a stiff competition from synthetic fibres. Export of cotton yarn, fabrics and apparels enables the country to earn substantial amounts of foreign exchange and provides livelihood to vast majority of the country. The foreign exchange earnings from the export of cotton are one-third of the total foreign exchange earnings of the country. The domestic and international trade from India is pegged at Rs. 150,000 crore (US$ 30 billion) annually (Anonymous 2013a). Cotton is produced in about 80 countries but only six countries (China, India, USA, Pakistan, Brazil and Uzbekistan) account for over 85 per cent of the global supplies. India, formerly barely self-sufficient or net cotton importing nation, has become the world's second largest producer and exporter of cotton after China. During 2011-12, India had area under cotton cultivation (12.17 million hectares) with production of 35.2 million tonne and an average productivity of 489 kg per hectare (Anonymous 2013a).

In India, cotton is cultivated in almost all the states, but nine states i.e. Punjab, Haryana, Rajasthan, Gujarat, Maharashtra, Karnataka, Madhya Pradesh, Tamil Nadu and Uttar Pradesh account for more than 95 per cent of the total area and production. It is a major cash crop of *kharif* season in south-western region of Punjab and was grown on 515 thousand hectares during 2011-12 with total production of 1621 thousand bales and an average yield of 535 kg per hectare (Anonymous 2013b). Punjab, a leader in cotton production till recent times has trailed behind other states in average productivity. The major factors attributed to low productivity of cotton in Punjab are poor plant stand, excessive vegetative growth, shedding of young fruiting bodies like buds, flowers and bolls and failure of insect pest control measures.

The low productivity of cotton was the major reason for shifting of the area from cotton-wheat to rice-wheat cropping system in south-western districts of Punjab. The introduction of *Bt* cotton hybrids by incorporation of the *Cry* 1 *AC* gene derived from the soil bacterium *Bacillus thuringiensis* var. *kurstaki* that confers resistance against bollworm complex has once again attracted the farmers to cotton cultivation. The commercial release of *Bt* cotton in India was approved in 2002 (Blaise and Prasad 2005).The Genetic Engineering Approval Committee (GEAC) approved the cultivation of *Bt* cotton in Punjab in 2004. Introduction of *Bt* cotton hybrids have evoked a considerable enthusiasm in farming and scientific community for boosting cotton productivity at reduced cost of production and

environmental pollution because of less pesticide load. The area under *Bt* cotton has increased from merely 29,000 hectares since its introduction in 2002 to nearly 9.3 million hectares in 2011. Many surveys indicate substantial environmental, health and socio-economic benefits with adoption of *Bt* cotton due to increased yields, reduced cost of production, reduction in pesticide use and enhanced population of beneficial insects (Ahuja 2006, Ramasundaram *et al* 2007 and Monga 2008).

Productivity of cotton largely depends upon the availability of high yielding varieties and hybrids along with improved agronomic production technology e.g. optimum sowing time, planting density, improved soil and water management practices and proper method of planting etc. Under optimum growing conditions, cotton crop produces excess vegetative biomass that is often associated with reduced yield (Heitholt 1994). Vigorous crop growth can be very frequent in mid to late season stages of crop development. Excessive vegetative growth often occurs at the expense of reproductive growth and a large fraction of squares and small bolls on the lower sympodia are shed resulting in late maturing and low yielding crop (Fowler and Ray 1977). All squares produced by the plant do not contribute to yield as some of the squares do not develop into bolls because of shedding (Sudararaj and Thulsidas 1993). Floral buds appear sequentially on sympodia and thus, fruiting forms of different age and at different positions on the sympodia compete for assimilates. Shortage in photosynthate supply has often been considered to be a major cause of abscission (Guinn 1985, Wullschleger and Oosterhuis 1990). The loss of reproductive structures alters the physiological growth and development of the plant by redirecting assimilates which normally are incorporated into these abscised organs to other plant parts. The removal of reproductive parts from cotton plant generally increases the ratio of vegetative growth to reproductive growth which is known as 'growth compensation' (Sadras 1994). However, abscission of cotton fruiting forms can elicit many morphological and physiological responses which results in production of replacement fruits in lieu of the lost earlier through reproductive compensation. According to Heitholt (1997) cotton normally produces only one floral bud per fruiting site. Therefore, to achieve compensation, cotton must set a higher percentage of existing flowers, produce additional flowers on more distal positions of sympodial branches or produce greater number of main stem internodes with additional sympodial branches. Fruiting forms at different positions on the sympodial branches have a marked influence on yielding behaviour of the cotton plant (Kerby and Buxton 1981). Under normal field conditions, more lint is harvested from cotton bolls on proximal fruiting sites than from the distal fruiting sites on sympodial branches (Constable 1991). It is due to the presence of more bolls with higher retention on first fruiting position than on the second, third or lateral positions (Jenkins *et al* 1990). Mathews (1979) emphasized that natural shedding of cotton bolls had a significant effect on adjacent bolls. The shedding of boll from the first fruiting position increases the tendency for the boll to be

retained at the second fruiting position. Thus, the removal of fruiting forms from specific fruiting positions may also help in understanding the relative contribution of fruiting sites to boll weight and fibre quality as well as the retention behaviour of fruiting bodies at different positions. It is therefore necessary to study the effect of fruiting form removal from selected positions on reproductive growth profile, more importantly yield compensation.

The key is to investigate how yield components are altered by method, intensity and timing of fruit removal and how these interact with genotype and growing conditions (Hearn and Room 1979, Brook *et al* 1992a)? Cotton can shed up to 70 per cent of all initial fruiting structures during reproductive stage of development (Peoples and Mathews 1981) but its extent in recently released *Bt* hybrids is unknown and warrants immediate attention. According to Heitholt and Schmidt (1994) whole plant boll retention i.e. total bolls per total flowers is an imperative process affecting lint yield. A dense and lavish growth causes abnormal shedding of young fruiting bodies like buds, flowers and bolls, delayed maturity, boll rot (due to shading), and reduced yield (Zhao and Oosterhuis 2000).

The plant therefore must have a balance between vegetative and reproductive growth for adequate carbohydrate supply for fruit development, and not excessive vegetative growth that inhibits fruit development (Kerby *et al* 1997). Managing the equilibrium between vegetative and reproductive growth is an important part in cotton production. Plant growth can be modified by removal of floral buds from specific positions, detopping and the use of plant growth regulators (PGRs) which may help in improving the cotton productivity.

Loss of reproductive organs from cotton can be induced by a myriad of causes (Guinn 1982). Manual removal of squares simulates the shedding of fruiting forms by insect damage or physiological causes. Such losses can increase the vegetative growth in relation to the reproductive growth and this increased vegetative growth provide existing fruits with a greater potential assimilate supply per boll (Jones *et al* 1996a). The removal of squares at higher rates increases the vegetative growth of plant was also confirmed by Mustafa *et al* (2004), and increased growth helps in enhancing the radiation use efficiency and ultimately the better assimilate partitioning within the plant. Sadras (1995) also suggested that fruit loss may enhance photosynthetic rate in cotton. Thereafter, Holman and Oosterhuis (1999) confirmed that canopy photosynthesis increased after fruit loss due to insect damage. Canopy photosynthesis was 21 per cent greater in infested than non infested plants at four weeks after the initiation of flowering. Infested plants also exhibited four per cent greater light penetration than control plants. As fruiting structures (squares and bolls) are shed from the sympodia, a redistribution of assimilates destined for these structures occur. Heitholt and Schmidt (1994) also reported that first position produce largest fruit, more fruit and higher retention at this particular position and the fruiting position affects not only yield components but also fibre

properties. Heitholt (1997) also showed that second position fruit was also important as first position fruit because with the removal of fruits from second position yield was significantly reduced. This suggests it is essential to retain both first and second position fruits wheather the removal of first position fruit reallocated assimilates to the second position boll which were destined for the first position bolls and resulting in a larger fruiting structure.

Applying plant growth regulators (PGRs) to modify early and midseason growth is similar to other management practices. The key to modify plant growth is to know what the plant needs at each stage of development to reach the final goal of higher yield and quality. The next step is to do everything possible to provide for those needs.

PGRs have emerged as magic chemicals that could increase agricultural production at an unprecedented rate and help in removing and circumventing many of the barriers imposed by genetics and environment (Kumar *et al* 2005). PGRs include a broad category of compounds that promote, inhibit or modify plant's physiological or morphological behaviour. They have the potential to promote crop earliness, improve square, flower and boll retention, increase nutrient uptake and keep harmony between vegetative and reproductive growth thus improving lint yield and quality. Growth retardants like mepiquat chloride (MC) and 2, 3, 5-tri iodo benzoic acid (TIBA) are known to reduce internodal length, thereby, reducing plant height and stimulating the translocation of photosynthates towards reproductive sinks (bolls), all of which result in higher yields (Kumar *et al* 2005).

Removing the terminal main stem bud (detopping) is considered as an adjustment in cotton plants to modify the architecture of plant grown on irrigated fertile soils. Detopping, decrease plant height and number of main-stem nodes, increase number of retained boll and cotton yield but has a nonsignificant effect on boll weight and percent lint (Bennett *et al* 1965, Kennedy *et al* 1991 and Pettigrew 1994). Detopping increases cotton yield mainly due to readjustments in assimilate partitioning in the plant, which strengthens reproductive growth and inhibits vegetative growth. Both the inhibition of vegetative growth and strengthening of reproductive growth have been identified as the driving factors for early maturity or short lifespan of the cotton crop. In many cotton growing countries, selection of small canopy or short duration varieties, combined with the application of growth regulators/chemical effectively control excessive vegetative growth, and therefore provides a viable alternative to detopping. Kerby *et al* (1986) and Reddy *et al* (1990) reported increase in lint yield due to detopping of cotton plants. The detopping of Pima cotton at 15 days intervals (starting from mid July) decreased plant height and number of main stem nodes, increased boll set on top sympodia and caused additional branch nodes and bolls on top of fruiting branches.

Effect of fruiting form removal and plant growth regulation may differ with hybrids in view of their profound impact on canopy structure, phenological behaviour, growth and

fruiting pattern. It is therefore necessary to study the interactive influence of growth regulation and fruiting form removal with different hybrids.

In view of aforesaid, the present investigation entitled "Studies on source sink relationship for realization of higher productivity in *Bt* cotton (*Gossypium hirsutum* L.)" was undertaken with the following objectives:

Objectives

1. To quantify the effects of fruiting form removal at selected fruiting sites on yield and yield components of *Bt* cotton.
2. To study the effect of fruiting form removal on within-plant yield distribution of *Bt* cotton.
3. To characterize the growth and development of *Bt* cotton hybrids by detopping and use of plant growth retardants for improving cotton productivity.

CHAPTER II

REVIEW OF LITERATURE

The literature pertinent to the present investigation "Studies on source sink relationship for realization of higher productivity in *Bt* cotton (*Gossypium hirsutum* L.)" has been reviewed and presented below under following heads:

2.1 PERFORMANCE OF CULTIVARS

Various workers have reported that growth (morphological and physiological) and yield differences exist among different cultivars due to their genetic variability. Bhardwaj and Dua (1972) investigated the causes of varietal variation in boll shedding, patterns of boll growth and seed abortion, and the endogenous levels of growth regulatory substances in the developing bolls of low and high shedding varieties of American cotton. The differences in varieties were based on the differences in the endogenous levels of auxins and gibberellins in the seed, abscissins in the pericarp, and the distribution pattern of cytokinins in the seeds and the pericarps. According to them, these differences caused inherent variations in the relative growth rates of bolls and seeds and the magnitude of seed abortion.

Transgenic cultivars with *Bacillus thuringiensis* gene generally gave seed cotton yields which were greater or equal to their recurrent parents and were competitive with other conventional cultivars as reported by Bourland *et al* (1997).

2.1.1 Effect on growth and growth attributes

An experiment was conducted at Punjab Agricultural University, Ludhiana by Brar (1997) to study the growth and development of three cultivars F 846, *Fateh* (hybrid) and *Jhurar* (local variety). He reported that genotypes did not differ for plant height and monopodial branches plant^{-1}. A study was conducted by Deol (2001) to evaluate performance of two American cotton cultivars F 846 and LH 1556, an American cotton hybrid LHH 144 and a *desi* cotton cultivar LD 327. He reported that *desi* cotton cultivar LD 327 attained maximum plant height and sympodial branches as compared to both American cotton cultivars and the hybrid. He further reported that higher dry matter accumulation, leaf area index (LAI) and monopodial branches plant^{-1} were recorded in hybrid LHH 144 as compared to the *desi* and American cotton cultivars. Srinivasulu *et al* (2006a) conducted a field experiment with different hybrids and reported that PRCHH 5 attained maximum plant height (144 cm) followed by RAHH 99 (137 cm) and both were significantly superior to Bunny (127 cm).

While, on the basis of trial conducted at Cotton Research Station, Srivilliputtur Srinivasan (2006) concluded that cotton hybrids differed significantly for growth and development. While, comparing different cotton hybrids, viz. MECH 162 *Bt,* MECH 184 *Bt* and RCH 2 non *Bt* he reported that RCH 2 non *Bt* produced 2.6 monopodia plant^{-1} which were significantly higher than other *Bt* hybrids. He further reported that among the hybrids MECH 162 *Bt,* MECH 184 *Bt* and RCH 2 non *Bt*, hybrid MECH 162 *Bt* produced significantly taller plants (86.5 cm) as compared to MECH 184 *Bt* and RCH 2 non *Bt*. Similarly, in an another experiment Srinivasulu *et al* (2006b) observed a significant difference in different cotton hybrids and concluded that the plant height of MECH 12 *Bt* and MECH 184 *Bt* hybrids was markedly lower than the other hybrids (VCH 225, NSPHH 8 and PRCHH 5). Singh *et al* (2011) conducted a field experiment at Punjab Agricultural University, Regional Research Station, Faridkot to study the growth habit of three *Bt* cotton hybrids MRC 7361, Bioseed 6488 and RCH 134 and they found that LAI was greater in MRC 7361(5.91) as compared to the other two hybrids.

2.1.2 Effect on yield and yield attributes

The performance of two genotypes, i.e. okra leaf cotton genotype and its normal isoline was compared for different morphological characters by Heitholt *et al* (1992). They reported that okra leaf genotype out yielded the normal leaf genotype due to higher number of mature bolls produced per unit ground area and not due to increased fruit size.

In a field experiment at Punjab Agricultural University, Ludhiana, Brar *et al* (2002) studied the performance of two varieties LD 327 and LD 694 of *desi* cotton and reported that variety LD 694 out yielded LD 327 by a significant margin of 25.3 per cent and the higher yield of LD 694 could be attributed to its higher boll number per plant as compared to LD

327. Deol (2001) studied the performance of different cotton cultivars and reported that LHH 144 yielded maximum seed cotton as compared to *desi* cotton cultivar LD 327, it was due to the higher number of flowers, and bolls plant^{-1}, setting percentage and boll weight of LHH 144. He further reported that both the American cotton cultivars i.e. F 846 and LH 1556 were statistically at par with each other for total seed cotton yield.

A field experiment was conducted by Wankhade *et al* (1992) at Akola, Maharashtra and they reported that PKMF 806 significantly out yielded AKH 4. Similarly, in another study conducted by Hoogar and Gidnavar (1997), it was observed that hybrids differed significantly for the seed cotton yield. They reported that DHB 105 recorded significantly higher yield than DCH 32. In a field experiment at Hisar, Haryana the yield components of two cotton cultivars were studied and it was reported that H 777 produced more bolls and seed cotton yield plant^{-1} than HS 50, but boll weight was higher in HS 50 (Chhabra and Bishnoi 1993).

Basavanneppa *et al* (2001) studied the performance of three cotton hybrids *viz*. DHH 11, NHH 44 and DHB 105 and revealed that NHH 44 (1726 kg ha^{-1}) recorded 84 per cent higher yield over DHB 105 (945 kg ha^{-1}) and it was at par with DHH 11. Puri (2001) also observed that there was a varietal difference in seed cotton yield and he observed that the cultivar F 846 produced significantly higher flowers plant^{-1}, total bolls plant^{-1} (4.5 %) and seed cotton yield (8.4 %) than LH 1556.

Singh *et al* (2003) conducted a field experiment at Faridkot and observed significantly higher seed cotton yield and number of bolls plant^{-1} in F 1946 which were statistically at par with F 1861 and these two were significantly better than F 1914, LH 1556 and F 1378. The per cent increase in seed cotton yield of F 1946 was 4.8, 14.8, 17.0 and 20.0 over F 1861, F 1914, F 1378 and LH 1556 respectively. In another field experiment difference in seed cotton yield between Phule 492 (19.73 q ha^{-1}) and NHH 44 (19.27 q ha^{-1}) was significant. Number of bolls plant^{-1} (60.0), boll weight (3.40 g) and yield plant^{-1} (99.5 g) were higher in Phule 492 as compared to NHH 44 (Thokale *et al* 2004). A field experiment was conducted by Raut *et al* (2005a) at Rahuri and they reported that difference of seed cotton yield between Phule 388 (23.72 q ha^{-1}) and DCH 32 (23.0 q ha^{-1}) was significant. In an experiment, different varieties were evaluated by Raut *et al* (2005b) and they revealed that NHH 44 recorded significantly higher seed cotton yield (18.27 q ha^{-1}) and was significantly superior to Ankur 5642 (13.29 q ha^{-1}) and Ajeet AHH 90-20 (15.66 q ha^{-1}). The increase in seed cotton yield was attributed to increase in yield attributes like bolls plant^{-1}, boll weight and yield plant^{-1}.

A field experiment was conducted at Multan, Pakistan by Hassan *et al* (2005) to check the performance of three cotton cultivars, namely, MNH 700, MNH 768 and FH 900. Higher seed cotton yield was reported in MNH 700 (2528 kg ha^{-1}) followed by MNH 768 (2408 kg ha^{-1}) and FH 900 (2315 kg ha^{-1}). A significant difference between different cotton

hybrids was also observed by Kaur and Brar (2005) in a field experiment conducted at Department of Agronomy, Punjab Agricultural University, Ludhiana. They observed that highest seed cotton yield of 18.4 q ha^{-1} was recorded by LH 1961 which was 22.42 and 9.85 per cent more than LH 1556 and LH 1995, respectively. The higher yield of LH 1961 was due to more number of bolls $plant^{-1}$ (35.6) and yield $plant^{-1}$ (129.8 g) as compared to LH 1995 and LH 1556. Srinivasulu *et al* (2006a) at Guntur reported that, the hybrids RAHH 99 and NSPHH 7 recorded comparable number of bolls $plant^{-1}$ with hybrid Bunny. However, the seed cotton yield recorded by PRCHH 5, RAHH 99 and NSPHH 7 was almost similar to Bunny. Whereas, these hybrids gave significantly more seed cotton yield by producing more number of bolls $plant^{-1}$ than hybrids Ankur 5642 and PSCH 504.

A study was conducted by Bourland *et al* (1997) in which transgenic cultivars were compared with their recurrent parents and conventional cultivars and they reported that transgenic cultivars with *Bacillus thurigenesis* gene generally gave higher or equal seed cotton yield as compared to their recurrent parents and were competitive with other conventional cultivars.

Buttar and Singh (2006) conducted a field experiment at Bathinda and found that *Bt* hybrids performed strikingly different than non *Bt* hybrids. They observed that RCH 134 *Bt* (2834 kg ha^{-1}) and RCH 317 *Bt* (3610 kg ha^{-1}) produced significantly higher seed cotton yield in comparison to their non *Bt* hybrids i.e. RCH 134 (2096 kg ha^{-1}) and RCH 317 (1621 kg ha^{-1}). The significantly higher seed cotton yields recorded in *Bt* hybrids was due to significantly higher number of sympods and bolls $plant^{-1}$ as compared to non *Bt* hybrids.

Srinivasan (2006) at Srivilliputtur evaluated cotton hybrids MECH 162 *Bt,* MECH 184 *Bt* and RCH 2 non *Bt,* and reported that MECH 162 *Bt* recorded the highest number of sympodia $plant^{-1}$ (22.0) and bolls $plant^{-1}$ (46.5) which were significantly superior to MECH 184 *Bt* and RCH 2 non *Bt*. However, MECH 184 *Bt,* recorded heaviest bolls of 3.59 g and was significantly superior to other hybrids. The highest seed cotton yield of 1994 kg ha^{-1} was obtained in MECH 162 *Bt* which was significantly higher than MECH 184 *Bt* with seed cotton yield of 1712 kg ha^{-1} and RCH 2 non *Bt* which produced the lowest seed cotton yield (674 q ha^{-1}). Srinivasulu *et al* (2006b) conducted an experiment at Guntur and reported that the hybrid MECH 12 *Bt* and MECH 184 *Bt* produced lesser but bigger size bolls than the other hybrids (VCH 225, NSPHH 8 and PRCHH 5). Though the hybrids MECH 12 *Bt* and MECH 184 *Bt* produced less number of bolls $plant^{-1}$ but the seed cotton yields was compensated by the bigger size of bolls.

The performance of three *Bt* hybrids MECH 184 *Bt,* MECH 162 *Bt* and MECH 12 *Bt* was evaluated by Blaise *et al* (2003) at CICR,Nagpur and they reported higher seed cotton yield in hybrid MECH 184 *Bt* (17.18 q ha^{-1}) followed by MECH 162 *Bt* (17.17 q ha^{-1}) and MECH 12 *Bt* (11.43q ha^{-1}). Nehra *et al* (2004) also observed that *Bt* cotton hybrids differed

significantly among each other and had more potential for seed cotton yield. They reported that MECH 162 *Bt* produced significantly higher seed cotton yield (1095 kg ha^{-1}) than MECH 915 *Bt* (997 kg ha^{-1}). The increase in seed cotton yield was attributed to more number of bolls $plant^{-1}$ and boll weight. Singh *et al* (2011) at Faridkot also conducted a field experiment to check the performance of three *Bt* hybrids (MRC 7361, Bioseed 6488 and RCH 134) and concluded that MRC 7361 had heavier and more bolls $plant^{-1}$ and thereby recorded significantly higher seed cotton yield (2795 kg ha^{-1}) than Bioseed 6488 (2217 kg ha^{-1}) and RCH 134 (1897 kg ha^{-1}).

Bhamra (2008) observed a significant difference between two *Bt* cotton hybrids (RCH 134 and MRC 6301). Hybrid RCH 134 was found to be superior to MRC 6301 by producing significantly higher seed cotton yield as well as its attributes. Likewise, Singh *et al* (2011) observed a significant difference among *Bt* cotton hybrids (RCH 134, RCH 314 and MRC 6304) and they reported that RCH 134 produced significantly higher seed cotton yield (24.4 q ha^{-1}) as compared to other hybrids. According to them the significant increase in yield in RCH 134 was due to the more sympodial branches $plant^{-1}$, picked bolls $plant^{-1}$ and boll weight. The difference in seed cotton yield among the genotypes might be due to different genetic potential of these three hybrids.

2.2 EFFECT OF FRUITING FORM REMOVAL

The loss of reproductive structures alters the physiological growth and development of plant. Assimilates normally incorporated into these missing structures are redirected to other sinks. In determinate species, fruit loss induced by insect, disease, physical damage, or unfavourable weather can have devastating effects on reproductive yields. Indeterminate plants, however are better able to withstand a limited exposure to fruit abscising influences, since these plants flower over long times. The previous fruit removal studies on cotton have demonstrated that removal of reproductive structures can cause increased vegetative growth (Eaton 1955, Kennedy *et al* 1986). Others (Kletter and Wallach 1982 and Ungar *et al* 1987) reported that there was an increase in fruiting rate later in the season after early fruit removal.

2.2.1 Effect on photosynthates

A field experiment was conducted by Wells (2001) and he reported that removal of flowers for two weeks had 15 per cent higher area under the seasonal photosynthetic curve and leaf chlorophyll content was also higher in flower removal treatments at hundred days after planting as compared to no removal. However, Guinn (1985) observed that removal of all flowers during the first three weeks of flowering decreased the demand for photosynthates. Holman and Oosterhuis (1999) revealed that there was four per cent increase in light penetration through the canopy with the loss of floral buds, which may have contributed to the 17 per cent increase in photosynthesis of the eighth main stem leaf from the terminal leaf as compared with the control plants.

2.2.2 Effect on growth and growth attributes

Cheema *et al* (2005) conducted an experiment in which they manually removed 100 per cent squares for three weeks each of early, mid and late flowering stages at a three days interval. They revealed that the vegetative growth (number of main stem nodes and plant height) in 100 per cent square removal treatment increased significantly than that of control among all growth stages and crop sowing dates. Similarly, Mustafa *et al* (2004) found that manual removal of all squares for three weeks each of early, mid and late flowering stages at a three days interval significantly increased the vegetative growth (number of main stem nodes and plant height) as compared to undamaged control among all growth stages. Earlier Bednarz and Roberts (2000) also concluded that square removal resulted in increased plant height whereas, Goodell *et al* (1990) observed that square removal did not affect final plant height or number of main stem nodes.

Holman and Oosterhuis (1999) found that floral bud loss increased the plant height but node number was not affected. Likewise, Kennedy *et al* (1986) found that removal of floral buds early in the season resulted in larger plant size. In contrast to this Cook and Kennedy (2000) found that early bud loss resulted in small increase in vegetative growth. Whereas, Malik *et al* (1981) found that removal of squares help in more accumulation of dry matter into the vegetative parts resulting from the complete suppression of fruiting activity.

Brook *et al* (1992b) suggested that early insect damage to flower buds may extend the period of canopy expansion with the consequent increase in light interception and growth in crops with incomplete cover. It increased the ability of the crop to supply carbon to the fruits. Removal of fruiting form results in greater leaf nitrogen content that may increase photosynthetic rate per unit leaf area and more stored carbon (Evans 1989, Sinclair and Horie 1989). It has also been seen that enhanced photosynthesis may be an important component of compensatory growth in cotton. Radiation use efficiency was also increased in crop debudded during three weeks. Furthermore, regrowth after damage is related to the ability of the plant to store resources (Chapin *et al* 1990, Belsky *et al* 1993). Many researchers have investigated the ability of cotton to compensate for square loss under ambient CO_2 conditions also. Wu *et al* (2007) observed significantly higher leaf area per plant in 100 per cent removal of squares for one week and for two consecutive weeks as compared to control, where no removal of squares was done during 2004 and 2005 under elevated CO_2 environment. Moreover, they found that the interaction between CO_2 concentration and square removal had a significant effect on plant leaf dry weight.

2.2.3 Effect on yield and yield attributes

Ungar *et al* (1987) observed that the removal of 120 small squares m^{-2} over two weeks and 200 small squares m^{-2} over four weeks did not significantly reduce yield. They found that removal of 120 squares m^{-2} yielded 94 per cent of the control when squares were

removed early and 79 per cent of the control when squares were removed late. While, Oosterhuis *et al* (1999) found that square removal significantly increased lint weight of the boll at five nodes above white flower but not the total boll weight. However, Oosterhuis *et al* (2000) found that boll weight of lower developing bolls could be enhanced with the removal of upper canopy squares.

The partial fruit prune treatment had a 16 per cent greater boll mass and a 10 per cent greater seed mass than control (Pettigrew 1994). A study conducted by Pettigrew *et al* (1992) to check the compensation ability of cotton revealed that cotton has a potential to compensate for early square loss, but it did not suggest that early square removal consistently leads to improved yields or fibre quality. In an another study by Malik *et al* (1981) it was observed that removal of flower bud did not reduce number of flowers produced or number of bolls plant^{-1}.

Mustafa *et al* (2004) studied the response of cotton to total square removal and observed that the reproductive growth (number of squares plant^{-1} and seed cotton yield) was significantly decreased than undamaged control at different growth stages of crop. Similarly, Gore *et al* (2000) and Abaye *et al* (2000) observed that 100 per cent removal of fruiting form greatly reduced the yield of cotton. Whereas, Moss and Bednarz (1999) and Stewart *et al* (2001) reported that even 100 per cent early square removal produced slightly lower yields, whereas, mid and late season square removal produced significantly lower yields than control.

Jones *et al* (1996a) observed that early flower removal treatments delayed boll development, but no significant reduction in yield was found at season's end. Whereas, later flower removal significantly reduced the total fibre yields (13-33 per cent) when compared with early season removals and no removal.

Jones *et al* (1996b) studied the effect of early and late season removal of flowers and observed that removal of flowers at early stage increased number of bolls developing above node 10 and decreased the number of bolls developing at first positions on sympodial branches. According to their study, late season removal decreased the final number of total bolls and significantly reduced the number of bolls residing at main stem nodes 11 and higher. Kennedy *et al* (1986) and Kennedy *et al* (1991) also observed that early removal of flower buds produced greater lint yield than late season floral bud removal. Whereas, Dong *et al* (2005) reported that the flower removal did not significantly affect seed yield, but removal of late season or both early and late season flowers significantly improved seed quality. In another study by Cheema *et al* (2005) it was observed that the reproductive growth (number of squares plant^{-1} and seed cotton yield) significantly decreased in 100 per cent square removal treatments in which all squares were removed for three weeks each of early, mid and late flowering stages at three days interval in comparison to undamaged control at different growth stages of crop.

Bednarz and Roberts (2001) concluded that with increase in intensity of early season floral bud removal (50 per cent removal for one week to 100 per cent removal for consecutive three weeks) the probability of harvesting a mature boll in the lower canopy decreased but it increased in the upper canopy. They further reported that, removal of floral buds resulted in fewer first sympodial position fruit but more third sympodial position fruit at harvest. Thus, early season removal of floral buds resulted in additional seed cotton production on more apical and distal fruiting positions.

A field experiment was conducted by Lu *et al* (2012) to test the thresholds using artificial damage to different fruiting structures (squares or bolls or both) at three stages of cotton growth. It was found that at early flowering, bollgard II cotton plants tolerated 100 per cent square removal from all plants without significant yield loss. It was due to the substantial compensation which was primarily through increased survival of subsequently produced fruit. This delay in the fruiting cycle, however, resulted in delayed maturity of up to 6-13 days. They found that at peak flowering, only 100 per cent square removal or the combination of 30 per cent boll damage and 100 per cent square removal caused significant yield loss. However, compensation in other treatments was primarily through increased boll weight. They also observed that square removal or square removal plus boll damage significantly delayed cotton maturity by about 5 days, but boll damage alone did not. At late flowering, the heaviest damage treatments (30 per cent bolls damaged across 50 per cent or all plants) significantly reduced yield, and there was a trend toward lower yield as damage increased, suggesting limited compensation.

Wu *et al* (2007) conducted an experiment to determine the response of 100 per cent manual square removal for one week (SR1) and for two consecutive weeks (SR2) and they reported that significantly higher lint yield and delayed maturity was observed for SR0 (No removal), SR1 and SR2 under elevated CO_2 in 2004 and 2005. Moreover, the interaction between CO_2 concentration and square removal also had a significant effect on lint yield and maturity. Their results indicated that transgenic cotton plants can compensate for the manual removal of 100 per cent of the initiated squares for one and two weeks under ambient and elevated CO_2. Similar results were obtained by Kletter and Wallach (1982) and Ungar *et al* (1987) that cotton has an indeterminate growth habit and the loss of fruiting forms from proximal fruiting positions during earlier period resulted in more productive fruiting forms. These productive fruiting forms were developed on distal positions irrespective of the proximal or the positions near to the main stem from which earlier fruiting forms were removed and the fruit obtained from these positions compensated partially to fully for earlier losses by producing heavier bolls.

2.2.4 Effect on fruit positioning

The effects of proximal or distal floral bud removal on yield, yield distribution, yield components and fibre properties was quantified by Heitholt 1997 and it was found that a greater percentage of bolls (82 vs. 68 per cent) and larger bolls (1.61 vs. 1.50 g lint $boll^{-1}$) were found at first fruit position (FP1) on the P1 treatment (FP2 and FP3 and greater squares removed) than on the check. However, the composite fibre micronaire, maturity and wall thickness were significantly greater (5-6 per cent) in both P1 and P2 treatments than control. Greater percentage of bolls (42) were found at second fruit position (FP2) in the P2 (FP1, FP3 and greater squares removed) treatment than in other treatments (10-24 per cent). Similar results were found by Cook and Kennedy (2000) that early bud loss yielded 25 per cent higher seed cotton at position 2 on lower sympodia. They also found that boll set was also increased by 21 per cent and lint per boll was increased by 7 per cent with early bud loss. While in another study Bednarz *et al* (2006) found that the superior fruiting positions in terms of overall fibre quality (i.e., longer, more uniform and mature fibres) occurred at first sympodial positions generally in the mid canopy region (i.e., main stem nodes 10-17), also known as inner fruiting positions.

Jenkins *et al* (1990) observed that bolls at position one on sympodial branches produced 66-75 per cent of total yield and those at position two produced 18-21 per cent, all other positions on sympodial branches contributed only 2-4 per cent of the total yield. Goodell *et al* (1990) studied the effect of square removal and observed that the boll retention at the first position was reduced but boll retention at the second position was less affected by square removal. Hearn and Da Roza (1985), Lieth *et al* (1986) and Constable (1991) found that the susceptibility to abscission of the fruiting form is age dependent and squares can abscise at any age but most do so during the first seven days after appearance. While, Kerby and Buxton (1981) and Constable (1991) concluded that the abscission rate of cotton fruiting forms of the same age differs according to their position on the sympodium.

Hofs *et al* (2006) conducted a study to assess the agronomic efficiency of *Bt* cotton. In a comparison between *Bt* and non-*Bt* cultivars they observed that *Bt* cotton had better early boll retention rates at the first and second positions on the fruiting branches. Whereas, beyond the third position this trend was reversed, indicating that non *Bt* cotton varieties offset losses occurring at the first two positions by producing fruits at further positions. *Bt* cotton thus had a higher average boll weight, shorter vegetative cycle, earlier boll opening, and 13 per cent higher yield potential on average than the conventional varieties.

Crozat *et al* (1999) studied the susceptibility of cotton to fruiting form abscission with age, sympodial position and fertilizer application. In no fertilizer application, the duration of fruiting and the appearance rates of fruiting forms were lower than in the high fertilizer doses. They also found that for a given age class of fruiting form, the abscission rate increased from

the innermost to the outermost position on the sympodium but the relative pattern of susceptibility with age did not change. Pettigrew (1994) also found that bolls at the first sympodial position had a 25 per cent greater boll mass than the bolls at second sympodial position and seed mass was also found to be greater by 8 per cent at first sympodial position than second sympodial position.

2.3 EFFECT OF PLANT GROWTH REGULATORS (PGRs)

PGRs have been profitably exploited in the past two decades to enhance cotton production and quality by overcoming the barriers like excessive vegetative growth, unsynchronized flower initiation, shedding of reproductive structures and those imposed by genetics and environmental factors. These are organic compounds, other than nutrients, that when applied in small concentrations affect physiological processes of plants. These compounds represent diverse chemistries and mode of action, and provide numerous opportunities for altering crop growth and development. Overall, benefits from the use of PGRs in cotton include yield enhancement, improved fibre quality and greater ease of harvest (Cothren 1994). More specific responses include alteration of carbon partitioning, enhanced photosynthesis, altered nutrient uptake, improved water status, and altered crop canopy. Growth retardants like mepiquat chloride, 2, 3, 5-tri iodobenzoic acid (TIBA) and Maleic hydrazide (MH) checks excessive vegetative growth, elongation of main stem and fruiting branches.

2.3.1 Effect of Mepiquat Chloride (MC)

Mepiquat chloride (1, 1-dimethyl piperidinium chloride) well known as Pix, is the first plant growth regulator in cotton production to make a significant impact on growth and yield. Since its introduction by BASF Corporation in early 1980's it has been widely studied and frequently used in major cotton growing areas. It is an anti-gibberellin that inhibits the production of gibberellins in the plants which normally would enlarge the plant cells, by blocking the cyclization of geranylgeranyl pyrophosphate to copalyl pyrophosphate and also blocks further transformation of copalyl pyrophosphate to ent-kaurene in the gibberellic acid biosynthesis pathway (Halmann 1990). Lower GA concentrations affect movement between cells due to decreased cell wall relaxation, decreased cell wall plasticity, and increased cell wall stiffness (Yang *et al* 1996). By increasing the amount of friction between cells, the ability of the cells to elongate and replicate is hampered, and thus plant height is reduced. Reddy *et al* (1996) reported that MC decreased plant height, number of main stem nodes and internodal length, which could be attributed to the pix reduced gibberellic acid which is responsible for cell elongation.

Application of MC at 0, 100 or 200 ppm decreased plant height and increased chlorophyll a, b, carotenoid content and earliness of yield, though seed yield increased only with application of 100 ppm MC (Azab *et al* 1993). Cotton plants grown in pots were sprayed

with 0, 7.65, 15.3, 30.6 or 61.2 g MC ha^{-1} at first square by Reddy *et al* (1996). They observed that plant height was reduced with MC application and the total length of vegetative and fruiting branches were 40 to 50 per cent lower than in untreated control. Total leaf area in MC treated plants was 16 per cent lower than in control. Net photosynthetic rate was 25 per cent lower in MC treated leaves but had higher chlorophyll and starch contents. The activity of ribulose bisphosphate carboxylase (RuBP) decreased in MC treated plants. Reduced growth responses induced by MC resulted in partial loss of photosynthetic capacity in cotton at least up to 20 days after application of the growth regulator. Norton *et al* (2005) reported that application of pix to cotton plants provided balance between reproductive components (squares, flowers and bolls) and vegetative components (leaves, stem and roots). They also revealed that the application of MC increased chlorophyll content and fruiting nodes which resulted in high fruit load and ultimately increased the lint yield. Reduction in plant height, improved leaf CO_2 exchange rate and increased leaf starch content with MC application was also reported by Zhao and Oosterhuis (2000).

It was observed that MC did not affect the accumulation of biomass on whole plant basis, but affects the biomass partitioning into various plant parts by inhibiting the growth of branches and stem and promoting the growth of fine roots. MC also inhibited expansion of leaves and extension of stem internodes and petioles, which led to the development of a more compact structure (Fernandez *et al* 1991). Wu *et al* (1994) reported that MC treatment at different stages helped in the formation of suitable plant type with high photosynthetic activity to improve the nutritional regime of squares and bolls and increased seed cotton yield by 112.5 to 157.5 kg ha^{-1}, (an increase of 15.08 to 21.45 per cent) compared with control. Fan *et al* (1999) also concluded that higher photosynthetic efficiency, good population type and canopy structure with dwarf plants, smaller leaves and bigger bolls were obtained by chemical regulation with MC. Bolonhezi *et al* (1999) and Moraes *et al* (1999) also reported that application of MC produced smaller and more compact plants. In an experiment it was found that plants treated with MC tend to be shorter and more compact than untreated plants. This height reduction is accomplished by reducing the concentration of GA_3 in the plant (Reddy *et al* 1992). Shorter and compact plants with reduced internode length and leaf expansion with MC application were also reported by Cothren and Oosterhuis (1993). Landivar *et al* (1995) reported that MC application (12 mg kg^{-1}) reduced leaf area expansion to 80 per cent and main stem elongation to 47 per cent.

When plants were sprayed at flowering with 49 g MC ha^{-1}, it decreased plant height and number of main stem nodes and the effect on boll number varied with cultivars (Reddy *et al* 1992). Derrick *et al* (2000) reported that MC application to cotton reduces plant height by shortening internodal length. According to Siebert and Stewart (2006), MC reduced plant height by 14.6 and 10.0 per cent as compared with control although yield responses to MC

application were found to be inconsistent. Similarly, 9 per cent reduction in plant height and 4 per cent increase in specific leaf weight were also reported by Pettigrew and Johnson (2005) when mepiquat type plant growth regulators (MC or mepiquat pentaborate) were applied to cotton. According to Weir *et al* (1997), MC treatments produced significant differences in plant height, height to node ratio and total nodes compared with the untreated control, but without any consistent pattern. Boman and Westerman (1994) sprayed cotton with 0.022 or 0.044 lb MC $acre^{-1}$ at early flowering and obtained a significant reduction in mean plant height by 5.7 inches over control. The reduction in plant height by 13-18 per cent was also reported by Dippenaar *et al* (1990) with MC application and they also concluded that application of 6.3 to 12.5 g ha^{-1} MC at 14 day intervals limited the growth rate of the main stem in cotton to 8-9 cm per 100 degree day (DD).

Kerby *et al* (1996) reported that plant height was reduced with MC resulting in shorter plant canopy. Reduction of vegetative growth with applications of MC shifts nutrient resources to developing bolls, and a greater proportion of boll production is shifted to lower nodal positions than in untreated cotton. Significantly shorter plants were also observed by Brar *et al* (2001) with MC (250 ppm) application at 60 DAS. MC had the tendency to cause the dwarfness in cotton plants ranging from 22 to 24 per cent when it was applied at 60 DAS as compared to 14 to 17 per cent when applied at 80 DAS as compared to control. Higher number of harvested bolls $plant^{-1}$ were observed with MC (250 ppm) applied at 80 DAS and the per cent increase in total seed cotton yield was reported to be 33.9 per cent during 1996 and 26.5 per cent during 1997 from control, whereas early application of MC (60 DAS) reduced both the seed cotton yield and number of harvested bolls $plant^{-1}$. Similarly, Rajni (2010) observed that foliar application of MC at 200 and 300 ppm significantly reduced plant height, leaf area index and total dry matter accumulation as compared to control. According to her, the application of MC at 200 and 300 ppm resulted in higher amount of dry matter allocation towards the fruiting bodies rather than the vegetative parts of plant which significantly improved setting percentage, increased sympodial branches $plant^{-1}$ and number of bolls $plant^{-1}$. The significant increase in yield attributes with the application of MC 200 and 300 ppm resulted in higher seed cotton yield than the untreated control.

Mekki (1999) reported significant reduction in plant height, number of leaves $plant^{-1}$ and plant dry weight with 100 ppm MC compared to untreated plants. Seed cotton yield, number of sympodia $plant^{-1}$, number of open bolls $plant^{-1}$, average boll weight and seed weight were significantly increased following MC application. Kumar *et al* (2006) in a field experiment in Karnataka studied the effect of MC on hybrid *Bt* cotton (DDH-11) and revealed that MC 50 ppm sprayed at 90 DAS was most effective in reducing plant height and leaf area which resulted in higher boll weight (5.58 g) and significantly higher seed cotton yield of 1040 kg ha^{-1}, which was 12 per cent more than control.

The foliar application of MC 250 ppm at 80 DAS or MC 125 ppm at 60 and 80 DAS resulted in 11.2 and 8.1 per cent reduction in plant height than control, respectively. Maximum seed cotton yield of 21.6 q ha^{-1} was recorded when 250 ppm MC was applied at 80 DAS which was 13.7 per cent more over control, while its application at 125 ppm (60 and 80 DAS) resulted in 9.5 per cent reduction in seed cotton yield from control (Deol and Brar 2003). Zakaria *et al* (2006) studied the effect of MC at 70 and 95 DAS and reported that the number of opened bolls $plant^{-1}$, boll weight, seed index, lint yield, yield $plant^{-1}$ and lint yield ha^{-1} were increased. They also revealed that application of MC reduced final plant height by 15 cm compared to control and main stem nodes were also decreased.

Increase in yield attributes (bolls $plant^{-1}$, boll weight and seed cotton yield $plant^{-1}$) were observed with application of MC at the rate of 100 ppm by Siddique *et al* (2002) at New Delhi and they reported that MC also reduced the plant height by 26 per cent and increased the seed cotton yield during both the years (2575.0 and 2946.3 kg ha^{-1} in 1999 and 2000, respectively). Athayde and Lamas (1999) gave total applications of 55-95 g MC ha^{-1}, in different proportions at 50, 64 and 78 days after emergence. Plant height was more affected by total application rate than by proportion applied in different splits. Branch length decreased with MC application, but boll weight, 100 seed weight and seed cotton yield were not significantly affected. Application of 50, 75, 100 or 125 g MC ha^{-1} in 2-3 equal or unequal splits decreased the number of unripe fruits but increased 100 seed weight and average boll weight (Lamas *et al* 1999).

In a field experiment, the effect of MC on cotton was studied by Nichols *et al* (2003) in which MC was sprayed two and four times with four different rates starting at pin head stage (4 X 0.29, 2 X 0.58, 4 X 0.58 and 4 X 0.88 l ha^{-1}). They observed that plant height and number of plant nodes were reduced with foliar applications of MC and height to node ratio was highest with no MC application. They also found that MC application at 0.58 l ha^{-1} during pin head square stage followed by second application at two weeks later was effective in controlling excessive vegetative growth and increased yield in 1999 but had no effect on seed cotton yields in 1998 and 2000. In an another study, four rates of MC were applied two and four times (4 X 123, 2 X 246, 4 X 246 and 4 X 370 ml ha^{-1}) along with a control by Iqbal *et al* (2004) at cotton research station, Multan (Pakistan) and it was reported that MC application increased seed cotton yield for all the treatments compared with untreated check by an average of 1096 kg ha^{-1} and 1143 kg ha^{-1} during 2002 and 2003, respectively. Highest yield of 2883 and 2960 kg ha^{-1} was obtained with four applications of MC at the rate of 123 ml ha^{-1} for the year 2002 and 2003 respectively.

El-Shahawy (1999) sprayed MC two or four times with 250 or 500 ml fed^{-1}(1 feddan = 0.42 ha) and reported increased number of sympodia, total dry matter, number of main stem internodes, boll retention, earliness, number of open bolls $plant^{-1}$, boll weight, lint percentage,

seed index and seed cotton yield plant^{-1} while it decreased plant height, main stem internodal length and number of aborted sites plant^{-1}, compared with untreated control. Whereas, MC application did not exert any significant effect on number of monopodia and number of unopened bolls plant^{-1}.

MC application at the rate of 0.15 l ha^{-1} at first flowering and two weeks after first flower stage resulted in significantly higher seed cotton yield by 8.1 and 14.4 q ha^{-1}, respectively over the untreated control. Increase in average number of bolls (14.1 per cent over control) was also reported with MC application at two weeks after first flower (Gormus 2006). MC sprayed on cotton cv. Giza 80 at the start of flowering resulted in significant reduction in plant height and length of internodes but it increased number of open bolls plant^{-1} and seed cotton yield while seed index and lint percentage were not significantly affected (Ghourab *et al* 2000). Similarly, Cook and Kennedy (2000) also observed reduction in plant height and height to main stem node ratio with MC application. The low rate multiple four weekly MC application of 12.25 g ha^{-1} started at pin head square stage with moderate early bud loss produced 10 per cent greater yield than control.

While in another study it was found that MC significantly reduced plant height. It was also observed that multiple applications were most effective as compared to untreated control however, lint yield increased with single application but it was reduced with multiple applications (Phipps *et al* 1996). Under irrigated and high rainfall conditions, MC at 4 oz acre^{-1}, applied in low rate multiple doses, increased lint yields by 9.5 per cent over untreated control (Livingston *et al* 1992). Under dry land conditions, the 2 oz and 4 oz acre^{-1} MC low rate multiple application increased yields by 6.9 and 3.6 per cent, respectively. Increase in lint yield with MC treatment was associated with increase in bolls plant^{-1}, boll size and improved earliness. Whereas, McConnell *et al* (1992) studied the effect of early multiple applications of MC (0, 0.006 and 0.012 kg MC ha^{-1}) on field grown cotton fertilized with high rates of soil applied urea-N and were of the view that lint yield was suppressed by 0.012 kg MC ha^{-1}.

Early low rate applications of MC tended to have a greater effect on the early growth parameters of plant height, node number and internode length while the early bloom treatments tended to have a greater effect on boll retention of exisiting fruits (Wallace *et al* 1993). Crozat and Kasemsap (1997) reported that in Thailand, MC application at early flowering significantly decreased vegetative growth (node production and internode length) during the reproductive period and shortened crop duration of cotton. Seed yield was not significantly increased by MC despite significant changes in boll distribution pattern and boll size. Application of MC resulted in shorter plants and a greater yield of cotton seed (Furlani *et al* 1999). Brar (1997) also studied the effect of different concentrations of MC on cotton when sprayed in single or as repeated application. He observed that double spray with low concentration (150 ppm) at flower initiation and 15 days later and single spray at higher

concentration (250 ppm) only at flower initiation reduced plant height but improved the number of monopodial and sympodial branches plant^{-1}, number of pickable bolls, boll weight, total seed cotton yield and earliness index.

Flowering and yield response of cotton to MC 585.1 ml ha^{-1} applied at pinhead stage and PGR-IV [0.001per cent indole-butyric acid (IBA) and 0.001per cent gibberellic acid (GA)] 292.6 ml ha^{-1} applied at pinhead and early bloom stage was studied by Biles and Cothren (2001). They concluded that the application of MC and PGR-IV increased the rate of flowering, boll number plant^{-1} and seed cotton yield. MC increased seed cotton yield by 23 and 10 per cent than control and PGR-IV respectively, whereas, the lint yield was 18 per cent greater than the untreated control. The MC and PGR-IV + MC resulted in 0.55 and 0.48 more flowers metre^{-1} of row per day, respectively than the untreated plants. Munk *et al* (1998), however, were of the view that applications of MC at early bloom were not economical and could occasionally result in a yield decline. Late season application, however, tended to have more positive results. Best overall yields were obtained from mid and late bloom sequential applications of MC at a rate of 0.025 kg ha^{-1}, applied at 14 days following first bloom and again at 10 to 14 days following the first application.

Maximum seed cotton yield (16.86 q ha^{-1}) was observed by Reddy *et al* (1992) when MC 200 ppm was sprayed at 80 DAS. The increase in seed cotton yield was 22.4 per cent as compared to control. It was also reported that early application of MC 200 ppm at 60 DAS had adverse effect on both growth and yield but its late application at 80 DAS had beneficial effect on seed cotton yield. Sawan *et al* (2001) reported that foliar application of growth retardants (Pix, cycocel, Alar at 300 ppm) resulted in increased cotton seed yield ha^{-1}, seed index, seed protein content, seed oil and protein yield. Donald *et al* (2001) reported that the application of MC in cotton resulted in a significant increase in lint and fibre yield. While, Owen and Craig (2003) reported that MC significantly hastened the progress of flowering, increased fruit harvest percentage relative to untreated cotton. Sawan *et al* (2001) at Giza (Egypt) recorded the highest seed, oil and protein yield ha^{-1} with MC applied at 288 g. ha^{-1} followed by cycocel. MC application resulted in a significant increase in cotton seed yield ha^{-1} (12.08 per cent) as compared to the untreated plants. Increase in seed cotton yield was also reported by Gadakh *et al* (1992) and they obtained 60 per cent increase in seed cotton yield over control with application of 100 ppm MC.

In North Carolina (USA) it was found that MC caused more bolls to set in the fruiting profile as compared to untreated control (Nuti *et al* 2006). Application of MC (2 or 4 oz acre^{-1}) applied four times, increased lint yields from 1001 to 1033 lb acre^{-1} (an increase of 3.2 per cent) over 4 year period (Ebelhar *et al* 1996). The highest rate (4 oz acre^{-1}) gave no significant benefit. In most years response to MC was non significant, although in some years there was a trend, which led to a significant response over the four years. Russel *et al* (2006)

conducted an experiment and reported that application of MC increased the yield. They further reported that the lint and fibre quality were also improved with the MC application.

Sawan (2007) at Giza (Egypt) observed that number of opened bolls plant^{-1}, boll weight, seed index, seed cotton yield plant^{-1}, seed cotton and lint yield ha^{-1} increased with foliar application of MC at 48 g ha^{-1} (75 DAS) + 24 g ha^{-1} (90 DAS). The per cent increase in seed cotton yield plant^{-1}, seed cotton and lint yield ha^{-1} was 9.5, 9.6 and 9.3 per cent respectively as compared with the untreated control. Increase in average number of bolls plant^{-1} and seed cotton yield with MC application was also reported by Gencsoylu (2009). McCarty *et al* (1989) also observed that MC increased yield and the percentage of total bolls at the first position on sympodial branches.

Kerby *et al* (1986) reported that MC stimulated early boll load and late season boll load was decreased, not by limited initation of fruiting positions, but by increased abortion of fruiting forms. Kerby (1983) reported that lint yields were not affected by the MC application but plant height was reduced by 15 per cent. There was also a little difference in the percentage of fruiting positions on which bolls matured (32.4 and 30.3 in treated and control plots, respectively). However, MC increased the number of bolls at the bottom and middle nodes of the plant while decreasing those at the upper nodes. Treated plants matured earlier (26.5 per cent of the final yield was obtained in the first week of harvest as opposed to 21.1 per cent in the control plots) and this was due to an earlier cutout. Walter *et al* (1980) reported that treatment with 75 g MC ha^{-1} at first bloom stage reduced plant height and number of bolls plant^{-1} by 28 per cent, increased leaf thickness by 10 per cent, reduced leaf area by 17 per cent and increased boll dry weight by 16 per cent. In four trials, seed cotton yields averaged 3900 kg ha^{-1} and were not affected by various MC treatments whereas, under conditions of luxurious growth, the yield at first picking increased by 20-26 per cent, and total yield by 5 per cent.

Shumway (1997) reported decrease in plant height and main stem node number with MC as compared to control, but it did not affect boll number or seed cotton yield. Whereas, Biles and Cothren (1997) were of the view that MC did not affect the total lint yield and earliness but it altered the distribution of bolls on the plant, thereby increasing the first position lint yield. Gherbin *et al* (1996) reported that application of 49 g MC ha^{-1} reduced plant height and dry matter accumulation in stems and bolls. Seed cotton yield was not significantly increased by MC treatment, but the seed cotton yield to total dry weight ratio was higher than in untreated control.

Azevedo *et al* (1998a) reported that application of 50 g ha^{-1} MC reduced plant height significantly from 96.9 to 86.4 cm whereas, the higher rate (100 g ha^{-1}) of application significantly reduced the seed cotton yield without further significant reduction in plant height. Azevedo *et al* (1998b) applied a total of 75 g MC ha^{-1} in 1-5 splits and observed that

plant height and stem diameter were reduced significantly by application in two splits i.e. 30 and 60 days after emergence. Seed cotton yields did not differ significantly between treatments. Wankhade *et al* (2002) also reported 12.7 per cent increase in seed cotton yield over control with application of MC at the rate of 25 ppm. Whereas, higher concentration of MC (75 ppm) significantly reduced the seed cotton yield by 13.9 per cent than untreated control.

Zhao and Oosterhuis (1999) reported that MC shortened cotton plants three or six weeks after its application. Lint yield was not significantly affected in 1998, while in 1997, MC decreased yield as compared to control. Similarly, Cathey and Meredith (1988) reported that MC applied at the rate of 49 g ha^{-1} when the plants had about 0.7 white flowers m^{-1} of row caused a 4.5 per cent reduction in lint yield from the early sown plots (mid-April), and 5.4 and 12.7 per cent yield increases from the optimum (early-May) and late planted cotton (mid-May), respectively. Plant height in MC treated plots was reduced by 8.5, 17.6 and 19.5 per cent in early, intermediate and late planted plots.

In 35 replicated experiments in the San Joaquin Valley of California conducted over a five year period, application of MC did not show a consistent increase in yield, but did reduce plant height, increased final harvestable bolls by 5 per cent and reduced main stem nodes by one (Kerby 1985). While, in an experiment conducted by Kerby *et al* (1986) for four years, it was observed that MC decreased number of bolls by 3.1 per cent and they reported decrease in yield was due to the higher retention of early boll load.

Edmisten (2000) concluded that mepiquat pentaborate treatment could hasten maturity, reduce plant height, decrease boll rot and increase yield. He found that internodes along the stem and fruiting branches were shortened and the total number of fruiting branches were also slightly reduced. The increase in yield was due to the diversion of assimilates towards the bolls instead of vegetative growth because mepiquat pentaborate ceased apical dominance in plants by suppressing the gibberillin biosynthesis which resulted in dwarf plants by shortening the internodes by virtue of which the assimilates produced in plant were translocated towards the reproductive parts.

Phillip *et al* (2000) reported that pentia (mepiquat pentaborate) application in cotton prevents excessive vegetative growth and plant height which ultimately help in yield increase. Similarly, Joel (2005) reported that mepiquat pentaborate, a new product containing boron molecule which aids in preventing excess vegetative growth reduced plant height and increased boll number. It was also observed that application of mepiquat pentaborate shortened internodal length and further increased the lint yield. Joseph and Johnson (2006) studied the effect of mepiquat pentaborate on cotton plants and they reported that mepiquat pentaborate caused reduction in height to node ratio and nodes above white flower which further contributed to increase in yield. Jonathan and Alexander (2006) also reported that the

application of mepiquat pentaborate caused a reduction in plant height, height to node ratio, nodes above white flower.

Kennedy and Hutchinson (2001) observed that higher yield was related to faster and early season crop growth with the application of MC. Even though the effect on yield was not found to be consistent by Reddy *et al* (1992) but they reported that MC was continuously used not only for reducing vegetative growth but also to promote early maturity.

According to Pazzetti *et al* (1999) there was no significant difference between productivity without MC and with MC at 50 g ha^{-1}, while MC at 100 g ha^{-1} caused a significant reduction in productivity. Although, the major benefit from using the MC was uniformity in maturation and advancement of harvest. Oosterhuis and Zhao (1999) were also of the view that MC hastened physiological maturity of cotton. Whereas, Brar *et al* (2000) found that MC did not significantly influence the maturity coefficient.

Neither earliness in maturity nor seed cotton yield was affected by application of MC at the rate of 2.5 g ha^{-1} (Dippenaar and Meyer 1994). Kerby (1987) observed that use of MC improved earliness without a negative impact on yield and benefited yield in short growing season. Mert and Calisken (1998) treated cotton with 100 or 150 g MC ha^{-1} in 1, 2 or 3 splits at the beginning of budding, flowering and at maximum flowering. MC treatment reduced plant height and improved earliness of cotton while its effect on yield exhibited inconsistency between years. Seed cotton yield and earliness were improved with multiple applications. MC increased seed cotton yield and weight $boll^{-1}$ as compared to untreated control but did not significantly affect other morphological characteristics.

Deol (2001) reported non significant effect on ginning out turn, lint index, 2.5 per cent span fibre length, fibre bundle strength and micronaire with 200 ppm MC but Bartlett's index was significantly higher (0.683) over control (0.676). MC improved Bartlett index because it diverts more of assimilates into the fruiting bodies by restricting the excessive vegetative growth, thereby improving the growth of earlier formed bolls.

Puri (2001) at Ludhiana observed that MC application (500 ml $acre^{-1}$) at 80 DAS did not affect Bartlett index, ginning out turn, seed and lint indices than untreated control. While, Mekki (1999) reported that ginning percentage was reduced by MC treatment at the rate of 100 ppm but fibre length (2.5 and 50 per cent span length) was less affected. Fibre strength (g tex^{-1}) was slightly decreased, but micronaire values were increased under the same conditions of MC application. Athyayde and Lamas (1999) reported that fibre percentage was not affected by MC application. Similarly, Mert and Caliskan (1998) reported that treatment with MC did not significantly affect the fibre characteristics. Likewise, Siebert and Stewart (2006) were also of the view that ginning out turn, micronaire, fibre strength, uniformity and elongation were not influenced by MC treatments.

Boman and Westerman (1994) sprayed cotton with 0, 0.022 or 0.044 lb MC acre^{-1} at early flowering. They reported that MC significantly increased fibre strength by 3.8 per cent. MC applied at 16 oz acre^{-1} either as a single dose or split into four equal weekly doses starting from early bloom of cotton had no harmful effect upon fibre properties or yield but MC applied in split doses reduced lint percentage (Phipps *et al* 1997). Ebelhar *et al* (1996) reported that MC application resulted in a slight increase (0.01 inches) in fibre length and had varying effects on fibre strength. Dippenaar and Meyer (1994) also reported that the fibre strength was improved and micronaire values were higher than those in the control by application of MC (25 g ha^{-1}). Shaw *et al* (1990) observed that MC application resulted in stronger, longer, less uniform fibres and lower micronaire values with MC at the rate of 25 g ha^{-1}. El-Shahawy (1999) observed increased earliness index, lint percentage and seed index. This increase was attributed by increased translocation of photosynthates to the fruiting structure.

2.3.2 Effect of 2, 3, 5 - tri iodobenzoic acid (TIBA)

TIBA is an auxin polar transport inhibitor. The embryo formation from embryogenic cells is suppressed with the application of TIBA, while cell division is not affected. On the basis of the *Avena* coleoptile curvature test, Galston (1947) has reported inhibition of the effectiveness of indoleacetic acid (IAA) by low concentrations of TIBA and a complete negation of the effect by higher concentrations. Thimann and Bonner (1948) obtained similar results with high molar ratios of TIBA/IAA, however lower molar ratios (up to 8.7) resulted in an increase in the effectiveness of IAA. Kraus and Mitchel (1947) found that TIBA induced changes mainly in the vegetative character of treated bean plants and observed that stem intermodal elongation was checked and axillary buds were also affected. Dhillon *et al* (1980) reported that higher concentration of TIBA proved to be more effective in suppressing the plant height by inhibiting the apical dominance. The decrease in plant height in turn increased the root length because of diversion of hormones from the shoot apical meristem to other plant parts. They also revealed that TIBA spray could produce more number of leaves during the later stages of crop growth and this might be possible due to the more branch number per plant.

2.3.2.1 Effect of TIBA on growth, yield and yield attributes of cotton

Dastur and parkash (1954) found that the application of TIBA at the rate of 0, 50, 100 and 150 ppm one month after sowing made the plants shorter and bushy due to shortening of internodes and the leaves became thick and dark in colour. In pot studies they also found that the application of TIBA at the rate of 0, 50, 100 and 150 ppm one month after sowing of *desi* and American cotton increased the number of flowers and number of bolls plant^{-1} in American cotton. TIBA 10 ppm when sprayed after 55 days of sowing did not show any noticeable effect on the yield of American cotton but in case of *desi* cotton 24.7 per cent

increase in yield was recorded over control (Bhatt 1958). In another study, TIBA was used by Thomas (1967) to reduce plant size and dry weight, but it also reduced the seed cotton yield significantly.

Asici (1973) observed that the application of TIBA at high concentrations reduced yields, but 4.94 g TIBA ha^{-1} applied 4 times at 5 day intervals gave a non significant increase in yield over control. TIBA had no effect on boll or fibre characteristics except at the highest concentration which increased lint percentage of the 4^{th} harvest. He further observed a significant increase in dry weight of the cotton plants treated with TIBA. The protein nitrogen of the vegetative and reproductive parts was also found to be higher in TIBA treated plots (Dastur and Bhatt 1956). Harvey (1965) and Coleman (1969) at Texas Tech University reported that the yield was not increased with TIBA application as compared to control. Cavendess (1967), at University of Arkansas applied TIBA in single applications on cotton and also found that the increase in yield was not significant in comparison to control.

The first positive results of an increase of cotton yield were with the multiple applications of TIBA in low concentrations. In 1968, International Minerals and Chemical Corporation (IMC) research station at Memphis, Tennessee, reported yield increases of 18 per cent on Dixie King and 10 per cent on Stoneville 213 cotton when TIBA was applied 5 times at 25 to 62 g ha^{-1} (Freytag *et al* 1968, Freytag *et al* 1969). In I969, at the IMC Florida station, multiple applications of TIBA were applied from 2 to 5 times, with total TIBA applications of 25, 62, and 125 g ha^{-1} and 8 to 21 per cent increase in seed cotton yield was observed (Prevatt and Freytag 1969).

Freytag and Coleman (1973) concluded that TIBA 5 g ha^{-1} applied at first flowering and 4 times thereafter at 7 day intervals increased average seed yields by 16 per cent, while 60 g ha^{-1} applied 2-3 times at 10 to 14 day intervals increased seed yields by 9.25 per cent but 112 g ha^{-1} applied once tended to reduce yields. Except at the highest rate, TIBA lowered first fruiting nodes and increased boll counts and weights. While TIBA application on cotton did not show any effect on boll retention (Asici 1973, Rowland 1974). However, in another study Mathur (1963) found that TIBA spray at the rate of 40 ppm accelerated the flowering but reduced the flower production and had little effect on flower retention.

Whereas, Dastur (1959) reported an increase in number of bolls with the application of TIBA in cotton at 70-80 DAS. Similarly, Djanaguiraman *et al* (2005) studied the effect of TIBA at 100 ppm and observed significant reduction in plant height and increase in the enzyme activity and yield of cotton. They reported that the increase in yield was due to increase in number of bolls $plant^{-1}$ over the control.

2.3.2.2 Effect of TIBA on growth, yield and yield attributes of other crops

Since relatively meager information is available on the effect of TIBA on cotton crop, so a brief review of TIBA on crops other than cotton is given as under

The effect of TIBA on growth of plants has been reported by several workers. TIBA caused vegetative buds on tomato plants to produce flowers and increased the growth of axillary buds (Zimmerman and Hitchcock 1942). Whereas, Galston (1947) showed that vegetative soybean plants were not induced to flower by TIBA, but photo induced plants set more flowers. It was also reported that TIBA may induce a rapid change from the vegetative to the reproductive cycle of development. Greer and Anderson (1965) were in agreement with Galston's results. They also found that leaf and plant morphology were altered, producing, a somewhat vertically oriented leaf and a triangular shaped plant with a more open canopy. They also revealed that plants treated with TIBA attained 1.9 to 3.3 branches plant^{-1}, while control had 0.8 branches plant^{-1}, and the TIBA treated plants were shorter in height. They also used multiple TIBA treatments and found no differences between 1, 3, or 5 applications. Apical dominance decreased with TIBA treatments, and high concentrations aborted the apical meristem. An unexpected result was decrease in lodging with the use of TIBA. Burton and Curley (1966) reported that application of TIBA during early blossom period of soybean reduced plant height by 26 per cent, and shortened leaf petiole but increased branching. Hicks *et al* (1967) also reported an anti lodging effect of TIBA treated soybeans. They also observed that TIBA reduced leaf area by 26 per cent.

Bauer *et al* (1969) studied the effects of TIBA on soybean and they observed smaller leaves with vertical orientation and deep green colour. Plants treated with TIBA also showed increased branching and shorter nodes. They were particularly interested in the effect of TIBA on root nodulation of soybeans, and found that TIBA had no effect on the nodulation.

Nawalgatti *et al* (1991) studied the effect of different levels of plant growth regulators on growth of groundnut and found that application of 50 ppm TIBA increased LAI, dry matter production, net assimilation rate (NAR) and crop growth rate (CGR) as compared to control. Ravichandran and Ramaswami (1991) reported that LAI decreased with the foliar application of TIBA in soybean but dry matter accumulation, CGR and NAR increased. Patil (1994) reported that foliar application of TIBA significantly increased absolute growth rate (AGR), relative growth rate (RGR), NAR and CGR in soybean. It was also observed that foliar application of growth regulators increased chlorophyll content in leaves. Parvin *et al* (2001) reported that the foliar application of TIBA (50 and 100 ppm) at 45 days after planting resulted an increase in chlorophyll a, b and total chlorophyll contents in potato.

Ganiger *et al* (2002a) studied the effects of plant growth regulators *viz*. NAA (250 or 500 ppm), TIBA (25 or 50 ppm), gibberellic acid (25 or 50 ppm), CCC (250 or 500 ppm) and cytozyme (500 or 1000 ppm), and foliar application of 2 per cent urea on the growth of cowpea. They observed that treatment with TIBA at 50 ppm resulted in the highest total dry matter weight (25.58 g plant^{-1}), number of branches plant^{-1} (5.38) and leaf area (10.08 dm^2

plant^{-1}) at harvest. Whiting and Murray (1948) found that applications of TIBA in red kidney beans exceeded axillary structures over control.

Deotale *et al* (1994) reported that foliar application of TIBA from 110 to 600 ppm in safflower increased the number of leaves and branches but beyond 600 ppm it decreased both number of leaves and branches. In another study, it was revealed that application of TIBA (25, 50, 75 and 240 ppm) increased the number of leaves in sunflower as compared to control (Lakshminarasimhan 2002). Similarly Castro *et al* (1990) reported an increase in number of leaves in TIBA treated bean plants.

Greer and Anderson (1965) reported that foliar spray of TIBA recorded increased seed yield in soybean and postulated that anti auxin effect of TIBA reduced the vegetative growth and produced more photosynthesis for reproductive growth. Similarly, Prasad and Sastry (1978) reported that, the application of TIBA (200 ppm) along with NAA (50 ppm) increased the proportion of filled seeds, 100 seed weight and seed yield as compared to control.

In greenhouse studies, Thomas (1967) reported that foliar applications of TIBA on soybean reduced plant size, dry weight, and seed yield. While, Greer and Anderson (1965) confirmed that branching increased with TIBA application and they also reported a partial breakdown of apical dominance by TIBA treatment. They further reported no differences in yield and oil content of the soybean seeds but observed a decrease of 6 per cent in leaf nitrogen and 1.5 per cent in seed protein with TIBA treatment. The findings of Wax and Pendelton (1968) were in agreement with the other workers, with the exception of finding no reduction in leaf nitrogen and seed protein content of soybeans.

A field experiment was conducted by Vasudevan *et al* (2002) during the *kharif* season to study the effect of growth regulators on seed yield, yield parameters and oil content of sunflower. They observed that TIBA spray resulted in highest head diameter (19.2 cm), filled seeds (10.6 per cent increase over control), seed filling percentage (85.2 per cent), seed yield (29.6 q ha^{-1}), test weight (63.3 g), seed density (0.546 q cl^{-1}) and volume weight (4.9 g higher than control).

Uppar and Kulkarni (1989) studied the effect of growth retardant, TIBA (50 or 100 ppm) in sunflower cv. Morden and reported that TIBA (100 ppm) was the most effective growth retardant which increased the number of filled seeds head^{-1} and seed yield plant^{-1} followed by 50 ppm TIBA. Similarly, Ravichandran and Ramaswami (1991) observed that foliar spray of TIBA at 50 ppm at pre flowering stage in soybean increased number of pods plant^{-1} and seeds pod^{-1}.

Hugar and Nalawadi (1999) studied the effect of growth regulators on morphological characters, flower production and seed yield of *Gaillardia pulchella* cultivar Picta. They applied TIBA at 100, 200 and 300 ppm, CCC at 750 ppm, kinetin at 75 ppm and reported that

TIBA at 200 ppm and kinetin at 50 ppm produced significantly higher flower yields than the control. The increase in yield was due to increased numbers of flowers plant^{-1} and the weight of 10 flowers.

Ganiger *et al* (2002a) studied the effects of different plant growth regulators NAA (250 or 500 ppm), TIBA (25 or 50 ppm), gibberellic acid (25 or 50 ppm), CCC (250 or 500 ppm) and cytozyme (500 or 1000 ppm), and foliar application of 2 per cent urea on the growth and yield of cowpea. They observed that treatment with 25 ppm TIBA resulted in the highest seed yield (1801 kg ha^{-1}), 1000 seed weight (132.4 g) and pod length (12.79 cm), whereas treatment with 50 ppm TIBA resulted in the highest number of pods plant^{-1} (19.33), total dry matter (25.58 g plant^{-1}) and leaf area (10.08 dm^2 plant^{-1}) at harvest. They also observed that treatment with 500 ppm TIBA resulted in the highest number of seeds pod^{-1} (10.14), which was at par with NAA 500 ppm. Similarly, in another experiment Ganiger *et al* (2002b) observed that application of TIBA at 25 and 50 ppm resulted in highest seed yield, pods plant^{-1}, number of seeds pod^{-1}, 1000 seed weight and pod length.

2.3.3 Effect of Maleic Hydrazide (MH)

Maleic hydrazide is a plant growth regulator, which inhibits plant cell division but not cell enlargement. MH was first synthesized in 1895 but its ability to regulate plant growth was not discovered until 1949. It was first registered as a plant growth regulator in 1952. For about many years MH has been studied extensively as an inhibitor of plant growth and as an antimitotic agent. When applied to plants, it moves through the cuticle and is actively transported to tissues where cell division is occurring. Because of its action in plants, MH is used by growers to control unwanted sucker (axilliary bud) growth in tobacco and to control undesired sprouting of potatoes and onions in storage. MH is also be used to control growth of utility turf grass. The growth inhibiting property of MH was reported by Schoene and Hoffmann (1949) for the first time in tomato and later on several workers have reported the similar action of MH in suppression of apical dominance in different crops.

Since relatively little information is available on the effect of MH on cotton crop, a brief review of MH on crops other than cotton is given as under:

2.3.3.1 Effect of MH on growth, yield and yield attributes of other crops

Gowda and Gowda (1990) studied the effect of MH on chlorophyll content of jasmine leaves and reported that the foliar application of MH (2000 ppm) increased the chlorophyll a and total chlorophyll content in jasmine leaves. Similarly, Sangeeta and Varshney (1992) reported an increase in chlorophyll content of oat leaves with foliar application of MH.

MH proved to be a good growth retardant when it was sprayed on young plants of sunflower and maize at 0.25 per cent concentration. It significantly decreased their plant height and number of leaves (Abramyan *et al* 1972). Rowland (1974) also reported that MH

and CCC were more effective in decreasing the plant height of cotton. Similarly, Suryanarayana (1977) studied the effect of different growth regulators viz., gibberellic acid, TIBA, MH, 2, 4-dichloro acetic acid (2, 4 D) and NAA in groundnut and reported that MH application caused significant reduction in plant height during both *kharif* and *rabi* seasons.

Zode and Durge (1988) applied CCC and MH at 200 and 400 ppm and 400 ppm of GA on sorghum and reported that CCC and MH significantly decreased plant height. Pal and Das (1990) conducted an experiment on *longiflorum* with GA and NAA (200 ppm) and IAA and MH (100-200 ppm) and reported that MH reduced plant height and number of leaves while NAA and IAA increased both plant height and number of leaves. Mehetre and Lad (1995) applied MH, CCC, GA and abscisic acid (ABA) on soybean during flower initiation and seven days later and reported a reduction in plant height and leaf area by MH and CCC application. Similarly, Crafts and Sutton (1994) reported that application of MH (1.68 to 13.44 kg ha^{-1}) decreased tobacco leaf area.

Retarded vegetative growth of pea plants at higher concentration of (10-20 mg l^{-1}) was reported by Rakava and Minor (1970). Reduction in peanut plant height by reduction in node number due to MH application was also reported by Lin *et al* (1987). Similarly, a decrease in plant height by MH application was observed in calendula (Shrivastava and Bajpai 1964).

Rahman *et al* (2004) studied the effects of PGRs on the dry matter production and growth attributes of soybean. Plants were sprayed at 15, 30 and 45 DAS with GA_3 and MH at 100 or 200 ppm. They observed that time of application had a significant effect on dry matter production by roots, stems and leaves, total dry matter $plant^{-1}$ and growth attributes such as LAI, CGR, RGR and NAR. They concluded that both the growth regulators had a positive effect on dry matter production and growth of soybean over the control but GA_3 was more effective than MH.

Ayala *et al* (2004) studied the effect of PGRs like MH, TIBA and CCC on flax plants and reported increase in fibre yield over control. Norton *et al* (2005) also studied the effect of MH on flax and they reported that application of MH resulted in high fruit load on crop and it contributed to high yield, high fruit fibre and lint yield. Treatment of wheat plants with MH at 15 or 20 days after flowering increased the grain yield significantly due to increase in 1000 grain weight (Sobolev and Dubko 1985). Kene *et al* (1991) also reported maximum seed yield (1.21 t ha^{-1}) of sunflower when MH was applied as compared to NAA, water spray and control. Increased pod set and yield $plant^{-1}$ was also observed by Sharma *et al* (2005) with foliar application of MH @ 100 at anthesis on soybean.

Kumar *et al* (2003) applied four PGR's including control (water spray), 20 ppm NAA, 50 ppm CCC and 50 ppm MH on chickpea and reported that grain yield increased due

to NAA, CCC and MH which was 25.42, 24.16 and 26.12 per cent higher over control respectively. The grain protein content improved over the control by 19.98, 17.91 and 20.65 per cent with application of NAA, CCC and MH, respectively. They further reported that among the different growth regulators higher yield was obtained with the application of MH. Rai *et al* (2003) used two concentrations (100 and 200 mg l^{-1}) of MH given as drenching around bitter gourd plants at the two leaf stage. MH at 200 mg l^{-1} was the best treatment for increasing the yield.

The effects of MH 50 mg l^{-1} and irrigation level (50, 75, 100 or 125 per cent of cumulative pan evaporation (CPE) through drip irrigation, and 100 or 125 per cent of CPE through furrow irrigation on the performance of bottle gourd (*Lagenaria siceraria*) was studied by Birbal *et al* (2003). They applied MH to plants at the two and four leaf stages and irrigation was given at three days interval and observed that the length of the main vine decreased with MH application, but increased with increasing irrigation by both methods. The number of branches significantly increased with MH application and with increasing irrigation level which helped in increasing the number of fruits $plant^{-1}$, fruit length and fruit weight. They revealed that the number of fruits $plant^{-1}$ (356.1 and 346.2) were highest with the combination between MH and drip irrigation at 100 per cent CPE. Higher fruit yield was recorded in MH treated plants (319.2 and 309.5 q ha^{-1}) than control (267.3 and 258.7 q ha^{-1}). Pandya and Dixit (1997) sprayed 10 ppm GA_3, 250 ppm ethephon, 50 ppm CCC, 50 ppm TIBA, 150 ppm MH, 3 ppm boron or 20 ppm calcium nitrate ($CaNO_3$) on *L. siceraria* seedlings at two leaf stage and again at four leaf stage. They found that MH application resulted in higher yields (33.50 t ha^{-1}) followed by ethephon (29.37 t ha^{-1}). The higher yield with the application of MH was attributed to significant reduction in length of the main axis by which the number of shoots $plant^{-1}$ increased. It also helped in increasing the number of female flowers, lowered the male female flower sex ratio and increased fruit girth and weight.

Sharma *et al* (2005) studied the effects of foliar application of IAA (25 ppm) and MH (100 ppm) under varying light intensities (LI) on the performance of soybean. They observed that with decreasing light intensity at nodule initiation (NI) and anthesis, chlorophyll and total soluble protein decreased but IAA and MH application at both stages increased the chlorophyll and total soluble protein contents under reduced LI. LI reduction also increased the number of abscission scars, especially at anthesis, and reduced pod set and yield $plant^{-1}$. Whereas, IAA and MH reduced the number of scars, and increased pod set and yield $plant^{-1}$. They also observed that MH application at NI and anthesis under 100 per cent LI resulted in the highest total chlorophyll (2.14 mg g^{-1} of tissue), total soluble protein (2.97 mg g^{-1} of tissue) and total free amino acid contents (41.2 mg g^{-1} of dry matter), pod set (79.89 per cent) and yield $plant^{-1}$ (21.98 g), and in the lowest number of abscission scars (22.18).

2.4 EFFECT OF DETOPPING

Cotton is a perennial plant, exhibiting indeterminate growth and fruiting habits and is grown as an annual crop, thereby increasing the necessity of intense management for profitable production (Cothren 1994). Provision of sufficient resources, such as fertilizer, adequate moisture, is required for profitable yield. However, these inputs may contribute to excessive vegetative growth, thus lowering the resource utilization efficiency. The indeterminate growth habit of cotton crop throws up many intricacies in respect of growth and developmental events in terms of varied expressions which set competition for nutrients among simultaneously growing stem, developing bolls and newly formed flowers. Under luxuriant growing conditions, maintaining a proper balance between the reproductive and vegetative components of the crop is sometimes difficult to accomplish and more photosynthates are shifted towards vegetative development (Buttar and Aggarwal 2004). Increased production of vegetative parts (stems and leaves) at the expense of reproductive parts (squares, flowers and bolls) can lead to decreased yield. The tendency of the cotton plant to abort fruiting forms may result in the disruption of a vegetative/reproductive balance. This ability of the cotton plant to shed fruit and then also to compensate, necessitates crop monitoring to properly manage the vegetative/reproductive ratio of the crop. Besides this, excessive vegetative growth of cotton reduces penetration of sunlight through the canopy, increases relative humidity in the lower canopy, and lowers the efficiency of picking and increases boll rot.

One of the effective ways of reducing shedding of fruiting bodies and maintaining proper balance between vegetative and reproductive growth is by detopping or removal of main stem, alone or together with the main branches (Arnon 1972). The purpose of detopping is to get good plant architecture so that crop can get required sunlight with reduction of mutual shading and thus the picking efficiency can be increased with the advancement of crop maturity. Extirpation of vegetative buds produced smaller and more compact plants (Bolonhezi *et al* 1999). It checks unwanted vegetative growth of plants and ensures redistribution of the nutritive substances in the plant which prevents shedding of fruiting bodies and increases seed cotton yield (Arnon 1972).

2.4.1 Effect on growth, yield and yield attributes

Detopping at 75, 90 and 105 DAS showed a significant reduction in plant height in two cotton hybrids (Varalaxmi and DCH 32). The reduction was more pronounced with early detopping which resulted in significantly higher number of bolls plant^{-1}, seed cotton yield and harvest index over control (Rao and Lakshminarayna 1985). Detopping at boll development stage had no pronounced effect on plant height (Wankhade *et al* 1991). According to Singh (1996) detopping at 60 or 80 DAS reduced the plant height significantly but monopodial

branches remained unaffected whereas, the number of sympodial branches plant^{-1} increased significantly from control.

Various growth and yield contributing characters such as plant height, dry matter accumulation, number of monopodial and sympodial branches plant^{-1}, shedding of buds or bolls and seed cotton yield were significantly influenced by detopping (Nobrega *et al* 1993). Brar (1997) at Ludhiana, revealed that detopping at 60 DAS significantly reduced plant height, but did not affect the boll weight. Whereas, sympodial branches plant^{-1}, open bolls and seed cotton yield were significantly improved over control.

Basnet (2006) at Bardiya, Nepal studied the impact of detopping at different growth stages (3-4, 6-7, 9-10 and 12-13 sympodial branches) on the productivity of cotton and reported higher seed cotton yield (1.00 t ha^{-1}) by detopping plants at the stage of 12-13 sympodial branches. He further noticed that the seed cotton yield increased from 0.75 to 1.00 t ha^{-1} with the postponed detopping from 3-4 to 12-13 sympodial branches, but significant difference was recorded between late (12-13 sympodial branches) and early (3-4 and 6-7 sympodial branches) stages of detopping.

Detopping at 60 and 80 DAS had beneficial effect on seed cotton yield and obtained 15.1 and 9.1 per cent higher seed cotton yield than control (Brar *et al* 2000). Whereas, a non significant influence on plant height, seed cotton yield and lint yield ha^{-1} was observed by Siddique *et al* (2002) at New Delhi by detopping plants at 90 DAS. It was also observed that detopping in *G hirsutum* was not advantageous in terms of growth and seed cotton yield (Turkhede *et al* 2003). Detopping at 60 DAS significantly increased the number of bolls plant^{-1}, boll setting percentage and total seed cotton yield as compared to control and detopping at 80 DAS (Singh 1996).

Detopping increased the number of sympodial branches plant^{-1} leading to higher production of squares and bolls, which ultimately resulted in increased seed cotton yield (Shrivasa and Thimmegowda 1997). In an another experiment it was found that detopping performed 15 days after flowering gave significantly higher seed cotton yield and improved the seed index (Deshmukh and Rao 1996). Reduction in plant height and significant increase in dry matter accumulation was reported by Sawaji *et al* (1994) with detopping at 50 DAS. Although detopping at 75 and 50 DAS recorded 6.1 and 3.7 per cent higher seed cotton yield, respectively, over no detopping but no significant effect on number of bolls, seed cotton yield, lint yield and ginning percentage was observed. Contrarily to the above reported Hallikeri *et al* (2010) confirmed that detopping of *Bt* cotton at 80 DAS did not improve the seed cotton yield significantly, but it reduced the plant height when compared with normal crop of cotton.

Detopping increased number of bolls per sympodium but reduced number of nodes and sympodia plant^{-1} and the reduction was highest for plants topped at 80 DAS (Ahmed *et al* 1989). The effect of late season detopping on lint yield of cotton was observed by Kittock and

Fry (1977). They reported that detopping of Pima S 4 cotton in mid July, early August and mid August reduced plant height and number of main stem nodes, but it helped in increase in boll set and additional branch nodes on the top fruiting branches. They further revealed that, plants detopped in mid July produced 300, 100 and 60 per cent more bolls on the first, second and third fruiting branch, respectively below the point of detopping whereas; the effect was less when detopping was done late in the season. Bennett *et al* (1965) reported that detopping did not affect the lint yield, number of bolls and seeds $boll^{-1}$. While, lint percentage, fibre length and micronaire was increased, when plants were detopped at 48 inches.

Detopping recorded significantly higher seed cotton yield of 25.22 q ha^{-1} over no detopping (23.51 q ha^{-1}) and resulted in an increase of 7 per cent of seed cotton yield over no detopping. Detopping recorded significantly higher lint index (5.85) and fibre length (32.19 mm) over no detopping (4.42 and 30.49 mm, respectively), but ginning percentage was not significantly influenced due to detopping (Shwetha *et al* 2009).

Yang *et al* (2008) reported that with topping total dry matter production declined but higher cotton lint yield was obtained, it was due to more dry matter allocation towards reproductive organs. They also found that growth in the number of main stem node ceased after detopping. Furthermore, there was more biomass allocation to reproductive organs, such as green and open bolls with detopping. Similarly, in an another experiment it was found that detopping increases cotton yield mainly due to readjustments in assimilate partitioning in the plant, which strengthens reproductive growth and inhibits the vegetative growth of the plant. Both the inhibition of vegetative growth and strengthening of reproductive growth resulted in early maturity or short life span of the cotton crop (Ma *et al* 1983, Xu *et al* 2001 and Dai *et al* 2003).

CHAPTER III

MATERIAL AND METHODS

The present investigation entitled "Studies on source sink relationship for realization of higher productivity in *Bt* cotton (G*ossypium hirsutum* L)" comprising of two field experiments and one pot experiment was carried out at the Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana, during *kharif* seasons of 2011 and 2012.

3.1 WEATHER AND CLIMATE

Ludhiana is situated at 30°54' N and 75°48' E at 247 metres above mean sea level. This region is characterized with subtropical, semiarid climate having three distinct seasons i.e. hot and dry summers (April-June), hot and humid monsoon (July-September) and cold winters (November-January). Considerable fluctuations are displayed by mean maximum and mean minimum temperatures during these seasons. Mean maximum temperature often reaches as high as 47°C in the month of June while freezing temperatures accompanied by frosty spells are quite common during the months of December and January. Average rainfall ranges from 500-750 mm, most of which is received during the monsoon period, the grand growth period of cotton crop. Some rainfall is also expected during winter months.

Weather during the crop seasons

The meteorological data recorded at meteorological observatory of the Punjab Agricultural University, Ludhiana during the two crop seasons has been presented in Appendix II and graphically represented in Fig 3.1.

The mean monthly relative humidity during crop seasons ranged from 44.7 to 82.7 per cent in 2011 and 31.8 to 77.0 per cent in 2012. Mean monthly maximum temperatures of 39.4° C and 39.6° C were recorded in the month of May in 2011 and 2012, respectively. Total rainfall received during the crop growing seasons of 2011 and 2012 was 1192.4 mm and 385.1 mm, respectively, exhibiting enormous variation in distribution pattern and total rainfall received during the two years. In 2011, rainfall received during the months of May and June, exceeded than normally received by 12.8 mm and 286.5 mm, respectively. The month of July, however witnessed a shortfall of 117.9 mm of rainfall from normal. The months of August and September once again experienced more than normal rainfall, the deviation being 333.7 mm and 75.3 mm, respectively for the year 2011. However, the total rainfall received in the month of August was 513.4 mm and 443.8 mm of it fell during meteorological standard week of 32 (06.08.11-12.08.11). The months of October and November again experienced less than normal rainfall during 2011. The rainfall pattern of the year 2012 was strikingly different than 2011. All the months during the crop season received meager amount of rainfall. On the

whole, crop season of year 2012 can be described as a dry in comparison to the crop season of the year 2011, during which the months of May, June, August and September received ample amount of rainfall i.e. 647.6 mm more than normal.

3.2 SOIL ANALYSIS

Representative samples of soil upto a depth of 0-15 cm and 15-30 cm from the experimental field were randomly collected from five places before sowing to determine the physico-chemical properties of the soil. The composite samples were subjected to mechanical and chemical analyses.

Mechanical Analysis

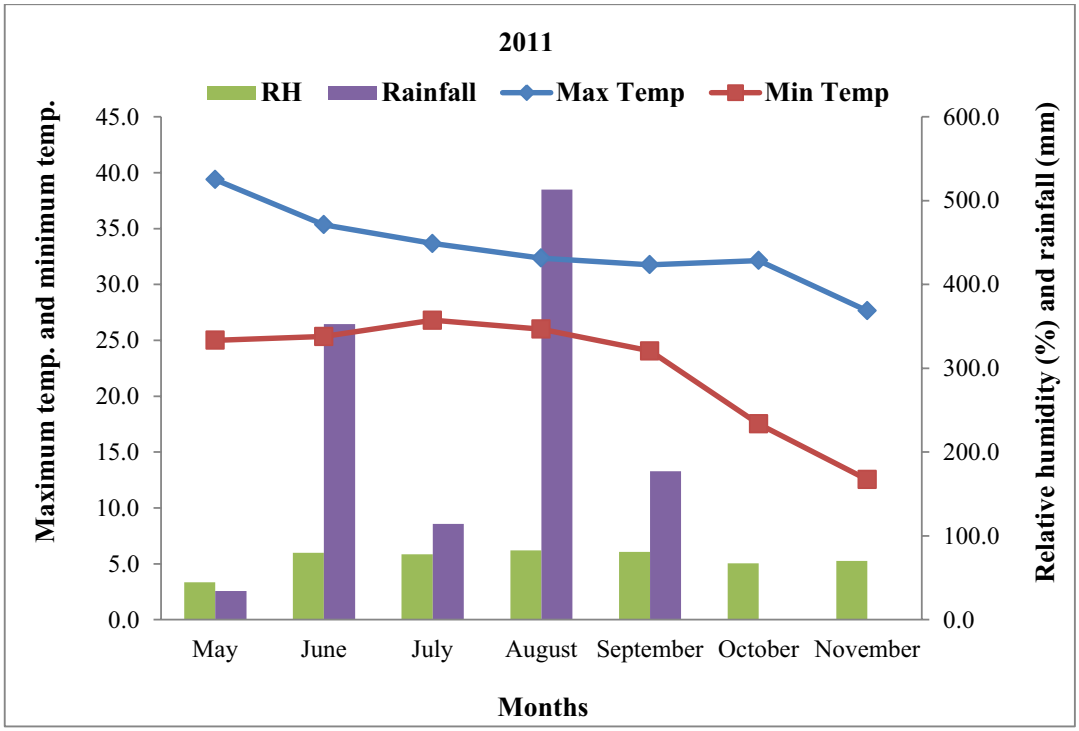
The mechanical analysis by International Pipette Method (Piper, 1966) revealed that the texture of the experimental field was loamy sand as concluded from the results presented in Table 3.1.

Chemical Analysis

Chemical properties of the soil were determined at the beginning of the experiment and are also presented in Table 3.1. The soil of the experimental field was normal in reaction and for content of soluble salts. The soil tested low in organic carbon and available nitrogen, high in available phosphorus and potassium.

Table 3.1: Physico-chemical properties of the soil and the method employed.

Soil property	Soil depth (cm)		Method employed
	0-15	15-30	
Sand (%)	78.4	76.4	International pipette method (Piper 1966)
Silt (%)	16.2	15.8	
Clay (%)	4.3	6.8	
pH (1:2, soil: water suspension)	8.1	7.9	Beckman's glass electrode pH meter (Jackson 1967)
Electrical conductivity (dsm^{-1})	0.25	0.21	Solubridge conductivity meter 1:2 soil water suspension (Jackson 1967)
Organic carbon (%)	0.31	0.22	Walkely and Black rapid titration method
Available N ($kg\ ha^{-1}$)	258.5	250.3	Alkaline potassium permanganate method (Subbiah and Asija 1956)
Available P ($kg\ ha^{-1}$)	24.4	23.1	0.5 N sodium bicarbonate method (Olsen *et al* 1954)
Available K ($kg\ ha^{-1}$)	339.4	325.7	Ammonium acetate extraction method (Jackson 1967)



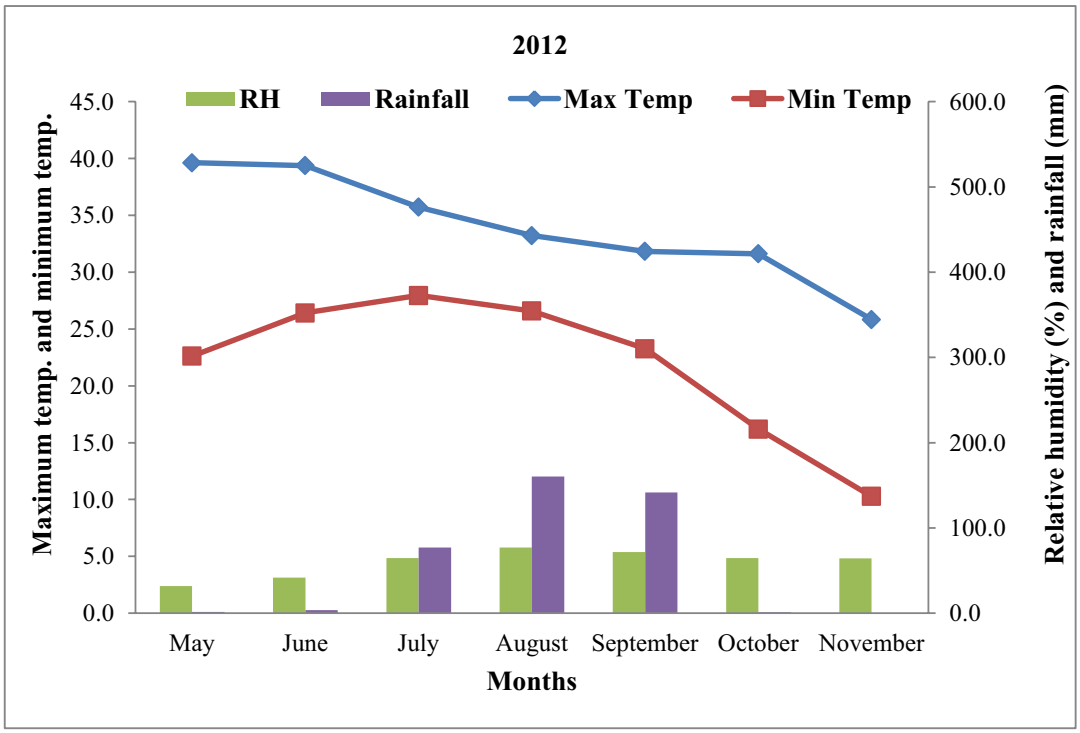


Fig 3.1: Mean monthly meteorological data during the crop seasons of 2011 and 2012

3.3 FIELD HISTORY

The various crops raised in the experimental field prior to the present investigation are presented in Table 3.2.

Table 3.2 Cropping history of the experimental field

Year	*Kharif*	*Rabi*
2007-2008	Cotton	Fallow
2008-2009	Cotton	Fallow
2009-2010	Cotton	Fallow
2010-2011	Cotton	Wheat
2011-2012	Cotton*	Wheat
2012-2013	Cotton *	--------

* Experimental crop

3.4 EXPERIMENTAL DETAILS AND LAYOUT

The present investigation consisted of three experiments, the details of which are summarized below:

Experiment I: Reproductive compensation behaviour of different cotton cultivars in response to fruiting form removal.

The experiment was laid out in a split plot design as depicted in Fig 2 with following details:

Main Plots: Three Hybrids

i) MRC 7017 (BG II)
ii) MRC 7031 (BG II)
iii) RCH 314 (BG I)

Sub Plots: Different fruiting form removal treatments were kept in sub plots according to the following details:

S.No.	Treatment	Details	Time of application
1	0%	No removal of squares	-
2	25% removal	25 % squares were removed for a period of month from the day squares were initiated	At pin head stage upto 1 month
3	50% removal	50 % squares were removed for a period of month from the day squares were initiated	do
4	P1	All fruiting forms were removed except first position	At pin head stage till boll open initiation
5	P2	All fruiting forms were removed except second position	do
6	P3	All fruiting forms were removed except first and second position	do

Number of replications: Four

Total number plots: 72

Gross plot size: 3.37 m X 5.25 m

Plate 3.1: Fruiting form removal from different positions

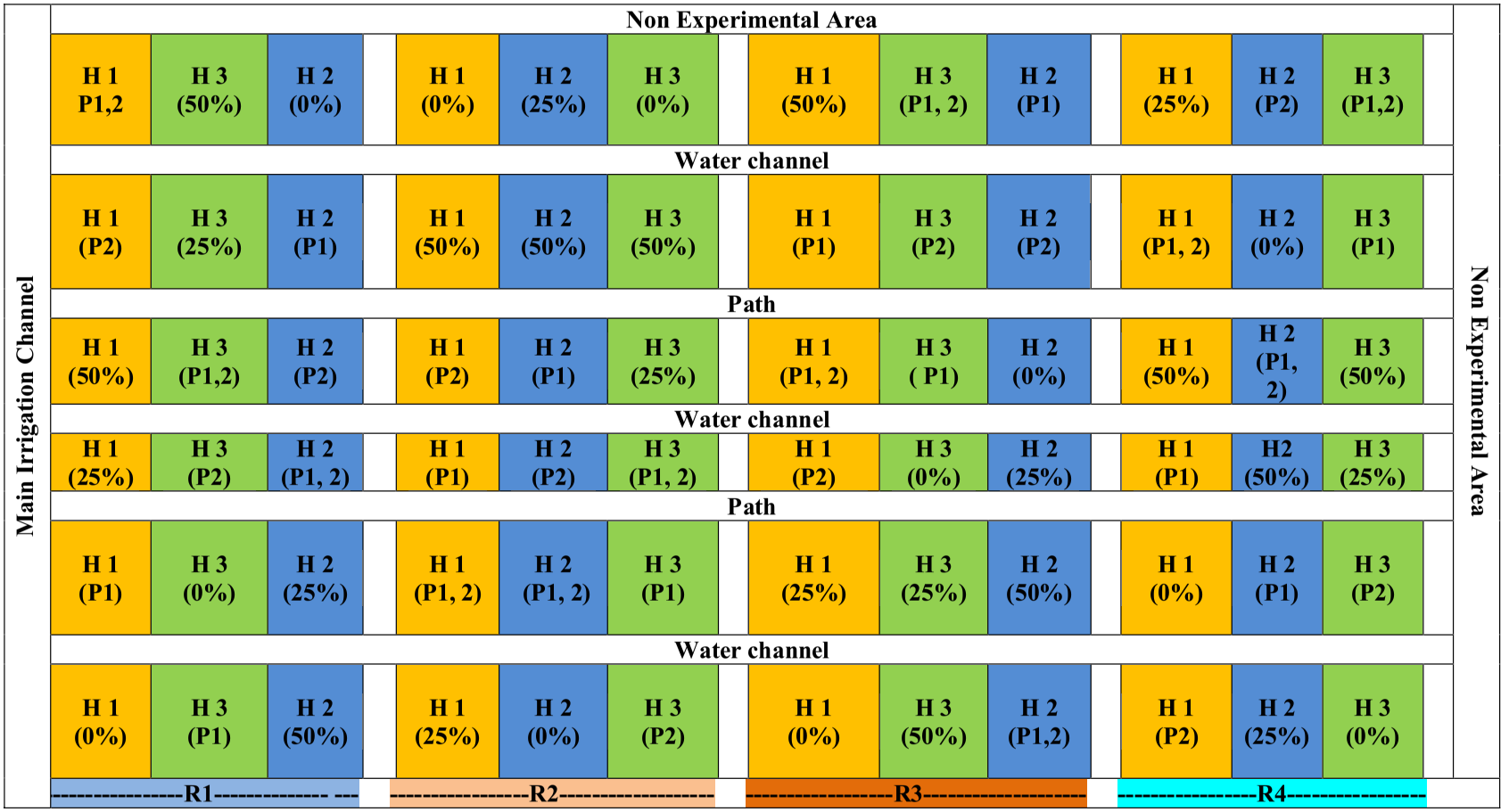
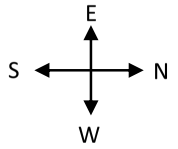


Fig 3.2: Lay out of Experiment 1

R 1 - Replication 1
R 2 - Replication 2
R 3 - Replication 3
R 4 - Replication 4

H **1** – MRC 7017
H **2** – MRC 7031
H **3** – RCH 314



Experiment II: Reproductive compensation behaviour of different cotton cultivars in response to fruiting form removal.

A pot experiment was also conducted in a split plot design as depicted in Fig 3 with following details:

Main Plots: Three Hybrids

i) MRC 7017 (BG II)
ii) MRC 7031 (BG II)
iii) RCH 314 (BG I)

Sub Plots: Different fruiting form removal treatments were kept in sub plots according to the following details:

S.No.	Treatment	Details	Time of application
1	0%	No removal of squares	-
2	25% removal	25 % squares were removed for a period of month from the day squares were initiated	At pin head stage upto 1 month
3	50% removal	50 % squares were removed for a period of month from the day squares were initiated	do
4	P1	All fruiting forms were removed except first position	At pin head stage till boll open initiation
5	P2	All fruiting forms were removed except second position	do
6	P3	All fruiting forms were removed except first and second position	do

Number of replications: Four

Total number of pots: 72

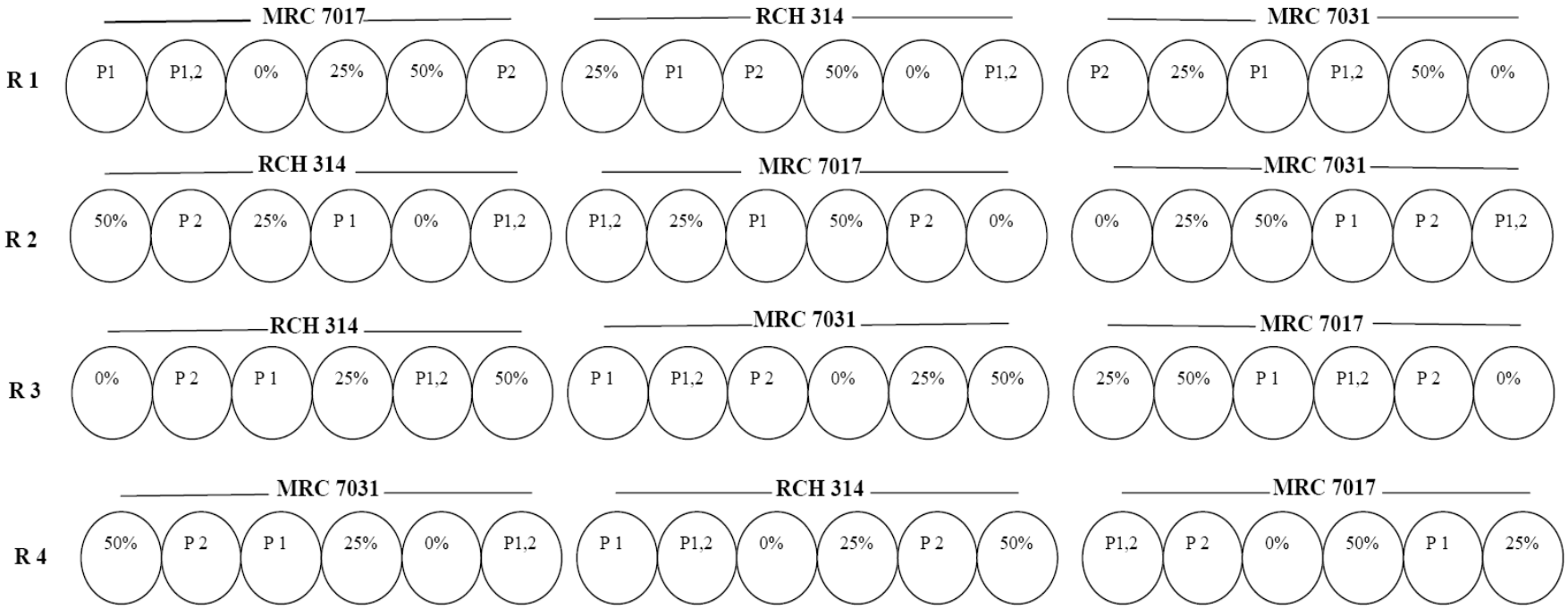
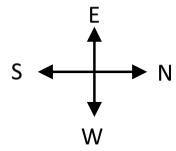


Fig 3.3: Layout of Experiment 2

R 1 - Replication 1 **R 2** - Replication 2

R 3 - Replication 3 **R 4** - Replication 4



Experiment III: Productivity of cotton as influenced by detopping and growth retardants.

Treatments: The third experiment with following details was laid out in a split design as illustrated in Fig: 4

Main Plots: Three Hybrids

i) MRC 7017 (BG II)
ii) MRC 7031 (BG II)
iii) RCH 314 (BG I)

Sub Plots: Different growth regulation treatments were kept in sub plots according to the following details:

S.No.	Treatment	Concentration (ppm)	Time of application
1	Control (C)	-	-
2	Detopping (D)	-	80 DAS*
3	Mepiquat chloride (MC)	300	do
4	2,3,5-tri iodo benzoic acid (TIBA)	150	do
5	Maleic hydrazide (MH)	300	do

* Days after sowing

Number of replications: Four

Total number of plots: 60

Gross plot size: 3.37 m X 5.25 m

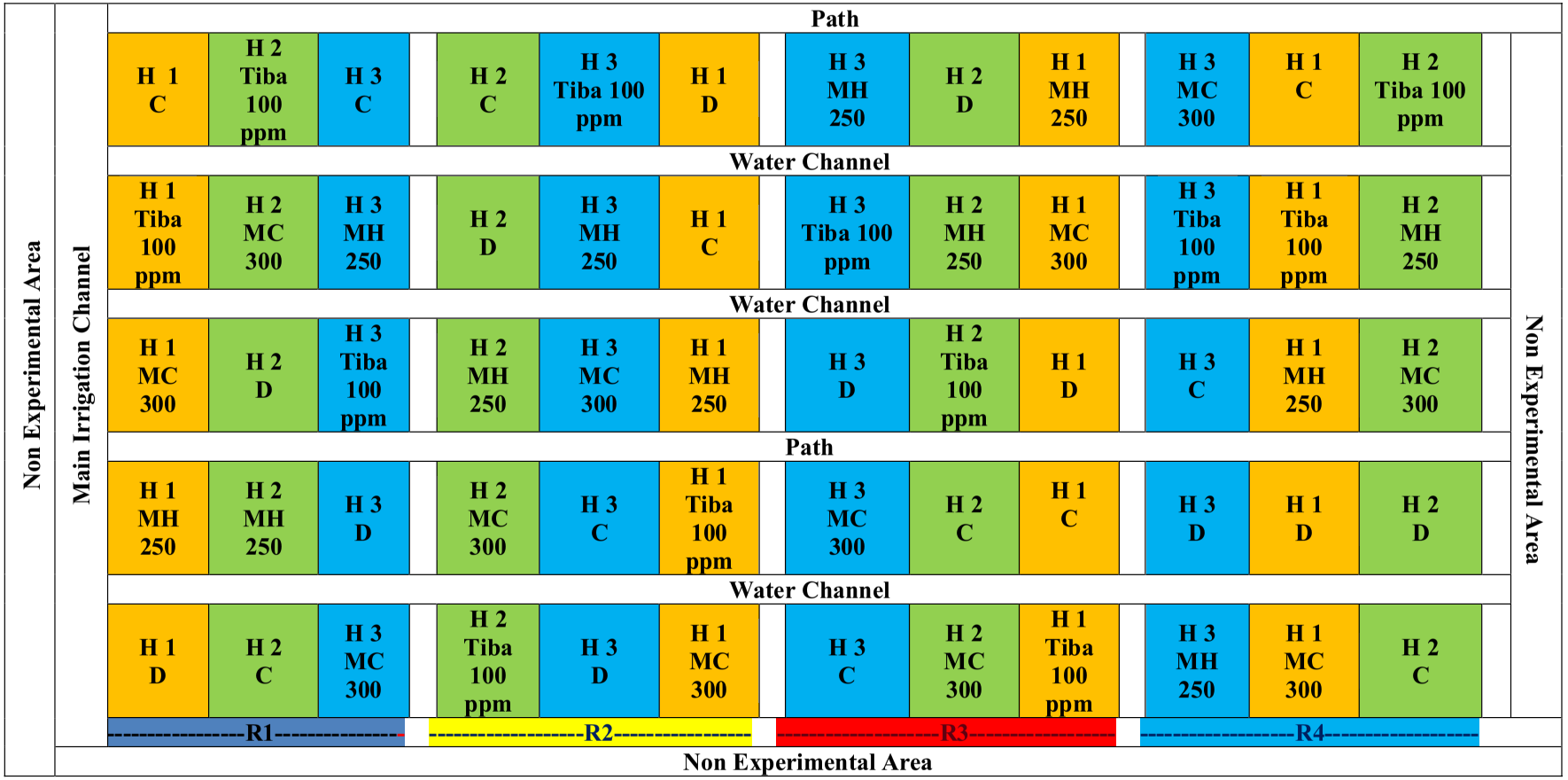
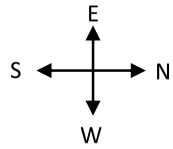


Fig 3.4: Layout of Experiment 3

R 1 - Replication 1
R 2 - Replication 2
R 3 - Replication 3
R 4 - Replication 4

H 1 – MRC 7017
H 2 – MRC 7031
H 3 – RCH 314



3.5 DETAILS OF THE CHEMICALS USED:

MEPIQUAT CHLORIDE (MC)

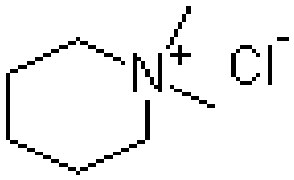
IUPAC Name: 1, 1-dimethyl piperidinium chloride

Molecular Formula: $C_7H_{16}N.Cl$

Applied as: Foliar application

Mode of Action: Anti-gibberellin

Molecular Structure:



TRI IODO BENZOIC ACID (TIBA)

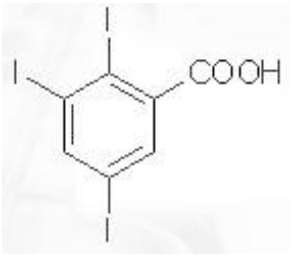
IUPAC Name: 2, 3, 5 – TRI IODO BENZOIC ACID

Molecular Formula: $C_7H_3O_2I_3$

Applied as: Foliar application

Mode of Action: An auxin polar transport inhibitor

Molecular Structure:



MALEIC HYDRAZIDE (MH)

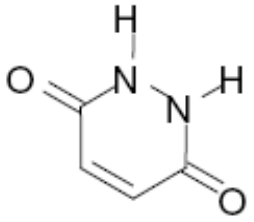
IUPAC Name: 1, 2-dihydro-3,6-pyridazinone

Molecular Formula: $C_4H_4N_2O_2$

Applied as: Foliar application

Mode of Action: An antimitotic agent inhibit cell division

Molecular Structure:



3.5 CULTURAL OPERATIONS

3.5.1 Field Preparation

A primary harrowing tillage operation was given with a tractor drawn disc harrow. Pre sowing irrigation (*rauni*) was applied to the experimental field. At proper moisture condition (*watter*), a fine seed bed was prepared by giving two cultivations with a tractor drawn cultivator followed by planking.

3.5.2 Sowing

Bt cotton hybrids MRC 7017, MRC 7031 and RCH 314 were sown on 13-05-2011 during first year and on 11-05-2012 during second year of experiment, on a well prepared seed bed. Sowing was done with a uniform seed rate of 0.750 kg $acre^{-1}$ by dibbling two seeds per hill and keeping row to row and plant to plant spacing of 67.5 cm and 75 cm, respectively.

3.5.3 Gap Filling and Thinning

Gap filling was done 25 days after sowing to maintain 100 per cent crop stand. For gap filling 3 week old nursery raised in polythene bags, which were filled with soil and farm yard manure in the ratio of 1:1. Whereas, thinning of seedlings was done after first irrigation keeping one plant $hill^{-1}$.

3.5.4 Fertilizer Application:

The recommended dose of nitrogen (187.5 kg ha^{-1}) was applied as urea in two equal splits, first at sowing and remaining half at the appearance of the first flower. The recommended dose of phosphorus (30 kg ha^{-1} P_2O_5) as single super phosphate (SSP) was applied at the time of sowing.

3.5.5 Weed Control

Stomp 30 EC at the rate of 1.0 litre $acre^{-1}$ was applied as a pre-emergence herbicide i.e. within 24 hours of sowing. Thereafter, hoeing was done after first irrigation to keep the fields weed free. Two more hoeings were done at 60 and 85 DAS to keep the weeds under control. One directed spray of Roundup (glyphosate) at the rate of 1 litre $acre^{-1}$ was also done to keep the fields weed free.

3.5.6 Irrigation

Following irrigation schedule was followed for the two field experiments.

Irrigation	2011	2012
1st	14-06-2011	10-06-2012
2nd	4-07-2011	03-07-2012
3rd	27-08-2011	22-07-2012
4th	22-09-2011	11-08-2012
5th		7-09-2012

3.5.7 Plant Protection Measures

The following insecticide spray schedule was adopted for insect control during the two crop growth seasons.

Insecticide spray schedule during 2011

Date	Insecticide	Dose (ml ha^{-1})
15-07-2011	Confidor (Imidacloprid 200 SL)	100
5-08-2011	Fosmite (Ethion 50 EC)	2000
20-08-2011	Confidor (Imidacloprid 200 SL)	100
22-09-2011	Confidor (Imidacloprid 200 SL)	100

Insecticide spray schedule during 2012

Date	Insecticide	Dose (ml ha^{-1})
16-07-2012	Confidor (Imidacloprid 200 SL)	100
06-08-2012	Hostathion (Triazophos 40 EC)	1500
20-08-2012	Ethion 50EC	2000
03-09-2012	Monocrotophos 36 SL	1250

3.5.8 Pickings

A total of three pickings were done in field experiments and two in pot study according to the schedule as given below:

	2011			2012		
	Experiment I	**Experiment II**	**Experiment III**	**Experiment I**	**Experiment II**	**Experiment III**
1st Picking	October 7	October 7	October 11	October 12	October 12	October 17
2nd Picking	October 21	October 21	October 24	November 2	October 31	November 6
3rd Picking	November 18		November 23	November 29		December 6

3.6 OBSERVATIONS RECORDED DURING THE CROP GROWTH PERIOD

3.6.1 Growth Attributes

Five plants were randomly selected from each plot and tagged. The following observations were recorded:

3.6.1.1 Plant height

Periodic plant height at 30 days interval till last picking was recorded in centimetres of the five tagged plants from each plot. The measurements were taken from the base of main stem to the base of top leaf. The mean plant height of five tagged plants was computed at various stages.

3.6.1.2 Leaf area index

The periodic leaf area index (LAI) of plants was recorded with the sun scan canopy analyzer at 30 days interval till maturity. The observations were taken at random from four places in each plot at 12:00 noon to 12:30 pm.

3.6.1.3 Dry matter accumulation (DMA) and partitioning

Three randomly selected plants from each plot were uprooted for determining the dry matter accumulation at monthly interval. The plants were then separated into stem, leaves and fruiting bodies. The plant parts were first dried in the sun and then in an oven at 60°C til constant weight. Dried samples were weighed and weight was expressed in g plant^{-1}.

3.6.1.4 SPAD (Soil plant analysis development) value

SPAD or Chlorophyll meters are reliable alternatives to traditional tissue analysis as plant nitrogen nutritional diagnostic tools. Most widely used chlorophyll meter is the hand-held Minolta SPAD-502. It instantly provides an estimate of leaf nitrogen status as chlorophyll content by clamping the unplucked leafy tissue in the meter. It uses two LEDs (light emitting diodes) which emit red light with a peak wavelength of 650 nm and an infrared radiation with a peak wavelength of 940 nm. The red and infrared radiations are made to pass through the leaf. A portion of light is absorbed and the remainder is transmitted through the leaf and a silicon photodiode detector converts it into an electrical signal. The amount of light reaching the photodiode detector is inversely proportional to the amount of chlorophyll in the path of the light. Leaf chlorophyll content is displayed in arbitrary units (0–99.9). The SPAD meter readings are unit less and the mean of 10 values reported as SPAD value.

3.6.1.5 Crop growth rate (CGR)

It is the rate of growth of crop per unit area and expressed as g m^{-2} day^{-1}. This was calculated using formula.

$$CGR = \frac{W2 - W1}{T2 - T1} \times \frac{1}{P}$$

Where,

W1 – Dry matter (g) at time T1 (days)

W2 – Dry matter (g) at time T2 (days)

P – Ground area (m^2)

3.6.1.6 Relative growth rate (RGR)

This parameter indicates rate of growth per unit dry matter. It is expressed as gram of dry matter produced by a gram of existing dry matter (g g^{-1} day^{-1}). It was calculated as:

$$RGR = \frac{\log_e W2 - \log_e W1}{T2 - T1}$$

Where,

W1 - Dry matter (g) at time T1 (days)

W2 – Dry matter (g) at time T2 (days)

3.6.1.7 Net assimilation rate (NAR)

Net assimilation rate indirectly indicates the rate of net photosynthesis. It is expressed as gram (g) of dry matter produced cm^{-2} of leaf area in a day. This was calculated according to following formula:

$$NAR = \frac{(W2 - W1)(\log_e L2 - \log_e L1)}{(T2 - T1)(L2 - L1)}$$

Where,

W1 - Dry matter (g) at time T1 (days)

W2 – Dry matter (g) at time T2 (days)

L1 – Leaf area (cm^2) at time T1 (days)

L2 – Leaf area (cm^2) at time T2 (days)

3.6.1.8 Specific leaf area

This is an index of the leafiness of leaf and is a measure of density or of relative thikness which involves an assessment of the leaf area in relation to its dry weight. It is expressed as cm^2 g^{-1}. This was calculated as following formula:

$$SLA = \frac{LA}{LW}$$

Where,

LA – Leaf area (cm^2)

LW – Leaf Weight (g)

3.6.1.9 Main stem internodes

At maturity, the number of main stem internodes of five tagged plants from each plot were counted and expressed on per plant basis.

3.6.1.10 Height to node ratio (HNR)

This measurement uses the number of main stem nodes and plant height and was calculated as:

$$HNR = \frac{\text{Final plant height}}{\text{Number of main stem internodes}}$$

3.6.1.11 Monopodial branches per plant

At maturity, the number of monopodial (vegetative) branches of five tagged plants were counted and expressed on per plant basis.

3.6.1.12 Sympodial branches per plant

At maturity, the number of sympodial (reproductive) branches of five tagged plants were counted and expressed on per plant basis.

3.6.2 Crop Phenology

3.6.2.1 Number of days to square initiation

The time when a square was initiated in each treatment plot was recorded and the number of days from sowing to this date was counted and given as number of days taken to square initiation.

3.6.2.2 Number of days to 50 % squaring

The date when 50 per cent of the plants in each treatment had atleast one square was recorded. The number of days from sowing to this date was taken as number of days required for 50 % squaring.

3.6.2.3 Number of days to flower initiation

The date of appearance of a flower in each treatment was recorded and the number of days from sowing to this date was counted and given as number of days taken to flower initiation.

3.6.2.4 Number of days to 50 % flowering

The date, when a flower appeared in 50 per cent of the plants in each treatment was recorded. The number of days from sowing to this date was taken as number of days required for 50% flowering.

3.6.2.5 Number of days to boll formation initiation

The date of appearance of a fully developed boll in each treatment was recorded and the days from sowing to this date was taken as number of days taken to boll initiation.

3.6.2.6 Number of days to 50 % boll formation

The date when 50 per cent of the plants in each treatment had atleast one fully developed boll was recorded. The number of days from sowing to this date was taken as number of days required for 50 % boll formation.

3.6.2.7 Number of days taken to boll opening initiation

The date when at least one opened boll appeared in each treatment was recorded and

the number of days from sowing to this date were counted and given as number of days taken to boll open initiation.

3.6.2.8 Number of days taken to 50 % boll opening

The date when 50 per cent of the plants in each treatment had atleast one opened boll was recorded. The number of days from sowing to this date was taken as number of days required for 50% boll opening.

3.6.3 Yield and Yield Attributes

3.6.3.1 Number of squares abscised per plant

The number of squares abscised in each plant were counted daily from the time of square initiation upto boll open initiation stage.

3.6.3.2 Number of flowers abscised per plant

The number of flowers abscised in each plant were counted daily from the time of first flower appears upto the boll open initiation stage.

3.6.3.3 Number of flowers per plant

The number of flowers of five tagged plants were counted daily from the time of square initiation upto end of flowering period and expressed as per plant basis.

3.6.3.4 Setting percentage

Setting percentage denotes that out of total flowers formed, how many were eventually set into bolls. This was calculated according to the following formula:

$$\text{Setting percentage} = \frac{\text{Total number of bolls plant}^{-1}}{\text{Total number of flowers plant}^{-1}} \text{ X } 100$$

3.6.3.5 Number of total bolls per plant

Total bolls were calculated as total opened bolls at each picking plus total unopened bolls at the time of last picking from each plot from five tagged plants and their mean was taken to express it on per plant basis

3.6.3.6 Number of picked bolls per plant

Total number of the bolls picked at each picking from five tagged plants were counted and their mean was taken to express it on per plant basis.

3.6.3.7 Boll opening percentage

Boll opening percentage (BOP) was calculated by the given formula:

$$\text{BOP} = \frac{\text{Number of open bolls plant}^{-1}}{\text{Total number of bolls plant}^{-1}} \text{ X } 100$$

3.6.3.8 Boll weight

Five bolls from each tagged plant were picked and the average weight of seed cotton from these bolls was taken as boll weight and expressed as g.

3.6.3.9 Seed cotton yield

The seed cotton of each picking was collected from each plot and was weighed. The total yield of all the pickings was expressed as q ha^{-1}.

3.6.4 Quality Parameters:

3.6.4.1 Bartlett index

Bartlett index was worked out with the help of following formula given by Bartlett (1937):

$$\text{Bartlett index} = \frac{(P_1) + (P_1+P_2) + (P_1+P_2+P_3) + (P_1+P_2+P_3+\ldots\ldots..+P_n)}{N\,(P_1+P_2+P_3+\ldots\ldots P_n)}$$

Where,

P_1 = seed cotton yield in the first picking.

P_2 = seed cotton yield in the second picking.

P_3 = seed cotton yield in the third picking.

N = number of pickings.

3.6.4.2 Seed index

The weight of 100 seeds in each treatment was recorded as seed weight.

3.6.4.3 Lint index

It was calculated on the basis of the formula given below:

$$\text{Lint index} = \frac{\text{Ginning outturn}}{100 - \text{Ginning outturn}} \times \text{Seed index}$$

3.6.4.4 Ginning outturn

Seed cotton weighing 100 g per plot was ginned after dividing it into four lots of 25 g each. The weight of lint was recorded. The average of lint was taken for calculating ginning outturn with the following formula:

$$\text{Ginning outturn} = \frac{\text{Lint weight (g)}}{\text{Weight of seed cotton (g)}} \times 100$$

3.7 STATISTICAL ANALYSIS

The various data were statistically analyzed by general linear model (GLM) procedure (SAS Software 9.2, SAS Institute Ltd., U.S.A.) for both years. All possible pairs of treatment means were compared with Duncan's multiple range test (DMRT) at 5 % probability level. The experiment wise analysis of variance (ANOVA) split up is as follows:

Experiment I: Reproductive compensation behaviour of different cotton cultivars in response to fruiting form removal.

Source of variation	Degrees of freedom
Block	3
Main plot factor (H)	2
Error (a)	6
Sub plot factor (F)	5
H X F	10
Error (b)	45
Total	71

Experiment II: Reproductive compensation behaviour of different cotton cultivars in response to fruiting form removal.

Source of variation	Degrees of freedom
Block	3
Main plot factor (H)	2
Error (a)	6
Sub plot factor (F)	5
H X F	10
Error (b)	45
Total	71

Experiment III: Productivity of cotton as influenced by detopping and growth retardants.

Source of variation	Degrees of freedom
Block	3
Main plot factor (H)	2
Error (a)	6
Sub plot factor (P)	4
H X P	8
Error (b)	36
Total	59

CHAPTER IV

RESULTS AND DISCUSSION

The experimental results from the observations recorded for plant growth parameters, yield attributes, yield and quality characteristics during the course of present investigation entitled "Studies on source sink relationship for realization of higher productivity in *Bt* cotton (G*ossypium hirsutum* L)" conducted during *kharif* seasons of 2011 and 2012 are presented and discussed in this chapter.

4.1 Experiment I: Reproductive compensation behaviour of different cotton cultivars in response to fruiting form removal

4.1.1 Plant Height

Plant height is a reliable index of plant growth and represents the infrastructure buildup over a period. The plant height was recorded periodically at 30 days interval starting from 60 days after sowing (DAS) during the crop growth seasons of 2011 and 2012. The scrutiny of data from Table 4.1 and Fig. 4.1 and 4.2 indicates that there was a progressive increase in plant height with advancement of crop age. A sharp increase was however, registered between 60 and 120 DAS, which is the grand growth phase of the crop.

Plant height of cotton hybrids did not differ significantly at 60 and 90 DAS, but thereafter, MRC 7017 and MRC 7031 though statistically at par among themselves attained significantly higher plant height than RCH 314 during both the years (Table 4.1). At 180 DAS also, MRC 7017 and MRC 7031 recorded statistically same plant height but produced significantly taller plants than RCH 314 during both 2011 and 2012. Plant height is a genetically controlled character and the ultimate height of plant or a particular hybrid is dependent upon its genetic make up. Results obtained by Brar (1997) also emphasize the same point.

Fruiting form removal treatments did not show any significant effect on plant height of cotton hybrids at 60 DAS during both the years because fruiting form removal treatments were applied at 55 DAS and their effect on plant growth did not occur within a short period i.e. at 60 DAS. At 90 DAS, maximum plant height (107.9 and 110.3 cm) was recorded where 50 % squares were removed and was statistically at par with where fruits were retained at first (P1) and second (P2) position but significantly higher than the crop where 0 and 25 % squares were removed and also with the crop where fruits were retained only at first and second position (P1, 2) during 2011 and 2012, respectively. At 120, 150 and 180 DAS, maximum plant height was attained in P2, which was statistically at par with P1 and P1, 2 but significantly higher than 0, 25 and 50 % square removal treatments during both the years.

Table 4.1: Effect of hybrids and fruiting form removal on plant height recorded at different stages

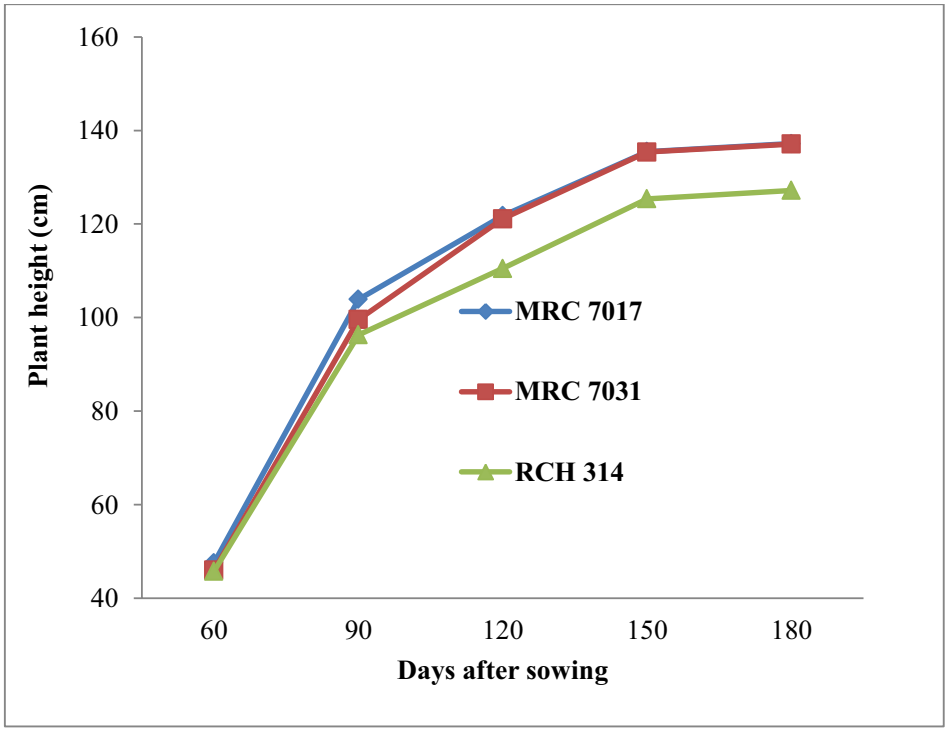
Treatment	Plant Height (cm)									
	60 DAS		90 DAS		120 DAS		150 DAS		180 DAS	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Hybrids										
MRC 7017	47.6 a	54.4 a	103.9 a	105.7 a	121.8 a	134.2 a	135.5 a	147.2 a	137.2 a	150.2 a
MRC 7031	46.0 a	54.0 a	99.6 a	101.6 a	121.1 a	132.9 a	135.4 a	145.1 a	137.1 a	148.1 a
RCH 314	45.8 a	53.6 a	96.3 a	97.9 a	110.5 b	123.1 b	125.4 b	134.7 b	127.2 b	137.3 b
SEm	**0.97**	**1.13**	**2.44**	**2.19**	**2.74**	**2.39**	**2.30**	**2.75**	**2.37**	**2.74**
F(p)	**0.28**	**0.82**	**0.01**	**0.02**	**<0.0001**	**0.0005**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**
Fruiting form removal										
0%	45.3 a	52.9 a	92.6 c	94.2 d	110.7 d	123.3 c	128.8 b	135.7 d	129.8 b	138.7 c
25%	46.9 a	54.0 a	97.3 bc	99.0 bdc	112.4 dc	124.5 c	129.7 b	139.8 bdc	131.8 b	142.7 bc
50%	48.6 a	55.3 a	107.9 a	110.3 a	117.7 bc	128.1 bc	129.1 b	136.1 dc	130.5 b	138.9 c
P1 (Retain at 1st position)	46.2 a	55.4 a	101.8 ba	103.5 bac	122.03 ba	134.6 ba	134.9 ba	146.4 ba	136.8 ba	149.3 ba
P2 (Retain at 2nd position)	46.4 a	53.9 a	105.1 a	107.0 ba	123.9 a	138.3 a	137.6 a	151.9 a	139.6 a	154.8 a
P1, 2 (Retain at 1st and 2nd position)	45.7 a	52.7 a	94.8 bc	96.3 dc	120.2 ba	131.7 bac	132.7 ba	144.2 bac	134.6 ba	147.1 bac
SEm	**1.18**	**1.37**	**2.55**	**2.68**	**1.92**	**2.83**	**2.22**	**2.74**	**2.36**	**2.71**
F(p)	**0.43**	**0.63**	**0.0005**	**0.0005**	**<0.0001**	**0.002**	**0.03**	**0.0006**	**0.04**	**0.0005**
Interaction F(p)	**0.99**	**0.84**	**0.99**	**0.99**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**

-The treatment means are compared using Duncan's multiple range test (DMRT)

-F(p) values of 0.05 or lesser means significant effect

-Treatment means superscripted by the different alphabets are statistically different

(a)



(b)

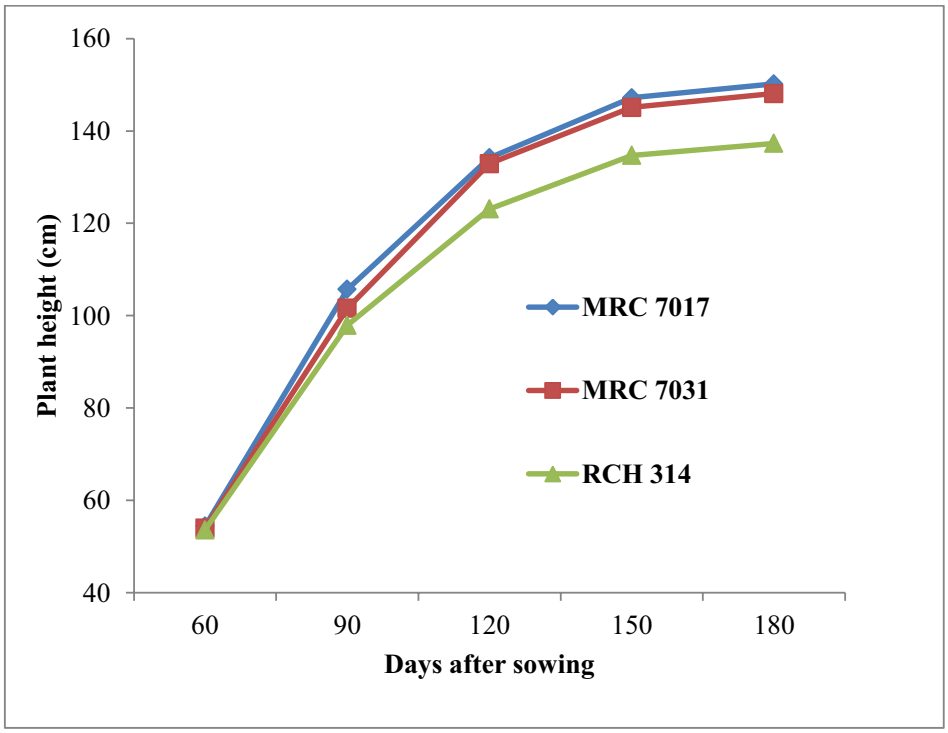
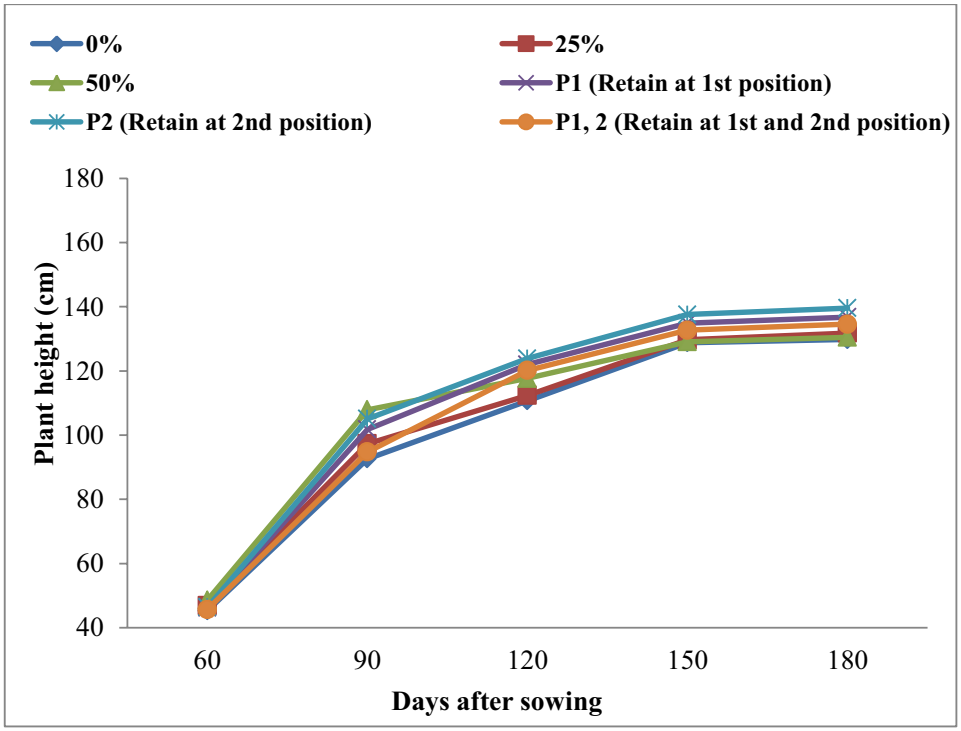


Fig 4.1: Plant height of *Bt* cotton hybrids during 2011 (a) and 2012 (b)

(a)



(b)

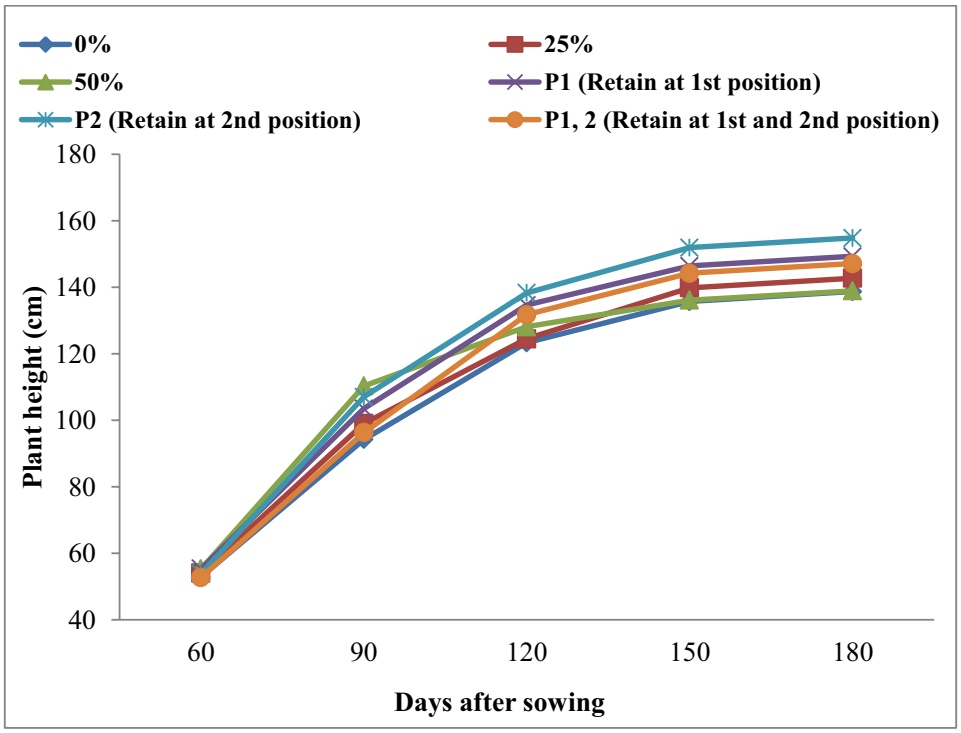


Fig 4.2: Plant height of *Bt* cotton hybrids as affected by fruiting form removal treatments during 2011 (a) and 2012 (b)

The diversion of assimilates from fruiting bodies towards the apical growing points with the removal of squares might be the possible reason for significantly higher plant height in 50 % square removal treatment than 0 and 25 % square removal treatments. Contrarily, in later stages (120, 150 and 180 DAS) continuous removal of fruiting forms from different positions in P2 treatment resulted in significantly higher plant height than 0, 25 and 50 % square removal treatments where squares were removed at pin head stage for a period of one month. The higher plant height in P2 treatment might be attributed to diversion of assimilates to the other plant parts which normally are incorporated into reproductive structures removed from different positions. The interaction effect between cotton hybrids and fruiting form removal treatments was non significant during both the years. Bednarz and Roberts, (2000) also reported that the loss of reproductive structures can alter the physiological growth and development of the plant. A severe fruit loss diverted excess carbohydrates to vegetative growth which resulted in increased plant height. The increase in plant height with intense flower removal was also reported by Montez and Goodell (1994) and Mustafa *et al* (2004).

(a)

4.1.2 Leaf Area Index

Leaf area index (LAI) is an important parameter of plant growth, which has direct influence on solar radiation interception and ultimately the total biomass production. Perusal of the data in Table 4.2 and as illustrated in Fig. 4.3 and 4.4 reveal that, there was a progressive increase in LAI recorded from 60-120 DAS and thereafter a decline in LAI was observed during both the crop growth seasons due to leaf abscission.

Hybrids did not differ significantly for LAI at all growth stages. However, at 150 DAS maximum LAI was recorded in MRC 7017 (2.45 and 3.25) followed by MRC 7031 (2.41 and 3.23) and RCH 314 (2.38 and 3.16) during 2011 and 2012, respectively.

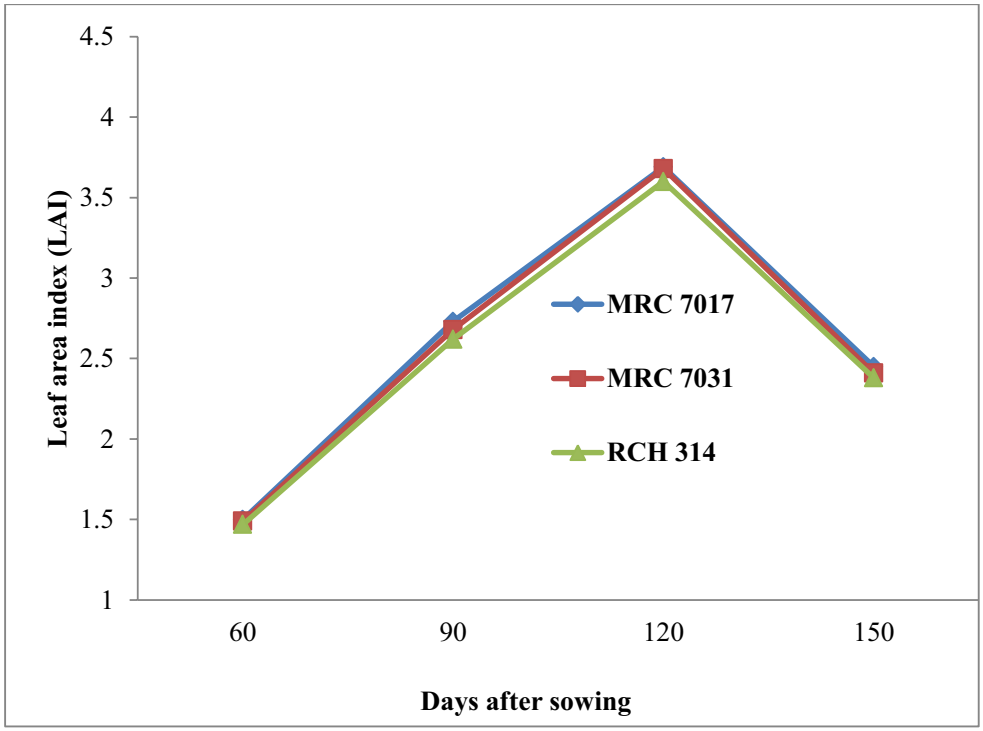
Removal of fruiting forms failed to influence the LAI at 60 DAS whereas, these had a significant influence on LAI at 90 and 120 DAS. At 60 DAS the non significant effect was due to the reason that fruiting form removal treatments were applied at 55 DAS and their effect on plant growth did not occur within a short period i.e. at 60 DAS.

At 90 DAS, 50 % square removal treatment recorded maximum LAI (2.75 and 3.30 in 2011 and 2012, respectively) but was statistically at par with the treatments where fruits were retained at first (P1) and second (P2) position and also with the treatment where fruits were retained at both first and second position (P1, 2). However, the LAI recorded in the treatment where 50 % squares were removed was significantly higher than the treatments where 0 and 25 % squares were removed during both the years. The higher LAI in 50 % square removal treatment was due to more vegetative growth as a result of higher translocation of assimilates towards the vegetative parts due to the removal of fruiting forms at higher rates as compared to 0 and 25 % square removal treatments.

Table 4.2: Periodic leaf area index (LAI) of *Bt* cotton as affected by hybrids and fruiting form removal treatments

Treatment	Leaf Area Index							
	60 DAS		90 DAS		120 DAS		150 DAS	
	2011	2012	2011	2012	2011	2012	2011	2012
Hybrids								
MRC 7017	1.50 a	1.62 a	2.73 a	3.24 a	3.69 a	4.26 a	2.45 a	3.25 a
MRC 7031	1.49 a	1.60 a	2.68 a	3.22 a	3.68 a	4.25 a	2.41 a	3.23 a
RCH 314	1.47 a	1.56 a	2.62 a	3.20 a	3.60 a	4.17 a	2.38 a	3.16 a
SEm	**0.04**	**0.03**	**0.05**	**0.05**	**0.05**	**0.14**	**0.03**	**0.05**
F(p)	**0.40**	**0.06**	**0.10**	**0.62**	**0.36**	**0.44**	**0.20**	**0.24**
Fruiting form removal								
0%	1.46 a	1.58 a	2.57 c	3.12 c	3.54 c	4.10 c	2.38 a	3.18 a
25%	1.50 a	1.61 a	2.60 bc	3.14 bc	3.55 c	4.11 bc	2.41 a	3.20 a
50%	1.53 a	1.63 a	2.75 a	3.30 a	3.57 bc	4.13 bac	2.40 a	3.19 a
P1 (Retain at 1st position)	1.47 a	1.57 a	2.73 ba	3.28 ba	3.76 a	4.33 ba	2.43 a	3.23 a
P2 (Retain at 2nd position)	1.50 a	1.60 a	2.72 ba	3.26 bac	3.77 a	4.35 a	2.44 a	3.24 a
P1, 2 (Retain at 1st and 2nd position)	1.46 a	1.57 a	2.69 bac	3.22 bac	3.75 ba	4.31 bac	2.42 a	3.22 a
SEm	**0.03**	**0.02**	**0.04**	**0.04**	**0.06**	**0.07**	**0.03**	**0.05**
F(p)	**0.45**	**0.50**	**0.04**	**0.04**	**0.01**	**0.03**	**0.86**	**0.96**
Interaction F(p)	**0.99**	**0.99**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**

(a)



(b)

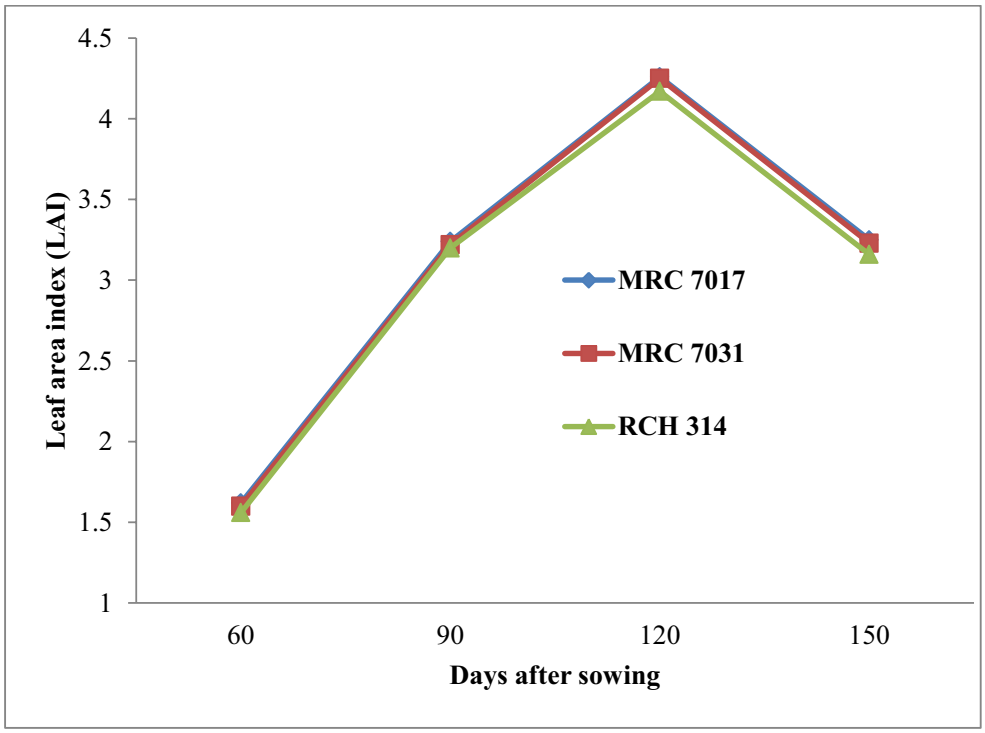
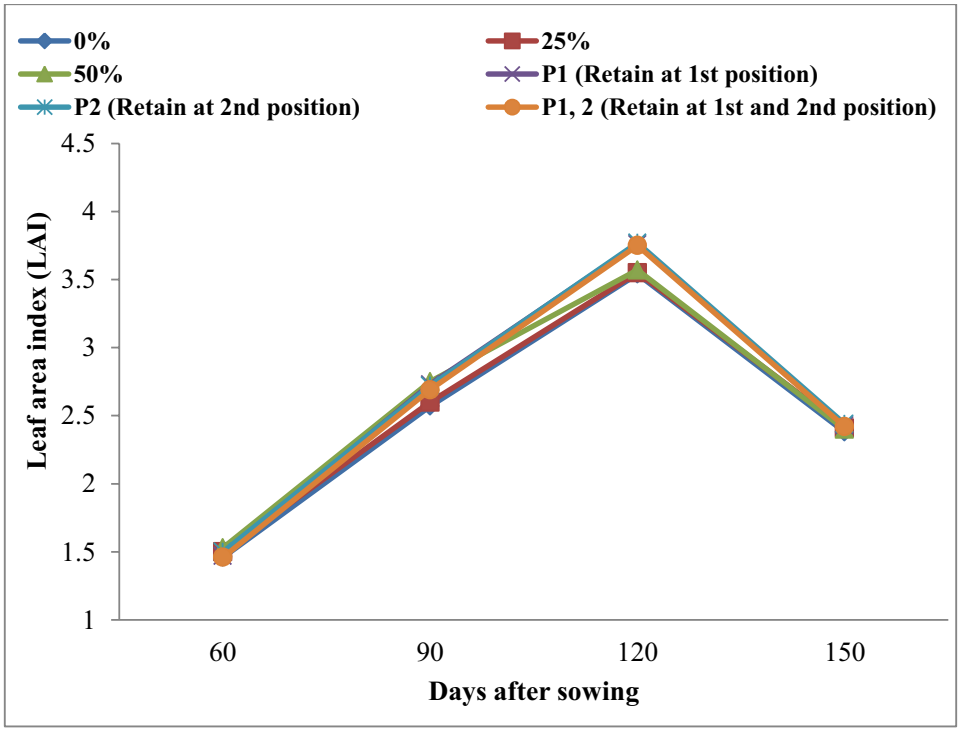


Fig 4.3: Leaf area index of *Bt* cotton hybrids during 2011 (a) and 2012 (b)

(a)



(b)

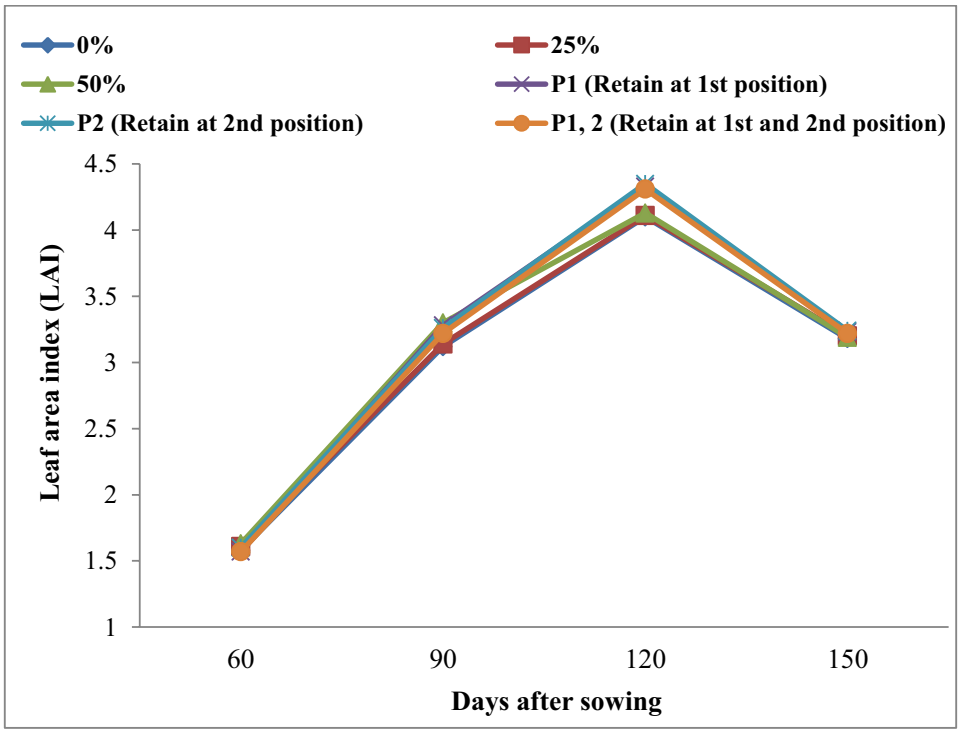


Fig 4.4: Leaf area index of *Bt* cotton hybrids as affected by fruiting form removal treatments during 2011 (a) and 2012 (b)

The trend for LAI at 120 DAS changed from the LAI recorded at 90 DAS. At 120 DAS maximum LAI (3.77 and 4.35) was recorded in P2 during 2011 and 2012 respectively, which was statistically at par with P1 and P1, 2 treatments but significantly higher than 0, 25 and 50 % square removal treatments during 2011. However, during 2012, LAI for P2 was statistically at par with all the fruiting form removal treatments except for 0 and 25 % square removal treatments. The increase in LAI recorded at 120 DAS in P2 might be attributed to increased plant height (Table 4.1) and higher dry matter accumulation at this stage (Table 4.3 to 4.6). A sharp decline in LAI after 120 days of crop was observed in all the treatments due to leaf abscission resulting in a non significant variation for LAI among treatments during both the years. All the interaction effects for hybrids and fruiting form removal treatments were non significant at all the growth stages.

4.1.3 Dry Matter Accumulation and Partitioning

Dry matter accumulation (DMA) is one of the most important parameter reflecting the crop growth. The optimum accumulation of dry matter followed by adequate partitioning of assimilates to the sinks results in higher yield realization. The data presented in Tables 4.3, 4.4, 4.5 and 4.6 and represented in Fig. 4.5 and 4.6 depict a progressive increase in DMA with the advancement in crop age during both the years of study. A sharp increase in DMA was registered between 60 and 120 DAS, which is grand growth phase of the crop and thereafter, the increase in DMA was comparatively at slow pace till maturity. Total dry matter accumulation (TDMA) in *Bt* cotton hybrids did not differ significantly at 60 and 90 DAS during 2011 and 2012. Whereas, differences in TDMA recorded by hybrids at 120 and 150 DAS was significant in both the years. At 120 and 150 DAS, MRC 7017 accumulated maximum dry matter (216.7 and 261.8 g plant^{-1} respectively), during 2011 and (236.4 and 286.5 g plant^{-1} respectively), during 2012. However, hybrid MRC 7017 was statistically at par with MRC 7031 but accumulated significantly higher dry matter than RCH 314 during both the years. Similar trend was observed for fruiting bodies, whereas the DMA into stem, branches, and leaves showed a non significant difference at all the growth stages during both the years. The maximum dry weight of fruiting bodies was recorded in MRC 7017, (27.9 and 34.6 g plant^{-1}) at 120 DAS and at 150 DAS (62.1 and 72.8 g plant^{-1}) which was statistically at par with hybrid MRC 7031 during both the years. Hybrid RCH 314 accumulated significantly less amount of dry matter in fruiting bodies as compared to hybrids, MRC 7017 and MRC 7031. The higher dry weight in MRC 7017 was due to the vigorous plant growth which was as evident from higher plant height (Table 4.1), a genetic character of the hybrids. The difference in dry weight due to the genetic character of the hybrids had also been reported by Heitholt (1992).

A perusal of data presented in Table 4.3 to 4.6 and illustrated in Fig. 4.6 depict that, at 60 DAS, non significant results were obtained for TDMA and its partitioning into various

plant parts in all the fruiting form removal treatments during both the years. It was due to the fact that fruiting form removal treatments were applied at 55 DAS and their effect on plant growth did not occur within a short period i.e. at 60 DAS. Whereas, at 90 and 150 DAS, fruiting form removal exhibited significant influence on TDMA and its partitioning into various plant parts during both the crop growth seasons. However, fruiting form removal treatments failed to influence the TDMA at 120 DAS but it significantly affected the dry matter accumulated in stem, branches, leaves and fruiting bodies during both the years. The non significant variation for TDMA at 120 DAS was might be because of the cumulative effect of dry matter accumulated by stem, branches, leaves and fruiting bodies. The amount of dry matter accumulated in stem, branches and leaves was higher in P1, P2 and P1, 2 treatments while higher dry matter in fruiting bodies was observed in 0 , 25 and 50 % square removal treatments which resulted in non significant variation for TDMA when all the plant parts (stem, branches, leaves and fruiting bodies) were summed up.

At 90 DAS, maximum amount of TDMA was recorded in treatment where 50 % squares were removed for the period of one month (156.1 and 160.3 g plant^{-1}) whereas, it was statistically at par with P1 which accumulated total dry matter of 151.2 and 156.7 g plant^{-1} and P2 where 153.7 and 157.6 g plant^{-1} of dry matter was accumulated during 2011 and 2012, respectively. The minimum amount of TDMA (139.9 and 144.2 g plant^{-1} during 2011 and 2012, respectively) was recorded in treatment where no squares were removed (0 %). DMA into various plant parts like stem, branches, and leaves was also maximum in 50 % square removal treatment and minimum dry weight was accumulated in 0 and 25 % square removal treatments in both the crop growth seasons. Significantly higher dry weight of fruiting bodies (18.2 and 20.4 g plant^{-1}) was recorded in the treatments where 0 % squares were removed as compared to all other fruiting form removal treatments but was statistically at par with the treatment where 25 % squares were removed which accumulated 17.5 and 19.9 g plant^{-1} of dry weight in fruiting bodies during 2011 and 2012, respectively. Whereas, significantly lower dry matter for fruiting bodies (11.7 and 12.9 g plant^{-1}) was recorded in treatment where 50 % squares were removed during 2011 and 2012, respectively. The maximum DMA by fruiting bodies in 0 and 25 % square removal treatments as compared to 50 % square removal, P1, P2 and P1, 2 treatments might be because of less removal of fruiting forms which caused higher retention of fruiting bodies in 0 and 25 % square removal treatments which is evident from higher number of flowers (Table 4.16), total bolls and picked bolls plant^{-1} (Table 4.17).

Fruiting form removal treatments had a non significant effect on TDMA at 120 DAS whereas, it was observed that accumulation of dry matter into different plant parts *viz*. stem, branches, leaves and fruiting bodies differed significantly during both the years of experimentation. The treatment where fruits were removed from all the positions except for the second position (P2) accumulated maximum amount of dry matter in stem and branches

(128.8 and 133.5 g plant^{-1} during 2011 and 2012 respectively) and was statistically at par with P1 and P1, 2 during 2011 and with P1, P1, 2 and 50 % fruiting form removal treatments during 2012. Accumulation of dry matter in leaves was maximum in P2 (71.0 and 78.6 g plant^{-1} during 2011 and 2012, respectively) which was statistically at par with the treatment where fruits were removed from all the fruiting positions except from the first position (P1). The amount of DMA by different plant parts *viz*. stem, branches and leaves was lower in 0 and 25 % square removal treatments, which might be due to the reason that photosynthates produced by the plant were translocated towards the existing fruiting bodies as less of fruiting forms were removed in these treatments. Whereas, in treatments where 50 % squares were removed for a period of one month and P1, P2 and P1, 2 in which fruiting forms were removed continuously upto the boll open initiation stage might have caused diversion of photosynthates towards the stem, branches and leaves resulting in higher amount of DMA into these plant parts.

DMA in fruiting bodies showed a different trend in relation to other plant parts because in 50 % square removal and in P1, P2 and P1, 2 treatments maximum number of fruiting forms were removed which resulted in decreased dry matter of remaining fruiting bodies. The amount of dry matter accumulated in fruiting bodies was higher in 0 and 25 % square removal treatments in both the crop growth seasons and P2 exhibited least amount of dry weight in fruiting bodies (13.8 and 19.7 g plant^{-1}) during 2011 and 2012, respectively at 120 DAS. During both the years, the DMA in fruiting bodies was significantly higher in P1 as compared to P2 because more number of flowers were shed in P2 as evident from lower number of total bolls (Table 4.17) due to physiological abscission from the second fruiting position but the shedding of flowers from P1 was less indicating thereby that the fruiting site P1 contributed more number of fruiting forms which ultimately developed into fruits.

At 150 DAS, 25 % square removal treatment accumulated higher TDM in 2011 (263.8 g plant^{-1}) and in 2012 it accumulated 295.8 g plant^{-1} of TDM and was statistically at par with 0 and 50 % square removal treatments in 2011 whereas, during 2012 it was statistically at par with 50 % square removal treatment only but significantly higher than all other fruiting form removal treatments. The least amount of TDMA 244.7 g plant^{-1} was obtained in P1, 2 treatment during 2011 while, during 2012, the lesser amount of TDMA was recorded in P1 (266.8 g plant^{-1}). The total accumulation of dry matter in P1, P2 and P1, 2 was less as compared to 25 and 50 % square removal treatments and it might be due to the less weight of fruiting bodies as a component of the total dry matter, as more of these were removed.

At 150 DAS, maximum DMA in stem and branches (146.7 and 154.0 g plant^{-1}) and in leaves (62.7 and 70.3 g plant^{-1}) was recorded in P2 and was significantly higher than 0, 25 and 50 % square removal treatments during 2011 and 2012, respectively. However, P2 was

Table 4.3: Dry matter accumulation of *Bt* cotton as affected by hybrids and fruiting form removal treatments during 2011

Treatment	Dry matter accumulation (g plant^{-1})						
	60 DAS			90 DAS			
	Stem and branches	Leaves	Total	Stem and branches	Leaves	Fruiting bodies	Total
Hybrids							
MRC 7017	35.9 a (69.4)	15.8 a (30.5)	51.7 a	81.9 a (54.7)	51.9 a (34.6)	15.6 a (10.4)	149.6 a
MRC 7031	35.9 a (69.7)	15.6 a (30.2)	51.5 a	81.1 a (54.7)	51.3 a (34.6)	15.7 a (10.6)	148.1 a
RCH 314	34.4 a (69.0)	15.4 a (30.9)	49.8 a	80.9 a (55.1)	50.4 a (34.3)	15.6 a (10.6)	146.6 a
SEm	**1.03**	**0.62**	**1.35**	**2.13**	**1.49**	**0.46**	**1.94**
F(p)	**0.31**	**0.85**	**0.38**	**0.76**	**0.50**	**0.98**	**0.45**
Fruiting form removal							
0%	34.2 a (70.0)	14.7 a (30.1)	48.8 a	76.5 c (54.6)	45.1 c (32.2)	18.2 a (13.0)	139.9 c
25%	36.1 a (69.2)	16.0 a (30.7)	52.1 a	79.8 bc (54.6)	48.5 c (33.2)	17.5 ba (11.9)	145.9 bc
50%	36.5 a (69.1)	16.3 a (30.8)	52.8 a	86.5 a (55.4)	57.8 a (37.0)	11.7 d (7.5)	156.1 a
P1 (Retain at 1st position)	35.4 a (69.6)	15.5 a (30.5)	50.8 a	82.3 ba (54.4)	53.5 b (35.3)	15.3 c (10.1)	151.2 ba
P2 (Retain at 2nd position)	35.6 a (69.2)	15.7 a (30.5)	51.4 a	83.3 ba (54.2)	55.4 ba (36.0)	14.9 c (9.6)	153.7 a
P1, 2 (Retain at 1st and 2nd position)	34.8 a (68.3)	15.3 a (30.0)	50.9 a	78.7 bc (55.9)	46.9 c (33.3)	16.1 bc (11.4)	140.7 c
SEm	**1.11**	**0.70**	**1.50**	**1.84**	**1.25**	**0.54**	**2.25**
F(p)	**0.70**	**0.65**	**0.47**	**0.005**	**<0.0001**	**<0.0001**	**<0.0001**
Interaction F(p)	**1.00**	**1.00**	**1.00**	**0.99**	**0.99**	**0.89**	**0.99**

Values in parenthesis are percentage of total dry matter

Table 4.4: Dry matter accumulation of *Bt* cotton as affected by hybrids and fruiting form removal treatments during 2011

Treatment	Dry matter accumulation (g plant^{-1})							
	120 DAS				150 DAS			
	Stem and branches	Leaves	Fruiting bodies	Total	Stem and branches	Leaves	Fruiting bodies	Total
Hybrids								
MRC 7017	122.7 a (56.6)	66.1 a (30.5)	27.9 a (12.9)	216.7 a	141.5 a (54.0)	58.1 a (22.2)	62.1 a (23.7)	261.8 a
MRC 7031	120.9 a (57.4)	63.8 a (30.3)	25.9 a (12.3)	210.7 ba	138.7 a (54.5)	56.4 a (22.2)	59.2 a (23.3)	254.4 ba
RCH 314	119.5 a (59.2)	61.0 a (30.2)	21.3 b (10.6)	201.8 b	135.5 a (55.5)	53.8 a (22.0)	54.9 b (22.5)	244.2 b
SEm	**2.80**	**1.71**	**0.61**	**4.03**	**3.59**	**1.48**	**1.23**	**4.80**
F(p)	**0.41**	**0.04**	**<0.0001**	**0.0004**	**0.20**	**0.01**	**<0.0001**	**<0.0001**
Fruiting form removal								
0%	112.0 d (54.8)	58.0 d (28.4)	34.2 a (16.7)	204.3 a	130.8 d (51.3)	49.1 c (19.3)	75.0 a (29.4)	255.0 bac
25%	114.9 dc (54.7)	58.9 dc (28.0)	36.1 a (17.2)	210.0 a	134.8 bdc (51.1)	53.1 c (20.1)	75.8 a (28.7)	263.8 a
50%	120.8 bc (56.8)	61.6 dc (29.0)	30.3 b (14.2)	212.7 a	133.2 dc (51.3)	52.6 c (20.2)	73.9 a (28.4)	259.8 ba
P1 (Retain at 1st position)	126.7 ba (60.1)	67.6 ba (32.1)	16.5 d (7.8)	210.8 a	144.1 ba (58.2)	60.5 ba (24.5)	42.8 b (17.3)	247.4 c
P2 (Retain at 2nd position)	128.8 a (60.3)	71.0 a (33.2)	13.8 e (6.5)	213.7 a	146.7 a (58.7)	62.7 a (25.1)	40.5 b (16.2)	250.0 bc
P1, 2 (Retain at 1st and 2nd position)	122.8 ba (59.4)	64.7 bc (31.3)	19.2 c (9.3)	206.9 a	141.6 bac (57.9)	58.5 b (23.9)	44.5 b (18.2)	244.7 c
SEm	**2.40**	**2.00**	**0.67**	**3.42**	**3.35**	**1.38**	**1.48**	**3.68**
F(p)	**<0.0001**	**<0.0001**	**<0.0001**	**0.38**	**0.006**	**<0.0001**	**<0.0001**	**0.004**
Interaction F(p)	**1.00**	**0.99**	**0.07**	**0.99**	**0.99**	**0.97**	**0.99**	**0.99**

Values in parenthesis are percentage of total dry matter

Table 4.5: Dry matter accumulation of *Bt* cotton as affected by hybrids and fruiting form removal treatments during 2012

Treatment	Dry matter accumulation (g plant^{-1})						
	60 DAS			90 DAS			
	Stem and branches	Leaves	Total	Stem and branches	Leaves	Fruiting bodies	Total
Hybrids							
MRC 7017	37.3 a (69.9)	16.0 a (30.0)	53.4 a	83.5 a (53.9)	53.6 a (34.6)	17.6 a (11.4)	154.9 a
MRC 7031	36.8 a (69.8)	15.8 a (30.0)	52.7 a	83.1 a (54.4)	52.2 a (34.2)	17.3 a (11.3)	152.8 a
RCH 314	35.6 a (70.4)	15.0 a (29.6)	50.6 a	81.7 a (54.4)	51.4 a (34.2)	17.0 a (11.3)	150.2 a
SEm	**1.05**	**0.37**	**1.28**	**2.62**	**1.33**	**0.46**	**1.89**
F(p)	**0.41**	**0.04**	**0.12**	**0.70**	**0.23**	**0.56**	**0.27**
Fruiting form removal							
0%	35.7 a (70.1)	15.1 a (29.7)	50.9 a	77.9 b (54.0)	45.8 c (31.8)	20.4 a (14.1)	144.2 c
25%	36.6 a (70.0)	15.7 a (30.0)	52.3 a	80.8 ba (53.8)	49.3 c (32.8)	19.9 a (13.3)	150.1 bc
50%	37.9 a (69.8)	16.3 a (30.0)	54.3 a	88.0 a (54.9)	59.4 a (37.1)	12.9 c (8.0)	160.3 a
P1 (Retain at 1st position)	37.1 a (69.9)	16.0 a (30.1)	53.1 a	84.8 ba (54.1)	54.6 b (34.8)	17.2 b (11.0)	156.7 ba
P2 (Retain at 2nd position)	36.3 a (69.9)	15.5 a (29.9)	51.9 a	85.1 ba (54.0)	56.4 ba (35.8)	16.1 b (10.2)	157.6 ba
P1, 2 (Retain at 1st and 2nd position)	35.8 a (70.2)	15.1 a (29.6)	51.0 a	80.1 b (54.6)	49.0 c (33.4)	17.6 b (12.0)	146.8 c
SEm	**1.31**	**0.42**	**1.35**	**2.32**	**1.30**	**0.55**	**2.89**
F(p)	**0.84**	**0.04**	**0.47**	**0.03**	**<0.0001**	**<0.0001**	**0.0009**
Interaction F(p)	**0.95**	**0.75**	**0.75**	**1.00**	**0.99**	**1.00**	**0.99**

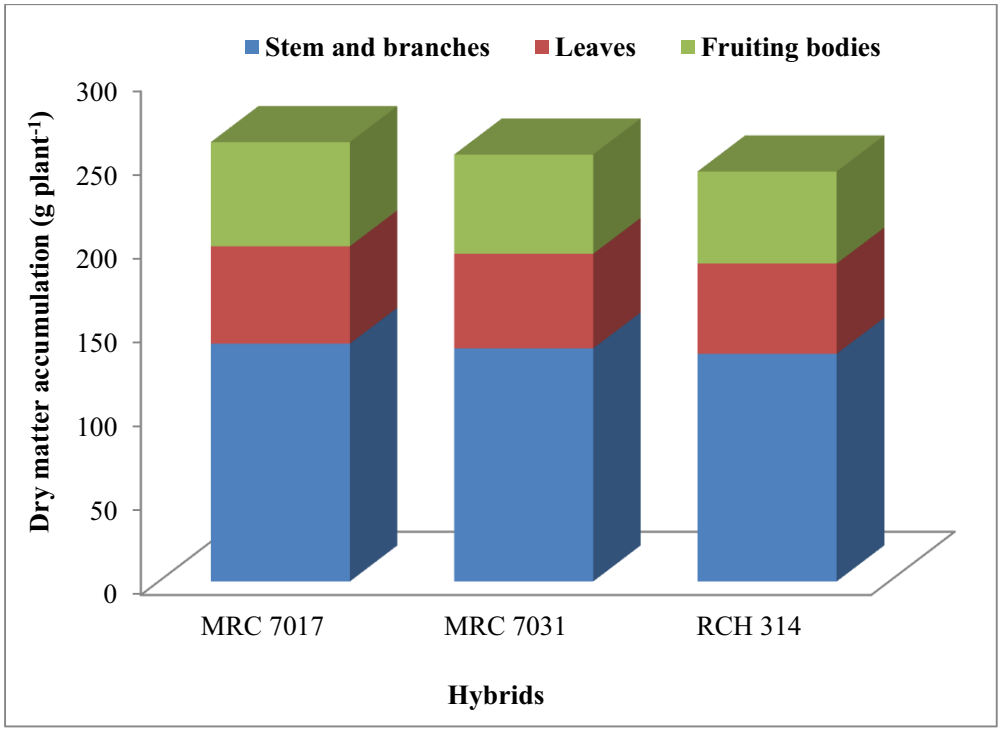
Values in parenthesis are percentage of total dry matter

Table 4.6: Dry matter accumulation of *Bt* cotton as affected by hybrids and fruiting form removal treatments during 2012

Treatment	Dry matter accumulation (g plant^{-1})							
	120 DAS				150 DAS			
	Stem and branches	Leaves	Fruiting bodies	Total	Stem and branches	Leaves	Fruiting bodies	Total
Hybrids								
MRC 7017	127.6 a (54.0)	74.0 a (31.3)	34.6 a (14.6)	236.4 a	148.7 a (51.9)	64.9 a (22.7)	72.8 a (25.4)	286.5 a
MRC 7031	126.7 a (55.0)	70.5 a (30.6)	33.2 a (14.4)	230.5 ba	147.0 a (52.4)	62.5 a (22.3)	70.9 a (25.3)	280.6 ba
RCH 314	124.1 a (56.0)	69.5 a (31.4)	27.9 b (12.6)	221.6 b	143.5 a (53.3)	61.4 a (22.8)	64.2 b (23.9)	269.1 b
SEm	**2.43**	**1.60**	**0.92**	**3.97**	**2.60**	**1.71**	**1.70**	**4.51**
F(p)	**0.43**	**0.06**	**<0.0001**	**0.0008**	**0.12**	**0.08**	**0.0002**	**0.0003**
Fruiting form removal								
0%	116.7 c (52.4)	65.5 d (29.4)	40.6 a (18.2)	222.9 a	139.4 d (49.5)	56.1 e (19.9)	86.0 a (30.6)	281.5 bc
25%	119.7 bc (51.5)	69.5 bcd (29.9)	43.1 a (18.5)	232.4 a	145.8 bdc (49.3)	61.3 dc (20.7)	88.7 a (30.0)	295.8 a
50%	125.0 ba (54.3)	67.4 cd (29.3)	37.5 b (16.3)	230.0 a	141.7 dc (49.6)	58.6 de (20.5)	85.0 a (29.8)	285.4 ba
P1 (Retain at 1st position)	132.5 a (57.3)	74.7 ba (32.3)	23.8 d (10.3)	231.2 a	149.9 ba (56.2)	67.0 ba (25.1)	49.8 c (18.7)	266.8 d
P2 (Retain at 2nd position)	133.5 a (57.6)	78.6 a (33.9)	19.7 e (8.5)	231.9 a	154.0 a (56.8)	70.3 a (25.9)	46.6 c (17.2)	271.0 dc
P1, 2 (Retain at 1st and 2nd position)	129.4 a (56.5)	72.4 bc (31.6)	26.6 c (11.6)	228.9 a	147.8 bac (54.4)	64.1 bc (23.6)	59.8 b (22.0)	271.8 dc
SEm	**2.76**	**2.00**	**0.90**	**3.62**	**2.57**	**1.53**	**1.99**	**3.96**
F(p)	**0.0002**	**0.0003**	**<0.0001**	**0.46**	**0.002**	**<0.0001**	**<0.0001**	**<0.0001**
Interaction F(p)	**1.00**	**1.00**	**0.38**	**0.99**	**0.99**	**0.99**	**0.99**	**0.99**

Values in parenthesis are percentage of total dry matter

(a)



(b)

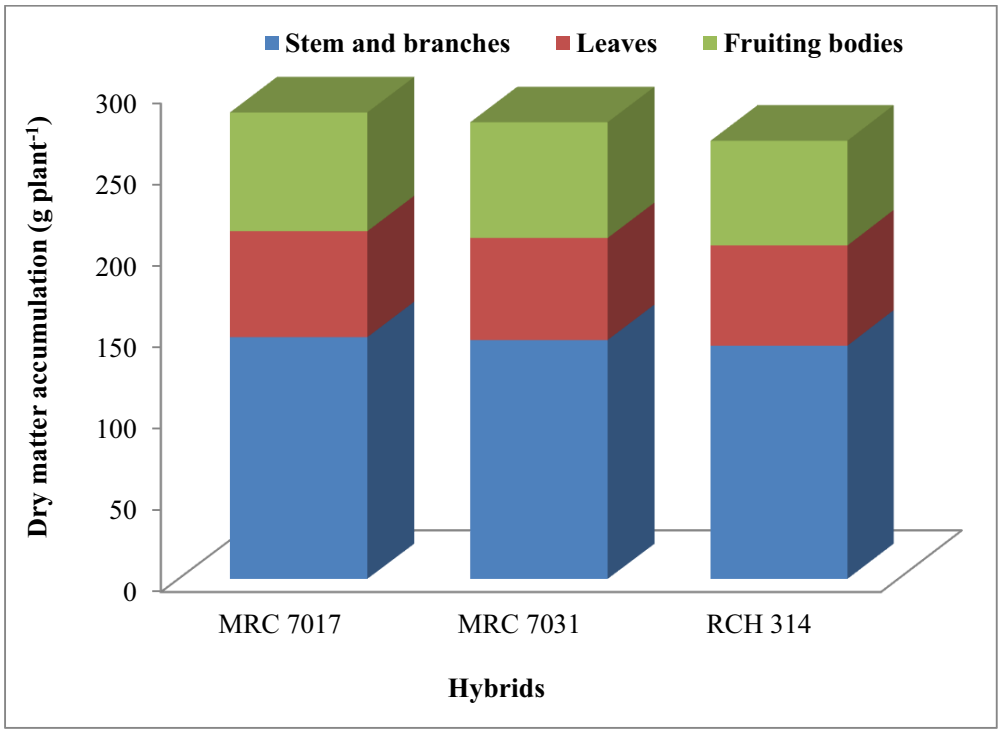
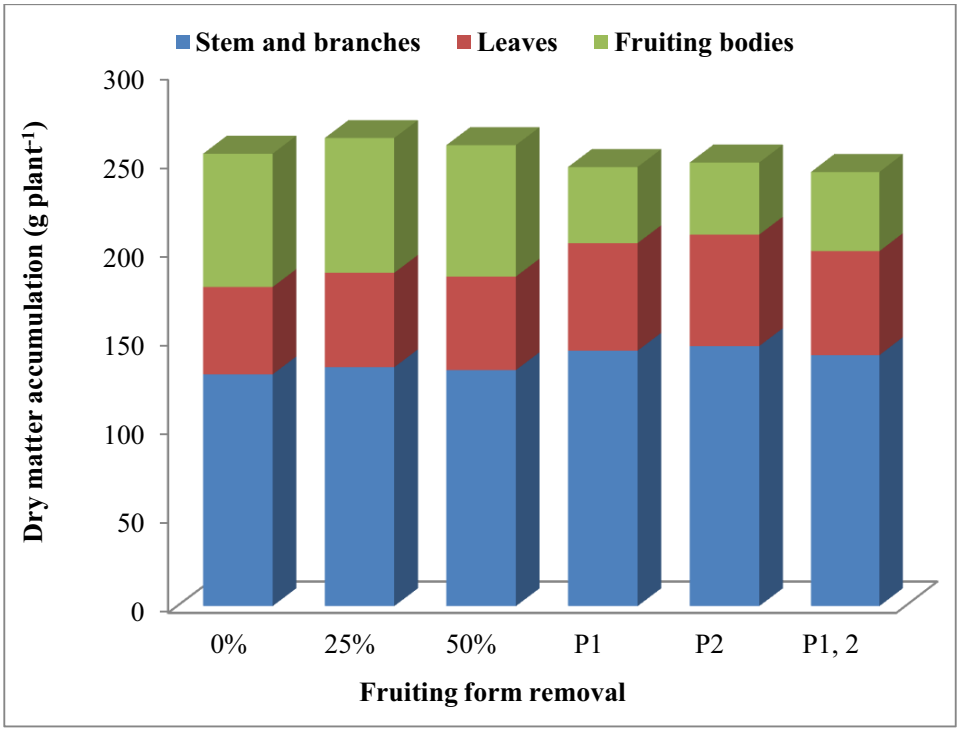


Fig 4.5: Dry matter accumulation as affected by hybrids at maturity during 2011 (a) and 2012 (b)

(a)



(b)

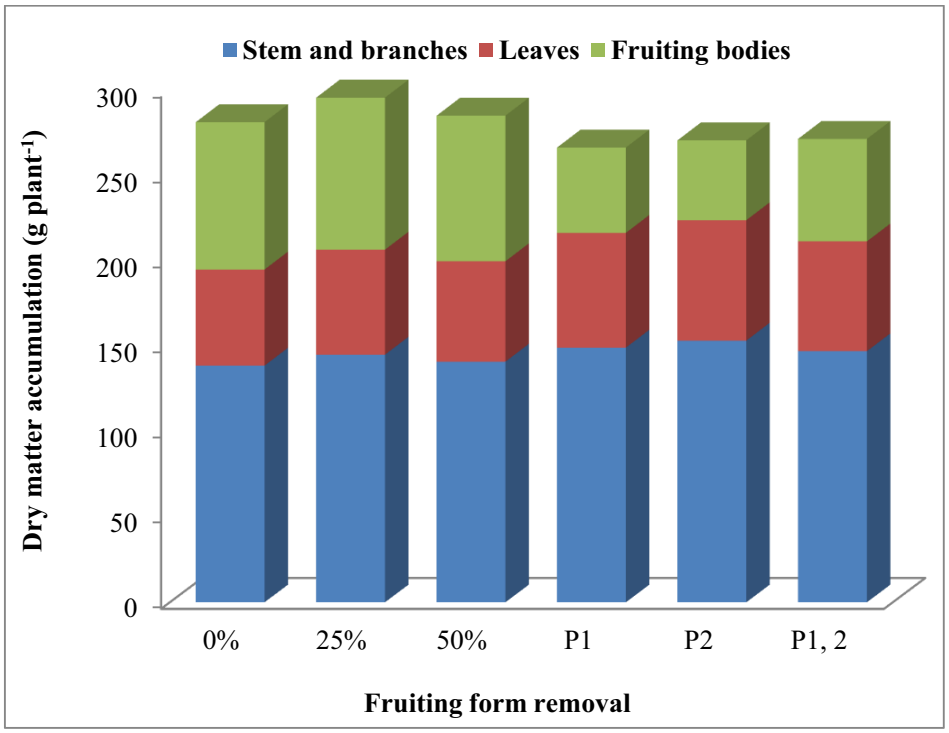


Fig 4.6: Dry matter accumulation of *Bt* cotton hybrids as affected by fruiting form removal treatments at maturity during 2011 (a) and 2012 (b)

statistically at par with P1 and P1, 2 for DMA in stem and branches and only with P1 for DMA in leaves during both the years. Better all-round growth as evident from the highest LAI (Table 4.2) and significantly taller plants (Table 4.1) in fruiting form removal treatments (P1, P2 and P1, 2) enabled them to accumulate significantly higher dry matter in stem, branches and leaves than all other fruiting form removal treatments.

Higher accumulation of dry matter in vegetative parts in the treatments where fruiting bodies were retained at specific sites (P1, P2 and P1, 2) was due to mobilization of the photosynthates to stem, branches and leaves instead of fruiting forms removed earlier.

However, fruiting bodies showed a varying trend in DMA, 25 % square removal treatment resulted in maximum dry matter of 75.8 and 88.7 g plant^{-1} during 2011 and 2012, respectively. It was also observed that 0 and 50 % square removal treatments performed statistically similar to 25 % square removal treatment for DMA in fruiting bodies during both the years. In the treatments where 0, 25 and 50 % squares were removed, contribution of dry matter of fruiting bodies was higher as compared to the treatments where fruiting forms were removed from specific positions i.e. P1, P2 and P1, 2. It therefore suggested that the removal of fruiting forms upto the later stages of crop had a deleterious effect on DMA in fruiting bodies as well as on TDMA. Higher amount of dry matter of fruiting bodies in 0, 25 and 50 % square removal treatments might be attributed to the presence of more number of fruiting bodies as these were removed for one month in these square removal treatments while in treatments P1, P2 and P1, 2 fruiting forms were removed in higher amounts from the day squares started developing to the boll open initiation stage.

The perusal of data in Tables 4.3 to 4.6 clearly shows that removal of fruiting forms facilitated transportation of photosynthates to the other plant parts and also helped in enhancing the vegetative growth as compared to the treatments where squares were not removed or removed to a lesser extent. However, in 25 and 50 % square removal treatments, less vegetative growth was observed at later stages i.e. at 120 and 150 DAS, because removal of fruiting forms was done only for a month from the day square development started but had higher number of fruiting bodies which eventually helped in increasing the total dry matter of plant. While, in the treatments where fruits were retained at specific fruiting positions, fruiting forms were removed from the day squares started developing till the boll open initiation stage which helped in increasing the dry weight in vegetative parts. The increase in dry weight of cotton plant might be due to remobilization of assimilates into vegetative organs resulting from the complete suppression of fruiting activity. These results were also in accordance with Malik *et al* (1981) as they found that removal of fruiting forms help in more accumulation of dry matter into the vegetative parts. All the interaction effects for different hybrids and fruiting form removal treatments were non significant during both the years.

4.1.4 Crop Growth Rate

Crop growth rate (CGR) reflects the dry matter gained by a unit area of a crop in unit time or it is the rate of growth of crop per unit area. The CGR reached its peak between 60-90 DAS, thereafter, it showed a declining rate during both the crop growth seasons. The higher CGR during 60-90 DAS was due to maximum leaf production and expansion of the plant as this is a grand growth period of the crop. The data presented in Table 4.7 reveal that all the hybrids were statistically similar for CGR at all the crop growth stages during both the years. Hybrid MRC 7017 recorded a relatively higher CGR than MRC 7031 and RCH 314 at all the growth stages, but failed to reach the level of significance. Maximum CGR for all the hybrids recorded during the period of 90-120 DAS which was 4.42 and 5.36 g m^{-2} day^{-1} for MRC 7017, 4.12 and 5.11 g m^{-2} day^{-1} for MRC 7031 and 3.96 and 4.70 g m^{-2} day^{-1} for RCH 314 during 2011 and 2012, respectively.

Fruiting form removal treatments showed a marked influence on CGR during both the years (Table 4.7). During early growth stages i.e. 30-60 DAS, fruiting form removal treatments did not differ significantly for CGR during both the years, but during the period of 60-90 DAS, maximum CGR (6.68 and 6.98 g m^{-2} day^{-1} during 2011 and 2012, respectively) was recorded by the crop where 50 % squares were removed for a period of one month which was statistically at par with P1 and P2 but significantly higher than 0 %, 25 % and P1, 2 treatments during 2011. However, during 2012, the treatment where 50 % squares were removed for a period of one month recorded maximum CGR values and was statistically at par with 25 and 50 % square removal treatments and also with the treatments where fruiting bodies were retained at specific positions (P1, P2 and P1, 2) but significantly higher than 0 % square removal treatment.

During the period of 90-120 DAS, CGR was unaffected by all the fruiting form removal treatments during both the years. Whereas, during the period of 120-150 DAS, maximum CGR was recorded in 25 % square removal treatment (3.54 and 4.17 g m^{-2} day^{-1}) which was statistically at par with the treatments where 0 and 50 % squares were removed but significantly higher than P1 and P2 during 2011 and 2012, respectively.

The higher amount of square removal in 50 % square removal treatment translocated assimilates towards the vegetative plant parts which resulted in vigorous plants having more dry matter accumulation (Table 4.3 and 4.5) and LAI (Table 4.2) resulting in higher photosynthetic activity (Wells, 2001), thereby increasing CGR as compared to other fruiting form removal treatments. In contrast, at 120-150 DAS, higher CGR was recorded in 25 % square removal treatment, it was because of higher TDMA which was a result of higher dry matter of fruiting bodies (Tables 4.4 and 4.6) due to less removal of fruiting forms as compared to 50 % square removal treatment and the treatments where fruiting forms were removed from all the positions except from first (P1), second (P2) and both first and second (P1, 2) positions during both the years. The interaction between hybrids and fruiting form removal treatments were non significant at all the crop growth stages.

Table 4.7: Effect of fruiting form removal on CGR of *Bt* cotton hybrids

Treatment	Crop growth rate (g m^{-2} day^{-1})							
	30-60 DAS		60-90 DAS		90-120 DAS		120-150 DAS	
	2011	2012	2011	2012	2011	2012	2011	2012
Hybrids								
MRC 7017	2.86 a	2.80 a	6.44 a	6.68 a	4.42 a	5.36 a	2.96 a	3.29 a
MRC 7031	2.87 a	2.77 a	6.36 a	6.59 a	4.12 a	5.11 a	2.87 a	3.29 a
RCH 314	2.78 a	2.65 a	6.04 a	6.55 a	3.96 a	4.70 a	2.79 a	3.12 a
SEm	**0.07**	**0.09**	**0.17**	**0.18**	**0.23**	**0.29**	**0.43**	**0.31**
F(p)	**0.63**	**0.22**	**0.008**	**0.83**	**0.24**	**0.06**	**0.87**	**0.82**
Fruiting form removal								
0%	2.68 a	2.63 a	5.89 b	6.14 b	4.34 a	5.18 a	3.33 ba	3.85 a
25%	2.91 a	2.77 a	6.06 b	6.43 ba	4.33 a	5.41 a	3.54 a	4.17 a
50%	2.96 a	2.87 a	6.68 a	6.98 a	3.84 a	4.58 a	3.10 ba	3.65 ba
P1 (Retain at 1st position)	2.80 a	2.78 a	6.49 a	6.82 ba	4.04 a	4.90 a	2.40 b	2.34 c
P2 (Retain at 2nd position)	2.88 a	2.74 a	6.62 a	6.96 a	4.06 a	4.89 a	2.39 b	2.57 c
P1, 2 (Retain at 1st and 2nd position)	2.81 a	2.63 a	5.92 b	6.30 ba	4.39 a	5.37 a	2.49 ba	2.85 bc
SEm	**0.09**	**0.08**	**0.12**	**0.21**	**0.26**	**0.28**	**0.34**	**0.31**
F(p)	**0.43**	**0.36**	**<0.0001**	**0.03**	**0.64**	**0.27**	**0.06**	**0.0004**
Interaction F(p)	**1.00**	**0.73**	**0.97**	**0.99**	**0.99**	**0.99**	**0.99**	**0.99**

4.1.5 Relative Growth Rate

Relative growth rate (RGR) is an efficiency index because it expresses the rate of growth per unit of existing dry matter in a day. Normally RGR is expressed as gram of dry matter produced by a gram of existing dry matter in a day. At initial 30-60 DAS the RGR was more and later on it decreased due to the initiation of reproductive stage and the demand for photosynthates was more by the fruiting bodies which resulted in less increase of dry matter in vegetative parts. The data presented in Table 4.8 reveal that the RGR of all the hybrids was not significantly affected at all the crop growth stages during both the years.

RGR data in Table 4.8 reveal that fruiting form removal treatments also had a non significant influence on RGR in initial growth stages during both the years, it was due to the fact that the removal of fruiting forms was initiated at about 55 DAS and as apparent from the Table 4.13 resulted in non significant variation in TDM at initial growth stages (Tables 4.3 and 4.5) while, at 90-120 and 120-150 DAS, fruiting form removal treatments had a significant influence on RGR but only during the crop growth season of 2012. At 90-120 DAS, significantly higher RGR (0.019 g $g^{-1}day^{-1}$) was recorded in P1, 2 and it was statistically at par with all the fruiting form removal treatments except 50 % square removal treatment.

Whereas, during the period of 120-150 DAS, RGR of 0.0092 g g^{-1} day^{-1} was recorded in 25 % square removal treatment which was statistically at par with 0 and 50 % square removal treatments but significantly higher than the treatments where fruits were retained at first (P1), second (P2) and on both first and second positions (P1, 2) during 2012. The RGR increased at later stages i.e. 120-150 DAS, in square removal treatments due to the existence of more number of fruiting bodies as evident from the data in Table 4.17 which resulting in higher dry matter of fruiting bodies and it eventually increased the TDMA (Tables 4.4 and 4.6) thereby, increasing the RGR as compared to the treatments where fruiting forms were removed from all the positions except first (P1), second (P2) and both first and second (P1, 2). The non significant variation for RGR during 2011 might be due to heavy rainfall throughout the season as compared to the year 2012 (Appendix II) affecting growth in plants. There was a non significant interaction between hybrids and fruiting form removal treatments at all the crop growth stages.

Table 4.8: Effect of fruiting form removal on RGR of *Bt* cotton hybrids

Treatment	Relative growth rate (g $g^{-1}day^{-1}$)							
	30-60 DAS		60-90 DAS		90-120 DAS		120-150 DAS	
	2011	2012	2011	2012	2011	2012	2011	2012
Hybrids								
MRC 7017	0.18 a	0.132 a	0.064 a	0.064 a	0.0152 a	0.0178 a	0.0069 a	0.0071 a
MRC 7031	0.18 a	0.134 a	0.062 a	0.064 a	0.0144 a	0.0172 a	0.0070 a	0.0072 a
RCH 314	0.19 a	0.131 a	0.061 a	0.066 a	0.0142 a	0.0162 a	0.0072 a	0.0073 a
SEm	**0.005**	**0.007**	**0.003**	**0.003**	**0.0008**	**0.001**	**0.0011**	**0.0007**
F(p)	**0.37**	**0.85**	**0.53**	**0.79**	**0.60**	**0.37**	**0.95**	**0.96**
Fruiting form removal								
0%	0.17 a	0.127 a	0.061 a	0.061 a	0.0160 a	0.018 ba	0.0083 a	0.0090 a
25%	0.19 a	0.139 a	0.059 a	0.063 a	0.0152 a	0.018 ba	0.0083 a	0.0092 a
50%	0.19 a	0.137 a	0.064 a	0.065 a	0.0129 a	0.015 b	0.0074 a	0.0082 ba
P1 (Retain at 1^{st} position)	0.17 a	0.131 a	0.065 a	0.065 a	0.0139 a	0.016 ba	0.0059 a	0.0052 c
P2 (Retain at 2^{nd} position)	0.19 a	0.137 a	0.065 a	0.068 a	0.0138 a	0.016 ba	0.0058 a	0.0050 c
P1, 2 (Retain at 1^{st} and 2nd position)	0.19 a	0.122 a	0.061 a	0.063 a	0.0159 a	0.019 a	0.0063 a	0.0060 bc
SEm	**0.009**	**0.005**	**0.002**	**0.003**	**0.0011**	**0.001**	**0.0009**	**0.0007**
F(p)	**0.31**	**0.29**	**0.33**	**0.74**	**0.25**	**0.08**	**0.12**	**0.001**
Interaction F(p)	**0.97**	**0.36**	**0.99**	**0.97**	**0.99**	**0.99**	**0.99**	**0.99**

4.1.6 Specific Leaf Area

Specific leaf area (SLA) is an index of the leafiness of the leaf, a measure of density or of relative thickness, which assesses the leaf's area in relation to its dry weight. Data presented in Table 4.9 reveal that SLA of all the hybrids was statistically similar at all the crop growth stages during 2011 and 2012.

Fruiting form removal treatments had a significant effect on SLA at various growth stages except at 60 DAS (Table 4.9). At 90 DAS, higher SLA (294.3 and 352.1 $cm^2 g^{-1}$) was recorded in the treatment where 0 % squares were removed and was statistically at par with the treatment where 25 % squares were removed which recorded 273.2 and 328.6 $cm^2 g^{-1}$ of SLA and was also statistically at par with the treatment where fruits were retained at both first and second position (P1, 2) which recorded 294.0 and 337.4 $cm^2 g^{-1}$ of SLA during 2011 and 2012 respectively. However, 0 % square removal treatment proved to be significantly higher for SLA as compared to the treatments where fruits were retained at first position (P1) which had a SLA of 262.3 and 310.8 $cm^2 g^{-1}$, second position (P2) which had 252.7 and 299.5 $cm^2 g^{-1}$ of SLA and also with the treatment where 50 % squares were removed (244.3 and 287.0 $cm^2 g^{-1}$) during 2011 and 2012 respectively.

At 120 DAS, higher SLA (311.9 $cm^2 g^{-1}$) was recorded in 25 % square removal treatment during 2011 while, during 2012, higher SLA (319.2 $cm^2 g^{-1}$) was recorded in 0 % square removal treatment. However, both these treatments were statistically at par with each other and with all other fruiting form removal treatments except for the treatment where fruits were retained at second position (P2) which recorded 271.6 and 283.6 $cm^2 g^{-1}$ of SLA during 2011 and 2012, respectively. At 150 DAS, 0 % square removal treatment resulted in maximum SLA (248.0 and 290.4 $cm^2 g^{-1}$), which was statistically at par with 25 % (231.7 and 266.2 $cm^2 g^{-1}$) and 50 % (231.9 and 279.3 $cm^2 g^{-1}$) square removal treatments but was significantly higher than P1, P2 and P1, 2 during 2011 and 2012, respectively. The reason for lesser leaf thickness or SLA in treatments like 50 % square removal, P1, P2 and P1, 2 in comparison to 0 and 25 % square removal treatments might be due to the higher leaf weight in proportion to leaf area of these treatments (50 %, P1, P2 and P1, 2). Interaction between hybrids and fruiting form removal treatments were non significant.

Table 4.9: Effect of fruiting form removal on SLA of *Bt* cotton hybrids

Treatment	Specific leaf area (cm^2g^{-1})							
	60 DAS		90 DAS		120 DAS		150 DAS	
	2011	2012	2011	2012	2011	2012	2011	2012
Hybrids								
MRC 7017	503.4 a	519.9 a	272.5 a	313.2 a	284.5 a	292.3 a	217.0 a	256.8 a
MRC 7031	485.9 a	515.8 a	269.6 a	322.5 a	294.4 a	306.8 a	218.3 a	265.2 a
RCH 314	486.0 a	531.7 a	268.3 a	322.0 a	306.9 a	310.7 a	227.2 a	264.9 a
SEm	**20.26**	**17.79**	**9.02**	**6.40**	**7.50**	**15.37**	**6.19**	**9.73**
F(p)	**0.73**	**0.56**	**0.86**	**0.50**	**0.14**	**0.13**	**0.27**	**0.55**
Fruiting form removal								
0%	502.5 a	533.4 a	294.3 a	352.1 a	310.6 a	319.2 a	248.0 a	290.4 a
25%	486.9 a	526.6 a	273.2 ba	328.6 ba	311.9 a	303.3 ba	231.7 a	266.2 bac
50%	491.6 a	508.0 a	244.3 c	287.0 c	295.8 ba	313.9 a	231.9 a	279.3 ba
P1 (Retain at 1st position)	488.6 a	503.4 a	262.3 bc	310.8 bc	284.0 ba	295.6 ba	204.5 b	246.3 dc
P2 (Retain at 2nd position)	494.1 a	529.0 a	252.7 bc	299.5 c	271.6 b	283.6 b	198.3 b	234.6 d
P1, 2 (Retain at 1st and 2nd position)	487.0 a	534.4 a	294.0 a	337.4 ba	297.7 ba	303.9 ba	210.6 b	257.0 bdc
SEm	**25.59**	**15.32**	**8.24**	**8.95**	**11.19**	**9.52**	**6.86**	**8.72**
F(p)	**0.99**	**0.58**	**0.0001**	**<0.0001**	**0.10**	**0.13**	**<0.0001**	**0.0004**
Interaction F(p)	**0.99**	**0.83**	**0.99**	**0.98**	**0.99**	**1.00**	**0.99**	**1.00**

4.1.7 Net Assimilation Rate

Net assimilation rate (NAR) indirectly indicates the rate of net photosynthesis. The data presented in Table 4.10 depict that NAR was not significantly influenced by the hybrids at all growth stages of crop during both the years. The NAR was higher at early periods i.e. 30-60 DAS and it was 0.90 and 0.45 mg cm^{-2} day^{-1} for MRC 7017, MRC 7031 recorded the NAR of 0.89 and 0.45 mg cm^{-2} day^{-1} and RCH 314 recorded NAR of 0.93 and 0.47 mg cm^{-2} day^{-1} during 2011 and 2012, respectively. After 30-60 DAS, NAR continuously declined upto the period of 120-150 DAS during both the years and it reached 0.080 and 0.077 mg cm^{-2} day^{-1} for MRC 7017, 0.079 and 0.078 mg cm^{-2} day^{-1} for MRC 7031 and for RCH 314 the values were 0.078 and 0.075 mg cm^{-2} day^{-1} during 2011 and 2012, respectively. The decrease in NAR at later stages might be because of less growth of plants which resulted in less leaf area production over the existing leaf area as well as most of leaves abscised towards maturity due to senescence which also lowered leaf area as evident from the less LAI at later stages (Table 4.2).

A scrutiny of data presented in Table 4.10 shows that fruiting form removal treatments did not differ significantly for NAR during the period of 30-60 and 60-90 DAS during both the years, while it was significantly affected at 90-120 DAS during 2012 only however, during the period of 120-150 DAS, these treatments again had a significant effect on NAR during both the crop growth seasons. At 90-120 DAS, 25 % square removal treatment recorded maximum NAR (0.17 mg cm^{-2} day^{-1}) which was statistically at par with all the fruiting form removal treatments but recorded significantly higher NAR than the crop where 50 % squares were removed for a period of one month. Among different fruiting form removal treatments the lower NAR of 0.13 mg cm^{-2} day^{-1} was recorded in the treatment where squares were removed upto 50 %. Likewise, during the period of 120-150 DAS, treatment where 25 % squares were removed for a period of one month recorded the highest NAR of 0.100 mg cm^{-2} day^{-1} which was statistically similar to the treatments where 0 and 50 % squares were removed for a period of one month but recorded significantly higher NAR than the fruiting form removal treatments where fruiting bodies were retained at specific fruiting sites (P1, P2 and P1, 2) during both the years. The treatments where fruiting bodies were retained at first (P1), second (P2) and at both first and second position (P1, 2) recorded statistically similar NAR during both the years. The increase in NAR where 25 % squares were removed for a period of one month may be attributed to higher TDMA which was due to the higher weight of fruiting bodies as compared to the treatments where fruiting bodies were retained at specific positions which recorded less weight from fruiting bodies as these were removed in higher amount. There was no significant interaction between hybrids and fruiting form removal at all the crop growth stages during both the years.

Table 4.10: NAR of *Bt* cotton hybrids as affected by fruiting form removal treatments

Treatment	Net assimilation rate (mg cm^{-2} day^{-1})							
	30-60 DAS		60-90 DAS		90-120 DAS		120-150 DAS	
	2011	2012	2011	2012	2011	2012	2011	2012
Hybrids								
MRC 7017	0.90 a	0.45 a	0.42 a	0.41 a	0.16 a	0.16 a	0.080 a	0.077 a
MRC 7031	0.89 a	0.45 a	0.43 a	0.41 a	0.15 a	0.15 a	0.079 a	0.078 a
RCH 314	0.93 a	0.47 a	0.41 a	0.41 a	0.15 a	0.14 a	0.078 a	0.075 a
SEm	**0.02**	**0.01**	**0.01**	**0.01**	**0.009**	**0.008**	**0.01**	**0.006**
F(p)	**0.71**	**0.54**	**0.29**	**0.84**	**0.54**	**0.08**	**0.97**	**0.95**
Fruiting form removal								
0%	0.88 a	0.43 a	0.41 a	0.39 a	0.16 a	0.16 ba	0.094 ba	0.094 a
25%	0.90 a	0.47 a	0.40 a	0.39 a	0.16 a	0.17 a	0.100 a	0.100 a
50%	0.92 a	0.48 a	0.44 a	0.42 a	0.14 a	0.13 b	0.087 bac	0.090 a
P1 (Retain at 1st position)	0.85 a	0.45 a	0.44 a	0.43 a	0.14 a	0.14 ba	0.064 c	0.054 b
P2 (Retain at 2nd position)	0.94 a	0.47 a	0.44 a	0.43 a	0.14 a	0.14 ba	0.064 c	0.058 b
P1, 2 (Retain at 1st and 2nd position)	0.93 a	0.44 a	0.40 a	0.40 a	0.16 a	0.16 ba	0.067 bc	0.066 b
SEm	**0.05**	**0.02**	**0.01**	**0.01**	**0.010**	**0.009**	**0.009**	**0.007**
F(p)	**0.77**	**0.56**	**0.06**	**0.16**	**0.23**	**0.07**	**0.02**	**0.0001**
Interaction F(p)	**0.85**	**0.96**	**0.99**	**0.99**	**0.99**	**0.99**	**0.99**	**0.99**

4.1.8 Main Stem Internodes

There was no significant difference in total number of main stem internodes plant^{-1} of different hybrids during both the years (Table 4.11). Hybrid MRC 7017 recorded relatively higher main stem internodes than MRC 7031 and RCH 314, but failed to reach the level of significance. The number of main stem internodes produced in MRC 7017 were 19.7 and 28.4, in MRC 7031 (19.6 and 28.3) and RCH 314 produced 18.9 and 25.3 number of main stem internodes during 2011 and 2012, respectively.

Fruiting form removal treatments significantly affected the main stem internodes plant^{-1} during both the years (Table 4.11). The maximum number of main stem internodes (20.3 and 28.5) were recorded in the treatment where fruits were retained at first position (P1) during 2011 and 2012 respectively, which was statistically at par with all the fruiting form removal treatments but significantly higher than 0 % square removal treatment during both the years. Whereas, the crop where 0 % squares were removed produced, 17.8 and 25.2 main stem internodes plant^{-1} and was statistically at par with the treatment where 25% squares were removed and with the treatment where fruits were retained at both first and second position (P1, 2) during 2011 and 2012, respectively. The increase in number of main stem internodes plant^{-1} in 50 %, P1 and P2 fruiting form removal treatments indicated a shift in the source-sink relationship due to severe fruiting form loss which diverted excess assimilates for enhanced vegetative growth as evident from taller plants (Table 4.1) and more DMA in stem, branches and leaves (Tables 4.3 to 4.6) and higher LAI (Table 4.2) in these treatments as compared to 0 and 25 % square removal treatments. While, 0 % square removal treatment had sufficient demand from fruiting structures for available resources. Phelps *et al* (1997), Moss and Bednarz (1999) and Bednarz and Roberts (2000) also reported that number of main stem nodes increased by increasing the intensity of fruit removal. They observed that the severe (100 %) square loss diverted excess carbohydrates to vegetative growth which resulted in taller plants and finally the number of main stem internodes increased.

The interaction between hybrids and fruiting form removal treatments was non significant during both the years.

Table 4.11: Main stem internodes of *Bt* cotton hybrids as affected by fruiting form removal treatments

Treatment	Main stem internodes	
	2011	**2012**
Hybrids		
MRC 7017	19.7 a	28.4 a
MRC 7031	19.6 a	28.3 a
RCH 314	18.9 a	25.3 a
SEm	**0.48**	**0.87**
F(p)	**0.26**	**0.001**
Fruiting form removal		
0%	17.8 b	25.2 b
25%	18.9 ba	25.7 ba
50%	20.0 a	28.1 a
P1 (Retain at 1st position)	20.3 a	28.5 a
P2 (Retain at 2nd position)	20.1 a	28.3 a
P1, 2 (Retain at 1st and 2nd position)	19.3 ba	27.9 ba
SEm	**0.55**	**0.90**
F(p)	**0.02**	**0.04**
Interaction F(p)	**0.99**	**1.00**

4.1.9 SPAD value

The SPAD (Soil plant analysis development) meter measures the leaf colour as a proxy for leaf nitrogen, a simplification to use green colour as an indicator of leaf chlorophyll. SPAD meter measures relative differences in crop chlorophyll status between different treatments. Higher levels of chlorophyll content in leaves indicate enhanced photosynthetic efficiency of the crop which influences the crop growth and yield. The data pertaining to chlorophyll content indicated as SPAD value of leaves is presented in Table 4.12 and it show that all the hybrids had statistically same SPAD value during both the years.

The perusal of data in Table 4.12 reveal that fruiting form removal treatments had a significant effect on SPAD values at all the growth stages of crop except at initial growth stage i.e. 60 DAS. It was due to the reason that the removal of fruiting forms started at about 55 DAS and it did not exhibit any effect within a short span of five days. At 90 DAS, higher SPAD value (36.1 and 37.6 during 2011 and 2012, respectively) was recorded in the treatment where 50 % squares were removed, which was statistically at par with treatments where 25 % squares were removed and with the treatments where fruits were retained at specific fruiting sites (P1, P2 and P1, 2) but significantly higher than 0 % square removal treatment during both the years. At 120 DAS, the SPAD value in P2 treatment was significantly higher than the treatments where squares were removed upto 0, 25 and 50 % during both the years. The higher SPAD value (25.0 and 28.8) was recorded in the treatment where fruits were retained at second position (P2) which was statistically at par with the treatment where fruits were retained at first i.e. P1 (23.8 and 27.4) and also with the treatment where fruits were retained at both first and second positions i.e. P1, 2 (22.7 and 26.1) during 2011 and 2012, respectively. SPAD value of the treatment where fruiting forms were retained at first position (P1) was also statistically at par with 50 % square removal treatment at 120 DAS during both the years. While, the treatment where fruiting forms were retained at both first and second position (P1, 2) showed non significant variation in SPAD value with both 25 and 50 % square removal treatments at 120 DAS during both the years.

At 90 DAS, more removal of fruiting forms diverted the assimilates towards the leaves and other plant parts, which had a positive effect on chlorophyll content or greenness of crop in the treatment where 50 % squares were removed for a period of one month as compared to all other fruiting form removal treatments. Contrarily, at 120 DAS continuous removal of fruiting forms from all the positions except second (P2) resulted in higher SPAD value as compared to 0, 25 and 50 % square removal treatments.

Table 4.12: Effect of different hybrids and fruiting form removal on SPAD value of *Bt* cotton

Treatment	SPAD value					
	60 DAS		90 DAS		120 DAS	
	2011	2012	2011	2012	2011	2012
Hybrids						
MRC 7017	45.6 a	47.9 a	35.5 a	37.0 a	23.2 a	26.7 a
MRC 7031	45.1 a	47.0 a	35.0 a	36.4 a	22.5 a	25.8 a
RCH 314	44.2 a	46.5 a	33.6 a	35.0 a	21.4 a	24.6 a
SEm	**1.47**	**1.55**	**1.14**	**1.19**	**0.73**	**0.84**
F(p)	**0.72**	**0.76**	**0.17**	**0.17**	**0.10**	**0.10**
Fruiting form removal						
0%	41.6 a	45.9 a	32.2 b	33.5 b	19.8 d	22.8 d
25%	46.6 a	48.0 a	35.7 a	37.1 a	20.9 dc	24.0 dc
50%	47.6 a	49.0 a	36.1 a	37.6 a	22.0 bdc	25.3 bdc
P1 (Retain at 1st position)	44.5 a	46.5 a	34.7 ba	36.1 ba	23.8 ba	27.4 ba
P2 (Retain at 2nd position)	44.9 a	46.8 a	35.2 ba	36.6 ba	25.0 a	28.8 a
P1, 2 (Retain at 1st and 2nd position)	43.5 a	46.4 a	34.4 ba	35.7 ba	22.7 bac	26.1 bac
SEm	**1.79**	**1.87**	**1.04**	**1.08**	**0.81**	**0.92**
F(p)	**0.37**	**0.85**	**0.14**	**0.14**	**0.0005**	**0.0005**
Interaction F(p)	**1.00**	**1.00**	**0.99**	**0.99**	**0.99**	**0.99**

The removal of fruiting bodies increased vegetative growth due to the translocation of assimilates towards the leaves, stem and branches, that in turn increased the greenness of plant taken as SPAD value. Wells (2001) also observed that removal of flowers for two weeks had 15 per cent higher leaf chlorophyll content as compared to no removal which was ascribed to change in pattern of photosynthate translocation with the removal of floral parts. The interaction between hybrids and fruiting form removal treatments was non significant at all the crop growth stages during both the years.

4.1.10 Days Taken to Initiation of Squaring

Square initiation in *Bt* cotton hybrids started after 56 to 57 DAS and they did not differ significantly for the three hybrids. Similarly, fruiting form removal treatments did not differ significantly for square initiation during both the years. They initiated at 56-57 DAS during 2011 and 55-57 DAS during 2012 (Table 4.13 and Fig. 4.7 and 4.8). All the interaction effects were also non significant for the days taken to initiation of squaring during both years.

4.1.11 Days Taken to 50% Squaring

Different hybrids and fruiting form removal treatments did not vary among themselves for the days taken to 50 % squaring (Table 4.13 and Fig. 4.7 and 4.8). They took 63-64 DAS for 50 % squaring during 2011 and 65 to 66 DAS during 2012. All the interaction effects were also non significant for the days taken to 50 % squaring during both years.

4.1.12 Days Taken to Flower Initiation

Data presented in Table 4.13 and illustrated in Fig. 4.7 and 4.8 reveal that flowering initiated at 71 and 74 DAS during 2011 and 2012, respectively in all the three hybrids. Similarly, for different fruiting form removal treatments, flower initiation was not significantly affected and they initiated at 70-72 DAS during 2011 and 73-75 DAS during 2012. The interaction between hybrids and fruiting form removal treatments were statistically not significant during both the years.

4.1.13 Days Taken to 50% Flowering

To complete 50 % flowering hybrids took 84 days during 2011 and 88-89 days during 2012. However, days taken to 50 % flowering were not significantly affected by the hybrids and different fruiting form removal treatments during both the years. In fruiting form removal treatments they took 82-86 and 86-90 days to complete 50% flowering during both the crop growth seasons (Table 4.13 and Fig. 4.8). The interaction between hybrids and fruiting form removal treatments were also statistically not significant during both the years.

4.1.14 Days Taken to Initiation of Boll Formation

Hybrids did not show significant differences for the days taken to initiation of boll formation and it took 86-88 days and 90-91 days during the two crop growth seasons, respectively (Table 4.14 and Fig. 4.7).

Fruiting form removal treatments also showed non significant differences for days taken to initiation of boll formation and about 83-90 days and 89-93 days were taken for the initiation of boll formation during 2011 and 2012, respectively (Table 4.14 and Fig. 4.8). The interaction between hybrids and fruiting form removal treatments were also statistically not significant during both the years.

4.1.15 Days Taken to 50% Boll Formation

The data presented in Table 4.14 and depicted in Fig. 4.7 reveal that hybrids did not differ significantly for 50 % boll formation and they took 103-105 days in 2011 and 110-112 days in 2012. Similarly, fruiting form removal treatments were also not significantly affected for days taken to 50 % boll formation and all fruiting form removal treatments took 100-106 days and 110-113 days to complete 50 % boll formation during 2011 and 2012, respectively (Table 4.13 and Fig. 4.8). The interaction among the hybrids and fruiting form removal treatments was non significant during both the years.

4.1.16 Days Taken to Boll Opening Initiation

Perusal of the data presented in Table 4.14 and illustrated in Fig. 4.7 reveal that a non significant difference was observed between hybrids during both the years and they took about 129-132 days in 2011 and 130-133 days in 2012 to initiation of boll opening.

Fruiting form removal treatments differed significantly for days taken to boll opening initiation during both the years (Table 4.14 and Fig. 4.8). Less number of days were taken by 0 % square removal treatment for boll opening initiation i.e. 125 and 126 days as compared to all other fruiting form removal treatments during 2011 and 2012, respectively. Treatments where fruiting forms were removed took more number of days to initiate boll opening than the treatment where no square was removed. Maximum number of days (135 during 2011 and 136 during 2012) were taken by P2 and was statistically at par with all the fruiting form removal treatments but significantly higher than 0 % square removal treatment during both the years. The treatment where 25 % squares were removed needed 129 and 130 days during 2011 and 2012 respectively, to initiate boll opening and was statistically at par with 0 % square removal treatment. However, the days taken to initiate boll opening in 25 % square removal treatment was statistically similar to 50 % square removal treatment and the treatments where fruits were retained at first (P1), second (P2) and at both first and second (P1, 2) positions during both the years. The removal of fruiting forms shifts the assimilates towards the vegetative parts, which resulted in prolonged vegetative period in P1, P2 and P1, 2 treatments while, in 25 and 50 % square removal treatments the delay in boll open initiation was because of new fruiting forms developed in place of old ones which were removed earlier and the compensation for fruiting forms needed time. Lu *et al* (2012) also confirmed that square removal delayed cotton maturity by 6 to 14 days as compared to no removal treatments.

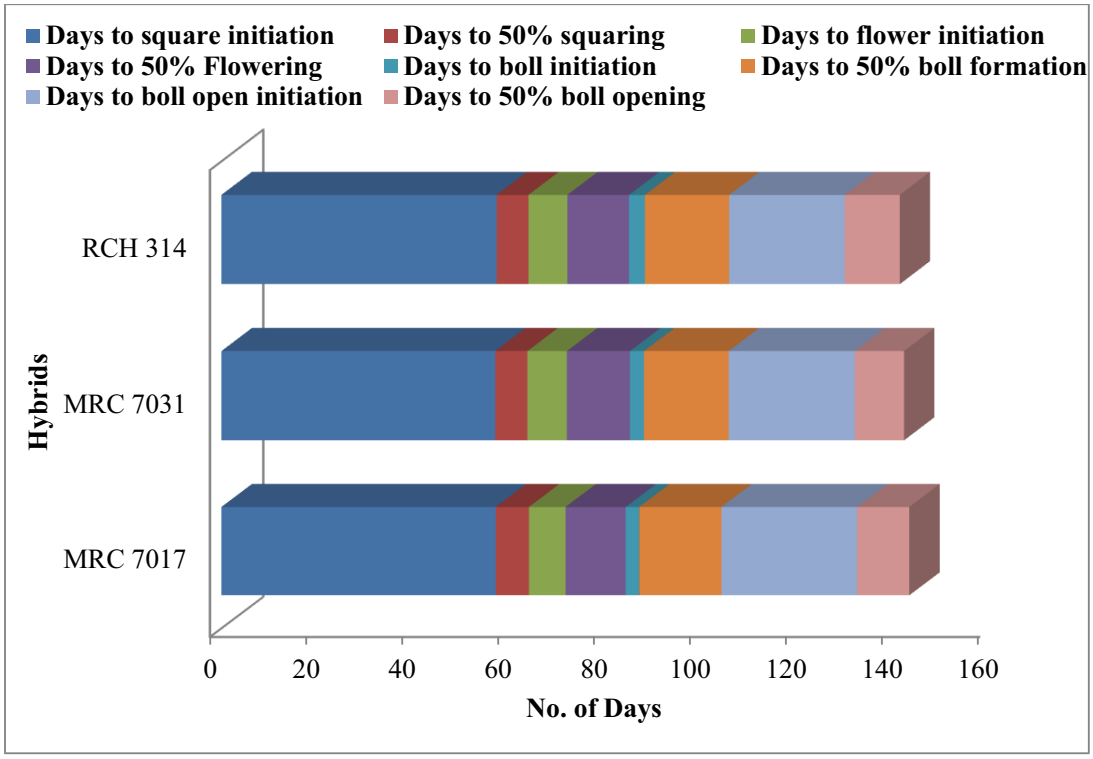
Table 4.13: Days taken to initiation of squaring, 50% squaring, flower initiation and 50% flowering as affected by hybrids and fruiting form removal treatments

Treatment	Days to square initiation		Days to 50% squaring		Days to flower initiation		Days to 50% Flowering	
	2011	2012	2011	2012	2011	2012	2011	2012
Hybrids								
MRC 7017	57 a	56 a	63 a	65 a	71 a	74 a	84 a	88 a
MRC 7031	56 a	56 a	63 a	65 a	71 a	74 a	84 a	89 a
RCH 314	57 a	56 a	63 a	65 a	71 a	74 a	84 a	88 a
SEm	**1.49**	**1.48**	**1.34**	**1.38**	**1.75**	**1.82**	**2.39**	**2.51**
F(p)	**0.96**	**0.96**	**0.97**	**0.97**	**0.97**	**0.97**	**0.84**	**0.84**
Fruiting form removal								
0%	56 a	55 a	63 a	65 a	70 a	73 a	82 a	86 a
25%	57 a	56 a	63 a	65 a	71 a	74 a	84 a	88 a
50%	57 a	56 a	63 a	65 a	72 a	74 a	85 a	89 a
P1 (Retain at 1st position)	57 a	56 a	63 a	65 a	71 a	74 a	84 a	88 a
P2 (Retain at 2nd position)	56 a	56 a	64 a	66 a	72 a	75 a	86 a	90 a
P1, 2 (Retain at 1st and 2nd position)	57 a	57 a	64 a	66 a	72 a	75 a	85 a	89 a
SEm	**1.19**	**1.17**	**1.40**	**1.44**	**1.55**	**1.61**	**1.72**	**1.81**
F(p)	**0.98**	**0.98**	**0.99**	**0.99**	**0.91**	**0.91**	**0.70**	**0.70**
Interaction F(p)	**1.00**	**1.00**	**0.99**	**0.99**	**1.00**	**1.00**	**1.00**	**1.00**

Table 4.14: Days taken to boll initiation, 50 % boll formation, boll open initiation and 50 % boll opening as affected by hybrids and fruiting form removal treatments

Treatment	Days to boll initiation		Days to 50% boll formation		Days to boll open initiation		Days to 50% boll opening	
	2011	2012	2011	2012	2011	2012	2011	2012
Hybrids								
MRC 7017	86 a	90 a	103 a	110 a	132 a	133 a	143 a	143 a
MRC 7031	87 a	91 a	105 a	112 a	131 a	132 a	141 a	143 a
RCH 314	88 a	91 a	105 a	112 a	129 a	130 a	141 a	142 a
SEm	**1.88**	**2.58**	**2.55**	**2.49**	**2.09**	**2.11**	**1.83**	**1.85**
F(p)	**0.83**	**0.84**	**0.82**	**0.64**	**0.45**	**0.45**	**0.67**	**0.78**
Fruiting form removal								
0%	83 a	89 a	100 a	110 a	125 b	126 b	136 b	137 b
25%	87 a	91 a	103 a	111 a	129 ba	130 ba	138 ba	139 ba
50%	88 a	92 a	106 a	111 a	132 a	134 a	143 a	144 a
P1 (Retain at 1st position)	87 a	91 a	105 a	111 a	132 a	133 a	144 a	145 a
P2 (Retain at 2nd position)	90 a	93 a	108 a	112 a	135 a	136 a	144 a	145 a
P1, 2 (Retain at 1st and 2nd position)	88 a	91 a	105 a	113 a	132 a	133 a	144 a	145 a
SEm	**1.96**	**1.86**	**2.86**	**2.13**	**2.15**	**2.17**	**2.18**	**2.20**
F(p)	**0.76**	**0.70**	**0.40**	**0.97**	**0.03**	**0.03**	**0.04**	**0.02**
Interaction F(p)	**1.00**	**1.00**	**1.00**	**0.99**	**1.00**	**1.00**	**1.00**	**1.00**

(a)



(b)

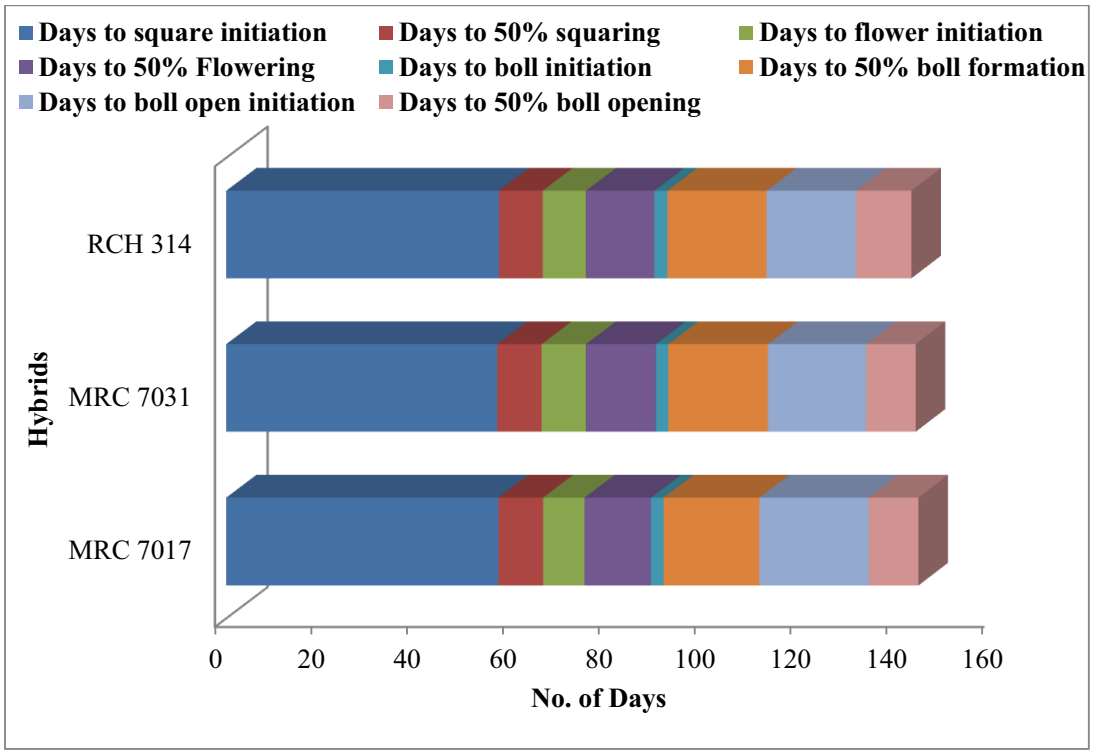
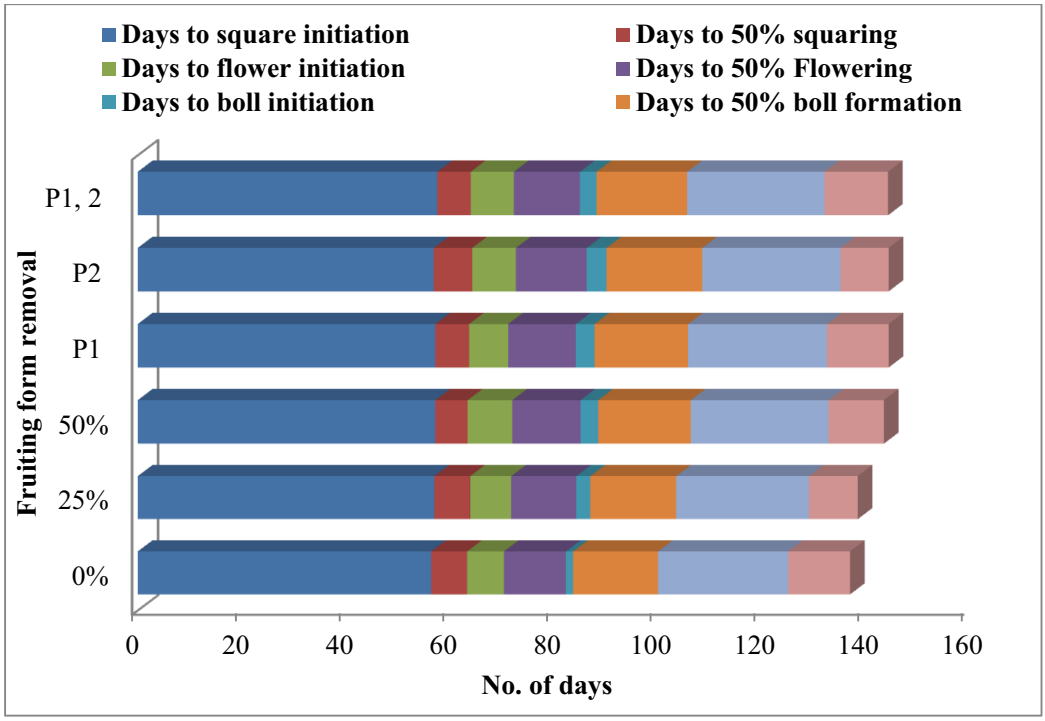


Fig 4.7: Phenological parameters as influenced by hybrids during 2011 (a) and 2012 (b)

(a)



(b)

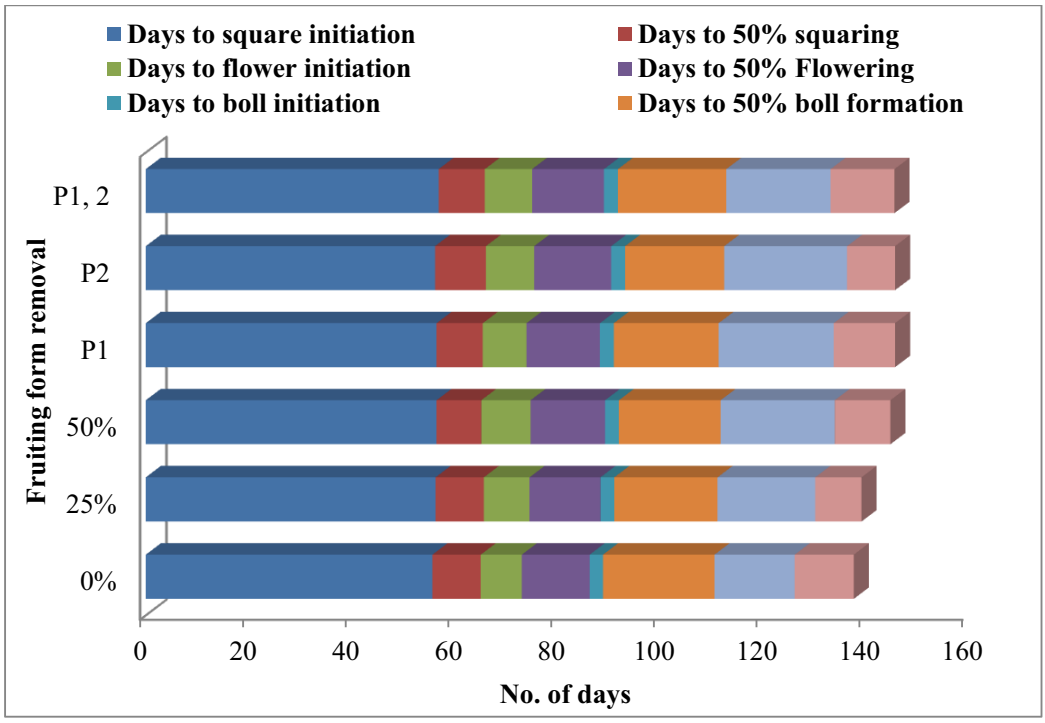


Fig 4.8: Phenological parameters of different hybrids as affected by fruiting form removal treatments during 2011 (a) and 2012 (b)

These results showed that cotton had a compensation ability for the removal of fruiting forms but they requires enough time to develop new squares or flowers which is the cause of late initiation of boll opening. The interaction between hybrids and fruiting form removal treatments were statistically not significant during both the years.

4.1.17 Days Taken to 50% Boll Opening

No significant effect was observed among hybrids for days taken to 50 % boll opening during both the crop growth seasons (Table 4.14 and Fig. 4.7). Hybrids took 141-143 days and 142-143 days to complete 50% boll opening during 2011 and 2012 respectively.

Data scrutinized from Table 4.14 and Fig. 4.8 depict that all the fruiting form removal treatments took significantly more number of days (143-144) during 2011 and (144-145) during 2012 as compared to 0 % square removal treatment to achieve 50 % boll opening. Among the treatments where fruits were retained at first (P1), second (P2) and at both first and second (P1, 2) position took similar number of days i.e. 144 and 145 during 2011 and 2012, respectively to reach 50 % boll opening and was statistically at par with 25 and 50 % square removal treatments. The treatment where 25 and 50 % squares were removed took 138 and 143 days respectively, during 2011 and 139 and 144 days respectively, during 2012 to reach 50 % boll opening stage. The delay in days to reach 50 % boll opening in 25 and 50 % square removal treatments as compared to 0 % square removal treatment, might be due to the removal of fruiting forms that elicit many morphological and physiological responses like increase in plant growth and rate of photosynthesis. The removal of fruiting bodies which were the potential sinks at the earlier stages stimulated assimilate translocation towards the vegetative parts like stem, branches and leaves. Thereafter, remobilization of assimilates occurred at later stages of crop growth from vegetative parts to new fruiting forms developed in place of the earlier removed because cotton crop has a compensation ability to form new fruiting forms if floral parts are shed or removed. The delay in harvest of cotton is due to its compensation ability which requires time to develop new fruiting forms. Gore *et al* (2000) and Stewart *et al* (2001) also concluded that heavy fruit loss significantly delayed crop maturity. Among the site specific fruit positioning treatments, no compensation for fruiting forms took place as the fruiting bodies were retained at specific positions throughout the growing season. The delay in 50 % boll opening might be due to prolonged vegetative period as a result of removing the fruiting forms from different positions which remobilized assimilates towards the vegetative parts resulting vigorous plant growth as evident from taller plants (Table 4.1) and higher accumulation of dry matter in stem, branches and leaves (Table 4.3 to 4.6).

The interaction between hybrids and fruiting form removal treatments were not statistically significant during both the years.

4.1.18 Monopodial Branches per Plant

Monopodial branches are the vegetative branches which arise from the lower nodes of plant. As evident from the data (Table 4.15) hybrids did not differ significantly for the number of monopodial branches plant^{-1}. Hybrids MRC 7017, MRC 7031 and RCH 314 produced 3.86, 3.72 and 3.68 monopods plant^{-1}, respectively during 2011 and 4.39, 4.29 and 4.17 monopods plant^{-1}, respectively during 2012. It was due to the reason that these three hybrids have same morphological behaviour to produce monopodial branches plant^{-1} which is attributed to their similar genetic make up. Heitholt *et al* (1996) and Brar (1997) also reported that similar genetic make up of hybrids resulted in almost same number of monopodial branches plant^{-1}.

Fruiting form removal treatments also failed to influence the number of monopodial branches significantly in any of the two years because these treatments were applied at 55 DAS, where as the monopodial branches arise from the lower nodes of the plant during the earlier growth period of the crop. This is in conformity with the findings of Gill (1997). No interaction was observed for the monopodial branches plant^{-1} during both years.

4.1.19 Sympodial Branches per Plant

Sympodial branches arise from monopodial branches and bear reproductive structures. Data presented in Table 4.15 indicate that hybrids differ significantly for the number of sympodial branches plant^{-1}. Hybrid MRC 7017 produced 24.2 and 29.2 number of sympodial branches plant^{-1} and was significantly superior to the hybrid RCH 314 which produced 22.1 and 26.3 number of sympodial branches plant^{-1} in 2011 and 2012, respectively. Hybrid MRC 7031 produced 23.3 number of sympodial branches plant^{-1} during 2011 and it was statistically at par with both MRC 7017 and RCH 314. Whereas, during 2012, hybrid MRC 7031 produced 28.6 number of sympodial branches plant^{-1} and it was statistically at par with MRC 7017 but proved to be significantly better than RCH 314. The variation in number of sympodial branches plant^{-1} recorded by different cotton hybrids could be attributed to their respective genetic constitution.

Fruiting form removal treatments exhibited a significant effect on sympodial branches plant^{-1} during both the crop growth seasons (Table 4.15). Maximum number of sympodial branches plant^{-1} (24.0) were recorded, where fruits were retained at position first (P1) during 2011. However, during the crop growth season of 2012, maximum number of sympodial branches plant^{-1} (29.3) were recorded in the treatment where fruits were retained at second position (P2).

Table 4.15: Effect of *Bt* cotton hybrids and fruiting form removal treatments on monopodial and sympodial branches per plant

Treatment	Monopodial branches plant^{-1}		Sympodial branches plant^{-1}	
	2011	2012	2011	2012
Hybrids				
MRC 7017	3.86 a	4.39 a	24.2 a	29.2 a
MRC 7031	3.72 a	4.29 a	23.3 ba	28.6 a
RCH 314	3.68 a	4.17 a	22.1 b	26.3 b
SEm	**0.13**	**0.11**	**0.47**	**0.64**
F(p)	**0.35**	**0.23**	**0.88**	**0.006**
Fruiting form removal				
0%	3.54 a	4.17 a	21.7 b	29.9 b
25%	3.55 a	4.19 a	22.6 ba	27.3 ba
50%	3.74 a	4.14 a	23.6 a	27.6 ba
P1 (Retain at 1st position)	3.95 a	4.53 a	23.9 a	28.7 ba
P2 (Retain at 2nd position)	3.90 a	4.30 a	23.7 a	29.4 a
P1, 2 (Retain at 1st and 2nd position)	3.80 a	4.36 a	23.6 a	28.2 ba
SEm	**0.13**	**0.13**	**0.59**	**0.69**
F(p)	**0.09**	**0.29**	**0.09**	**0.12**
Interaction F(p)	**0.99**	**0.99**	**1.00**	**0.99**

The treatments P1 and P2 were statistically at par with each other and were also statistically at par with other fruiting form removal treatments except the treatment where no square was removed for the number of sympodial branches plant^{-1} during both the years. Whereas, the treatments P1 and P2 proved significantly superior than 0 % square removal treatment by producing 9.6 and 8.7 per cent more sympodial branches plant^{-1}, respectively during 2011 and 6.7 and 9.3 per cent respectively during 2012 over 0 % square removal treatment. The higher number of sympodial branches plant^{-1} in P1 and P2 were due to the better growth and development of plants as evident from higher plant height (Table 4.1), higher LAI (Table 4.2) and DMA in stem, branches and leaves (Table 4.3 to 4.6). All the interaction effects were non significant for the sympodial branches plant^{-1} during both years.

4.1.20 Flowers per Plant

Flowers are the reproductive parts which develop into bolls and ultimately contribute to the seed cotton yield. The number of flowers produced plant^{-1} differed significantly among the hybrids during both the years (Table 4.16 and Fig. 4.9). Hybrid MRC 7017 produced maximum number of flowers plant^{-1} (95.6 and 124.0) and was statistically at par with hybrid MRC 7031 which produced 92.4 and 118.9 flowers plant^{-1} but was significantly higher than RCH 314 (87.4 and 112.1) during 2011 and 2012, respectively. Higher number of flowers plant^{-1} produced in MRC 7017 was due to its higher genetic potential as evident from better growth and development of plants which resulted in higher sympodial branches plant^{-1} (Table 4.15) on which fruiting bodies develop. Wankhade *et al* (1992) and Deol (1995) reported that different cultivars performed differently in respect to growth and development due to their different genetic make up.

Fruiting form removal treatments differed significantly for the number of flowers produced plant^{-1}. As evident from data presented in Table 4.16 and illustrated in Fig. 4.10, maximum number of flowers plant^{-1} were observed in treatments where 0 and 25 % squares were removed (123.4 and 123.6) respectively, during 2011 and (157.2 and 152.5) respectively, during 2012 and both the treatments were statistically at par with each other during both the years. Whereas, 0 and 25 % square removal treatments produced significantly higher number of flowers as compared to 50 % square removal treatment and with the crop in which fruiting bodies were retained at specific fruiting positions (P1, P2 and P1, 2) during both the years. The number of flowers decreased significantly when fruiting forms were removed for longer duration i.e. in P1, P2 and P1, 2 as compared to 0, 25 and 50 % square removal treatments.

Table 4.16: Effect of *Bt* cotton hybrids and fruiting form removal treatments on total flowers per plant and setting percentage

Treatment	Total Flowers plant^{-1}		Setting %age	
	2011	2012	2011	2012
Hybrids				
MRC 7017	95.6 a	124.0 a	46.1 a	50.8 a
MRC 7031	92.4 ba	118.9 ba	45.9 a	50.6 a
RCH 314	87.4 b	112.1 b	44.9 a	49.6 a
SEm	**1.71**	**2.46**	**1.63**	**2.12**
F(p)	**0.0007**	**0.0003**	**0.74**	**0.76**
Fruiting form removal				
0%	123.4 a	157.2 a	40.3 c	43.3 b
25%	123.6 a	152.5 a	40.7 c	43.5 b
50%	112.3 b	141.0 b	41.5 c	44.2 b
P1 (Retain at 1st position)	56.0 d	81.9 d	54.2 a	59.0 a
P2 (Retain at 2nd position)	53.7 d	79.8 d	46.8 b	55.3 a
P1, 2 (Retain at 1st and 2nd position)	81.9 c	97.6 c	50.3 ba	57.1 a
SEm	**2.01**	**2.72**	**1.62**	**1.74**
F(p)	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**
Interaction F(p)	**0.99**	**0.98**	**0.99**	**1.00**

However, among the site specific fruit retaining treatments, maximum number of flowers 81.9 and 97.6 were produced where fruiting bodies were retained at both first and second position (P1, 2) which was significantly higher than P1 and P2 during 2011 and 2012, respectively. The higher number of flowers plant^{-1} produced in P1, 2 might be due to the fact that fruits were retained at both first and second position, while in treatment P1 fruiting forms were retained at single position i.e. at first and similarly in treatment P2 fruiting forms were retained at single position but at second fruiting position of all the sympodial branches, with the result that P1, 2 contributing more number of flowers plant^{-1}. Least number of flowers were produced in P2 (53.7 and 79.8) which were statistically at par with P1 with flower count of 56.0 and 81.9 during 2011 and 2012, respectively.

These results reveal that number of flowers decreased in almost all fruiting form removal treatments than 0 and 25 % square removal treatments during both the crop growth seasons. It clearly indicates that removal of squares upto a certain extent resulted in higher number of flowers. It might be due to the production of replacement fruit for the fruit loss earlier as cotton has the compensation ability to produce more fruiting forms because of its indeterminate growth habit. Though, compensation for the fruiting bodies depends on the removal time and amount, as 50 % square removal treatment did not compensate for the fruiting bodies, which were removed earlier and produced significantly lower number of flowers plant^{-1} than 0 and 25 % square removal treatments. The findings are in accordance with those of Brown *et al* (2000), Gore *et al* (2000), and Abaye *et al* (2000) who reported that extremely heavy fruit damage of squares or flowers greatly reduced the total number of flowers plant^{-1}. No interaction was observed for the number of flowers plant^{-1} during both the years.

4.1.21 Setting Percentage

Setting percentage is one of the important parameters which determines the seed cotton yield. In a crop like cotton higher setting percentage of bolls means more economic yield per unit biomass. Data presented in Table 4.16 reveal that hybrids had no significant effect on the setting percentage during both the years.

Fruiting form removal treatments had a significant effect on setting percentage during both the years. Maximum setting percentage of 54.2 and 59.0 was registered in the crop where fruits were retained at position one (P1) during 2011 and 2012, respectively, and it was statistically at par with the crop where fruits were retained at both first and second position (P1, 2) during 2011. Whereas, during 2012, P1 statistically at par with the crop where fruits were retained at second fruiting position (P2) and at both first and second position (P1, 2). Square removal treatments where, 0, 25 and 50 % squares were removed recorded

significantly lower setting percentage of 40.3, 40.7 and 41.5, respectively, during 2011 and 43.3, 43.5 and 44.2, respectively, during 2012 as compared to P1, P2 and P1, 2. The significant improvement in the setting percentage with retaining of fruits at different positions *viz*. P1, P2 and P1, 2 might be due to better partitioning of assimilates towards the vegetative parts *viz*. stem, branches and leaves which resulted in more dry matter into these plant parts as evident from Table 4.3 to 4.6. Later on reproductive stage begun and the assimilates were reallocated towards the existing fruiting bodies at specific positions thereby exerting a favorable effect on retention of fruiting bodies by preventing their abscission. The interaction effects between cotton hybrids and fruiting form removal treatments were non significant during both the years.

4.1.22 Total Bolls per Plant

Total number of bolls plant^{-1} is an important parameter influencing yield. As shown in Table 4.17 and Fig. 4.9, hybrids differed significantly for total number of bolls plant^{-1}. MRC 7017 recorded maximum number of bolls plant^{-1} (42.7 and 60.3) and was statistically at par with MRC 7031 which produced 40.7 and 57.6 number of bolls plant^{-1} during 2011 and 2012, respectively. However, hybrid MRC 7031 was statistically at par with hybrid MRC 7017 for total number of bolls plant^{-1} and it was also statistically at par with hybrid RCH 314 which attained lowest number of total bolls plant^{-1} (37.8 and 53.5) during 2011 and 2012, respectively.

The production of higher number of total bolls plant^{-1} in hybrid MRC 7017 was due to the better growth and development of plants as a consequence of which higher number of sympodial branches bearing reproductive parts developed and this resulted in more number of flowers plant^{-1} (Table 4.16). The differences for the number of bolls plant^{-1} in *Bt* cotton hybrids had also been reported by Srinivasan (2006).

Fruiting form removal treatments had a significant effect on total bolls plant^{-1} (Table 4.17 and Fig. 4.10). Maximum number of total bolls plant^{-1} (50.3) were produced in treatment where 25 % squares were removed during 2011 which was statistically at par with the treatment where no square was removed (0 %) with 49.7 bolls plant^{-1} but produced significantly higher number of bolls plant^{-1} than all other fruiting form removal treatments. Whereas during 2012, maximum number of total bolls plant^{-1} was recorded in treatment where 0 % squares were removed (67.9) which was significantly higher than all other fruiting form removal treatments except the treatment where 25 % squares were removed. The treatment where 50 % squares were removed recorded significantly lower number of total bolls plant^{-1} than both 0 and 25 % square removal treatments but it was able to produce significantly higher number of total bolls than P1, P2 and P1, 2 during 2011 and 2012, respectively. The

results for the removal of squares emphasized that transgenic cotton has the ability to tolerate at least modest levels of square loss. Gore *et al* (2000) and Abaye *et al* (2000) also reported that extremely heavy fruit damage greatly reduced the boll number. Wu *et al* (2007) also confirmed that compensation capacity of cotton for square removal may depend on the removal time and amount of square removal.

Treatments where fruiting bodies were retained at specific fruit positioning sites (P1, P2 and P1, 2) produced significantly lower number of total bolls plant^{-1} as compared to 0, 25 and 50 % square removal treatments during both the years. This decrease in number of total bolls plant^{-1} in specific fruit position retaining treatments was due to less number of flower production (Table 4.16) which was as a result of continuous removal of fruiting forms upto 50 % boll open initiation stage. The treatment where fruiting bodies were retained at first position (P1) produced significantly more number of bolls plant^{-1} (29.9 and 48.1) as compared to P2 (24.9 and 43.3) during 2011 and 2012, respectively. It indicates that first position (P1) has a higher retaining capacity as it is the dominant carbohydrate sink on sympodia as compared to the second position (P2). The treatment in which fruits were retained at both first and second fruiting position (P1, 2) produced significantly higher number of bolls plant^{-1} (41.0 and 55.3) than P1 and P2 during 2011 and 2012, respectively. The production of higher bolls in P1, 2 as compared to P1 and P2 was might be because of less removal of fruiting forms than P1 and P2 which resulted in higher production of flowers plant^{-1}. No interaction was observed for the total number of bolls plant^{-1} during both the years.

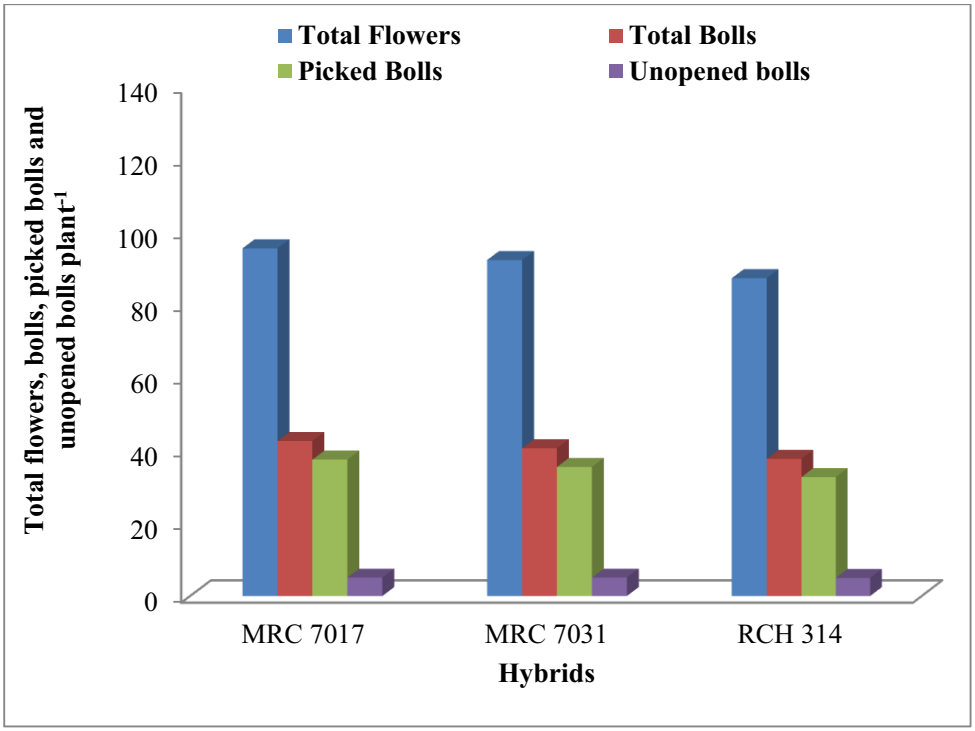
4.1.23 Picked Bolls per Plant

The most important character which directly contributes towards seed cotton yield is the number of picked or opened bolls plant^{-1}. As evident from the data presented in Table 4.17 and Fig. 4.9, hybrid MRC 7017 produced maximum number of picked bolls plant^{-1} as compared to other *Bt* hybrids during both the crop growth seasons. During 2011, hybrid MRC 7017 produced maximum number of picked bolls plant^{-1} (37.6) and it was statistically at par with hybrid MRC 7031 which produced 35.6 picked bolls plant^{-1}. Whereas, hybrid RCH 314 produced significantly lower number of picked bolls plant^{-1} (32.8) than MRC 7017 but it was statistically at par with hybrid MRC 7031. During 2012, hybrid MRC 7017 produced highest number of picked bolls plant^{-1} (52.9) followed by MRC 7031 (50.6) and both the hybrids were statistically at par with each other but produced significantly higher number of picked bolls plant^{-1} than RCH 314 (46.8). The difference in picked bolls plant^{-1} was due to the higher number of sympodial branches, total flowers and total bolls plant^{-1} in MRC 7017. The difference in picked bolls plant^{-1} among the *Bt* cotton hybrids had also been observed by Nehra *et al* (2004).

Table 4.17: Total bolls, picked bolls, unopenend bolls per plant and boll opening percentage of different *Bt* cotton hybrids as influenced by fruiting form removal treatments

Treatment	Total Bolls		Picked Bolls		Unopened bolls		Boll opening %age	
	2011	2012	2011	2012	2011	2012	2011	2012
Hybrids								
MRC 7017	42.7 a	60.3 a	37.6 a	52.9 a	5.07 a	7.40 a	88.2 a	88.1 a
MRC 7031	40.7 ba	57.6 ba	35.6 ba	50.6 a	5.07 a	6.94 a	87.5 a	88.2 a
RCH 314	37.8 b	53.5 b	32.8 b	46.8 b	4.98 a	6.73 a	86.7 a	87.6 a
SEm	**1.07**	**1.20**	**0.91**	**1.01**	**0.23**	**0.26**	**1.08**	**1.55**
F(p)	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**0.91**	**0.08**	**0.67**	**0.94**
Fruiting form removal								
0%	49.7 a	67.9 a	43.0 ba	58.7 a	6.68 a	9.17 a	86.4 a	86.8 a
25%	50.3 a	66.1 a	44.3 a	57.5 a	6.04 ba	8.67 a	88.0 a	87.1 a
50%	46.5 b	62.2 b	41.0 b	54.6 b	5.48 bc	7.65 b	88.3 a	87.9 a
P1 (Retain at 1st position)	29.9 d	48.1 d	26.6 d	43.2 d	3.24 d	4.85 d	89.0 a	89.7 a
P2 (Retain at 2nd position)	24.9 e	43.3 e	21.3 e	38.0 e	3.55 d	5.33 d	85.9 a	88.0 a
P1, 2 (Retain at 1st and 2nd position)	41.0 c	55.3 c	35.8 c	48.9 c	5.27 c	6.46 c	87.2 a	88.1 a
SEm	**0.97**	**1.27**	**0.96**	**0.99**	**0.25**	**0.29**	**1.74**	**1.94**
F(p)	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**0.80**	**0.92**
Interaction F(p)	**0.99**	**0.99**	**0.99**	**0.99**	**0.92**	**0.97**	**1.00**	**1.00**

(a)



(b)

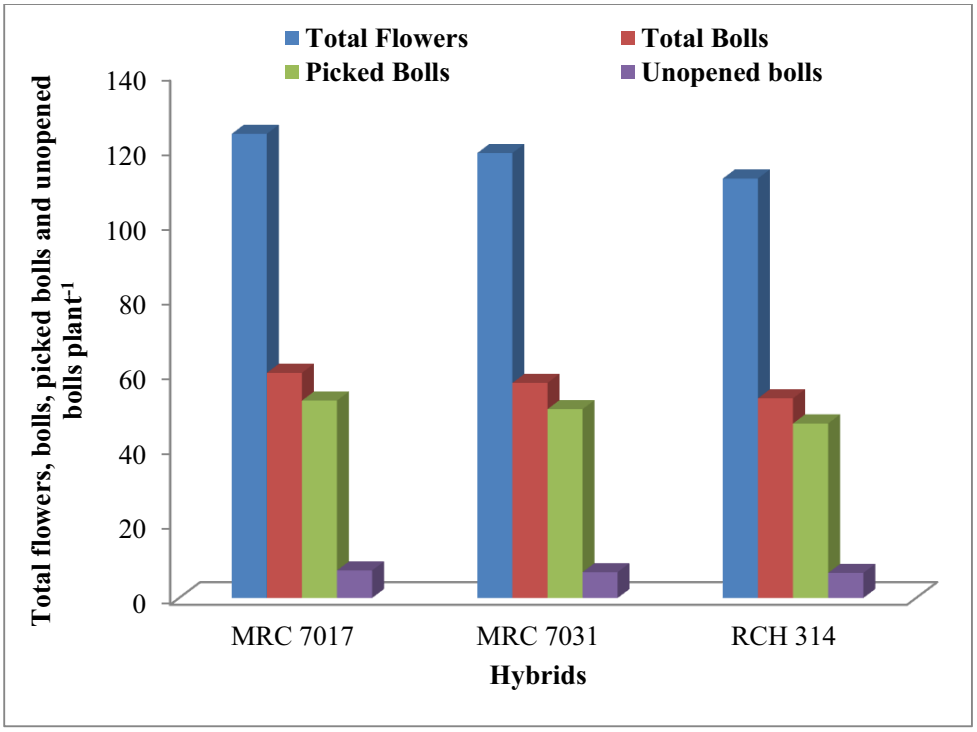
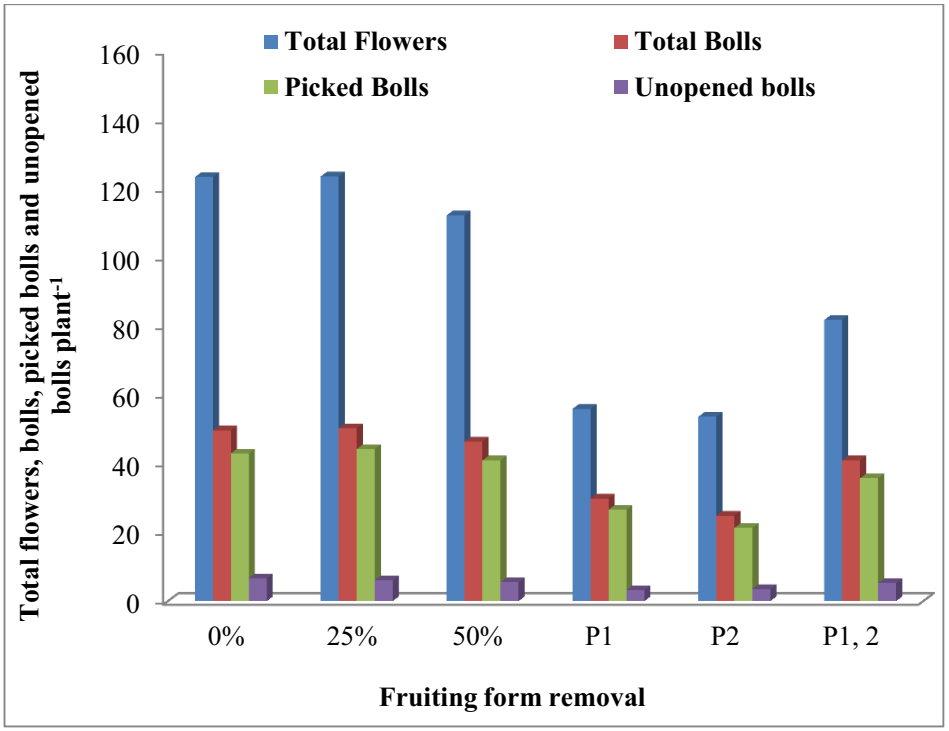


Fig 4.9: Total number of flowers, bolls, picked bolls and unopened bolls per plant as affected by hybrids during 2011 (a) and 2012 (b)

(a)



(b)

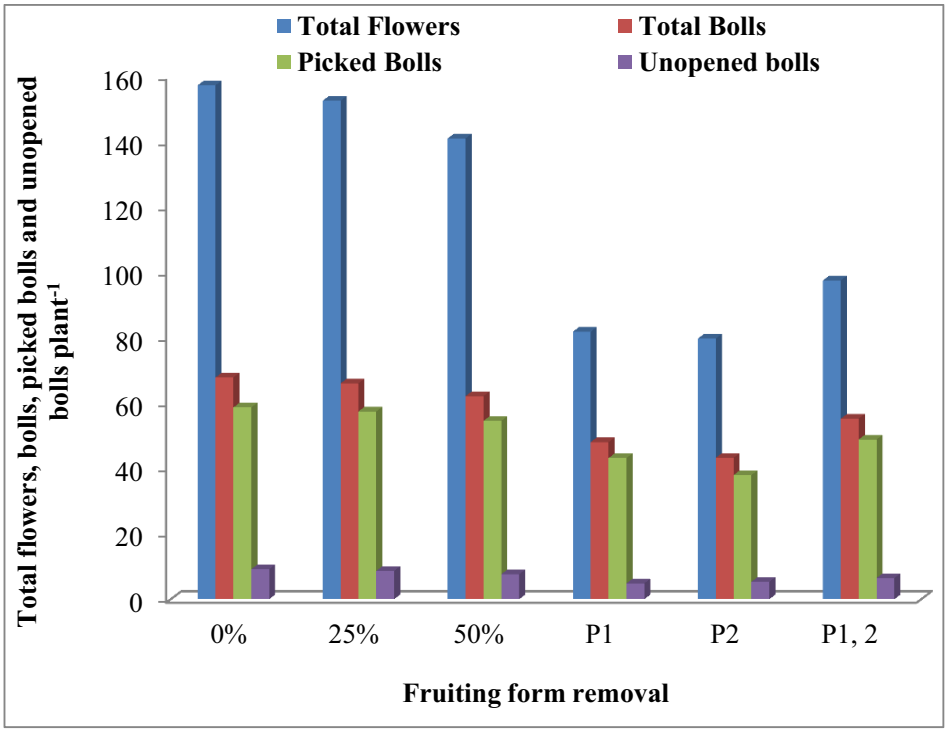


Fig 4.10: Total number of flowers, bolls, picked bolls and unopened bolls per plant of different hybrids as affected by fruiting form removal treatments during 2011 (a) and 2012 (b)

Data presented in Table 4.17 and illustrated in Fig. 4.10 depict that fruiting form removal treatments had a significant effect on picked bolls plant^{-1} during both the years. During 2011, 25 % square removal treatment produced significantly higher number of picked bolls plant^{-1} (44.3) as compared to all other fruiting form removal treatments but was statistically at par with 0 % square removal treatment. Treatment where 50 % squares were removed for a period of one month produced 41.0 picked bolls plant^{-1} and it was statistically at par with 0 % removal treatment during 2011. However, a different trend was observed during 2012 than the crop growth season of 2011, where maximum number of picked bolls (58.7) were observed in 0 % square removal treatment and it was statistically at par with 25 % square removal treatment which produced 57.5 picked bolls plant^{-1}. Whereas, both 0 and 25 % square removal treatments proved to be significantly higher for the production of picked bolls plant^{-1} than 50 % square removal treatment and the treatments where fruits were retained at first (P1), second (P2) and both first and second (P1, 2) positions.

Less production of picked bolls plant^{-1} in 50 % square removal treatment and in treatments where fruiting forms were removed from all positions, except first (P1), second (P2) and both first and second (P1, 2) positions as compared to 0 and 25 % square removal treatments might be due to the removal of fruiting forms at higher rates. The maximum removal of fruiting forms in 50 %, P1, P2 and P1,2 treatments resulted in less number of total flowers and bolls plant^{-1} which eventually resulted in less picked bolls plant^{-1}. These results indicate that square removal upto a certain extent can be compensated for the picked bolls plant^{-1} whereas, when higher percentage of squares are removed cotton plant cannot compensate for the picked bolls plant^{-1}.

Among the site specific fruit retention treatments, P1, 2 produced significantly more picked bolls plant^{-1} (35.8 and 48.9) during 2011 and 2012, than P1 and P2. However, P1 produced 26.6 and 43.2 picked bolls plant^{-1} which was significantly more than P2 which produced 21.3 and 38.0 picked bolls plant^{-1} during 2011 and 2012, respectively. The significantly more number of picked bolls at P1 rather than P2 emphasize that the boll retention at the first position (P1) was higher than boll retention at second position (P2). Heitholt (1997) also reported that the removal of fruiting forms from proximal or distal fruiting form positions produced greater percentage of bolls at first position (P1) as compared to second position (P2). The increase in picked bolls plant^{-1} at P1 as compared to P2 was due to the production of higher number of flowers and total bolls plant^{-1} which is obvious from Tables 4.16 and 4.17, respectively. The interaction between hybrids and fruiting form removal treatments was non significant during both years.

4.1.24 Unopened Bolls per Plant

As evident from the data presented in Table 4.17 and Fig. 4.9 and 4.10, hybrids MRC 7017, MRC 7031 and RCH 314 did not differ significantly for the number of unopened bolls

plant^{-1}. Whereas, fruiting form removal treatments had a significant effect on unopened bolls plant^{-1} and the least number of unopened bolls plant^{-1} (3.24 and 4.85) were observed in the treatment where fruits were retained at first position (P1) as compared to all other fruiting form removal treatments but it was statistically at par with the treatment where fruits were retained at second position (P2) during 2011 and 2012, respectively. The maximum number of unopened bolls plant^{-1} was obtained in 0 % square removal treatment (6.68 and 9.17) and it was statistically at par with 25 % square removal treatment which recorded 6.04 and 8.67 unopened bolls plant^{-1} during 2011 and 2012, respectively. The unopened bolls plant^{-1} recorded in 0 and 25 % square removal treatments were however, significantly higher than 50 %, P1, P2 and P1, 2 treatments where fruiting forms were removed at higher rates. Moreover, 0 and 25 % square removal treatments produced higher number of flowers plant^{-1} (Table 4.16), total bolls and picked bolls plant^{-1} (Tables 4.17). Decrease in number of unopened bolls plant^{-1} with higher removal of fruiting forms was due to remobilization of assimilates which normally are incorporated into these missing reproductive structures towards the vegetative parts of the plant and increased chlorophyll content (Table 4.12). The higher chlorophyll content resulted in higher photosynthetic rate, leading to more allocation of assimilates towards the existing fruiting bodies at later stages of crop growth thereby reducing the number of unopened bolls plant^{-1} by improving the source-sink relationship. There was no interaction between hybrids and fruiting form removal treatments during both the years.

4.1.25 Boll Opening Percentage

The effect of different hybrids and fruiting form removal treatments on boll opening percentage was non significant during both the years (Table 4.17). All the interaction effects between hybrids and fruiting form removal treatments were also non significant during both the years.

4.1.26 Boll Weight

The weight of seed cotton in each boll has a direct influence on the total seed cotton yield. A perusal of data presented in Table 4.18 reveal that hybrids did not differ significantly for boll weight. The relatively higher boll weight (3.28 and 3.81 g) was obtained in hybrid MRC 7017 than MRC 7031 and RCH 314 but it did not attain the level of significance during 2011 and 2012, respectively. The statistically similar boll weight of the hybrids might be due to the similar genetic potential. It is evident from the allocation of similar amount of assimilates to the bolls which in turn produced same amount of lint and seeds in each boll as manifested through non significant variations in lint and seed indices (Table 4.20). Fruiting form removal treatments differed significantly for boll weight during both the years (Table 4.18). Maximum boll weight was observed in treatment where fruiting bodies were retained at first position i.e. P1 (3.43 and 4.05 g) which was statistically at par with the treatments where fruiting bodies were retained at second positions i.e. P2 with boll weight of 3.33 and 3.84 g

and also with P1, 2 which recorded boll weight of 3.24 and 3.80 g, during 2011 and 2012, respectively.

Table 4.18: Effect of *Bt* cotton hybrids and fruiting form removal on boll weight (g)

Treatment	Boll weight (g)	
	2011	**2012**
Hybrids		
MRC 7017	3.28 a	3.81 a
MRC 7031	3.26 a	3.76 a
RCH 314	3.15 a	3.73 a
SEm	**0.10**	**0.07**
F(p)	**0.00**	**0.74**
Fruiting form removal		
0%	3.08 b	3.62 b
25%	3.11 b	3.63 b
50%	3.19 ba	3.68 b
P1 (Retain at 1st position)	3.43 a	4.05 a
P2 (Retain at 2nd position)	3.33 ba	3.84 ba
P1, 2 (Retain at 1st and 2nd position)	3.24 ba	3.80 ba
SEm	**0.08**	**0.09**
F(p)	**0.03**	**0.02**
Interaction F(p)	**0.99**	**1.00**

While, in 2011 treatment P1 was also statistically at par with 50 % square removal treatment for boll weight. The minimum amount of weight in bolls was recorded where 0 % squares were removed i.e. 3.08 and 3.62 g during 2011 and 2012, respectively.

However, it was statistically at par with the fruiting form removal treatments where 25 and 50 % squares were removed and also with the treatments where fruiting forms were removed from all positions except second (P2) and both first and second (P1, 2) positions during both the years. The increase in boll weight in P1 treatment as compared 0 % square removal treatment was due to the better growth and development of plants which was attributed to the translocation of assimilates towards leaves, stem and branches as a consequence of fruiting form removal. The assimilates which were earlier translocated to vegetative parts instead of fruiting bodies due to the removal of fruiting bodies were remobilized towards the existing fruits on first (P1) position. Bednarz *et al* (2006) also

observed that superior fruiting positions in terms of overall quality occur at first positions which are also known as inner fruiting positions. Increased boll size in response to fruiting form was also reported by Pettigrew (1994). The interactive effect of hybrids with fruiting form removal treatments was non significant during both the years.

4.1.27 Seed Cotton Yield of First Pick

Yield is the ultimate result of the interaction of various factors and is a valid criterion for comparing the efficiency of different treatments. *Bt* cotton hybrids differed significantly for the seed cotton yield harvested in first picking (Table 4.19 and Fig. 4.11). MRC 7017 gave maximum seed cotton yield (9.06 and 8.36 q ha^{-1}) and was statistically at par with MRC 7031 but significantly higher than RCH 314 during 2011 and 2012, respectively. Higher seed cotton yield in MRC 7017 and MRC 7031 might be attributed to better growth and development due to their higher genetic potential as evident from higher plant height, dry matter accumulation in fruiting bodies which resulted in increased number of sympodial branches $plant^{-1}$ (Table 4.15), total flowers $plant^{-1}$ (Table 4.16), total bolls and picked bolls $plant^{-1}$ (Table 4.17).

Data presented in Table 4.19 and depicted in Fig. 4.12 reveal that fruiting form removal treatments had a significant effect on the seed cotton yield of first picking during both the years. During crop growth season of 2011, maximum seed cotton yield was obtained in 25 % square removal treatment (11.17 q ha^{-1}) as compared to all other fruiting form removal treatments, while during 2012, maximum seed cotton was obtained in 0 % square removal treatment (10.32 q ha^{-1}) as compared to all other fruiting form removal treatments and both 0 and 25 % square removal treatments were statistically at par with each other for seed cotton yield during both the years. The crop where 50 % squares were removed for a period of one month and the crop in which fruiting forms were removed from specific positions (P1, P2 and P1, 2) yielded significantly lower seed cotton than 0 and 25 % square removal treatments during both the years. Perusal of data further reveal that removal of fruiting forms upto 25 % easily compensate for the seed cotton yield whereas, 50 % square removal cannot compensate for the seed cotton yield at first picking. It might be due to the fact that, cotton has an indeterminate plant and its vegetative growth continues even after flower initiation and continues to produce fruits as long as season persists (Brown *et al* 2001). The indeterminate growth pattern of cotton enables it to withstand the loss of many fruiting structures without significant reductions in yield but the removal of fruiting forms at higher amount cannot be compensated. The development of compensation fruiting forms at the expense of old fruiting forms requires sufficient time to develop and when the removal was higher, plant was not able to develop same number of fruiting bodies as were removed earlier resulting in less fruiting bodies. Gore *et al* (2000) and Abaye *et al* (2000) also observed that extremely heavy fruit damage greatly reduce the seed cotton yield.

Among the treatments where fruiting bodies were retained at specific sites during both the years, the maximum seed cotton yield was recorded where fruiting forms were kept at both first and second position (P1, 2) i.e. 8.21 and 7.46 q ha^{-1} which was significantly higher than the treatments where fruiting bodies were retained at first (P1) and second (P2) position. The data further manifested that productivity of *Bt* cotton increased significantly when the fruiting bodies retained at P1 as compared to P2. However, in both P1 and P2 treatments the retaining of fruiting forms was only at single fruiting position of all the sympodial branches though P1 produced significantly higher seed cotton yield by 26.0 and 26.1 per cent over P2 during 2011 and 2012, respectively, it was due to less shedding of bolls at first fruiting position as compared to second fruiting position as evident from higher retaining of total bolls and picked bolls $plant^{-1}$ (Table 4.17) in P1 treatment. Jenkins *et al* (1990) also observed that bolls at position one on sympodial branches produced more total yield than those at position two and all other positions on sympodial branches. The interactive effect of different hybrids with fruiting form removal treatments was non significant during both the years.

4.1.28 Seed Cotton Yield of Second Pick

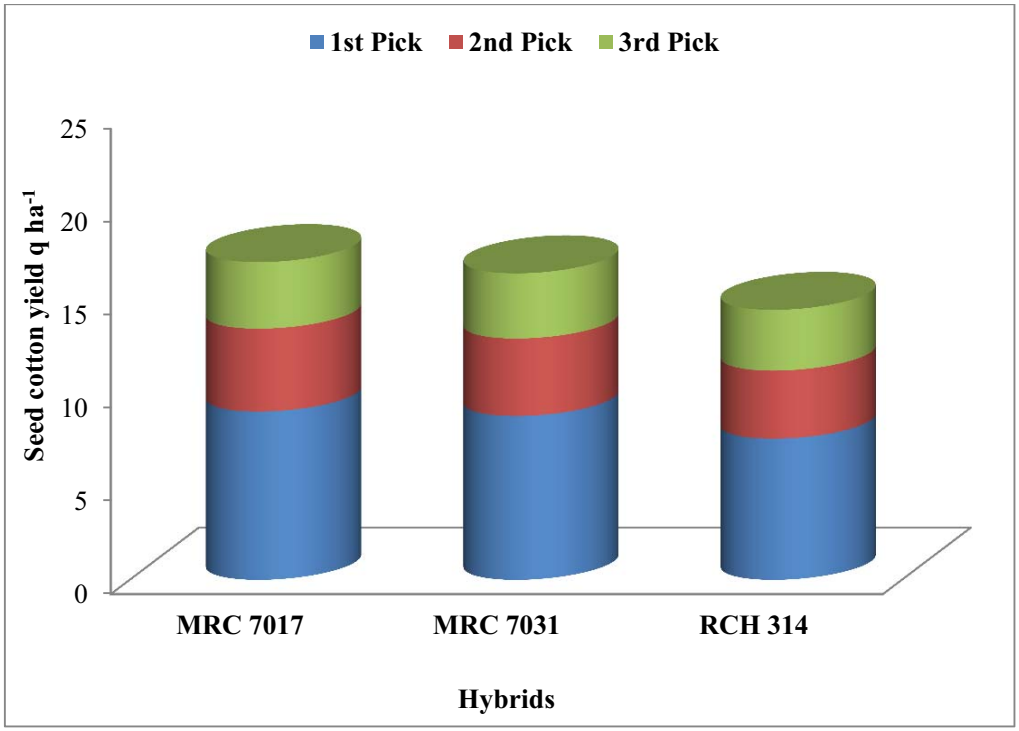
Data presented in Table 4.19 and illustrated in Fig. 4.11 reveal that hybrids differed significantly for seed cotton yield in second picking during both the years. Hybrid MRC 7017 produced maximum seed cotton yield of 4.46 and 6.87 q ha^{-1} and was statistically at par with MRC 7031 which produced 4.17 and 6.54 q ha^{-1} of seed cotton yield and both produced significantly higher seed cotton yield than RCH 314 during both the years. The higher seed cotton yield of MRC 7017 and MRC 7031 can be explained by the better growth and development as evident from the data on higher plant height and dry matter accumulation for fruiting bodies (Tables 4.3 to 4.6) which attributed to increased number of sympodial branches $plant^{-1}$ (Table 4.15), total flowers $plant^{-1}$ (Table 4.16), total bolls and picked bolls $plant^{-1}$ (Table 4.17).

Fruiting form removal treatments had a significant influence on seed cotton yield obtained from the second picking (Table 4.19 and Fig. 4.12). The maximum seed cotton yield (5.19 q ha^{-1}) was obtained from the treatment where no square was removed (0 %) during 2011 whereas, during 2012 maximum seed cotton yield was recorded in the crop where 50 % squares were removed for a period of one month (8.04 q ha^{-1}). However, all the square removal treatments i.e. 0, 25 and 50 % were statistically at par with each other but significantly better than all other fruiting form removal treatments (P1, P2 and P1, 2) during both the years.

Table 4.19: Effect of fruiting form removal treatments on seed cotton yield (q ha^{-1}) of different *Bt* cotton hybrids

Treatment	Seed cotton yield (q ha^{-1})							
	1st Pick		2nd Pick		3rd Pick		Total	
	2011	2012	2011	2012	2011	2012	2011	2012
Hybrids								
MRC 7017	9.06 a	8.36 a	4.46 a	6.87 a	3.57 a	7.92 a	17.1 a	23.1 a
MRC 7031	8.82 a	8.02 a	4.17 a	6.54 a	3.50 a	7.57 ba	16.4 a	22.1 a
RCH 314	7.60 b	6.96 b	3.66 b	5.58 b	3.27 a	6.88 b	14.5 b	19.4 b
SEm	**0.27**	**0.25**	**0.11**	**0.21**	**0.09**	**0.23**	**0.28**	**0.39**
F(p)	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**0.03**	**0.0003**	**<0.0001**	**<0.0001**
Fruiting form removal								
0%	10.35 a	10.32 a	5.19 a	7.48 a	4.33 a	9.32 a	19.8 a	27.1 a
25%	11.17 a	9.59 a	5.09 a	7.89 a	4.17 ba	9.09 a	20.4 a	26.6 a
50%	9.42 b	8.57 b	4.91 a	8.04 a	3.86 b	8.29 b	18.1 b	24.9 b
P1 (Retain at 1st position)	6.58 d	5.99 d	2.87 c	4.45 c	3.01 c	6.37 c	12.4 d	16.8 d
P2 (Retain at 2nd position)	5.22 e	4.75 e	2.61 c	4.05 c	2.05 d	4.63 d	9.9 e	13.4 e
P1, 2 (Retain at 1st and 2nd position)	8.21 c	7.46 c	3.91 b	6.06 b	3.26 c	7.03 c	15.3 c	20.5 c
SEm	**0.31**	**0.28**	**0.12**	**0.23**	**0.12**	**0.23**	**0.31**	**0.44**
F(p)	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**
Interaction F(p)	**0.85**	**0.84**	**0.72**	**0.79**	**0.99**	**0.94**	**0.81**	**0.95**

(a)



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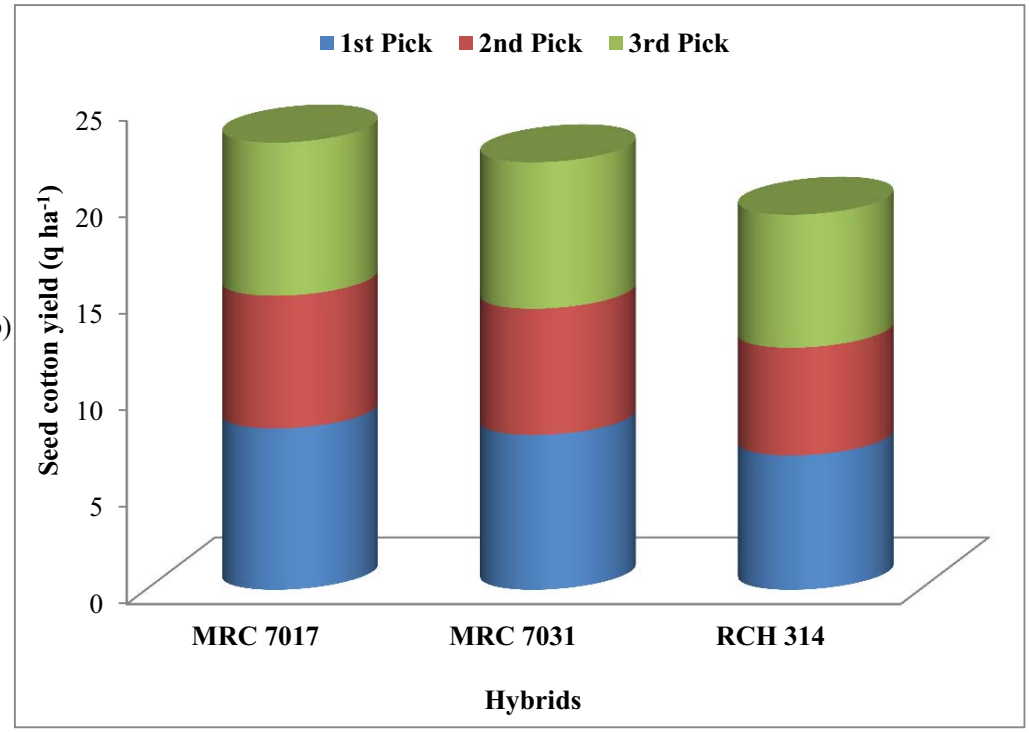
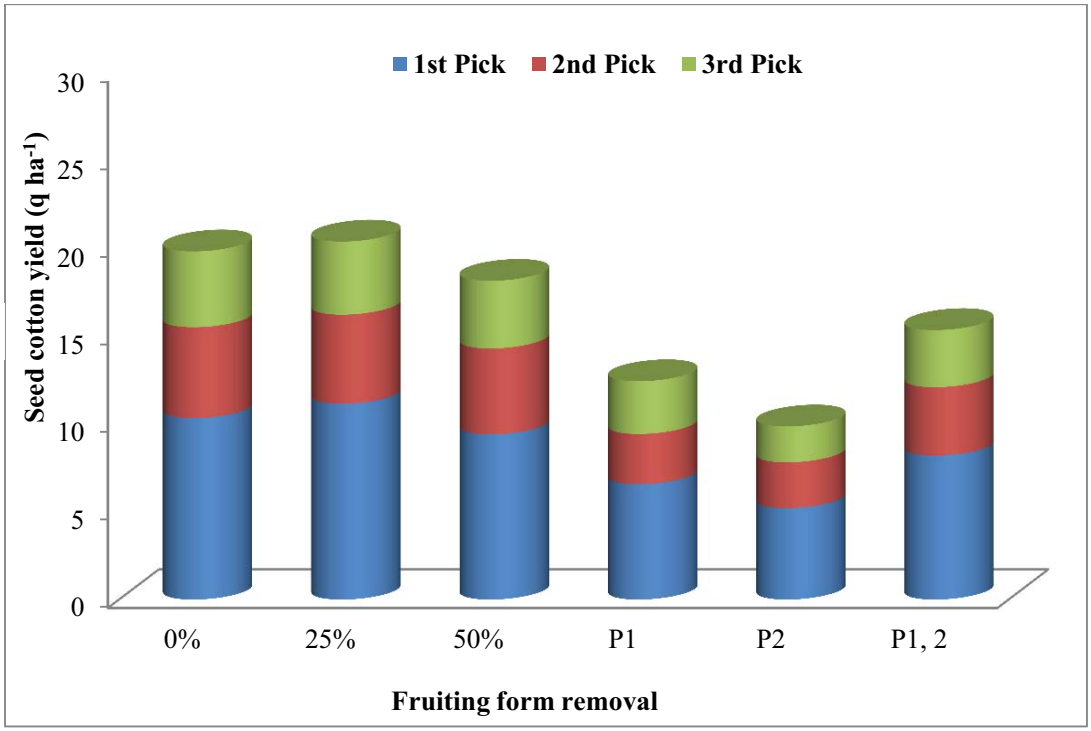


Fig 4.11: Seed cotton yield (q ha^{-1}) of different hybrids during 2011 (a) and 2012 (b)

(a)



(b)

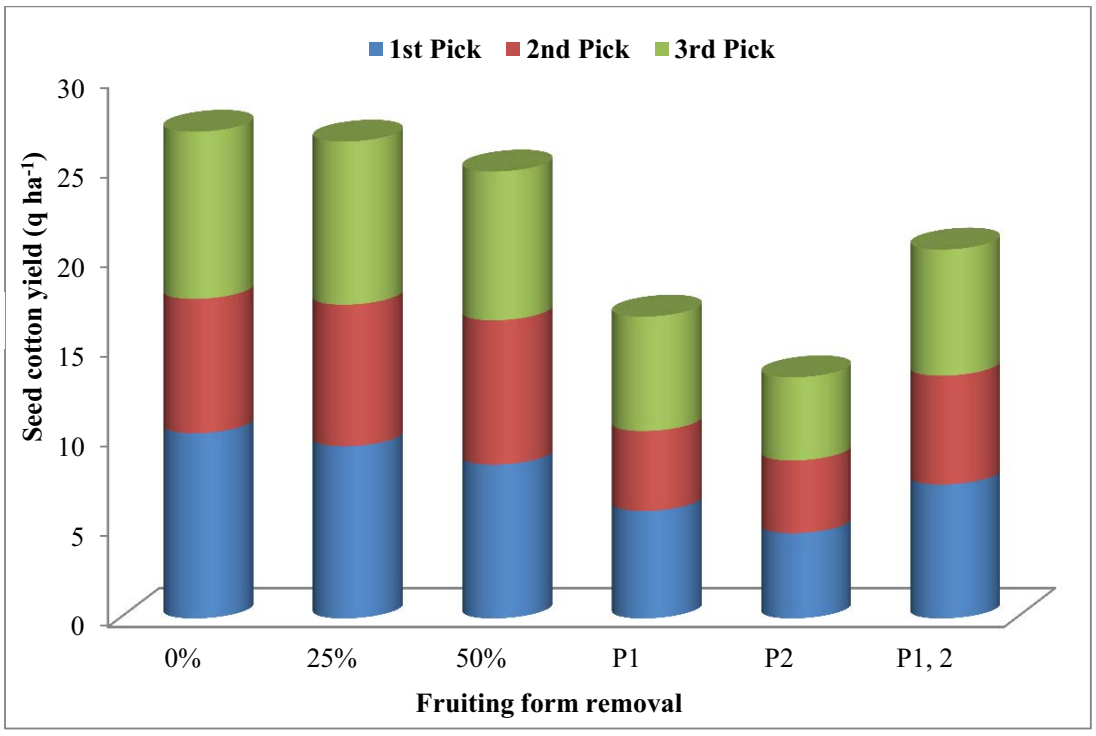


Fig 4.12: Seed cotton yield (q ha^{-1}) of hybrids as affected by fruiting form removal treatments during 2011 (a) and 2012 (b)

For the treatments in which fruits were retained at specific sites, maximum seed cotton yield (3.91 q ha^{-1} and 6.06 q ha^{-1} in 2011 and 2012, respectively) was recorded in P1, 2 where fruiting bodies were retained at first and second position than P1 and P2 but it failed to produce significantly higher seed cotton yield than 0, 25 and 50 % square removal treatments. The data also reveal that seed cotton yield of P1 (2.87 and 4.45 q ha^{-1}) and P2 (2.61 and 4.05 q ha^{-1}) did not differ significantly in second picking during 2011 and 2012, respectively. However, significantly lower seed cotton yield was obtained in P2 as compared to 0 % square removal treatment during 2011 and 2012, respectively. The interaction between hybrids and fruiting form removal treatments was not significant in any of the two years.

4.1.29 Seed Cotton Yield of Third Pick

Hybrids failed to significantly influence the seed cotton yield of third picking during the crop growth season of 2011 (Table 4.19 and Fig. 4.11). Whereas, during 2012, a significant difference was observed for seed cotton yield and highest seed cotton yield (7.92 q ha^{-1}) was recorded in hybrid MRC 7017. Seed cotton yield recorded in MRC 7031 was 7.57 q ha^{-1} which was statistically at par with MRC 7017 and RCH 314. However, hybrid RCH 314 produced significantly lower seed cotton yield (6.88 q ha^{-1}) than MRC 7017 with percentage decrease of 13.1 during 2012.

Higher seed cotton yield of hybrid MRC 7017 might be because of better growth and development as evident from higher plant height (Table 4.3) and dry matter accumulation in fruiting bodies (Tables 4.3 to 4.6) which resulted in increased number of sympodial branches $plant^{-1}$ (Table 4.15), total flowers (Table 4.16), total bolls and picked bolls $plant^{-1}$ (Table 4.17) recorded by the hybrid.

Seed cotton yield in third picking was significantly influenced by the fruiting form removal treatments during both the years (Table 4.19 and Fig. 4.12). Maximum seed cotton yield (4.33 q ha^{-1} and 9.32 q ha^{-1}) was recorded in the treatment where 0 % squares were removed which was statistically at par with the treatment where 25 % squares were removed (4.17 and 9.09 q ha^{-1}) during 2011 and 2012, respectively. However, both the square removal treatments were significantly better than all other fruiting form removal treatments in terms of seed cotton yield during both the years. The retention of fruiting forms at various positions also exerted significant effect on seed cotton yield during both the years. Maximum seed cotton yield (3.26 and 7.03 q ha^{-1}) was obtained in P1, 2 which was statistically at par with P1 but significantly higher than P2 during 2011 and 2012 respectively. However, seed cotton yield recorded in P1, 2 was 8.3 and 10.3 per cent higher than P1 and 59.0 and 51.8 per cent higher than P2 during 2011 and 2012, respectively. The data further reveal that seed cotton yield produced in P1 was 46.8 and 37.5 per cent significantly higher than P2 during 2011 and 2012, respectively. However, P2 produced lowest seed cotton yield during both the years. The interaction effect of different treatments was non significant during both the years.

4.1.30 Total Seed Cotton Yield

Data represented in Table 4.19 and illustrated in Fig. 4.11 depict that the hybrids differed significantly for the total seed cotton yield during both the years of experimentation. Maximum total seed cotton yield (17.1 and 23.1 q ha^{-1}) was recorded in hybrid MRC 7017 which was statistically at par with the hybrid MRC 7031 (16.4 and 22.1 q ha^{-1}) during 2011 and 2012, respectively. The total seed cotton yield of RCH 314 was significantly lower than MRC 7017 and MRC 7031 by 15.2 and 11.5 per cent, respectively during 2011 and during 2012 the percentage yield reduction in RCH 314 was 16.0 and 12.2 as compared to MRC 7017 and MRC 7031, respectively. Higher seed cotton yield in MRC 7017 and MRC 7031 might be because of better growth and development due to its higher genetic potential as evident from higher plant height and dry matter accumulation in fruiting bodies which eventually resulted in increased number of sympodial branches $plant^{-1}$ (Table 4.15), total flowers (Table 4.16), total bolls and picked bolls $plant^{-1}$ (Table 4.17) as recorded by the hybrids. These results are in conformity with findings of Buttar and Singh (2006) and Singh *et al* (2011).

Data presented in Table 4.19 and illustrated in Fig 4.12 reveal that the maximum seed cotton yield of 20.4 q ha^{-1} was obtained in the crop where 25 % squares were removed followed by the crop where 0 % squares were removed (19.8 q ha^{-1}) during 2011. However, during 2012, maximum seed cotton yield was recorded in treatment where 0 % squares were removed (27.1 q ha^{-1}) followed by the treatment where 25 % squares were removed (26.6 q ha^{-1}). However, both 0 and 25 % square removal treatments were statistically at par with each other but performed significantly better than all other fruiting form removal treatments during both the years. A perusal of data also reveal that transgenic cotton can tolerate only modest levels of square removal i.e. 25 %. The indeterminate growth pattern of cotton enables it to withstand the loss of fruiting structures without significant reduction in yield, whereas more damage to the fruiting structures resulted in lesser yield. The treatments where removal of fruiting forms was done at higher percentage (50 %) were not able to recuperate the same amount of fruiting bodies and the development of new fruiting forms in lieu of removed fruiting forms required time to develop into a mature boll. Cheema *et al* (2005) also observed that extremely heavy fruit damage greatly reduced the seed cotton yield. All the hybrids on an average yielded less in the year 2011 than in the year 2012 because of higher rainfall received during the month of August which resulted in shedding of flowers and also made congenial conditions for pest build up (Appendix II).

Among the site specific fruit retention treatments, the seed cotton yield of 15.3 and 20.5 q ha^{-1} was produced where fruiting bodies were kept at both first and second positions (P1, 2) and it recorded significantly higher seed cotton yield than P1 in which fruiting bodies were retained at first position and P2 where fruiting bodies were retained at second position during both the years. This significant increase of seed cotton yield in P1, 2 as compared to P1 and P2 was due to the less removal of fruiting parts from P1, 2 because fruiting forms were removed from the positions

lateral than first and second positions which commemorated more number of flowers, total bolls and picked bolls plant^{-1} and ultimately resulted in higher seed cotton yield as compared to P1 and P2. The data further manifested that the productivity of *Bt* cotton increased significantly when fruiting bodies were retained at first position (P1) as compared to second position (P2) of the sympodial branch. The treatment where fruiting bodies were retained at first position (P1) produced 25.2 and 25.4 per cent higher seed cotton than the treatment where fruiting bodies were retained at second position (P2) during 2011 and 2012, respectively. The increase in yield in P1 as compared to P2 was due to the higher number of total bolls and picked bolls plant^{-1} on first position which is evident from Table 4.17. Jenkins *et al* (1990) also observed that bolls at position one on sympodial branches produced more total yield than those at position two and all other positions on sympodial branches. The interaction effects of various treatments were non significant during the two years.

4.1.31 Bartlett Index

Bartlett index is an important indicator of maturity of the crop. The higher value of the Bartlett index indicates early maturity. Hybrids and fruiting form removal treatments did not exert any significant influence on the Bartlett index in both the two years as evident from Table 4.20. The interactive effect of different treatments was also not significant in any of the two years.

4.1.32 Ginning Outturn (GOT)

Ginning out turn is an important quality character which influences the price of cotton in the market. It indicates the amount of lint present in seed cotton. Perusal of the data presented in the Table 4.20 reveal that various hybrids and fruiting form removal treatments did not differ significantly for ginning outturn in any of the two years. The interaction between hybrids and fruiting from removal treatments was non significant during both the years.

4.1.33 Seed Index

Seed index is an important component of seed cotton yield and is expressed as the weight of 100 seeds in grams. A lower value of seed index indicates more immature seeds which deteriorates the industrial value of the cotton seed. A data presented in Table 4.20 indicates that different hybrids and fruiting form removal treatments did not influence the seed index significantly in both the years. No interaction was observed for seed index during both the years.

4.1.34 Lint Index

Lint index is a measure of surface area and density of fibres on the seed. It is directly related to seed index and ginning out turn. All the three Bt cotton hybrids and fruiting form removal treatments did not differ significantly for the lint index during both the years (Table 4.20). Interaction effect for all the hybrids and fruiting form removal treatments was also non significant during both the years.

Table 4.20: Seed index, lint index, ginning out turn (GOT) and Bartlett index as affected by hybrids and fruiting form removal treatments

Treatment	Seed Index		Lint index		GOT (%)		Bartlett Index	
	2011	2012	2011	2012	2011	2012	2011	2012
Hybrids								
MRC 7017	8.64 a	8.69 a	4.35 a	4.63 a	33.25 a	34.47 a	0.77 a	0.67 a
MRC 7031	8.60 a	8.65 a	4.29 a	4.53 a	33.12 a	34.22 a	0.76 a	0.66 a
RCH 314	8.58 a	8.63 a	4.45 a	4.74 a	33.91 a	35.21 a	0.76 a	0.66 a
SEm	**0.17**	**0.17**	**0.21**	**0.22**	**0.65**	**0.68**	**0.006**	**0.005**
F(p)	**0.95**	**0.95**	**0.78**	**0.70**	**0.48**	**0.37**	**0.31**	**0.65**
Fruiting form removal								
0%	8.66 a	8.71 a	4.34 a	4.57 a	33.22 a	34.21 a	0.76 a	0.67 a
25%	8.63 a	8.69 a	4.30 a	4.52 a	33.11 a	34.11 a	0.77 a	0.66 a
50%	8.66 a	8.71 a	4.34 a	4.57 a	33.19 a	34.19 a	0.76 a	0.66a
P1 (Retain at 1st position)	8.58 a	8.63 a	4.43 a	4.80 a	33.76 a	35.45 a	0.75 a	0.65 a
P2 (Retain at 2nd position)	8.53 a	8.58 a	4.35 a	4.70 a	33.57 a	35.14 a	0.76 a	0.66 a
P1, 2 (Retain at 1st and 2nd position)	8.57 a	8.62 a	4.41 a	4.64 a	33.70 a	34.72 a	0.77 a	0.67 a
SEm	**0.17**	**0.18**	**0.22**	**0.24**	**0.70**	**0.72**	**0.006**	**0.006**
F(p)	**0.99**	**0.99**	**0.99**	**0.96**	**0.97**	**0.70**	**0.30**	**0.37**
Interaction F(p)	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**0.97**	**0.91**

Experiment II: Reproductive compensation behaviour of different cotton cultivars in response to fruiting form removal.

4.2.1 Plant Height

Plant height recorded periodically at 30 days interval during the crop growth season of 2011 and 2012 and presented in Table 4.21 and Fig. 4.13 and 4.14. All the hybrids showed an early slow increase in plant height upto 60 DAS but after that gain in plant height was at a greater pace in all the hybrids upto 120 DAS during both the years. Further, the rate of increase in plant height declined and became very less after 120 DAS to maturity during both the crop growth seasons.

The hybrids differed significantly for plant height among themselves at all the growth stages except at 60 DAS, in both the years. At 90, 120 and 150 DAS, hybrid MRC 7017 recorded significantly higher plant height and was statistically at par with hybrid MRC 7031 and both the hybrids recorded significantly higher plant height than RCH 314 during both the years. However, at 150 DAS, MRC 7017 attained plant height of 95.8 and 98.7 cm which was statistically at par with MRC 7031 which possessed plant height of 94.4 and 97.3 cm during 2011 and 2012, respectively. Significantly lower plant height was recorded by hybrid RCH 314 (85.3 and 87.9 cm) during 2011 and 2012, respectively. On an average least plant height was recorded in hybrid RCH 314 at all the growth stages during both the years. Plant height of the crop or a particular hybrid is dependent upon its genetic makeup. Results obtained by Brar (1997) and Singh (1999) also emphasize the same point.

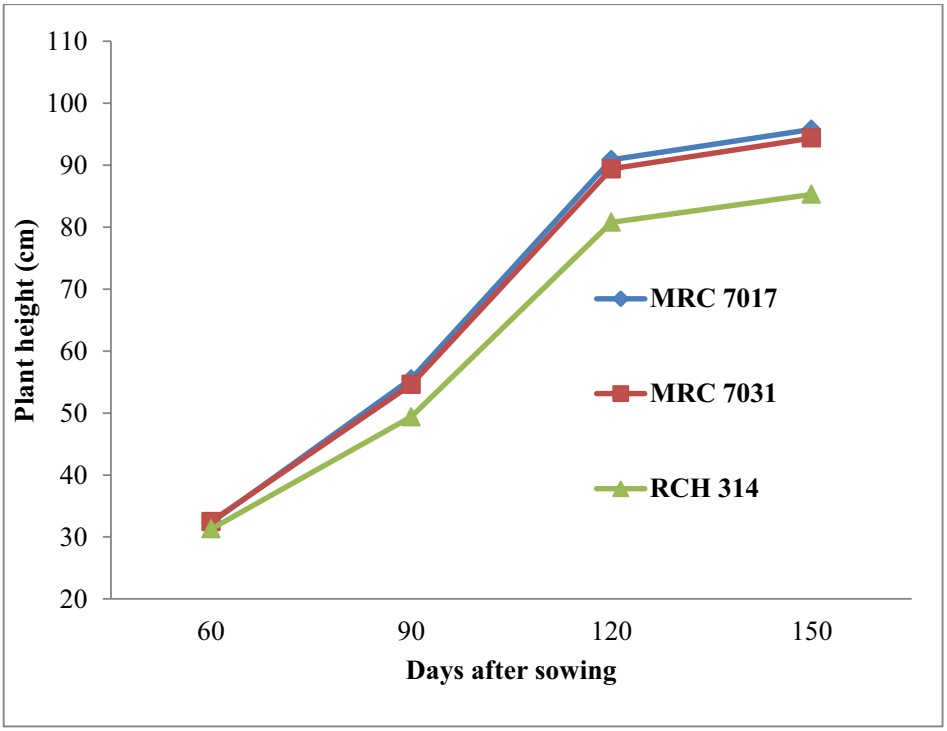
Fruiting form removal had a significant effect on plant height at 90, 120 and 150 DAS except at 60 DAS during both the years. At 90 DAS, significantly taller plants were recorded in 50 % square removal treatment (60.1 and 62.5 cm) as compared to 0 % (46.0 and 47.9 cm) and 25 % (48.7 and 50.6 cm) square removal treatments and from the treatment where fruits were retained at both first and second position i.e. P1, 2 which recorded the plant height of 48.8 and 50.7 cm during 2011 and 2012, respectively. However, 50 % square removal treatment produced statistically similar plant height to the treatments where fruits were retained at first position (P1) which attained the plant height of 57.2 and 59.5 cm and also with the treatment where fruits were retained at second position (P2) where plant height recorded to be 58.2 and 60.5 cm, during 2011 and 2012, respectively.

At 120 and 150 DAS, maximum plant height was attained in P2, which was statistically at par with P1 and P1, 2 but significantly higher than 0, 25 and 50 % square removal treatments during both the years. Significant increase in plant height at 90 DAS in 50 % square removal treatment as compared to 0, 25 and P1, 2 treatments might be attributed to the diversion of assimilates from floral bodies towards the apical growing points with the removal of squares.

Table 4.21: Effect of hybrids and fruiting form removal on plant height recorded at different stages

Treatment	Plant Height (cm)							
	60 DAS		90 DAS		120 DAS		150 DAS	
	2011	2012	2011	2012	2011	2012	2011	2012
Hybrids								
MRC 7017	32.3 a	32.2 a	55.5 a	57.7 a	90.9 a	94.5 a	95.8 a	98.7 a
MRC 7031	32.5 a	32.6 a	54.6 a	56.8 a	89.4 a	93.0 a	94.4 a	97.3 a
RCH 314	31.3 a	30.0 a	49.4 b	51.4 b	80.8 b	84.0 b	85.3 b	87.9 b
SEm	**0.61**	**0.62**	**0.84**	**0.87**	**1.26**	**1.31**	**1.48**	**1.52**
F(p)	**0.16**	**0.23**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**
Fruiting form removal								
0%	31.4 a	32.0 a	46.0 b	47.9 b	80.4 b	83.6 b	84.8 b	87.3 b
25%	31.9 a	32.1 a	48.7 b	50.6 b	83.7 b	87.1 b	88.2 b	90.9 b
50%	32.8 a	33.4 a	60.1 a	62.5 a	82.7 b	86.0 b	87.0 b	89.7 b
P1 (Retain at 1st position)	32.1 a	32.6 a	57.2 a	59.5 a	91.8 a	95.5 a	97.4 a	100.3 a
P2 (Retain at 2nd position)	32.7 a	33.4 a	58.2 a	60.5 a	93.7 a	97.5 a	98.9 a	101.8 a
P1, 2 (Retain at 1st and 2nd position)	31.4 a	32.2 a	48.8 b	50.7 b	89.8 a	93.4 a	94.7 a	97.6 a
SEm	**0.63**	**0.64**	**0.96**	**1.01**	**1.50**	**1.56**	**1.57**	**1.62**
F(p)	**0.47**	**0.41**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**
Interaction F(p)	**0.99**	**0.99**	**0.80**	**0.80**	**0.99**	**0.99**	**0.99**	**0.99**

(a)



(b)

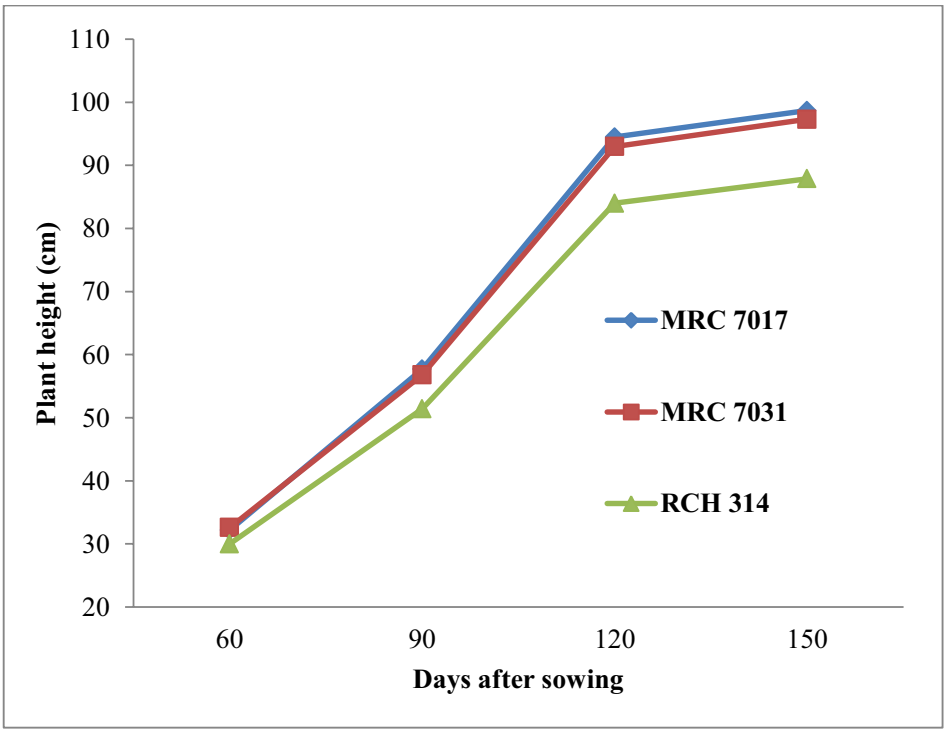
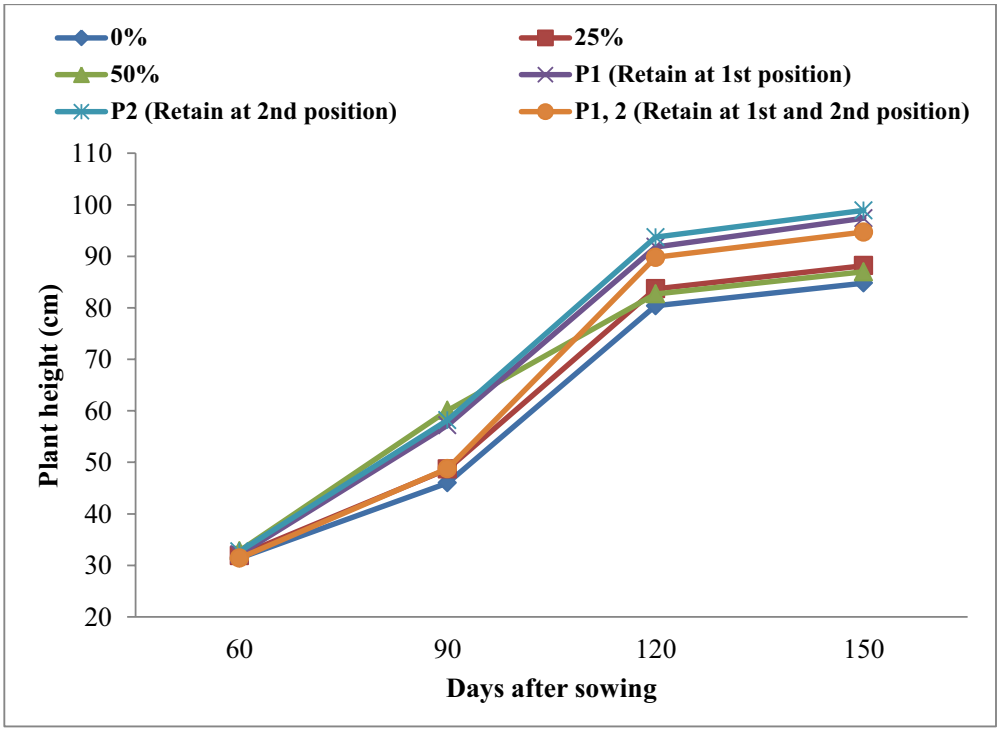


Fig 4.13: Plant height of different hybrids during 2011 (a) and 2012 (b)

(a)



(b)

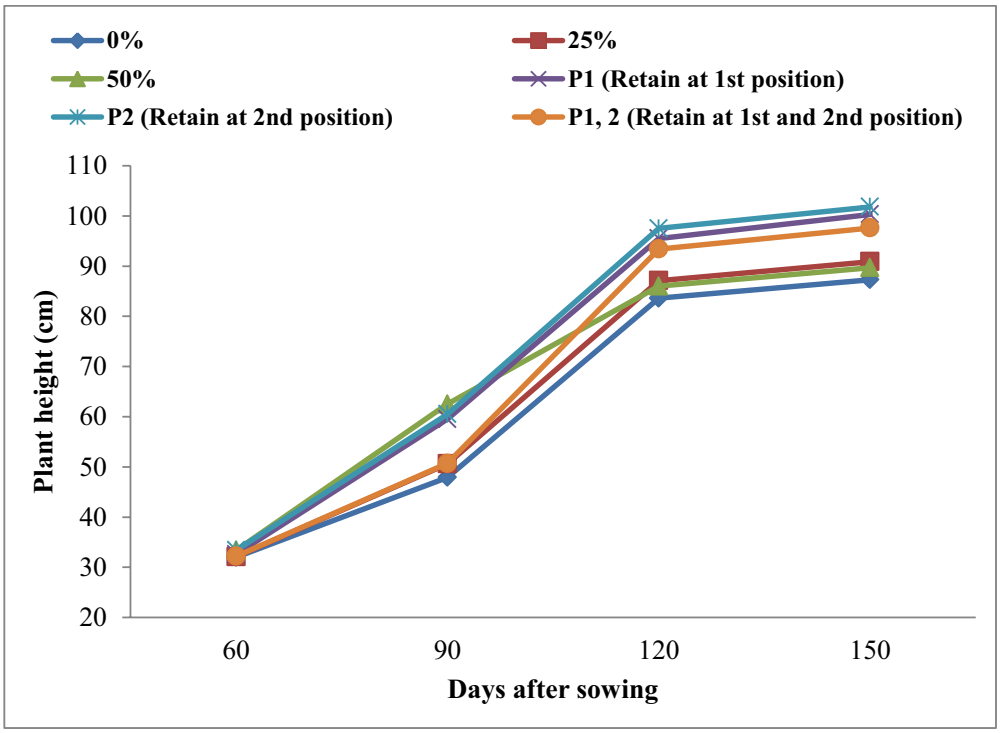


Fig 4.14: Plant height of different hybrids as influenced by fruiting form removal treatments during 2011 (a) and 2012 (b)

Contrarily, in later stages (120 and 150 DAS) continuous removal of fruiting forms from different positions in P2 treatment resulted in significantly higher plant height than 0, 25 and 50 % square removal treatments where squares were removed at pin head stage for a period of one month. The higher plant height at 120 and 150 DAS, in P1, P2 and P1, 2 as compared to 0, 25 and 50 % square removal treatments might be due to the diversion of assimilates towards the other plant parts i.e. leaves, stems and branches which are normally incorporated into reproductive structures which were removed. A Severe fruit loss diverted excess carbohydrates to vegetative growth which resulted in increased plant height. The increase in plant height under intense flower removal was also reported by Montez and Goodell (1994) and Mustafa *et al* (2004). A non significant interaction was observed between hybrids and fruiting form removal treatments at all the growth stages during both the years.

4.2.2 Main Stem Internodes

Data presented in Table 4.22 reveal that hybrids did not differ significantly for the total number of main stem internodes plant^{-1} during both the years. Hybrid MRC 7017 recorded relatively higher main stem internodes than hybrids MRC 7031 and RCH 314 but did not reach the level of significance during both the years. The number of main stem internodes produced in MRC 7017 was 24.5 and 25.7, followed by MRC 7031 (24.1 and 25.3) and RCH 314 which recorded 23.7 and 25.1 number of main stem internodes during 2011 and 2012, respectively.

Fruiting form removal treatments exerted a significant effect on main stem internodes plant^{-1} in both the years (Table 4.22). Maximum number of main stem internodes (25.3 and 26.6 in 2011 and 2012 respectively) was observed in P1 which was statistically at par with all other fruiting form removal treatments but significantly higher than 0 and 25 % square removal treatments during both the years. The lowest number of internodes (23.0 and 24.2) was recorded in 0 % square removal treatment which was statistically at par with 25 and 50 % square removal treatments during 2011 and 2012, respectively. The significant increase in number of main stem internodes plant^{-1} in site specific fruit positioning treatments (P1, P2 and P1, 2) than 0 and 25 % square removal treatments was due to the continuous removal of fruiting forms from different positions upto the boll open initiation stage which caused diversion of assimilates towards the vegetative parts that lead to an increase in plant height as evident from Table 4.21. While, 0 % square removal treatment had sufficient demand from fruiting structures to utilize the available resources. Similarly, in 25 and 50 % square removal treatments the response for the removal of fruiting forms was less exhibited by the vegetative parts of plant because the demand for assimilates was higher by the fruiting forms due to less removal of fruiting forms or for smaller duration as compared to the treatments where fruiting forms were retained on specific sites (P1, P2 and P1, 2) where fruiting forms were removed from the day squares started developing upto the boll open initiation stage or for longer duration. Montez and Goodell (1994) also reported in their work that excessive vegetative growth is associated with fruit loss in cotton plant.

Table 4.22: Main stem internodes and height to node ratio of *Bt* cotton hybrids as affected by fruiting form removal treatments

Treatment	Main stem internodes		Height to node ratio	
	2011	**2012**	**2011**	**2012**
Hybrids				
MRC 7017	24.5 a	25.7 a	3.90 a	3.83 a
MRC 7031	24.1 a	25.3 a	3.92 a	3.84 a
RCH 314	23.7 a	25.1 a	3.60 b	3.50 b
SEm	**0.35**	**0.37**	**0.06**	**0.06**
F(p)	**0.11**	**0.31**	**0.001**	**0.0002**
Fruiting form removal				
0%	23.0 b	24.2 b	3.68 bc	3.60 bc
25%	23.1 b	24.3 b	3.82 bac	3.73 bac
50%	24.2 ba	25.5 ba	3.60 c	3.52 c
P1 (Retain at 1st position)	25.3 a	26.6 a	3.85 bac	3.76 bac
P2 (Retain at 2nd position)	24.6 a	25.0 a	4.00 a	3.91 a
P1, 2 (Retain at 1st and 2nd position)	24.4 a	25.7 a	3.89 ba	3.80 ba
SEm	**0.40**	**0.42**	**0.08**	**0.08**
F(p)	**0.001**	**0.001**	**0.03**	**0.03**
Interaction F(p)	**0.98**	**0.98**	**0.96**	**0.96**

Lei (2001) also stated that the loss of reproductive organs shifted excess carbohydrates towards the alternate sinks and it also depends upon the number of fruits remaining on the plant. The interaction effect between hybrids and fruiting form removal treatments was non significant during both the years.

4.2.3 Height to Node Ratio

Height to node ratio (HNR) is a simple determination of the plant's vigour and growth potential, it reflects the degree of stress that plants experience throughout the season and is numerically equivalent to the average distance between nodes, called internodal length of the plant. As evident from the data presented in Table 4.22, hybrids differed significantly for the HNR during both the years of experimentation.

MRC 7031 recorded maximum HNR (3.92 and 3.84) which was statistically at par with hybrid MRC 7017 which recorded 3.90 and 3.83 of HNR and both the hybrids attained significantly higher HNR than RCH 314 (3.60 and 3.50) during 2011 and 2012, respectively. The higher HNR in MRC 7017 and 7031 was due to more vegetative growth of these two hybrids as compared to RCH 314 and was evident from the higher plant height (Table 4.21).

Data presented in Table 4.22 depict that fruiting form removal treatments also had a significant influence on HNR during both the years. Maximum HNR (4.00 and 3.91) was recorded in the treatment where fruits were retained at second position (P2) which was statistically at par with all other fruiting form removal treatments except 50 % square removal treatment which recorded 3.60 and 3.52 of HNR. The lowest HNR was recorded in 50 % square removal treatment than all other fruiting form removal treatments. Higher HNR in the crop where fruits were retained at second position (P2) was due to the higher translocation of assimilates towards the vegetative parts of plant with the removal of fruiting forms which resulted in more plant growth as evident from its higher plant height (Table 4.21). There was no interaction between hybrids and fruiting form removal treatments for HNR during both years.

4.2.4 SPAD value

SPAD meters are reliable alternatives to traditional tissue analysis of plant chlorophyll content and also used as nutritional diagnostic tools. Higher levels of chlorophyll in leaves indicate enhanced photosynthetic efficiency of the crop which influences the crop growth and yield. The data pertaining to chlorophyll content indicated as SPAD value is presented in Table 4.23 and it show that the hybrids did not differ significantly for the SPAD value at all the growth stages during both the years. However, maximum SPAD value at 120 DAS was recorded in hybrid MRC 7017 (25.0 and 26.5) as compared to MRC 7031 (24.7 and 26.2) and RCH 314 which recorded 24.1 and 25.8 reading on SPAD meter and all the hybrids were statistically similar with each other during 2011 and 2012, respectively.

Table 4.23: Effect of *Bt* cotton hybrids and fruiting form removal on SPAD value

Treatment	SPAD value					
	60 DAS		90 DAS		120 DAS	
	2011	2012	2011	2012	2011	2012
Hybrids						
MRC 7017	48.7 a	48.5 a	38.0 a	38.8 a	25.0 a	26.5 a
MRC 7031	47.7 a	48.9 a	37.4 a	38.2 a	24.7 a	26.2 a
RCH 314	47.0 a	48.1 a	36.0 a	36.7 a	24.1 a	25.8 a
SEm	**1.56**	**1.58**	**0.64**	**0.65**	**0.42**	**0.44**
F(p)	**0.67**	**0.90**	**0.03**	**0.02**	**0.05**	**0.19**
Fruiting form removal						
0%	46.2 a	47.3 a	34.5 b	35.2 b	21.8 e	23.2 e
25%	48.5 a	49.2 a	38.2 a	38.9 a	23.01 d	24.4 d
50%	49.5 a	50.3 a	38.6 a	39.4 a	24.2 c	25.7 c
P1 (Retain at 1st position)	47.7 a	48.0 a	37.2 a	37.9 a	26.2 b	27.9 b
P2 (Retain at 2nd position)	48.1 a	48.4 a	37.7 a	38.4 a	27.5 a	29.3 a
P1, 2 (Retain at 1st and 2nd position)	46.8 a	47.6 a	36.8 a	37.5 a	25.0 c	26.6 c
SEm	**1.90**	**1.92**	**0.76**	**0.78**	**0.38**	**0.41**
F(p)	**0.85**	**0.88**	**0.006**	**0.006**	**<0.0001**	**<0.0001**
Interaction F(p)	**1.00**	**1.00**	**0.99**	**0.99**	**0.57**	**0.56**

The perusal of data presented in Table 4.23 reveal that fruiting form removal treatments had a significant effect on SPAD value at 90 and 120 DAS except at initial growth stage i.e. 60 DAS.

At initial growth stage (60 DAS) of crop the removal of fruiting forms was started just five days before the data was recorded and the fruiting form removal did not exhibit its effect immediately on plants. At 90 DAS, higher SPAD value (38.7 and 39.4) was recorded where 50 % squares were removed during 2011 and 2012 respectively, which was statistically at par with all other fruiting form removal treatments except undamaged control (0 %).

At 120 DAS, a significant difference in SPAD value was observed for all the fruiting form removal treatments during both the years. The treatment where fruits were retained at second position (P2) recorded significantly higher SPAD value (27.5 and 29.3) as compared to all other fruiting form removal treatments during 2011 and 2012, respectively. Significantly lower SPAD value (21.8 and 23.2) was recorded in the treatment where 0 % square removal treatment as compared to all other fruiting form removal treatments during 2011 and 2012, respectively. The treatment where fruiting forms were retained at both first and second position (P1, 2) however, recorded higher SPAD value than 0 and 25 % square removal treatments but was statistically at par with 50 % square removal treatment during both the years. At 90 DAS, more removal of fruiting forms from 50 % square removal treatment diverted assimilates towards the leaves which resulted in more chlorophyll content or greenness than control. While at 120 DAS, higher SPAD value was recorded in the treatment where intensity of fruit removal was more (P2) and this removal of fruiting forms caused translocation of assimilates towards the vegetative parts like leaves, stem and branches irrespective of the fruiting positions and that enhanced the greenness of leaves recorded as SPAD value. Wells (2001) also observed that removal of flowers for two weeks had 15 per cent higher leaf chlorophyll content as compared to no removal. No interaction was observed for SPAD value during both the years.

4.2.5 Monopodial Branches per Plant

Monopodial branches are the vegetative branches which arise from the lower nodes of plant. As evident from the data (Table 4.24) hybrids did not differ significantly for the number of monopodial branches plant^{-1} during both the years. Hybrid MRC 7017 produced 3.20 and 3.30 number of monopodial branches plant^{-1} followed by MRC 7031 (3.16 and 3.26) and RCH 314 which produced 2.91 and 3.06 monopodial branches plant^{-1} during 2011 and 2012, respectively. It was due to the reason that these three hybrids have same morphological behaviour to produce monopodial branches which attributed to their similar genetic make up. Heitholt *et al* (1996) also reported that similar genetic make up of hybrids resulted in almost same number of monopodial branches plant^{-1}.

Table 4.24: Effect of fruiting form removal treatments on monopodial and sympodial branches per plant of *Bt* cotton hybrids

Treatment	Monopodial branches plant^{-1}		Sympodial branches plant^{-1}	
	2011	2012	2011	2012
Hybrids				
MRC 7017	3.20 a	3.30 a	24.9 a	26.9 a
MRC 7031	3.16 a	3.26 a	24.5 a	26.0 ba
RCH 314	2.91 a	3.06 a	22.7 b	24.1 b
SEm	**0.08**	**0.09**	**0.51**	**0.53**
F(p)	**0.002**	**014**	**0.007**	**0.007**
Fruiting form removal				
0%	3.16 a	3.26 a	23.1 b	24.7 b
25%	3.08 a	3.17 a	23.7 ba	25.3 ba
50%	3.00 a	3.15 a	24.1 ba	25.7 ba
P1 (Retain at 1st position)	3.16 a	3.26 a	24.4 ba	26.1 b a
P2 (Retain at 2nd position)	3.16 a	3.26 a	25.1 a	26.8 a
P1, 2 (Retain at 1st and 2nd position)	3.00 a	3.15 a	23.9 ba	25.5 ba
SEm	**0.10**	**0.12**	**0.54**	**0.56**
F(p)	**0.71**	**0.96**	**0.24**	**0.24**
Interaction F(p)	**0.96**	**0.99**	**0.79**	**0.79**

Fruiting form removal treatments also failed to influence the number of monopodial branches plant^{-1} in any of the two years (Table 4.24). It might be due to the reason that removal of fruiting forms was done on 55 days old crop when squares started developing, whereas, monopodial branches arise from the lower nodes of the plant during the earlier growth period of the crop. The interaction effect was also non significant for the monopodial branches plant^{-1} during both years.

4.2.6 Sympodial Branches per Plant

Sympodial branches arise from monopodial branches and bear reproductive structures. Data presented in Table 4.24 show that hybrids differed significantly among themselves for the number of sympodial branches plant^{-1} during both years. The higher number of sympodial branches plant^{-1} (24.9 and 26.9) were recorded in MRC 7017 which were statistically at par with MRC 7031 which produced 24.5 and 26.0 number of sympodial branches plant^{-1} during 2011 and 2012, respectively. RCH 314 produced significantly lower number of sympodial branches plant^{-1} (22.7) than MRC 7017 and MRC 7031 during 2011. While, during 2012, RCH 314 produced 24.1 sympodial branches plant^{-1} which were significantly lower than MRC 7017 but statistically similar to MRC 7031. The higher number of sympodial branches plant^{-1} in hybrid MRC 7017 were due to its higher genetic potential to produce more vigorous plants which was evident from higher plant height (Table 4.21) and had more potential to produce higher number of sympodial branches.

Fruiting form removal treatments significantly influenced the sympodial branches plant^{-1} during both the crop growth seasons (Table 4.24). Treatments where fruiting forms were removed from all the positions except second position (P2) attained significantly higher number of sympodial branches plant^{-1} (25.1 and 26.8) as compared to the treatment where no square was removed (0 %) which recorded 23.1 and 24.7 number of sympodial branches plant^{-1} during 2011 and 2012, respectively. The treatments where fruiting forms were removed upto 25 and 50 % and the treatments where fruits were retained at first (P1) and at both first and second (P1, 2) position were statistically at par with both 0 % and P2 during both the years. Higher sympodial branches plant^{-1} in P2 as compared to 0 % square removal treatment were due to the removal of fruiting forms which resulted in translocation of assimilates towards the vegetative parts rather than the fruiting bodies. The diversion of assimilates to vegetative portion increased plant height (Table 4.21) and main stem internodes (Table 4.22) which directly influenced the sympodial branches plant^{-1}. The interaction effects were non significant for the sympodial branches plant^{-1} during both years.

4.2.7 Days Taken to Initiation of Squaring

Data presented in Table 4.25 and represented in Fig. 4.15 and 4.16 reveal that days taken to initiation of squaring in all the *Bt* cotton hybrids and fruiting form removal treatments did not differ significantly during both the years and they took 56-57 days to

initiate in 2011 and 55-56 days in 2012 for initiation of squaring across all the treatments. The interaction between hybrids and fruiting form removal treatments was non significant during both the years.

4.2.8 Days Taken to Flower Initiation

Flowering initiated at 70-71 and 72 DAS during 2011 and 2012, respectively in all the hybrids (Table 4.25 and Fig. 4.15). All the hybrids did not show significant differences for the days taken to flower initiation during both the years. Similarly, for fruiting form removal treatments, flower initiation did not differ significantly and they initiated at 70-71 DAS during 2011 and 71-73 DAS during 2012 (Table 4.25 and Fig. 4.16). The interaction between hybrids and fruiting form removal treatments was non significant in both the years.

4.2.9 Days Taken to Initiation of Boll Formation

Hybrids did not show significant effect for days taken to initiation of boll formation and they took 84-86 days and 86-88 days to complete boll formation initiation during both the crop growth seasons (Table 4.25 and Fig. 4.15).

Data presented in Table 4.25 and represented in Fig. 4.16 reveal that fruiting form removal treatments had a significant effect on days taken to initiation of boll formation during both the years. The treatment where squares were removed upto 50 % and the treatments where fruiting bodies were retained at first (P1), second (P2) and at both first and second (P1, 2) position took similar number of days (86 and 88) to initiate boll formation and the number of days taken by all these treatments were significantly more as compared to 0 and 25 % square removal treatments to initiate boll formation which took 83 and 85 number of days during 2011 and 2012, respectively. However, 0 and 25 % square removal treatments took similar number of days for the initiation of boll formation.

The late initiation of boll formation in 50 % square removal treatment may be due to the initiation of new fruiting forms in place of old ones removed earlier and the compensation of fruiting forms for this replacement requires enough time. Whereas, in treatments where fruiting bodies were retained at specific positions (P1, P2 and P1, 2) late initiation of boll formation was probably due to the fact that fruiting form removal shifts the assimilates towards the vegetative parts as evident from higher plant height (Table 4.21) which prolonged vegetative period. There was no interaction between hybrids and fruiting form removal treatments during both the years.

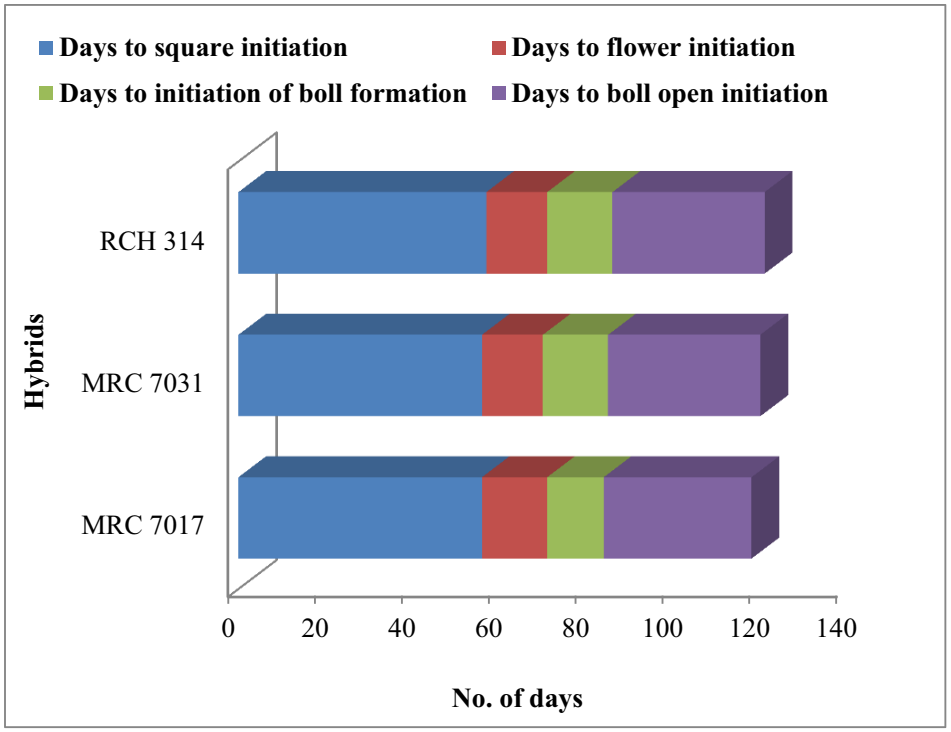
4.2.10 Days Taken to Initiation of Boll Opening

A perusal of data presented in Table 4.25 and illustrated in Fig 4.15 shows non significant difference among the *Bt* cotton hybrids during both the years and they took about 118-121 days in 2011 and 121-124 days in 2012 to initiate boll opening.

Table 4.25: Days taken to square initiation, flower initiation, initiation of boll and boll open initiation as affected by hybrids and fruiting form removal treatments

Treatment	Days to square initiation		Days to flower initiation		Days to initiation of boll		Days to boll open initiation	
	2011	2012	2011	2012	2011	2012	2011	2012
Hybrids								
MRC 7017	56 a	55 a	71 a	72 a	84 a	86 a	118 a	121 a
MRC 7031	56 a	56 a	70 a	72 a	85 a	87 a	120 a	122 a
RCH 314	57 a	56 a	71 a	72 a	86 a	88 a	121 a	124 a
SEm	**1.03**	**1.02**	**0.99**	**1.01**	**0.84**	**0.85**	**1.41**	**1.44**
F(p)	**0.64**	**0.64**	**0.52**	**0.83**	**0.03**	**0.02**	**0.01**	**0.02**
Fruiting form removal								
0%	57 a	56 a	70 a	71 a	83 b	85 b	117 b	119 b
25%	56 a	55 a	70 a	71 a	83 b	85 b	117 b	119 b
50%	56 a	55 a	70 a	71 a	86 a	88 a	121 a	123 a
P1 (Retain at 1st position)	57 a	56 a	70 a	72 a	86 a	88 a	121 a	123 a
P2 (Retain at 2nd position)	56 a	56 a	71 a	73 a	86 a	88 a	122 a	124 a
P1, 2 (Retain at 1st and 2nd position)	56 a	55 a	71 a	73 a	86 a	88 a	121 a	123 a
SEm	**0.70**	**0.69**	**0.58**	**0.59**	**0.58**	**0.59**	**0.92**	**0.93**
F(p)	**0.63**	**0.63**	**0.66**	**0.55**	**0.0003**	**0.0003**	**0.0009**	**0.0009**
Interaction F(p)	**0.90**	**0.91**	**0.68**	**0.58**	**0.94**	**0.94**	**1.00**	**1.00**

(a)



(b)

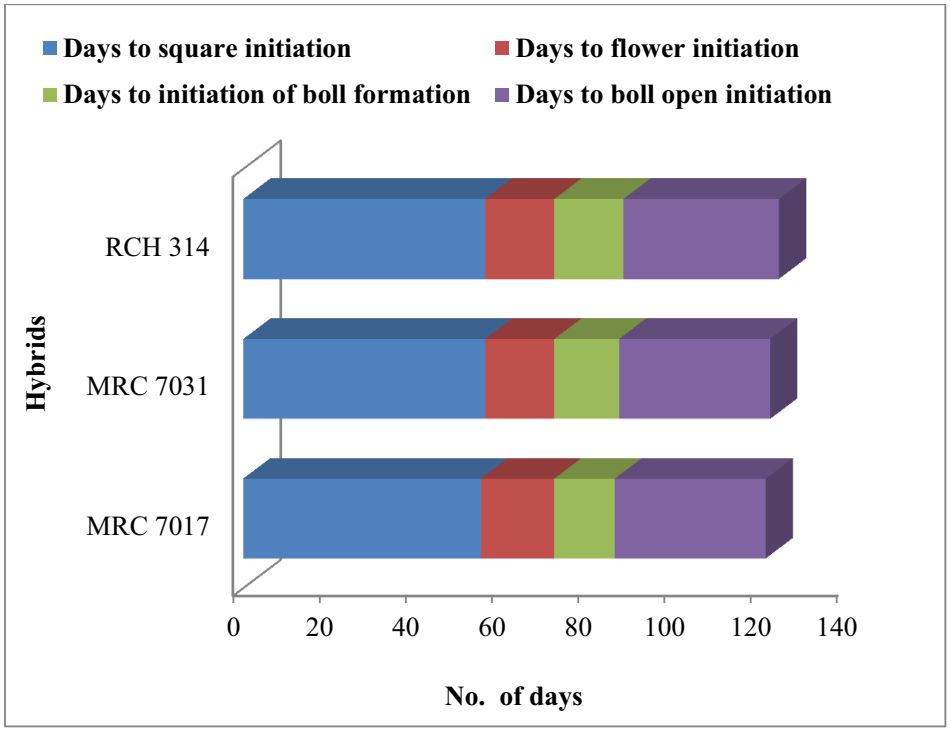
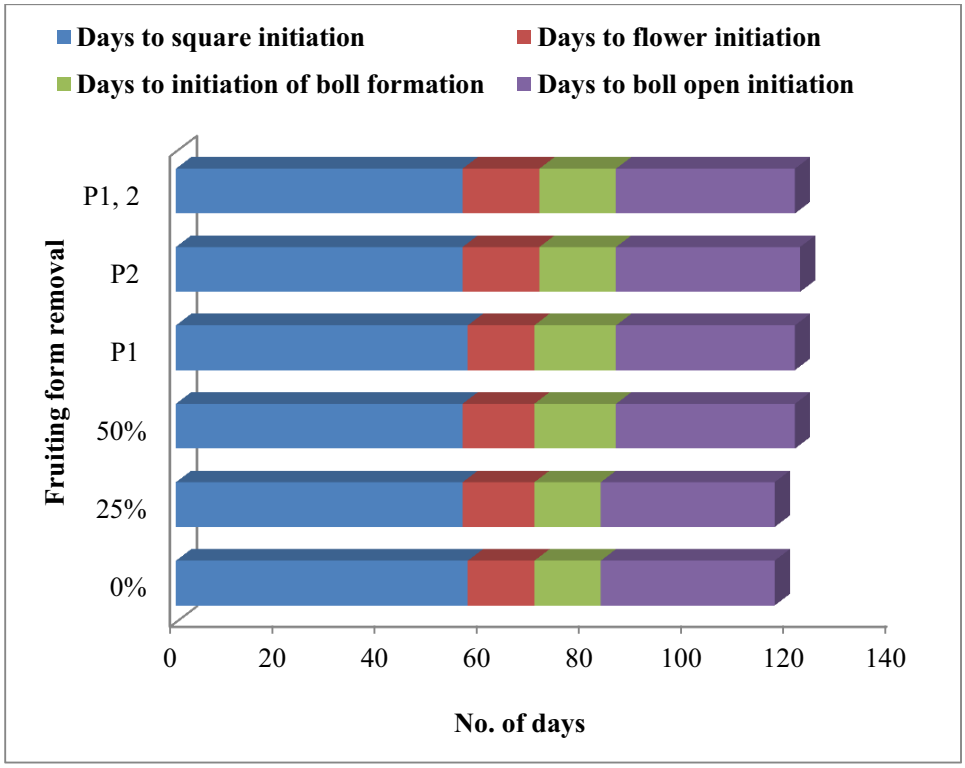


Fig 4.15: Phenological parameters as affected by hybrids during 2011 (a) and 2012 (b)

(a)



(b)

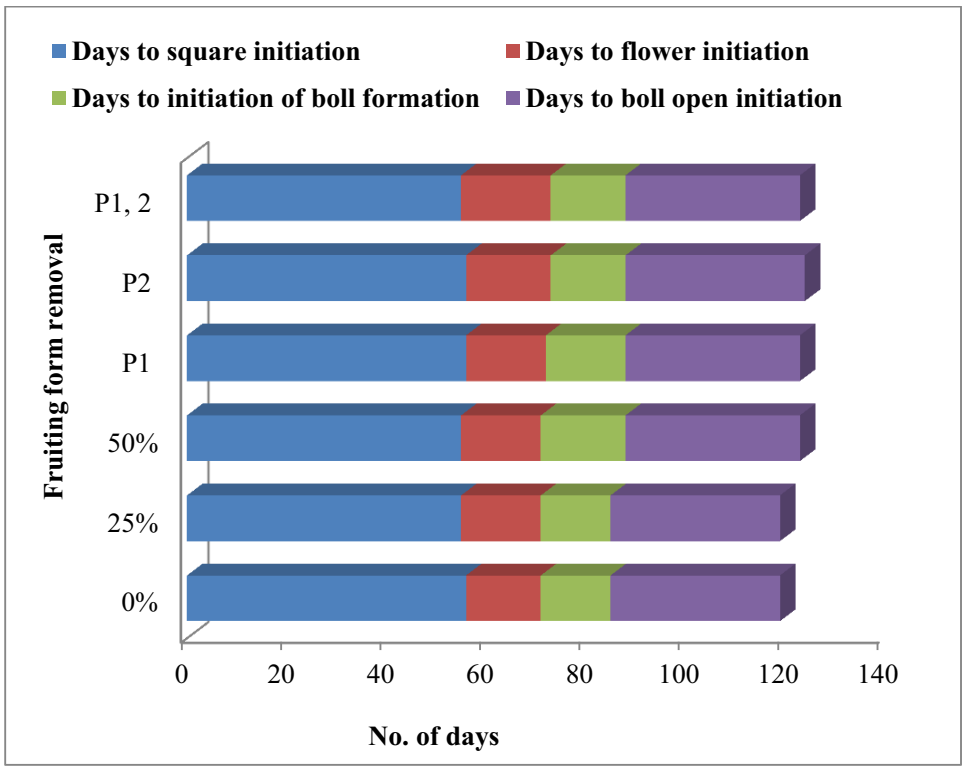


Fig 4.16: Phenological parameters of hybrids as affected by fruiting form removal treatments during 2011 (a) and 2012 (b)

Fruiting removal treatments differed significantly for days taken to initiation of boll opening (Table 4.25 and Fig 4.16). Maximum number of days were (122 and 124) taken by the crop where fruits were retained only at second position (P2) which was statistically at par with all other fruiting form removal treatments except 0 and 25 % square removal treatments during 2011 and 2012, respectively. Treatments where squares were removed upto 50 % and the treatments where fruits were retained at first (P1) and both first and second position (P1, 2) took almost similar number of days (121 and 123) to initiate boll opening during 2011 and 2012, respectively. Significantly less number of days (117 and 119) were taken by 0 and 25 % square removal treatments as compared to 50 % square removal, P1, P2 and P1, 2 treatments to initiate boll opening during both the years. Lu *et al* (2012) also confirmed that square removal delayed cotton maturity by 6-14 days compared with the undamaged control. The removal of fruiting forms remobilized assimilates towards the vegetative parts which resulted in taller plants with more number of main stem internodes which prolonged vegetative period in P1, P2 and P1, 2 treatments. Whereas, in 50 % square removal treatment the delay in boll open initiation was because of new fruiting forms were developed in place of the removed fruiting forms. These results show that cotton had a compensation ability for the removal of squares but it requires enough time to develop new fruiting forms which might be the cause of late initiation of boll opening. Stewart *et al* (2001) reported that heavy fruit loss significantly delayed crop maturity as compared to no loss. No interaction was observed for the days taken to initiation of boll opening during both the years.

4.2.11 Flowers per Plant

Flowers are the reproductive parts which develop into bolls and ultimately contribute to the seed cotton yield. A perusal of data presented in Table 4.26 and represented in Fig. 4.17, reveal that the total number of flowers produced plant^{-1} differed significantly among the hybrids in both the years**.** Scrutiny of data during 2011 and 2012 indicates that MRC 7017 and MRC 7031 though statistically at par among themselves but produced significantly higher number flowers plant^{-1} than RCH 314. Least number of flowers plant^{-1} was obtained in RCH 314 (55.3 and 58.5) during 2011 and 2012, respectively. Higher number of flowers plant^{-1} produced in MRC 7017 and MRC 7031 was due to their higher genetic potential as evident from better growth and development of plants which resulted in more fruiting points. Similarly Deol (1995) reported that different cultivars performed differently in respect to growth and development due to their different genetic make up.

Fruiting form removal treatments differed significantly among themselves for the number of flowers produced plant^{-1}. As evident from data (Table 4.26 and Fig. 4.18)

significantly higher number of flowers plant^{-1} (80.5 and 85.2) were obtained in the treatment where squares were removed upto 25 % as compared to 50 % square removal treatment and all the site specific fruit retention treatments (P1, P2 and P1, 2) during 2011 and 2012, respectively. However, 25 % square removal treatment produced statistically similar number of flowers as produced by 0 % square removal treatment (79.6 and 84.3) during 2011 and 2012, respectively. The number of flowers decreased significantly when fruiting forms were removed for longer duration i.e. in P1, P2 and P1, 2 and this decrease in rate of flowering was the direct result of the continuous removal of fruiting forms till the boll open initiation stage as compared to 0, 25 and 50 % square removal treatments where fruiting forms were removed for a period of one month starting from the day square started developing during both the years. However, the treatment where fruits were retained at both first and second position (P1, 2) had significantly higher number of flowers (81.9 and 97.6) as compared to P1 and P2 during 2011 and 2012, respectively. The higher number of flowers plant^{-1} produced in P1, 2 might be due to the reason that fruits were retained at both first and second fruiting position, while in treatment P1 and P2 fruits were retained only at single position and rest of the fruiting forms were removed, which resulted in less number of flowers plant^{-1} in P1 and P2 as compared to P1, 2. The data further manifested that least number of flowers plant^{-1} were obtained from P2 (35.7 and 37.8) which was statistically at par with P1 with flower count of 38.7 and 41.0 during 2011 and 2012, respectively.

These results reveal that number of flowers decreased in almost all fruiting form removal treatments except the treatment where 25 % squares were removed for a period of one month from the day squares started developing and that of 0 % square removal treatment during both the crop growth seasons. It clearly indicates that removal of squares upto a certain extent resulted in higher number of flowers. It might be due to the production of replacement fruit for the fruit loss earlier as cotton has the compensation ability to produce more fruiting forms because of its indeterminate growth habit. The compensation for fruiting forms depends on the removal time and amount, as 50 % square removal treatment did not compensate for the fruiting bodies, which were removed earlier and produced significantly less number of flowers plant^{-1} than 0 and 25 % square removal treatments. The findings are in accordance with those of Brown *et al* (2000), Gore *et al* (2000), and Abaye *et al* (2000) who reported that extremely heavy fruit damage of squares greatly reduced the total number of flowers plant^{-1}. The interaction between hybrids and fruiting form removal treatments was non significant in both the years.

4.2.12 Squares Abscised per Plant

All the hybrids differed significantly for the abscission of squares during both the years (Table 4.26 and Fig. 4.17). Significantly higher number of squares abscised in RCH 314 (16.63 and 14.49) as compared to both the other hybrids during 2011 and 2012, respectively. The number of squares abscised in hybrid MRC 7017 were 14.58 and 11.77 which were statistically at par with hybrid MRC 7031 (14.39 and 11.62) during 2011 and 2012, respectively. However, the abscission of squares in hybrid MRC 7031 was less as compared to the other two hybrids.

Different fruiting form removal treatments also exhibited a significant impact on abscission of squares plant^{-1} and as obvious from the data (Table 4.26 and Fig. 4.18) significantly less number of squares (9.20 and 7.44) abscised where fruits were retained at first position (P1) as compared to all other fruiting form removal treatments except P2 where 9.30 and 7.51 number of squares abscised during 2011 and 2012, respectively. Undamaged control (0 %) showed maximum abscission of squares plant^{-1} (20.57 and 16.72) and it was statistically at par with the treatment where squares were removed upto 25 % (20.08 and 16.23). The less abscission of squares from P1 and P2 as compared to all other fruiting form removal treatments may be due to higher translocation of assimilates towards the existing fruiting bodies as a result of fruiting form removal from all the positions except first and second. The translocation of assimilates into first and second fruiting position resulted better utilization of assimilates as single fruiting body was present on all sympodial branches. Higher abscission in 0 and 25 % square removal treatments was due to the fact that these treatments exhibited more number of squares plant^{-1} and there was competition for available photosynthates for their development. As we know cotton is an indeterminate crop and its vegetative growth continues after flowering which creates assimilate imbalance between vegetative and reproductive parts that causes abscission of squares. The less translocation of photosynthates can be justified by the less vegetative growth at later stages of crop which was obvious from the plant height (Table 4.21).

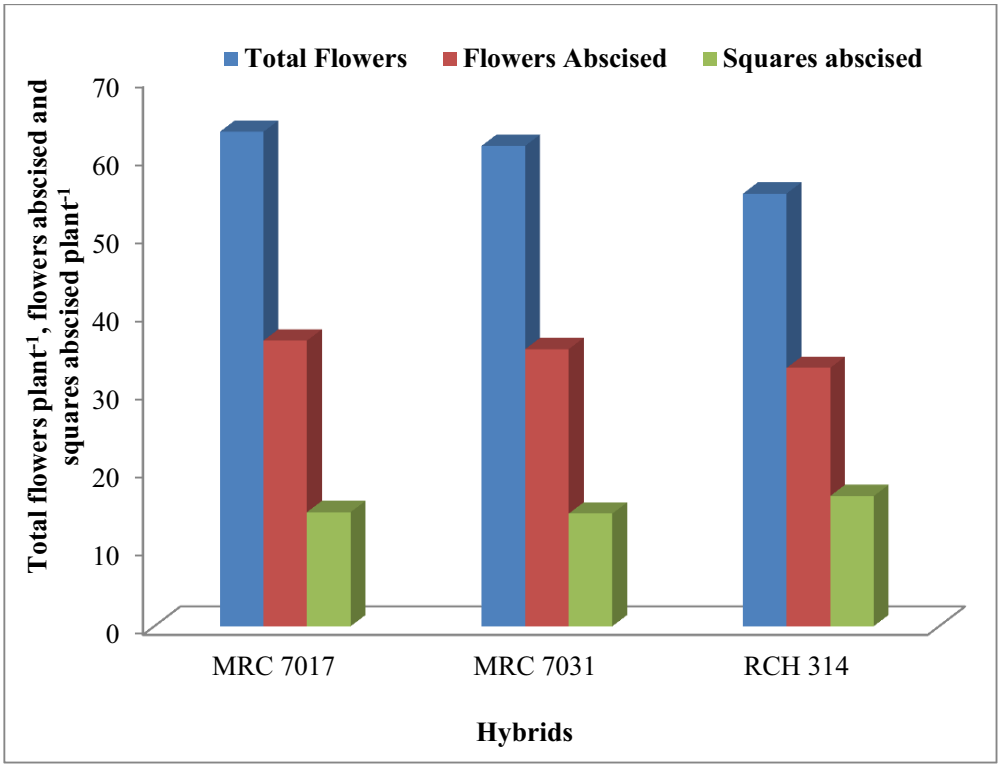
4.2.13 Flowers Abscised per Plant

Data presented in Table 4.26 and illustrated in Fig. 4.17 depict that all the hybrids differed significantly for the abscission of flowers plant^{-1}. The abscission of flowers from hybrid MRC 7017 were significantly more (36.5 and 34.6) as compared to hybrid RCH 314 (33.0 and 31.3) but it was statistically at par with MRC 7031 where 35.4 and 33.6 number of flowers abscised during 2011 and 2012, respectively. Cotton plant abscise some amount of flowers due to hormonal imbalance or due to adverse weather conditions (Sadras 1996b).

Table 4.26: Effect of fruiting form removal treatments on total flowers per plant, flowers abscised and squares abscised per plant of *Bt* cotton hybrids

Treatment	Total Flowers plant^{-1}		Flowers Abscised plant^{-1}		Squares abscised plant^{-1}	
	2011	2012	2011	2012	2011	2012
Hybrids						
MRC 7017	63.2 a	66.9 a	36.5 a	34.6 a	14.58 b	11.77 b
MRC 7031	61.4 a	65.0 a	35.4 ba	33.6 a	14.39 b	11.62 b
RCH 314	55.3 b	58.5 b	33.0 b	31.3 b	16.63 a	13.49 a
SEm	**1.20**	**1.27**	**0.77**	**0.58**	**0.31**	**0.25**
F(p)	**<0.0001**	**<0.0001**	**0.001**	**<0.0001**	**<0.0001**	**<0.0001**
Fruiting form removal						
0%	79.6 a	84.3 a	49.9 a	47.3 a	20.57 a	16.72 a
25%	80.5 a	85.2 a	47.1 b	44.7 b	20.08 a	16.23 a
50%	71.9 b	76.1 b	44.6 b	42.3 c	17.94 b	14.49 b
P1 (Retain at 1st position)	38.7 d	41.0 d	19.1 d	18.1 e	9.20 d	7.44 d
P2 (Retain at 2nd position)	35.7 d	37.8 d	19.9 d	18.8 e	9.30 d	7.51 d
P1, 2 (Retain at 1st and 2nd position)	53.1 c	56.2 c	29.3 c	27.7 d	14.12 c	11.40 c
SEm	**1.28**	**1.36**	**0.90**	**0.66**	**0.30**	**0.27**
F(p)	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**
Interaction F(p)	**0.90**	**0.90**	**0.56**	**0.18**	**0.19**	**0.25**

(a)



(b)

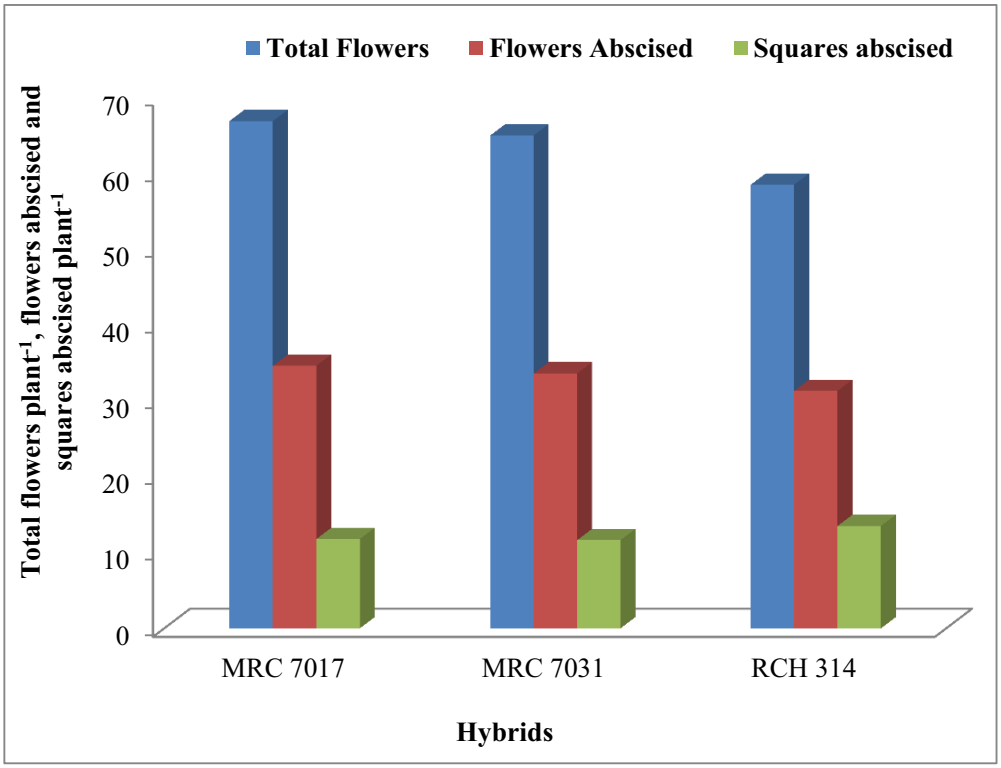
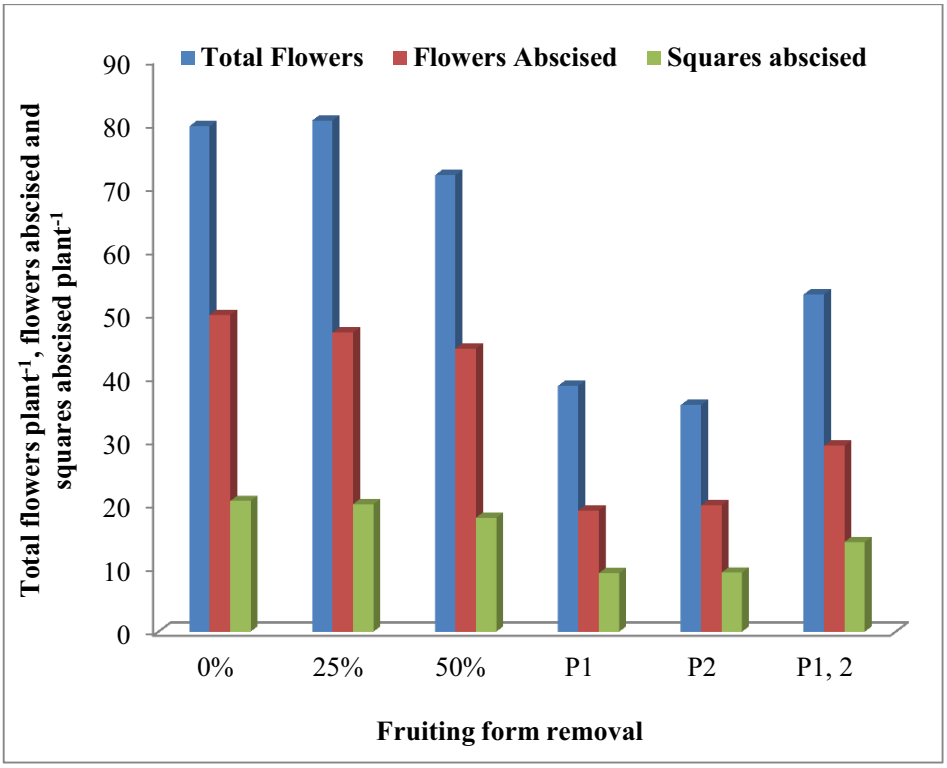


Fig 4.17: Total flowers per plant, squares abscised and flowers abscised per plant of different hybrids during 2011 (a) and 2012 (b)

(a)



(b)

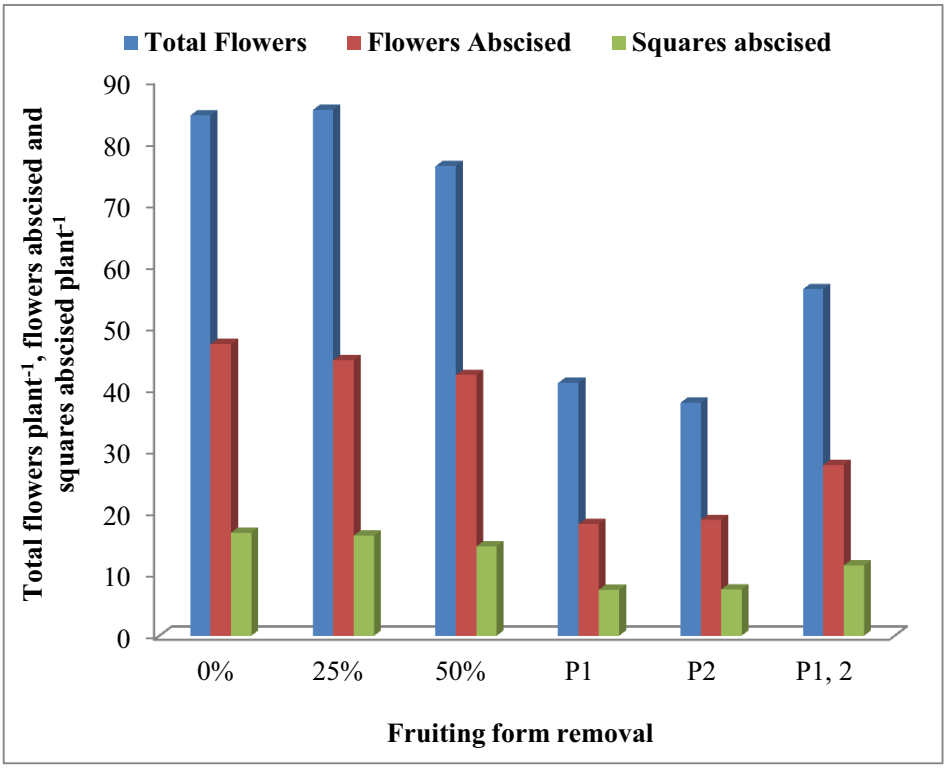


Fig 4.18: Total flowers, squares abscised and flowers abscised per plant of different hybrids as affected by fruiting form removal treatments during 2011 (a) and 2012 (b)

Scrutiny of data presented in Table 4.26 and depicted in Fig. 4.18 reveal that abscission of flowers were significantly higher in 0 % square removal treatment (49.9 and 47.3) than all other fruiting form removal treatments during 2011 and 2012, respectively. The treatments where squares were removed upto 25 and 50 % for a period of one month were statistically at par with each other for the number of flowers abscised during 2011 while during 2012, a significant difference was observed for the abscission of flowers between these two square removal treatments. However, the treatment where squares were removed upto 25 and 50 % for a period of one month had higher abscission rate as compared to P1, P2 and P1, 2 during both the years. Abscission of flowers in treatment P1, 2 was significantly more (29.3 and 27.7) as compared to P1 and P2 during both the years. P1 and P2 were statistically similar for the abscission of flowers during both the years. The abscission of flowers in 0 and 25 % square removal treatments were more because these treatments produced higher number of flowers plant^{-1} which raised the demand for assimilates from the vegetative parts for their development. Whereas, 0 and 25 % square removal treatments had less vegetative growth as compared to 50 % square removal treatment, P1, P2 and P1, 2 therefore, the supply of assimilates was less towards the existing fruiting bodies and as result of competition between the fruiting bodies for the available assimilates become the cause of higher abscission. Cotton has an indeterminate growth pattern which enables it to withstand the loss of many fruiting structures without significant reductions in yield.

4.2.14 Setting Percentage

Setting percentage is one of the important parameter which determines seed cotton yield. Data presented in Table 4.27 reveal that hybrids did not differ significantly for the setting percentage during both the years. Hybrid MRC 7017 and MRC 7031 recorded similar setting percentage (48.0 and 49.5) and RCH 314 recorded setting percentage of 47.4 and 48.8 during 2011 and 2012, respectively.

Fruiting form removal treatments had a significant effect on setting percentage. Data presented in Table 4.27 show that the treatment where fruits were retained at position one (P1) had significantly higher setting percentage (55.8 and 57.6) than all other fruiting form removal treatments during 2011 and 2012, respectively. Setting percentage in P2 was 48.3 and 49.8 and it was significantly less than P1. However, P1 and P2 had almost similar number of total flowers plant^{-1} during both the years. This decrease in setting percentage might be due to more shedding of flowers from second fruiting position. Heitholt, 1997 also observed that fruiting positions had a great impact on number of flowers and bolls.

Table 4.27: Effect of hybrids and fruiting form removal on setting percentage of *Bt* cotton

Treatment	Setting (%)	
	2011	**2012**
Hybrids		
MRC 7017	48.0 a	49.5 a
MRC 7031	48.0 a	49.5 a
RCH 314	47.4 a	48.8 a
SEm	**2.09**	**2.16**
F(p)	**0.92**	**0.92**
Fruiting form removal		
0%	43.3 c	44.6 c
25%	44.4 c	45.8 c
50%	44.3 c	45.7 c
P1 (Retain at 1st position)	55.8 a	57.5 a
P2 (Retain at 2nd position)	48.3 bc	49.8 bc
P1, 2 (Retain at 1st and 2nd position)	50.66 b	52.26 b
SEm	**1.81**	**1.87**
F(p)	**<0.0001**	**<0.0001**
Interaction F(p)	**1.00**	**1.00**

Among square removal treatments, where 0, 25 and 50 % squares were removed at pin head stage for a period of one month, recorded significantly lower setting percentage (43.3, 44.4 and 44.3) respectively, in 2011 and (44.6, 45.8 and 45.7) respectively, in 2012 as compared to P1 and P1, 2. Whereas 0, 25 and 50 % square removal treatments were statistically at par with each other and also with P2 treatment during both the years.

The significant improvement in the setting percentage with retaining of fruits at different positions *viz*. P1 and P1, 2 might be because of better partitioning of metabolites towards the leaves, stem and branches which resulted in taller plants (Table 4.21) and sympodial branches plant^{-1} (Table 4.24) during the grand growth period of crop. During reproductive period these assimilates were remobilized towards the existing fruiting bodies at specific positions thereby exerting a favourable effect on retention of fruiting bodies by preventing their abscission.

4.2.15 Total Bolls per Plant

Total number of bolls plant^{-1} is an important parameter influencing the yield. As shown in Table 4.28 and represented in Fig. 4.19, hybrids differed significantly for total number of bolls plant^{-1}. MRC 7017 recorded maximum number of bolls plant^{-1} (28.6 and 32.1) which was statistically at par with hybrid MRC 7031 which produced 27.8 and 31.2 bolls plant^{-1} but produced significantly higher number of bolls plant^{-1} than hybrid RCH 314 (24.6 and 27.7) during 2011 and 2012, respectively. Higher number of total bolls plant^{-1} in hybrid MRC 7017 was due to the better growth and development of plants which resulted in higher number of sympodial branches and flowers plant^{-1}. The differences for the number of bolls plant^{-1} in *Bt* cotton hybrids have also been reported by Srinivasan (2006) and Srinivasulu *et al* (2006a).

Different fruiting form removal treatments had a significant effect on total bolls plant^{-1} (Table 4.28, Fig. 4.20). Maximum number of total bolls plant^{-1} (34.7 and 39.0) were produced in treatment where 25 % squares were removed and was statistically at par with the treatment where 0 % squares were removed (33.4 and 37.5) but produced significantly higher number of total bolls than all other fruiting form removal treatments during 2011 and 2012 respectively. Total bolls plant^{-1} in 50 % square removal treatment were 30.8 and 34.6 which were significantly higher than the fruit retention treatments (P1, P2 and P1, 2) but recorded significantly lower total bolls plant^{-1} than 0 and 25 % square removal treatments. The results for the removal of squares emphasized that transgenic cotton has the ability to tolerate at least modest levels of square loss. Gore *et al* (2000) and Abaye *et al* (2000) who reported that extremely heavy fruit damage greatly reduced the boll number. Wu *et al* (2007) also confirmed that compensation capacity of cotton for square removal may depend on the removal time.

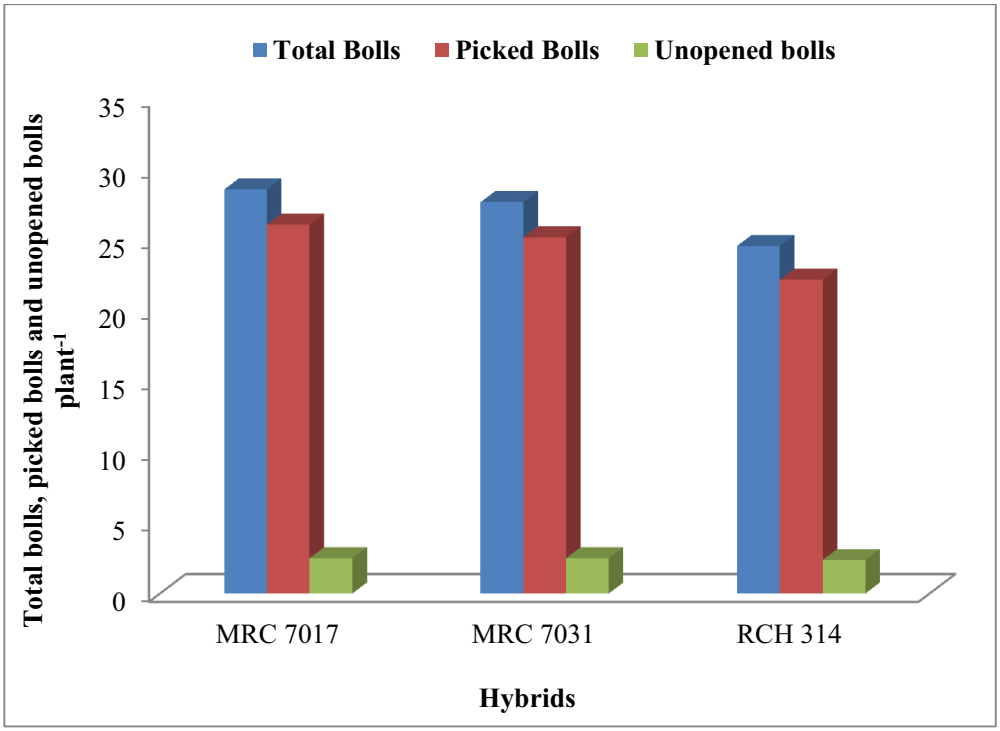
Treatments where fruiting forms were retained at specific fruit positioning sites (P1, P2 and P1, 2) produced significantly lower number of total bolls plant^{-1} as compared to 0, 25 and 50 % square removal treatments during both the years. The decrease in number of total bolls plant^{-1} in specific fruit position retaining treatments was due to the less number of flower production (Table 4.26) which was as a result of continuous removal of fruiting forms upto 50 % boll open initiation stage.

Among the site specific fruit retaining treatments the treatment where fruits were retained at first position (P1) recorded significantly more number of total bolls plant^{-1} (20.7 and 23.3) as compared to the treatment where fruits were retained at second position (P2). However, treatment where fruits were retained at second position (P2) recorded significantly less number of total bolls plant^{-1} (16.5 and 18.5) than all the fruiting form removal treatments during 2011 and 2012, respectively. It indicates that first position (P1) had higher retaining capacity as it might be the dominant carbohydrate sink on sympodia as compared to the second position (P2).

Table 4.28: Total bolls, picked bolls, unopened bolls and boll opening percentage as affected by hybrids and fruiting form removal treatments

Treatment	Total Bolls		Picked Bolls		Unopened bolls		Boll opening %age	
	2011	2012	2011	2012	2011	2012	2011	2012
Hybrids								
MRC 7017	28.6 a	32.1 a	26.1 a	29.3 a	2.50 a	2.84 a	91.4 a	91.3 a
MRC 7031	27.7 a	31.2 a	25.2 a	28.41 a	2.50 a	2.84 a	91.2 a	91.1 a
RCH 314	24.6 b	27.7 b	22.2 b	25.0 b	2.37 a	2.69 a	90.5 a	90.4 a
SEm	**0.43**	**0.49**	**0.47**	**0.53**	**0.31**	**0.35**	**0.97**	**0.96**
F(p)	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**0.92**	**0.92**	**0.78**	**0.78**
Fruiting form removal								
0%	33.4 a	37.5 a	30.1 a	33.8 a	3.25 a	3.69 a	90.3 a	90.2 a
25%	34.7 a	39.0 a	31.5 a	35.3 a	3.25 a	3.68 a	90.6 a	90.5 a
50%	30.8 b	34.6 b	28.0 b	31.4 b	2.83 a	3.21 a	90.9 a	90.8 a
P1 (Retain at 1st position)	20.7 d	23.3 d	19.0 d	21.4 d	1.66 b	1.89 b	91.9 a	91.8a
P2 (Retain at 2nd position)	16.5 e	18.5 e	15.0 e	16.9 e	1.41 b	1.61 b	91.2 a	91.2 a
P1, 2 (Retain at 1st and 2nd position)	25.9 c	29.1 c	23.5 c	26.4 c	2.33 ba	2.64 ba	91.0 a	90.9 a
SEm	**0.50**	**0.56**	**0.51**	**0.57**	**0.38**	**0.43**	**1.26**	**1.26**
F(p)	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**0.003**	**0.00**	**0.96**	**0.96**
Interaction F(p)	**0.92**	**0.92**	**0.97**	**0.97**	**1.00**	**1.00**	**1.00**	**1.00**

(a)



(b)

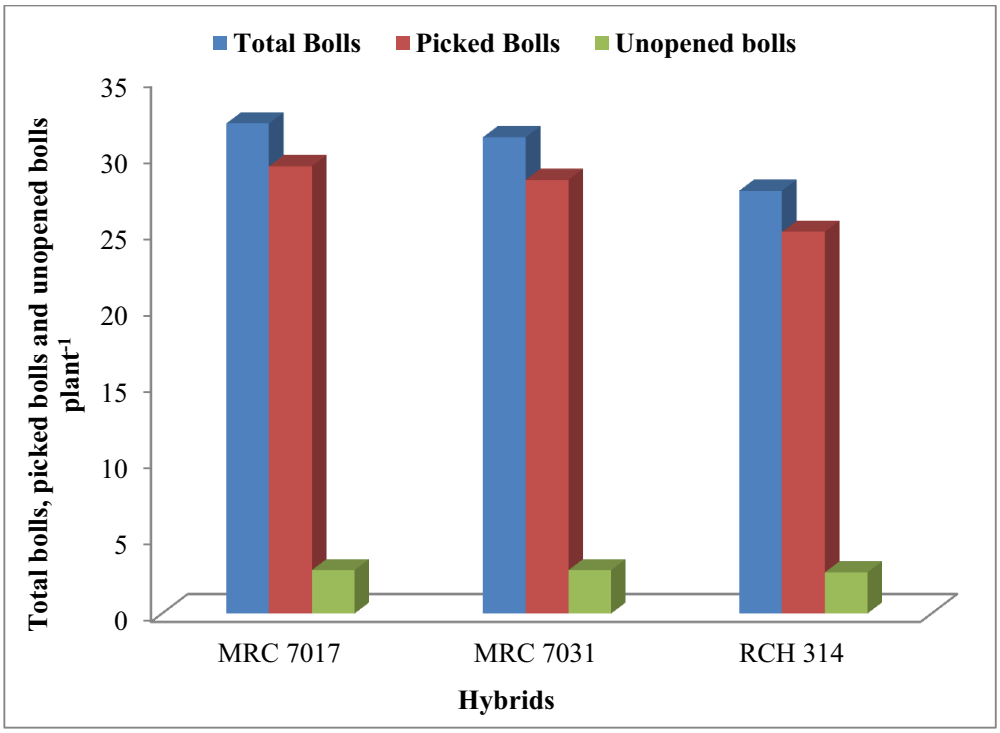
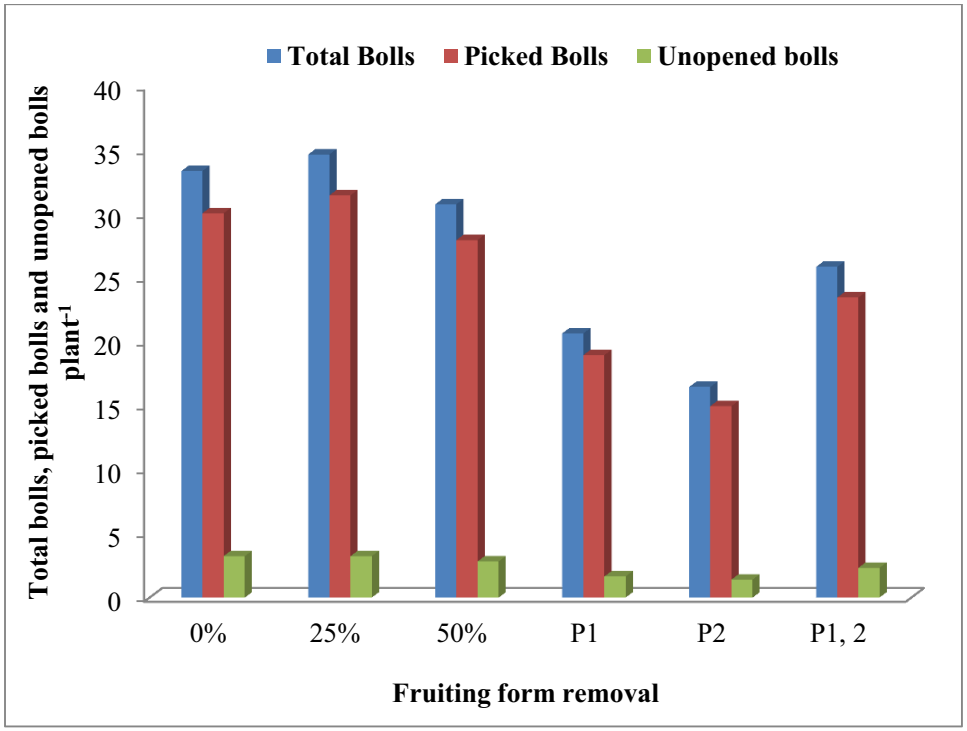


Fig 4.19: Total bolls, picked bolls and unopened bolls per plant of different hybrids during 2011 (a) and 2012 (b)

(a)



(b)

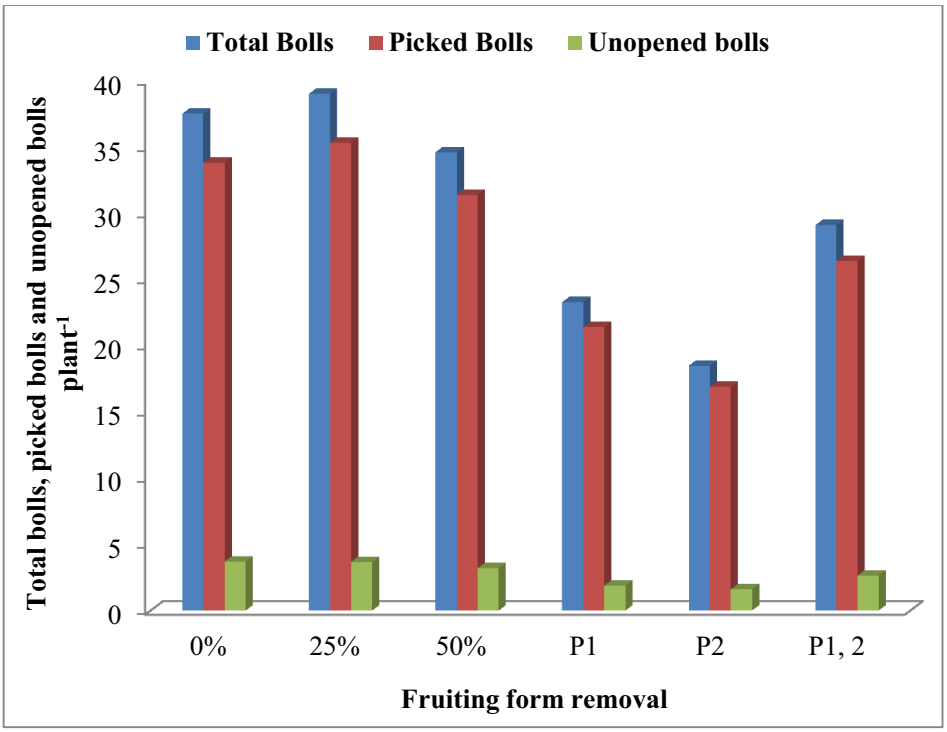


Fig 4.20: Total bolls, picked bolls and unopened bolls per plant of different hybrids as influenced by fruiting form removal treatments during 2011 (a) and 2012 (b)

It has also been observed that more retention on first fruiting site might help in increasing the yield potential of cotton. Constable (1991) had also been reported that better boll retention at first positions on fruiting branches is an agronomic advantage which helps in yield improvement in cotton. The interaction between hybrids and fruiting form removal treatments was non significant during both the years.

4.2.16 Picked Bolls per Plant

The most important character which directly contributes towards seed cotton yield is the number of picked or opened bolls plant^{-1}. A perusal of data presented in Table 4.28 and represented in Fig. 4.19, reveal that hybrid MRC 7017 produced maximum number of picked bolls plant^{-1} (26.1 and 29.3) and it was statistically at par with hybrid MRC 7031 (25.2 and 28.4) and both the hybrids produced significantly higher number of picked bolls plant^{-1} than RCH 314 which produced 22.3 and 25.0 number of picked bolls plant^{-1} during 2011 and 2012, respectively. The difference in picked bolls plant^{-1} was also observed by Puri (2001) and the difference in picked bolls plant^{-1} was due to the higher number of flowers and total bolls plant^{-1} in MRC 7017 and MRC 7031.

Scrutiny of data presented in Table 4.28 and depicted in Fig. 4.20 reveal that picked bolls plant^{-1} were significantly affected by fruiting form removal treatments during both the years. 25 % square removal treatment produced significantly higher number of picked bolls plant^{-1} (31.5 and 35.3) than all other fruiting form removal treatments except 0 % square removal treatment which produced 30.2 and 33.9 picked bolls plant^{-1} during 2011 and 2012, respectively. Treatment where 50 % squares were removed for a period of one month produced 28.0 and 31.4 picked bolls plant^{-1} had significantly higher number of picked bolls plant^{-1} than the treatments where fruiting bodies were retained at first (P1), second (P2) and at both first and second (P1, 2) position during both the years.

Among site specific fruit retaining treatments significantly more number of picked bolls plant^{-1} (23.6 and 26.5) were recorded in P1, 2 than the treatments where fruits were retained at first (P1) and at second (P2) position during 2011 and 2012, respectively. The picked bolls plant^{-1} in the treatment where fruits were retained at first position (P1) were 19.0 and 21.4 which were significantly higher than the treatment where fruits were retained at second position i.e. P2 (15.0 and 16.9) during both the years. It reveals that the retention of bolls at the first position (P1) was higher than retention at second position (P2). Heitholt (1997) also reported that the removal of floral bud forms from proximal or distal floral bud positions produced greater percentage of bolls at first fruit position P1 as compared to second position (P2). The increase in picked bolls plant^{-1} at P1 as compared to P2 was due to the production of higher number of total bolls plant^{-1} (Table 4.28). No interaction was observed for picked bolls plant^{-1} during both the years.

4.2.17 Unopened Bolls

Data presented in Table 4.28 and depicted in Fig. 4.19 and 4.20, show that hybrids MRC 7017, MRC 7031 and RCH 314 did not differ significantly for the number of unopened bolls plant^{-1}. Whereas, fruiting form removal treatments had significant effect on unopened bolls plant^{-1}, it was found that higher number of unopened bolls were obtained in 0, 25 and 50 % square removal treatments during both the years i.e. (3.25, 3.25 and 2.83) respectively, during 2011 and (3.69, 3.68 and 3.21) respectively, during 2012. Least number of unopened bolls were observed in P2 (1.41 and 1.61) which was statistically at par with P1 with 1.66 and 1.89 number of unopened bolls plant^{-1} during 2011 and 2012, respectively. More number of unopened bolls in 0, 25 and 50 % square removal treatment might be due to the nutritional imbalance within the plant as the higher number of flowers and bolls had to compete for the available assimilates in the plant. While in fruit retention treatments (P1, P2 and P1, 2) the existing number of fruiting bodies per sympodia were less and the supply of assimilates was ample for these fruiting bodies so, the shedding of fruiting bodies was less. Interactions between all the treatments were non significant in both the years.

4.2.18 Boll Opening Percentage

Data presented in Table 4.28 reveal that hybrids did not differ significantly for boll opening percentage during both the years. Scrutiny of the data presented in Table 4.28 clearly show that different fruiting form removal treatments did not significantly influence the boll opening percentage in any of the two years. The interaction between hybrids and fruiting form removal treatments was non significant during both the years.

4.2.19 Boll Weight

The weight of seed cotton in each boll has a direct influence on the total seed cotton yield. A perusal of the data presented in the Table 4.29 reveal that hybrids did not differ significantly for boll weight. The non significant variation among the hybrids was due to the allocation of similar amount of assimilates to the bolls which in turn produced same amount of lint and seeds in each boll as manifested through non significant variations in lint and seed indices (Table 4.31) of the hybrids

Different fruiting form removal treatments differed significantly for boll weight during both the years (Table 4.29). The treatment where fruits were retained at first position (P1) attained maximum boll weight (3.64 and 3.97 g) which was statistically at par with all other fruiting form removal treatments but recorded significantly higher boll weight than the treatment 0 % square removal treatment. The lower amount of weight in each boll (3.44 and 3.76 g) was recorded in 0 % square removal treatment than all the fruiting form removal treatments during 2011 and 2012, respectively. It was observed that the boll weight was not

significantly affected in 0, 25 and 50 % square removal treatments and also in P2 and P1, 2 treatments but better partitioning of assimilates into the first position boll helped in increasing the boll weight in P1. Bednarz *et al* (2006) also observed that superior fruiting positions in terms of overall quality occur at first positions which are also known as inner fruiting positions. There was no interaction between hybrids and fruiting form removal during both the years.

Table 4.29: Boll weight (g) as affected by hybrids and fruiting form removal treatments

Treatment	Boll weight (g)	
	2011	2012
Hybrids		
MRC 7017	3.55 a	3.87 a
MRC 7031	3.54 a	3.86 a
RCH 314	3.51 a	3.83 a
SEm	**0.05**	**0.05**
F(p)	**0.81**	**0.81**
Fruiting form removal		
0%	3.44 b	3.76 b
25%	3.47 ba	3.78 ba
50%	3.50 ba	3.82 ba
P1 (Retain at 1st position)	3.64 a	3.97 a
P2 (Retain at 2nd position)	3.60 ba	3.92 ba
P1, 2 (Retain at 1st and 2nd position)	3.54 ba	3.86 ba
SEm	**0.06**	**0.06**
F(p)	**0.20**	**0.20**
Interaction F(p)	**1.00**	**1.00**

4.2.20 Seed Cotton Yield of First Pick

Yield is the ultimate result of the interaction of various factors and is a valid criterion for comparing the efficiency of different treatments. Data presented in Table 4.30 and in Fig. 4.21 depict that hybrids differed significantly for the seed cotton yield harvested in first picking. Hybrids MRC 7017 and MRC 7031 were statistically at par with each other for the seed cotton yield obtained in first pick, though MRC 7017 obtained maximum seed cotton yield of 52.8 and 55.5 g plant^{-1} and both the hybrids recorded significantly higher seed cotton

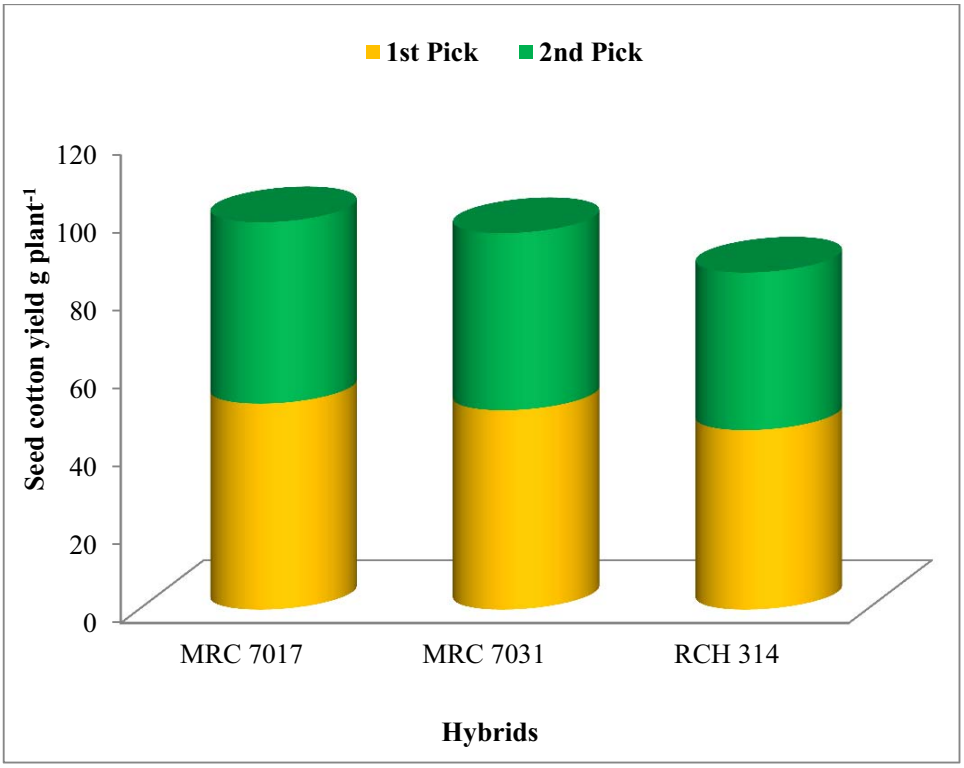
yield than RCH 314 (46.0 and 48.3 g plant^{-1}) during 2011 and 2012, respectively. Higher yield by the hybrid MRC 7017 can be explained by the better growth and development due to its higher genetic potential as evident from higher plant height (Table 4.21) which resulted in increased number of sympodial branches plant^{-1} (Table 4.24), total flowers plant^{-1} (Table 4.26), total bolls and picked bolls plant^{-1} (Table 4.28).

Fruiting form removal treatments also had a significant effect on the amount of seed cotton picked plant^{-1} in first picking (Table 4.30 and Fig. 4.22). Treatment where 25 % squares were removed for a period of one month recorded significantly higher seed cotton yield (64.1 and 67.3 g plant^{-1}) as compared to all other fruiting form removal treatments but was statistically at par with 0 % square removal treatment which produced 62.8 and 65.9 g plant^{-1} of seed cotton yield during 2011 and 2012, respectively. The treatment where 50 % squares were removed recorded significantly lower seed cotton yield (55.9 and 58.8 g plant^{-1}) as compared to 0 and 25 % square removal treatments during 2011 and 2012, respectively. The indeterminate growth pattern of cotton enables it to withstand the loss of fruiting structures without significant reductions in yield whereas, more damage i.e. upto 50 % resulted in lesser yield. Gore *et al* (2000) and Abaye *et al* (2000) also observed that extremely heavy fruit damage greatly reduced the seed cotton yield. The treatment where fruiting forms were removed from all the fruiting positions except first position (P1) recorded seed cotton yield of 38.8 and 40.7 g plant^{-1} which was significantly lower than 0, 25 and 50 % square removal treatments and also from P1, 2 treatment but produced significantly higher seed cotton yield than P2 which yielded 31.1 and 32.7 g plant^{-1} during 2011 and 2012, respectively. The significantly lower seed cotton yield of first pick was recorded in P2 as compared to all other treatments during both the years. Treatment where fruiting forms were removed from all the fruiting positions except first and second position (P1, 2) recorded significantly lower seed cotton yield (47.3 and 49.6 g plant^{-1} during 2011 and 2012, respectively) as compared to 0, 25 and 50 % square removal treatments, but attained significantly higher seed cotton yield than P1 and P2 during both the years. The decrease in yield in site specific fruit retention treatments (P1, P2 and P1, 2) might be because of continuous removal of fruiting forms upto the boll open initiation stage while, in 0, 25 and 50 % square removal treatments, squares were removed for period of one month from the day squares started developing which caused less removal of fruiting forms than P1, P2 and P1, 2 and resulted in more number of flowers, total bolls and picked bolls plant^{-1} and ultimately gave higher seed cotton yield during both the years.

Table 4.30: Effect of hybrids and fruiting form removal on seed cotton yield (g plant^{-1}) of *Bt* cotton

Treatments	Seed cotton yield (g plant^{-1})					
	1st Pick		2nd Pick		Total	
	2011	2012	2011	2012	2011	2012
Hybrids						
MRC 7017	52.8 a	55.5 a	46.5 a	47.9 a	99.4 a	103.4 a
MRC 7031	51.1 a	53.7 a	45.4 a	46.7 a	96.5 a	100.5 a
RCH 314	46.0 b	48.3 b	40.4 b	41.6 b	86.4 b	89.9 b
SEm	**0.92**	**0.96**	**0.86**	**0.89**	**1.35**	**1.40**
F(p)	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**
Fruiting form removal						
0%	62.8 a	65.9 a	54.2 a	55.8 a	117.1 a	121.8 a
25%	64.0 a	67.2 a	55.7 a	57.4 a	119.8 a	124.7 a
50%	55.9 b	58.7 b	51.2 b	52.7 b	107.2 b	111.5 b
P1 (Retain at 1st position)	38.7 d	40.7 d	33.5 d	34.5 d	72.3 d	75.2 d
P2 (Retain at 2nd position)	31.1 e	32.7 e	26.8 e	27.6 e	58.0 e	60.3 e
P1, 2 (Retain at 1st and 2nd position)	47.2 c	49.6 c	43.0 c	44.3 c	90.3 c	93.9 c
SEm	**1.02**	**1.07**	**0.89**	**0.92**	**1.17**	**1.22**
F(p)	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**
Interaction F(p)	**0.99**	**0.99**	**0.99**	**0.99**	**0.98**	**0.99**

(a)



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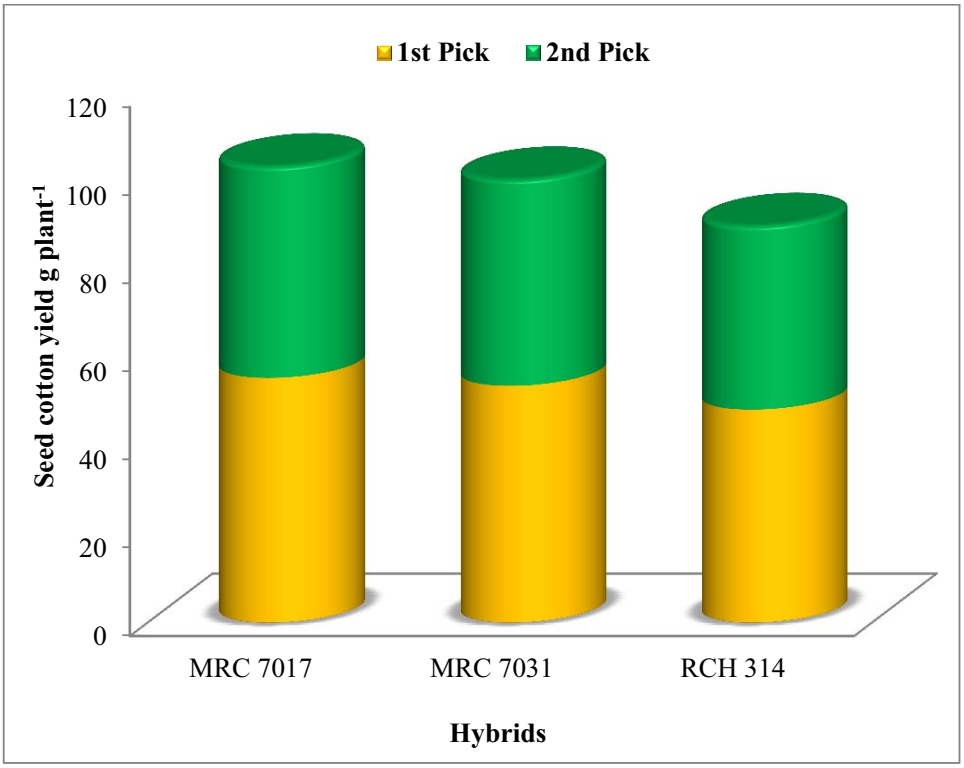
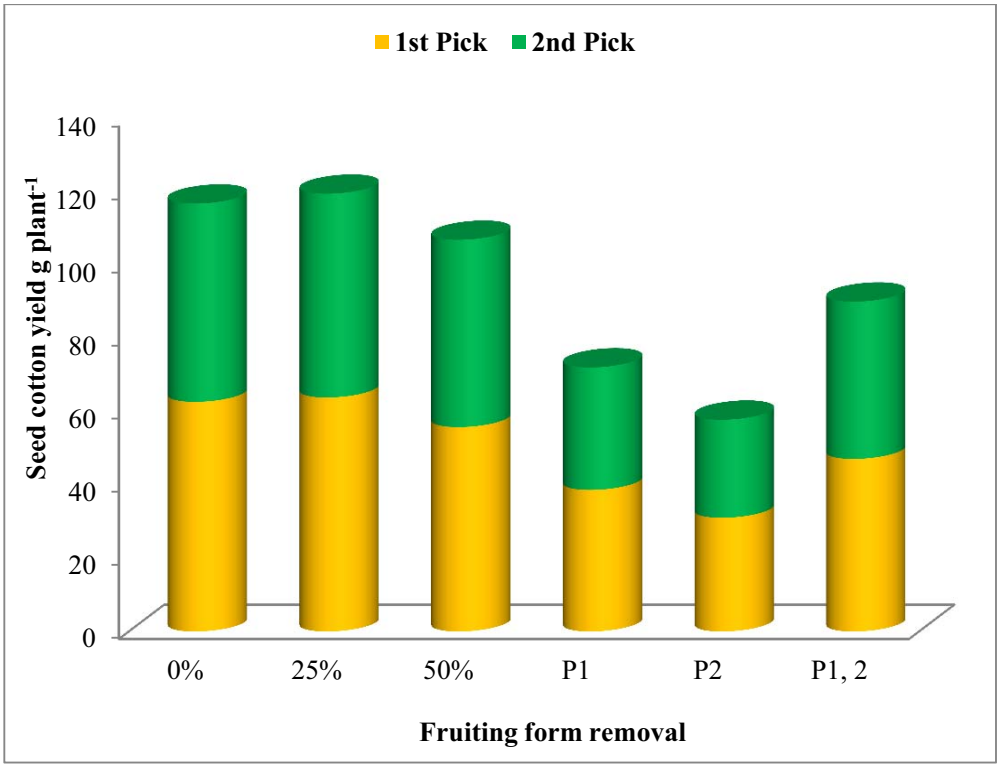


Fig 4.21: Seed cotton yield (g plant^{-1}) of different hybrids during 2011 (a) and 2012 (b)

(a)



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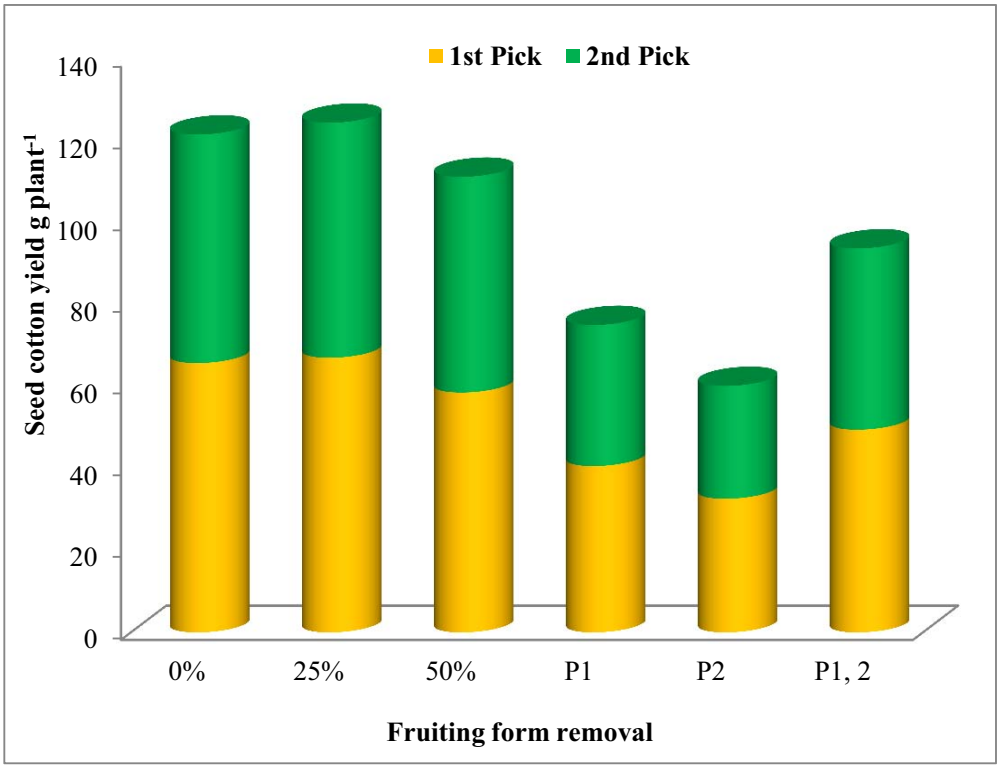


Fig 4.22: Seed cotton yield (g plant^{-1}) of different hybrids as influenced by fruiting form removal treatments during 2011 (a) and 2012 (b)

The treatment where fruits were retained at first position (P1) produced significantly higher seed cotton yield than the treatment where fruiting bodies were retained at second position (P2). Though, in P1 and P2 fruiting bodies were retained at single fruiting position of all the sympodial branches, still P1 attained 24.4 % higher yield than P2 during both the years. It was due to higher number of total bolls and picked bolls plant^{-1} at first fruiting position as compared to second fruiting position as evident from Table 4.28. Jenkins *et al* (1990) also observed that bolls at position one on sympodial branches produced more total yield than those at position two and all other positions on sympodial branches. All the interaction effects was non significant for the seed cotton yield of first pick during both the years.

4.2.21 Seed Cotton Yield of Second Pick

Data presented in Table 4.30 and illustrated in Fig. 4.21 reveal that, hybrids differd significantly for amount of seed cotton yield in second picking. Hybrid MRC 7017 yielded the highest seed cotton yield (46.6 and 47.9 g plant^{-1}) which was statistically at par with the hybrid MRC 7031 which obtained seed cotton yield of 45.4 and 46.8 g plant^{-1} but recorded significantly higher seed cotton than hybrid RCH 314 (40.4 and 41.6 g plant^{-1}) in second picking during 2011 and 2012, respectively. Significantly higher seed cotton yield of MRC 7017 can be explained by the better growth and development as evident from the higher plant height (Table 4.21) which resulted in increased number of sympodial branches plant^{-1} (Table 4.24), flowers plant^{-1} (Table 4.26), total bolls and picked bolls plant^{-1} (Table 4.28) recorded by the hybrid.

Data presented in Table 4.30 and in Fig. 4.22 depict that maximum seed cotton yield of 55.8 and 57.4 g plant^{-1} was recorded in the treatment where squares were removed upto 25 % which was statistically at par with 0 % square removal treatment (54.2 and 55.8 g plant^{-1}) but produced significantly higher seed cotton than all other fruiting form removal treatments during 2011 and 2012, respectively. The treatment where squares were retained at first and second position (P1, 2) recorded seed cotton yield of 43.1 and 44.4 g plant^{-1} which was significantly higher than P1 and P2 but failed to produce significantly higher seed cotton yield than 0, 25 and 50 % square removal treatments during 2011 and 2012, respectively. The treatment where fruits were retained at first position (P1) obtained significantly more seed cotton yield of 33.6 and 34.6 g plant^{-1} as compared to P2 which obtained 26.9 and 27.7 g plant^{-1} of seed cotton yield during 2011 and 2012, respectively. The interaction between all the treatments was non significant in both the years.

4.2.22 Total Seed Cotton Yield

A perusal of data presented in Table 4.30 and illustrated in Fig. 4.21 reveal that MRC 7017 recorded significantly higher total seed cotton yield of 99.4 and 103.5 g plant^{-1} as

compared to the hybrid RCH 314 which produced total seed cotton yield of 86.4 and 89.9 g plant^{-1} during 2011 and 2012, respectively. Whereas, hybrid MRC 7031 produced total seed cotton yield of 96.6 and 100.5 g plant^{-1} which was statistically at par with hybrid MRC 7017 during 2011 and 2012, respectively. Higher seed cotton yield produced by the hybrid MRC 7017 can be explained by the better growth and development due to its higher genetic potential as evident from higher plant height (Table 4.21) which resulted in increased number of sympodial branches plant^{-1} (Table 4.24), total flowers plant^{-1} (Table 4.26), total bolls and picked bolls plant^{-1} (Table 4.28). Significant difference among the hybrids for seed cotton yield was also reported by Hoogar and Gidnavar (1997) and Singh *et al* (2011) as they also reported that the yield difference among the hybrids was due to their varied genetic potential.

Fruiting form removal treatments also had a significant effect on the amount of total seed cotton yield of two pickings (Table 4.30 and Fig. 4.22). The treatments where 25 % squares were removed recorded maximum seed cotton yield (119.8 and 124.7 g plant^{-1}) than all other fruiting for removal treatments but was statistically at par with 0 % square removal treatment which produced 117.2 and 121.8 g plant^{-1} of seed cotton yield during 2011 and 2012, respectively. Treatment where 50 % squares were removed recorded significantly lower seed cotton yield (107.2 and 111.6 g plant^{-1}) as compared to 0 and 25 % square removal treatments during 2011 and 2012, respectively. However, 50 % square removal treatment recorded significantly higher seed cotton yield than the treatments where fruits were retained at first (P1), second (P2) and at both first and second (P1, 2) position during both the years. The higher seed cotton yield obtained in 0 and 25 % square removal treatment was due to the reason that removal of fruiting forms at earlier stages were compensated by the cotton as it has indeterminate growth pattern which enables it to withstand the loss of fruiting structures without significant reduction in yield, whereas damage of fruiting forms when exceeds to 50 % could not be compensated by the cotton and resulted in lesser yield. Gore *et al* (2000) also observed that extremely heavy fruit damage greatly reduced the yield. Scrutiny of data indicates that cotton can tolerate at least modest levels of square removal without yield reduction.

The treatments in which fruits were retained at specific fruit positioning sites, maximum seed cotton yield (90.3 and 93.9 g plant^{-1}) was recorded in P1, 2 which was significantly lower than 0, 25 and 50 % square removal treatments but recorded significantly higher seed cotton yield than P1 and P2 during 2011 and 2012, respectively. All the fruit retention treatments (P1, P2 and P1, 2) recorded significantly lower seed cotton yield than 0, 25 and 50 % square removal treatments. Lower yield in site specific fruit retention treatments

(P1, P2 and P1, 2) was due to the less number of flowers (Table 4.26), total bolls and picked bolls plant^{-1} (Table 4.28) as compared to square removal treatments (0, 25 and 50 %). The crop where fruiting bodies were retained at first position (P1) recorded total seed cotton yield of 72.3 and 75.2 g plant^{-1} which was significantly more than P2 which produced seed cotton yield of 58.0 and 60.4 g plant^{-1} during 2011 and 2012, respectively. Though, in the treatment where fruits were retained at first position (P1) and at second position (P2), almost same number of fruiting forms were removed still, P1 attained 24.6 and 24.8 per cent higher yield than P2, and it might be due to the higher number of total bolls at P1 as evident from the higher setting percentage (Table 4.27). Jenkins *et al* (1990) also observed that bolls at position one on sympodial branches produced more total yield than those at position two and all other positions on sympodial branches. The interaction between hybrids and fruiting form removal treatments was non significant during both the years.

4.2.23 Bartlett Index

Bartlett index is an important indicator of maturity period of the crop. The higher value of the Bartlett index indicates early maturity. Different hybrids and fruiting form removal treatments did not exert any significant influence on the Bartlett index in any of the two years as evident from Table 4.31. No interaction was observed for Bartlett index in both the years.

4.2.24 Ginning Outturn (GOT)

Ginning out turn is an important quality character which influences the price of cotton in the market. It indicates the amount of lint presented in seed cotton. Perusal of the data presented in the Table 4.31 reveals that various hybrids and fruiting form removal treatments did not differ significantly for ginning out turn in any of the two years. All the interaction effects was non significant for hybrids and fruiting form removal treatments.

4.2.25 Seed Index

Seed index is an important component of seed cotton yield and is expressed as the weight of 100 seeds in grams. A lower value of seed index indicates more immature seeds which deteriorates the industrial value of the cotton seed. A scrutiny of the data given in the Table 4.31 indicates that different hybrids and fruiting form removal treatments did not influence the seed index significantly in both the years. The interaction between hybrids and fruiting form removal treatments was non significant during both the years.

4.2.26 Lint Index

Lint index is a measure of surface area and density of fibres on the seed. It is directly related to seed index and ginning out turn. Data presented in the Table 4.31 reveals that there was a non significant difference in lint index as affected by different hybrids and various fruiting form removal treatments. No interaction was observed for lint index in both the years.

Table 4.31: Effect of hybrids and fruiting form removal on seed index, lint index, ginning out turn and Bartlett index of *Bt* cotton

Treatment	Seed Index		Lint Index		GOT (%)		Bartlett Index	
	2011	2012	2011	2012	2011	2012	2011	2012
Hybrids								
MRC 7017	8.70 a	8.72 a	4.69 a	4.73 a	34.7 a	34.8 a	0.76 a	0.76 a
MRC 7031	8.67 a	8.68 a	4.64 a	4.66a	34.7 a	34.7 a	0.76 a	0.76 a
RCH 314	8.65 a	8.66 a	4.86 a	4.93 a	35.7 a	36.0 a	0.76 a	0.76 a
SEm	**0.20**	**0.20**	**0.26**	**0.26**	**0.78**	**0.79**	**0.003**	**0.003**
F(p)	**0.95**	**0.94**	**0.58**	**0.49**	**0.26**	**0.18**	**0.98**	**0.98**
Fruiting form removal								
0%	8.73 a	8.75 a	4.66 a	4.68 a	34.6 a	34.6 a	0.76 a	0.77 a
25%	8.70 a	8.71 a	4.61 a	4.62 a	34.5 a	34.5 a	0.76 a	0.76 a
50%	8.72 a	8.74 a	4.65 a	4.71 a	34.5 a	34.8 a	0.76 a	0.76 a
P1 (Retain at 1st position)	8.65 a	8.67 a	4.88 a	4.97 a	35.8 a	36.2 a	0.76 a	0.77 a
P2 (Retain at 2nd position)	8.60 a	8.61 a	4.80 a	4.83 a	35.5 a	35.6 a	0.76 a	0.77 a
P1, 2 (Retain at 1st and 2nd position)	8.63 a	8.64 a	4.77 a	4.81 a	35.2 a	35.4 a	0.76 a	0.76 a
SEm	**0.17**	**0.18**	**0.22**	**0.23**	**0.72**	**0.73**	**0.004**	**0.004**
F(p)	**0.99**	**0.99**	**0.96**	**0.91**	**0.68**	**0.54**	**0.66**	**0.67**
Interaction F(p)	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**

Experiment III: Productivity of cotton as influenced by detopping and growth retardants.

4.3.1 Plant Height

Plant height is a reliable index of plant growth at a given stage in crop's growth cycle. Its measurement is often used to monitor the effect of different treatments on crop growth. The data on periodic plant height recorded at 90, 120, 150 DAS and at last picking are presented in Table 4.32 and illustrated in Fig. 4.23 and 4.24. The scrutiny of the data indicates that there is a progressive increase in plant height with the advancement of crop age during both the years of study. A sharp increase in plant height was registered between 90 and 120 DAS, which is the rapid growth phase of the crop. After that, the rate of increase in plant height declined and was very less from 150 DAS to maturity during both the crop growth seasons.

The data presented in Table 4.32 and depicted in Fig. 4.23 reveal that at initial crop growth stage i.e. at 90 DAS, the plant height of all the hybrids was statistically at par with each other. However, a significant difference was observed for plant height among the hybrids from the period of 120 DAS to maturity in both the years. At 120, 150 and 180 DAS a significant increase in plant height was observed in hybrid MRC 7017 as compared to hybrid RCH 314 but it was statistically at par with hybrid MRC 7031 in both the years. At 120 DAS, hybrid MRC 7017 attained significantly higher plant height of 113.4 and 128.1 cm than RCH 314 but was statistically at par with hybrid MRC 7031 with plant height of 112.7 and 127.3 cm during 2011 and 2012, respectively. Similarly, at 150 and 180 DAS maximum plant height was recorded in hybrid MRC 7017 which was statistically at par with MRC 7031 and both the hybrids attained significantly higher plant height than hybrid RCH 314 during both the years. On an average least plant height was observed in hybrid RCH 314 during all the crop growth stages and at the time of maturity it was 127.2 and 141.0 cm during 2011 and 2012, respectively. Plant height is a genetically controlled character and the ultimate height of the crop or a particular variety is dependent upon its genetic makeup. The results obtained by Brar (1997) and Singh (1999) also emphasize the same point.

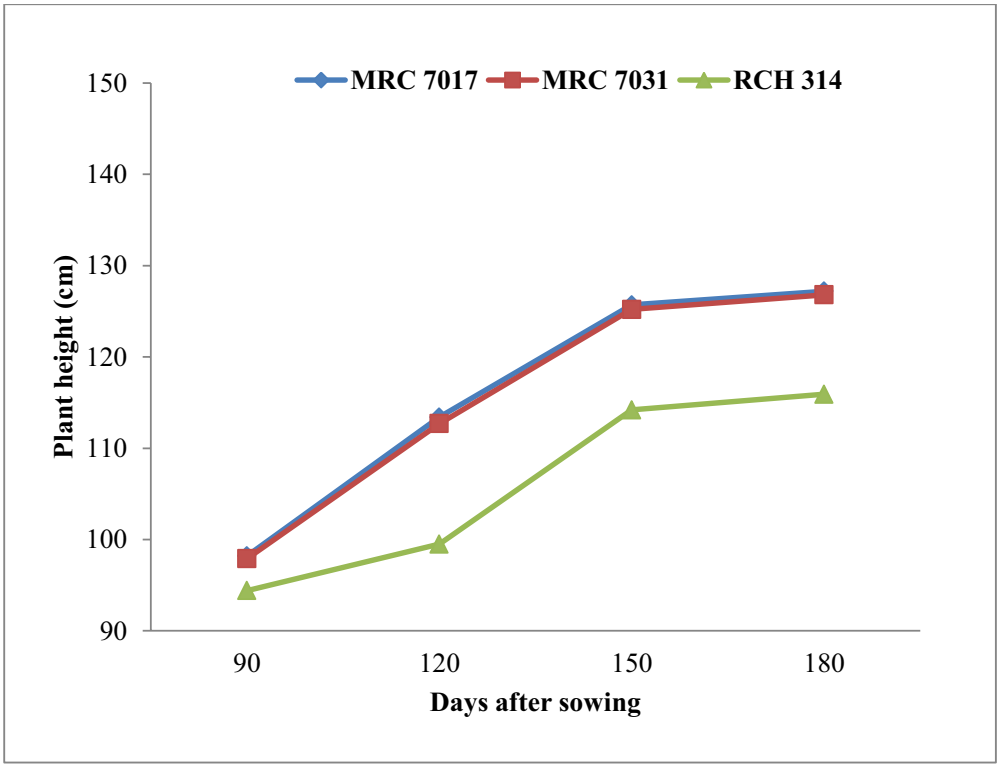
Different plant growth regulation treatments had a significant effect on plant height during both the years of investigation however, the response varied with the plant growth regulator (PGR) and its concentration (Table 4.32 and Fig. 4.24). The plant height measured at 90 DAS indicates that it was statistically similar in all the growth regulation treatments because the treatments were applied at 80 DAS and their effect was not manifested within 10 days of application. While, at 120 DAS the growth regulation treatments had a significant effect on plant height and it was observed that MC @ 300 ppm produced significantly shorter plants (101.4 and 115.2 cm during 2011 and 2012 respectively) as compared to control and detopping but was statistically at par with TIBA (100 ppm) and MH (250 ppm). At 150 DAS, significant influence on plant height was observed with application of different growth regulators. MC,

Table 4.32: Effect of hybrids and plant growth regulation treatments on plant height recorded at different stages

Treatment	Plant Height (cm)							
	90 DAS		120 DAS		150 DAS		180 DAS	
	2011	2012	2011	2012	2011	2012	2011	2012
Hybrids								
MRC 7017	98.2 a	103.1a	113.4 a	128.1 a	125.7 a	138.3 a	127.2 a	141.0 a
MRC 7031	97.9 a	102.7a	112.7 a	127.3 a	125.2 a	137.8 a	126.8 a	140.5 a
RCH 314	94.4 a	99.1 a	99.5 b	114.5 b	114.2 b	125.7 b	115.9 b	128.2 b
SEm	**2.35**	**2.49**	**3.06**	**3.03**	**2.46**	**2.71**	**2.40**	**2.87**
F(p)	**0.40**	**0.39**	**0.0002**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**
Plant growth regulation*								
Control	102.0 a	107.1a	122.4 a	139.0 a	139.8 a	153.8 a	141.4 a	156.9 a
Detopping	98.2 a	103.1a	113.4 b	128.9 a	130.9 b	144.0 b	132.2 b	146.9 b
TIBA @ 100 ppm	94.4 a	99.1 a	102.2 c	116.1 b	112.3 c	123.5 c	113.8 c	126.0 c
M C @ 300 ppm	93.8 a	98.5 a	101.4 c	115.2 b	111.7 c	122.9 c	113.3 c	125.3 c
M H @ 250 ppm	95.7 a	100.5 a	103.0 c	117.3 b	113.9 c	125.3 c	115.8 c	127.8 c
SEm	**2.78**	**2.89**	**3.05**	**3.61**	**2.41**	**2.66**	**2.39**	**2.73**
F(p)	**0.24**	**0.23**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**
Interaction F(p)	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**

* Applied at 80 days after sowing

(a)



(b)

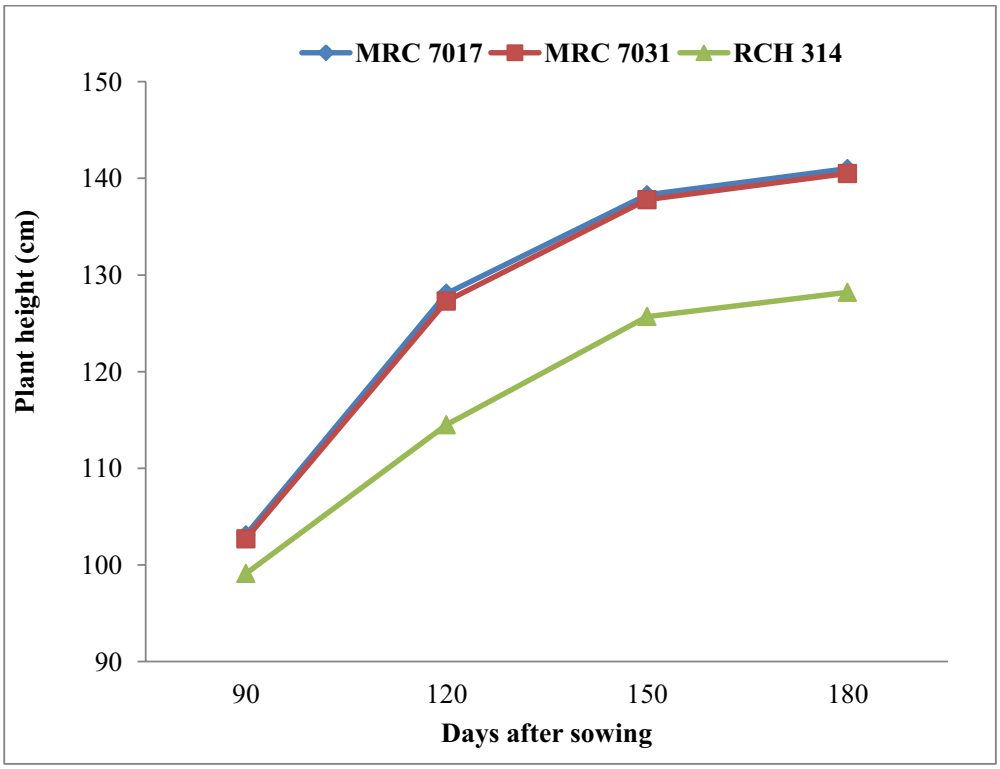
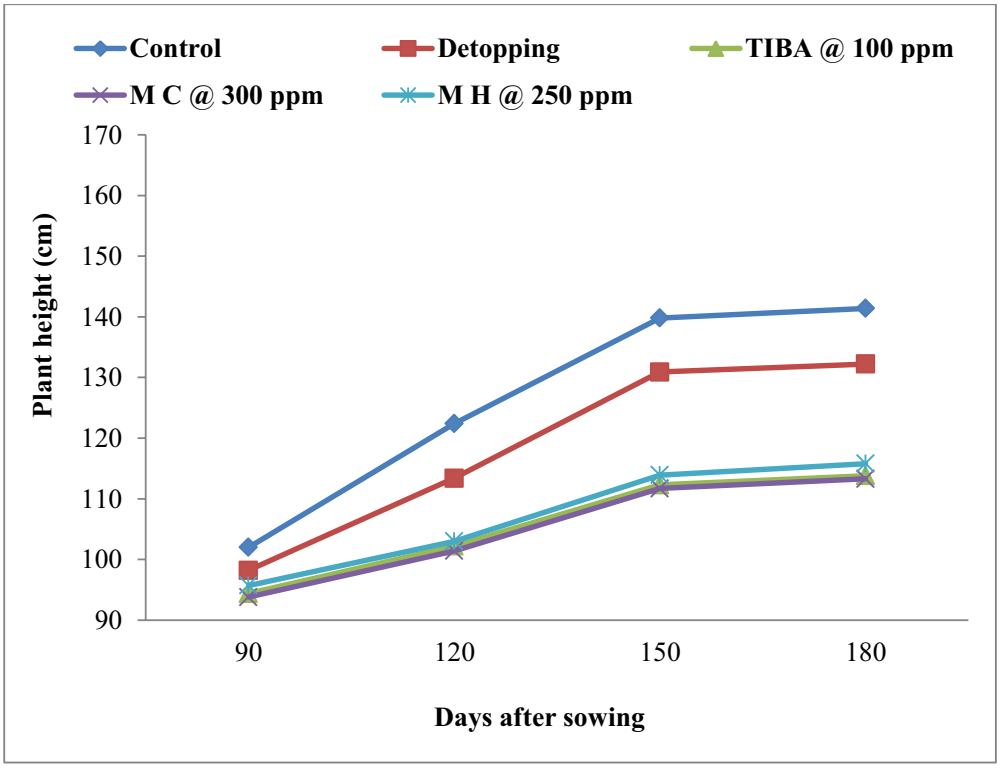


Fig 4.23: Plant height of different hybrids during 2011 (a) and 2012 (b)

(a)



(b)

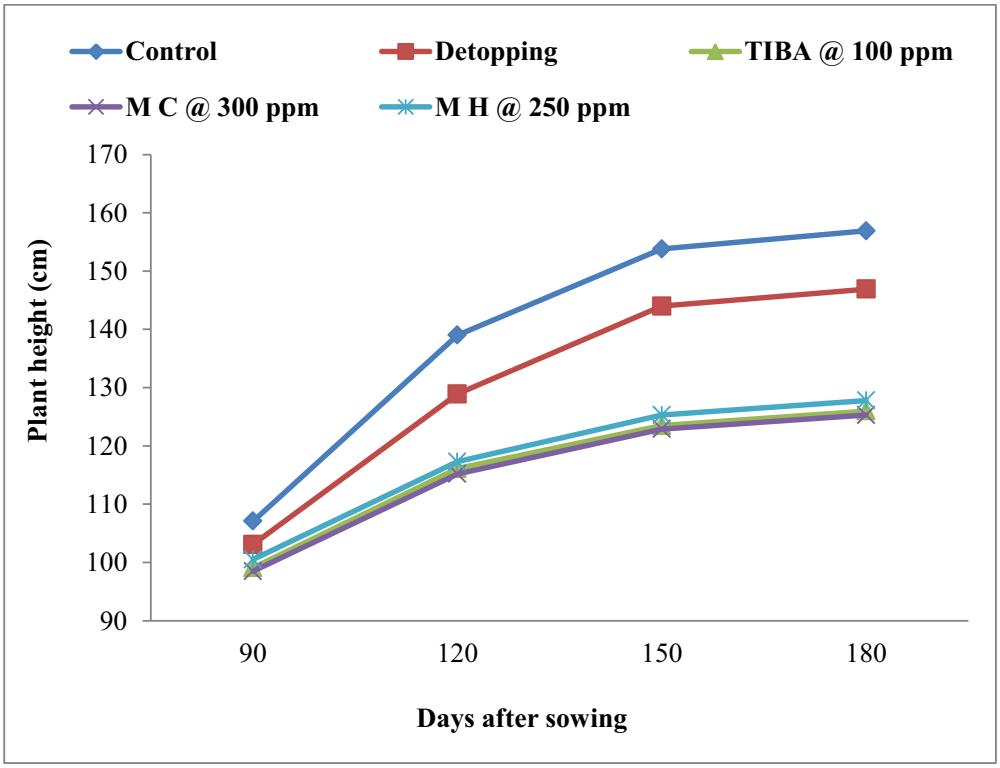


Fig 4.24: Plant **height of different hybrids as influenced by plant growth regulation treatments during 2011 (a) and 2012 (b)**

TIBA and MH application resulted in a significant reduction in plant height as compared to control and detopping. The foliar application of MC @ 300 ppm resulted in minimum plant height (111.7 and 122.9 cm) which was significantly shorter than control (139.8 and 153.8 cm) and detopping (130.9 and 144.0 cm) but was statistically at par with TIBA @ 100 ppm (112.3 and 123.5 cm) and MH @ 250 ppm (113.9 and 125.3 cm), during 2011 and 2012, respectively.

Similarly, at 180 DAS maximum reduction in plant height was recorded with MC application @ 300 ppm (113.3 and 125.3 cm) as compared to control (141.4 and 156.9 cm), which was statistically at par with TIBA 100 ppm (113.8 and 126.0 cm) and MH 250 ppm (115.8 and 127.8 cm) in 2011 and 2012, respectively.

Halmann (1990) reported that growth retardant MC caused more compact growth of plant by checking the apical dominance by acting as anti-gibberellin (by blocking the gibberellin biosynthesis). Siebert and Stewart (2006) and Kumar *et al* (2006) also reported that application of MC resulted in shorter and more compact plants. Similarly, Rao and Lakshminarayna (1985) found that detopping helped in decreasing the plant height when it was performed at 90 and 105 DAS. Pal and Das (1990) and Djanaguiraman *et al* (2005) reported that both TIBA inhibits the concentration of auxin at the axillary bud and resulted in reduced supply of auxin in the region of axillary and thereby relieves the bud inhibition which caused reduced stem elongation. Whereas, MH act as an antimitotic agent when applied to plants, it moves through the cuticle and is actively transported to tissues where cell division is occurring which results in reduced internodal length and plant growth. Koutroubas *et al* (2004) found that MH application cause significant reduction in plant height due to shortening of internodal length. All the interactions between hybrids and plant growth regulation treatments at all the growth stages were non significant during both the years.

4.3.2 Leaf Area Index (LAI)

LAI is an important parameter of plant growth which directly influences interception of solar radiation by the canopy, photosynthesis and ultimately the yield of a crop. The perusal of the data presented in Table 4.33 and represented in Fig. 4.25 reveals that during both the years, hybrids exhibited an increasing trend for LAI upto 120 DAS and thereafter it decreased because a sizable amount of crop foliage abscised due to crop senescence.

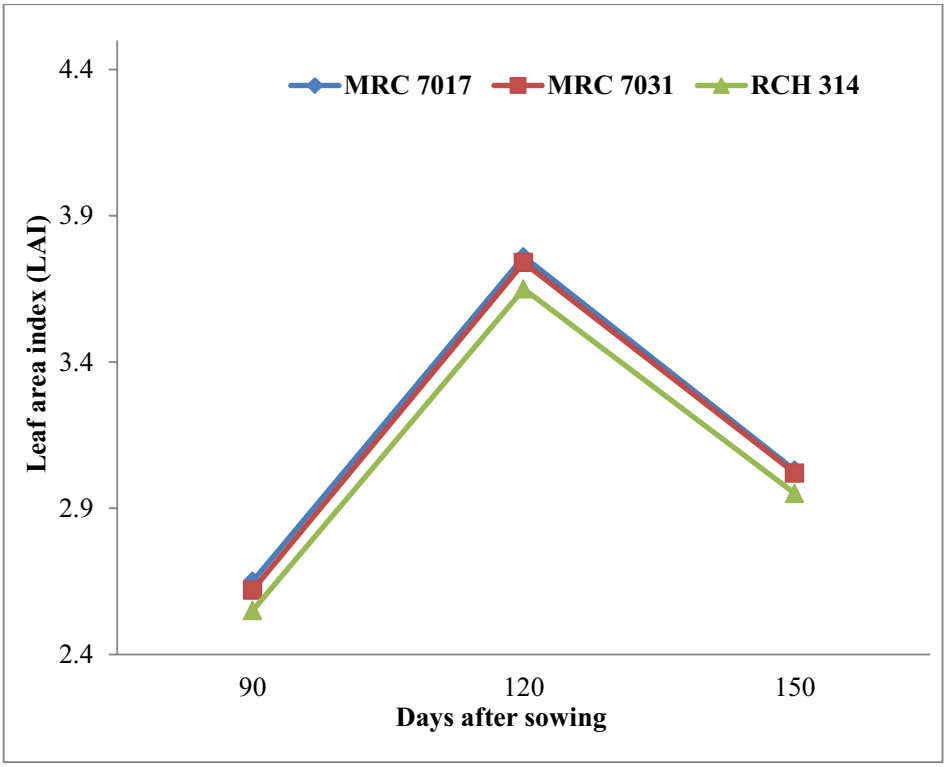
Hybrids did not vary significantly for LAI at all the crop growth stages however, hybrid MRC 7017 recorded a relatively higher LAI than MRC 7031 and RCH 314 at all the crop growth stages. Maximum LAI for all the hybrids were recorded at 120 DAS i.e. 3.69, 3.68 and 3.60 during 2011 and 4.26, 4.25 and 4.17 during 2012 in MRC 7017, MRC 7031 and RCH 314, respectively. The non significant variation among the hybrids was due to the same morphological behaviour of these three hybrids for growth and development which is attributed to their similar genetic make up. It was also confirmed by Singh (1999) and Puri (2001), that similar genetic make up of hybrids resulted in almost same growth pattern of the plant.

Table 4.33: Effect of hybrids and plant growth regulation treatments on leaf area index (LAI) recorded at different stages

Treatment	Leaf Area Index					
	90 DAS		120 DAS		150 DAS	
	2011	2012	2011	2012	2011	2012
Hybrids						
MRC 7017	2.65 a	3.23 a	3.76 a	4.32 a	3.03 a	3.26 a
MRC 7031	2.62 a	3.20 a	3.74 a	4.30 a	3.02 a	3.24 a
RCH 314	2.55 a	3.12 a	3.65 a	4.20 a	2.95 a	3.17 a
SEm	**0.06**	**0.07**	**0.09**	**0.11**	**0.06**	**0.07**
F(p)	**0.50**	**0.50**	**0.55**	**0.56**	**0.57**	**0.57**
Plant growth regulation*						
Control	2.71 a	3.29 a	3.94 a	4.53 a	3.28 a	3.42 a
Detopping	2.67 a	3.24 a	3.88 a	4.46 a	3.19 a	3.32 ba
TIBA @ 100 ppm	2.53 a	3.13 a	3.58 b	4.12 b	2.85 b	3.13 b
M C @ 300 ppm	2.52 a	3.07 a	3.57 b	4.10 b	2.81 b	3.09 b
M H @ 250 ppm	2.61 a	3.21 a	3.60 b	4.14 b	2.87 b	3.16 b
SEm	**0.07**	**0.09**	**0.09**	**0.11**	**0.07**	**0.07**
F(p)	**0.30**	**0.45**	**0.01**	**0.01**	**<0.0001**	**0.02**
Interaction F(p)	**0.99**	**0.97**	**1.00**	**1.00**	**1.00**	**1.00**

* Applied at 80 days after sowing

(a)



(b)

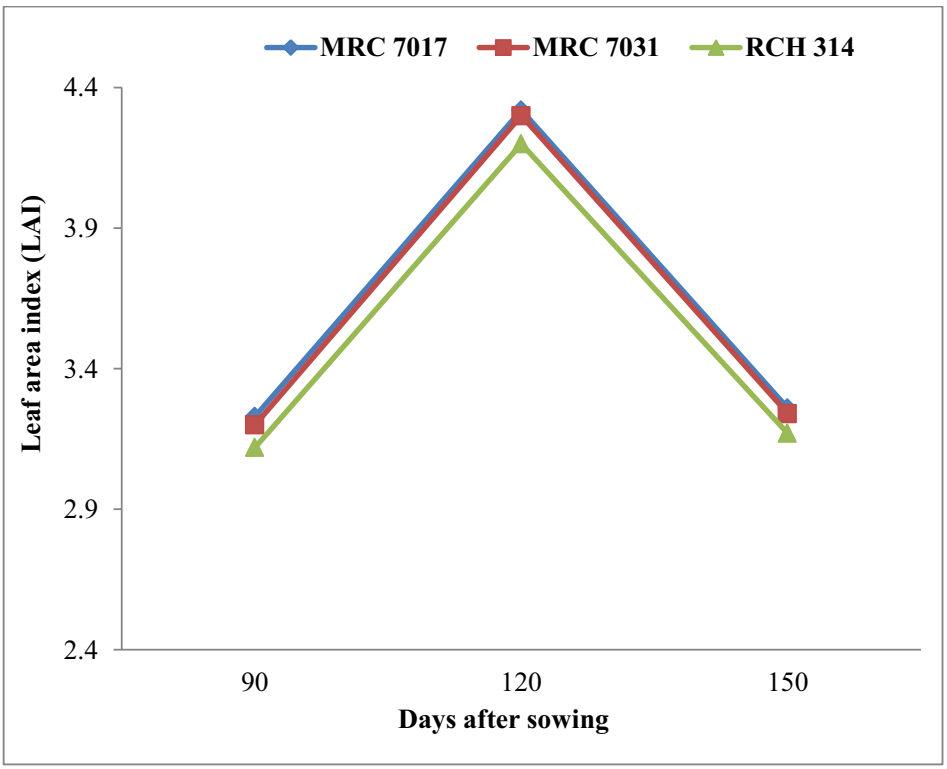
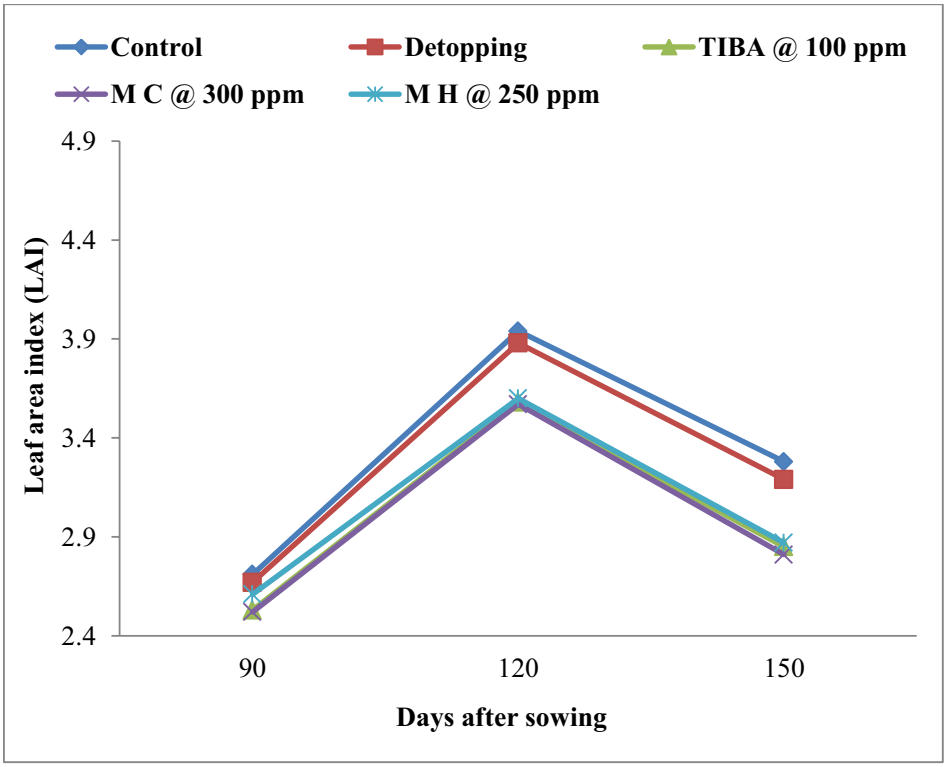


Fig 4.25: Leaf area index (LAI) of different hybrids during 2011 (a) and 2012 (b)

(a)



(b)

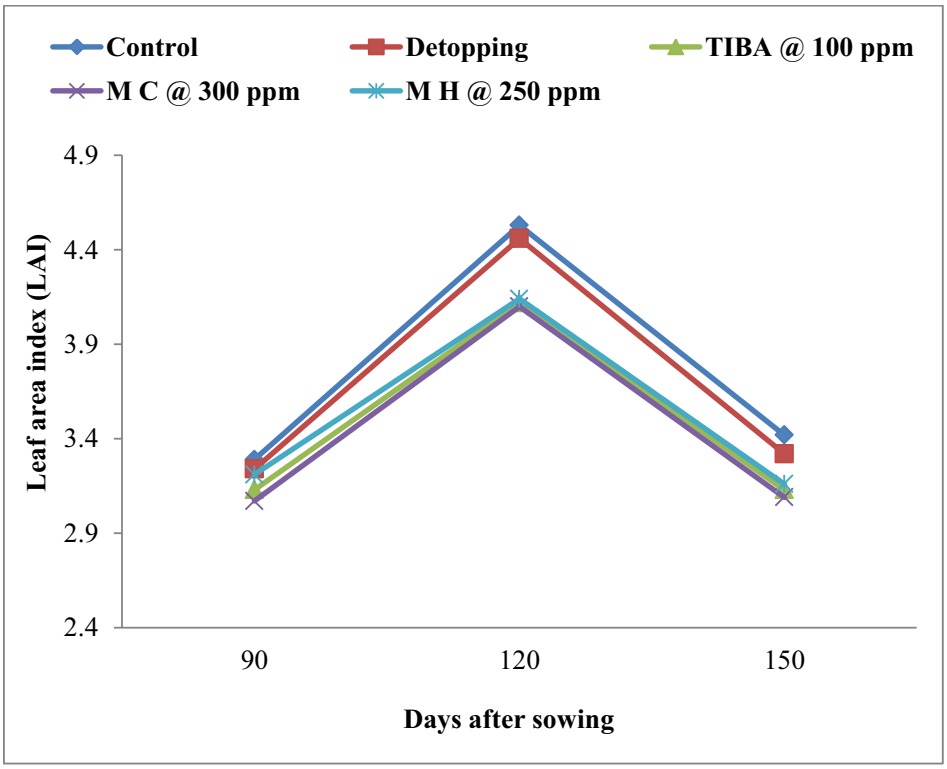


Fig 4.26: Leaf area index (LAI) of different hybrids as influenced by plant growth regulation treatments during 2011 (a) and 2012 (b)

Data presented in Table 4.33 and illustrated in Fig. 4.26 reveal that the LAI at 90 DAS was statistically similar in all the growth regulation treatments during both the years. Thereafter, at 120 and 150 DAS, application of MC @ 300 ppm resulted in significant reduction in LAI from control and detopping while it was statistically at par with the TIBA (100 ppm) and MH (250 ppm) during both the years. At 120 DAS, MC application @ 300 ppm resulted in maximum reduction in LAI (3.57 and 4.10) and was statistically at par with TIBA @ 100 ppm (3.58 and 4.12) and MH @ 250 ppm (3.60 and 4.14). MC (300 ppm), TIBA (100 ppm) and MH (250 ppm) showed a non significant variation for LAI with each other but recorded significantly lower LAI than control (3.94 and 4.53) and detopping (3.88 and 4.46) during 2011 and 2012, respectively.

Likewise, at 150 DAS, the application of MC @ 300 ppm resulted in significant reduction in the LAI from the control. The foliar applications of TIBA @ 100 ppm and MH @ 250 ppm were however statistically at par with MC (300 ppm) for LAI recorded at 150 DAS.

The LAI declined sharply after 120 DAS till maturity because of substantial amount of leaves had already abscised due to crop senescence before the crop attained maturity. Reduction in LAI with application of MC is due to the fact that it causes leaf thickness and checks the leaf expansion due to its anti-gibberellin activities (Erwin *et al* 1979). Similar results have been reported by Reddy *et al* (1990) and Kumar *et al* (2006). Reduction in LAI with TIBA and MH application might be because of reduced leaf expansion which is attributed to more leaf thickness (Table 4.42) than control and detopping as a result of higher translocation of assimilates into leaves. Bauer *et al* (1969) reported that TIBA application on soybean caused smaller leaves with vertical orientation and it resulted in lower LAI.

4.3.3 Dry Matter Accumulation (DMA) and Partitioning

DMA and its partitioning is one of the most important parameter and have a marked influence on final yield realization of a crop. The optimum accumulation of dry matter followed by adequate partitioning of assimilates to the developing sinks enables the crop to attain its true yield potential. The data presented in Tables 4.34, 4.35, 4.36 and 4.37 reveal that rate of increase in DMA was very sharp from 90 to 120 DAS. Although DMA continued to register an increase even after 120 DAS but the rate was comparatively sluggish. During both the years, maximum rate of increase in DMA was observed between 90 to 120 DAS which is the grand growth period of the crop.

During all the growth phases of crop the total dry matter accumulation (TDMA) for all the hybrids showed a non significant difference and a similar trend was observed for the partitioning of the total dry matter into stem and branches and also for leaves except for the fruiting bodies at 120 and 150 DAS.

Different hybrids varied significantly for the accumulation of dry matter into fruiting bodies with the maximum dry weight of 40.9 and 46.7 g plant^{-1} at 120 DAS and 74.4 and 83.4 g plant^{-1} at 150 DAS for hybrid MRC 7017 during 2011 and 2012, respectively as compared with other two hybrids. Hybrid MRC 7031 showed a non significant difference with MRC 7017 for dry matter partitioning in fruiting bodies at all the growth stages. However, both MRC 7017 and MRC 7031 recorded significantly higher dry weight of fruiting bodies as compared to hybrid RCH 314. The genetic build up primarily governs the amount of fruiting bodies formed by the crop and number of fruits attained by the plants of a particular hybrid. These results also confirm the findings of Heitholt *et al* (1992).

Growth regulation treatments had a significant influence on TDMA at 120 and 150 DAS during both the years. As regards to the dry matter partitioning towards the different plant organs, accumulation of dry matter by stem and branches almost followed the same pattern as that of total DMA. DMA by the leaves showed a decline from 120 DAS onwards, whereas DMA by the fruiting bodies continued to show an increase from 90 DAS onwards till maturity.

At 90 DAS, all the growth regulation treatments were statistically similar for the TDMA and its partitioning into various plant parts during both the years. It was due to the fact that growth regulation treatments were applied at 80 DAS and the effect of treatments was not observed within a short time span i.e. of 10 days. Whereas, at 120 and 150 DAS, different growth regulation treatments had a significant influence on TDMA and its partitioning into various plant parts as compared to control during both the crop growth seasons. At 120 DAS, a significant reduction in TDMA was recorded with application of MC @ 300 ppm (223.8 and 235.0 g plant^{-1}) as compared to control (237.8 and 251.8 g plant^{-1}) whereas, it was statistically at par with other two PGRs and detopping during 2011 and 2012, respectively. However, MC (300 ppm), TIBA (100 ppm) and MH (250 ppm) showed a significant reduction in dry matter partitioning towards stem and branches and leaves as compared to control and detopping but resulted significantly higher dry matter partitioning into the fruiting bodies as evident from Table 4.34 and 4.36.

Data presented in Tables 4.35 and 4.37 and depicted in Fig. 4.28 reveal that, at 150 DAS application of MC @ 300 ppm resulted in significant reduction in TDMA (260.8 and 281.0 g plant^{-1}) than control (276.0 and 297.6 g plant^{-1}) whereas, MH @ 250 ppm (265.7 and 286.4 g plant^{-1}), TIBA @ 100 ppm (265.7 and 286.5 g plant^{-1}) and detopping (272.0 and 293.5 g plant^{-1}) were statistically at par with both MC @ 300 ppm and control. However, all the growth regulators resulted in partitioning of significantly more dry matter into the fruiting bodies and less of it towards the vegetative parts in both the years as compared to control and detopping.

Table 4.34: Dry matter accumulation of *Bt* cotton hybrids as affected by plant growth regulation treatments during 2011

Treatment	Dry matter accumulation (g plant^{-1})							
	90 DAS				120 DAS			
	Stem and branches	Leaves	Fruiting bodies	Total	Stem and branches	Leaves	Fruiting bodies	Total
Hybrids								
MRC 7017	78.7 a (50.6)	51.5 a (33.1)	25.8 a (16.6)	156.2 a	124.7 a (53.4)	67.8 a (29.0)	40.9 a (17.5)	233.6 a
MRC 7031	77.2 a (50.8)	50.7 a (33.4)	24.5 a (16.1)	152.6 a	124.4 a (53.6)	67.1 a (28.9)	40.7 a (17.5)	232.3 a
RCH 314	73.8 a (51.2)	48.8 a (33.9)	24.0 a (16.7)	146.8 a	120.7 a (54.7)	62.9 a (28.5)	36.7 b (16.6)	220.5 a
SEm	**2.49**	**1.38**	**0.69**	**4.06**	**2.99**	**1.60**	**0.90**	**3.82**
F(p)	**0.16**	**0.07**	**0.05**	**0.01**	**0.34**	**0.02**	**0.001**	**0.007**
Plant growth regulation*								
Control	78.6 a (51.0)	51.6 a (33.5)	23.8 a (15.4)	154.1 a	132.4 a (55.7)	73.5 a (30.9)	31.8 b (13.4)	237.8 a
Detopping	77.4 a (50.6)	50.9 a (33.3)	24.6 a (16.1)	152.9 a	127.8 a (55.2)	69.5 a (30.0)	34.1 b (14.7)	231.5 ba
TIBA @ 100 ppm	75.7 a (50.9)	49.8 a (33.5)	25.6 a (17.2)	151.5 a	118.7 b (52.7)	62.4 b (27.7)	43.9 a (19.5)	225.1 b
M C @ 300 ppm	75.1 a (51.0)	49.8 a (33.8)	25.5 a (17.3)	149.6 a	118.0 b (52.7)	61.1 b (27.3)	44.5 a (19.9)	223.8 b
M H @ 250 ppm	76.3 a (51.0)	49.0 a (32.8)	24.5 a (16.4)	151.5 a	119.5 b (52.9)	63.2 b (28.0)	43.0 a (19.0)	225.8 b
SEm	**2.32**	**1.07**	**0.67**	**2.83**	**2.70**	**1.72**	**1.05**	**3.94**
F(p)	**0.83**	**0.48**	**0.35**	**0.82**	**0.001**	**<0.0001**	**<0.0001**	**0.009**
Interaction F(p)	**1.00**	**0.99**	**0.99**	**1.00**	**1.00**	**1.00**	**0.99**	**1.00**

* Applied at 80 days after sowing

Values in parenthesis are percentage values of total dry matter

Table 4.35: Dry matter accumulation of *Bt* cotton hybrids as affected by plant growth regulation treatments during 2011

Treatment	Dry matter accumulation (g plant^{-1})			
	150 DAS			
	Stem and branches	Leaves	Fruiting Bodies	Total
Hybrids				
MRC 7017	141.7 a (51.7)	58.0 a (21.2)	74.4 a (27.1)	274.2 a
MRC 7031	141.3 a (51.8)	57.4 a (21.0)	73.9 a (27.1)	272.7 a
RCH 314	137.1 a (53.3)	53.9 a (21.0)	66.0 b (25.7)	257.2 a
SEm	**3.39**	**1.45**	**1.80**	**4.52**
F(p)	**0.34**	**0.02**	**0.0007**	**0.002**
Plant growth regulation*				
Control	150.9 a (54.7)	63.2 a (22.9)	61.8 b (22.4)	276.0 a
Detopping	145.7 a (53.6)	59.8 a (22.0)	66.4 b (24.4)	272.0 ba
TIBA @ 100 ppm	135.4 b (51.0)	53.6 b (20.2)	76.6 a (28.8)	265.7 ba
M C @ 300 ppm	131.9 b (50.6)	51.2 b (19.6)	77.7 a (29.8)	260.8 b
M H @ 250 ppm	136.2 b (51.3)	54.4 b (20.5)	75.0 a (28.2)	265.7 ba
SEm	**3.07**	**1.41**	**2.02**	**4.46**
F(p)	**0.0004**	**<0.0001**	**<0.0001**	**0.002**
Interaction F(p)	**1.00**	**1.00**	**1.00**	**1.00**

*Applied at 80 days after sowing

Values in parenthesis are percentage of total dry matter

Table 4.36: Dry matter accumulation of *Bt* cotton hybrids as affected by different plant growth regulation treatments during 2012

Treatment	Dry matter accumulation (g plant^{-1})							
	90 DAS				120 DAS			
	Stem and branches	Leaves	Fruiting bodies	Total	Stem and branches	Leaves	Fruiting bodies	Total
Hybrids								
MRC 7017	82.7 a (50.2)	54.6 a (33.1)	27.4 a (16.6)	164.8 a	129.0 a (52.1)	71.9 a (29.0)	46.7 a (18.9)	247.6 a
MRC 7031	81.0 a (50.3)	54.0 a (33.5)	26.0 a (16.1)	161.1 a	128.6 a (52.2)	71.2 a (28.9)	46.4 a (18.8)	246.3 a
RCH 314	77.5 a (49.6)	53.2 a (34.0)	25.5 a (16.3)	156.4 a	125.1 a (53.6)	66.7 a (28.6)	41.4 b (17.7)	233.3 a
SEm	**2.48**	**1.29**	**0.61**	**4.03**	**2.80**	**1.55**	**1.13**	**3.99**
F(p)	**0.19**	**0.56**	**0.08**	**0.05**	**0.40**	**0.03**	**0.0004**	**0.007**
Plant growth regulation*								
Control	82.5 a (50.5)	55.4 a (33.9)	25.3 a (15.5)	163.3 a	137.7 a (54.7)	77.9 a (30.9)	36.1 b (14.3)	251.8 a
Detopping	81.2 a (50.1)	54.6 a (33.7)	26.0 a (16.0)	162.0 a	132.9 a (54.1)	73.7 a (30.0)	38.8 b (15.8)	245.5 ba
TIBA @ 100 ppm	79.5 a (49.6)	53.7 a (33.5)	27.1 a (16.9)	160.4 a	123.5 b (51.5)	66.1 b (27.6)	49.9 a (20.8)	239.6 ba
M C @ 300 ppm	79.4 a (49.8)	52.9 a (33.2)	27.0 a (16.9)	159.4 a	122.8 b (52.3)	64.8 b (27.6)	50.6 a (21.5)	235.0 b
M H @ 250 ppm	79.5 a (50.1)	53.1 a (33.4)	26.0 a (16.4)	158.8 a	124.3 b (51.7)	67.0 b (27.9)	48.8 a (20.3)	240.2 ba
SEm	**2.57**	**1.19**	**0.77**	**3.09**	**2.87**	**1.88**	**1.22**	**4.28**
F(p)	**0.88**	**0.54**	**0.42**	**0.83**	**0.0003**	**<0.0001**	**<0.0001**	**0.08**
Interaction F(p)	**1.00**	**1.00**	**0.99**	**0.99**	**1.00**	**1.00**	**0.99**	**1.00**

* Applied at 80 days after sowing

Values in parenthesis are percentage of total dry matter

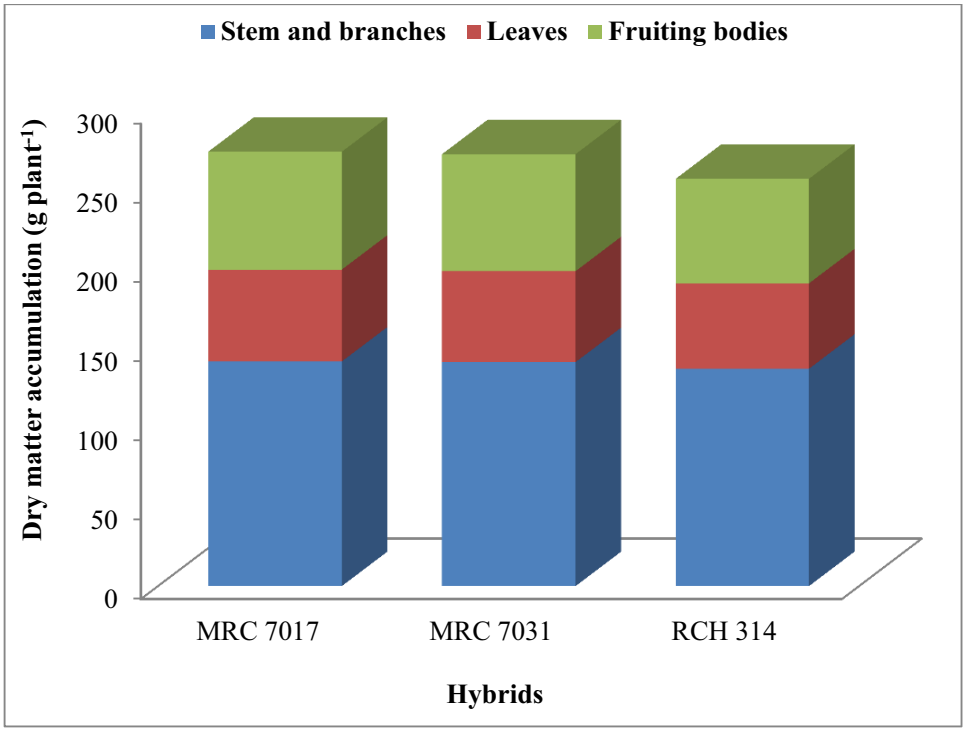
Table 4.37: Dry matter accumulation of *Bt* cotton hybrids as affected by plant growth regulation treatments during 2012

Treatment	Dry matter accumulation (g plant^{-1})			
	150 DAS			
	Stem and branches	Leaves	Fruiting Bodies	Total
Hybrids				
MRC 7017	150.0 a (50.7)	62.3 a (21.1)	83.4 a (28.2)	295.9 a
MRC 7031	149.4 a (50.8)	61.7 a (21.0)	82.8 a (28.2)	294.0 a
RCH 314	145.1 a (52.4)	57.8 a (20.9)	74.0 b (26.7)	277.1 a
SEm	**4.04**	**1.61**	**2.02**	**5.17**
F(p)	**0.35**	**0.01**	**0.0007**	**0.001**
Plant growth regulation*				
Control	160.0 a (53.8)	68.3 a (23.0)	69.2 b (23.3)	297.6 a
Detopping	154.4 a (52.6)	64.6 a (22.0)	74.4 b (25.3)	293.5 ba
TIBA @ 100 ppm	143.5 b (50.1)	57.9 b (20.2)	85.8 a (29.9)	286.5 ba
M C @ 300 ppm	138.7 b (49.4)	55.2 b (19.6)	87.0 a (31.0)	281.0 b
M H @ 250 ppm	144.4 b (50.4)	57.9 b (20.2)	84.0 a (29.3)	286.4 ba
SEm	**3.35**	**1.49**	**2.26**	**4.87**
F(p)	**0.0004**	**<0.0001**	**<0.0001**	**0.15**
Interaction F(p)	**1.00**	**1.00**	**1.00**	**1.00**

* Applied at 80 days after sowing

Values in parenthesis are percentage of total dry matter

(a)



(b)

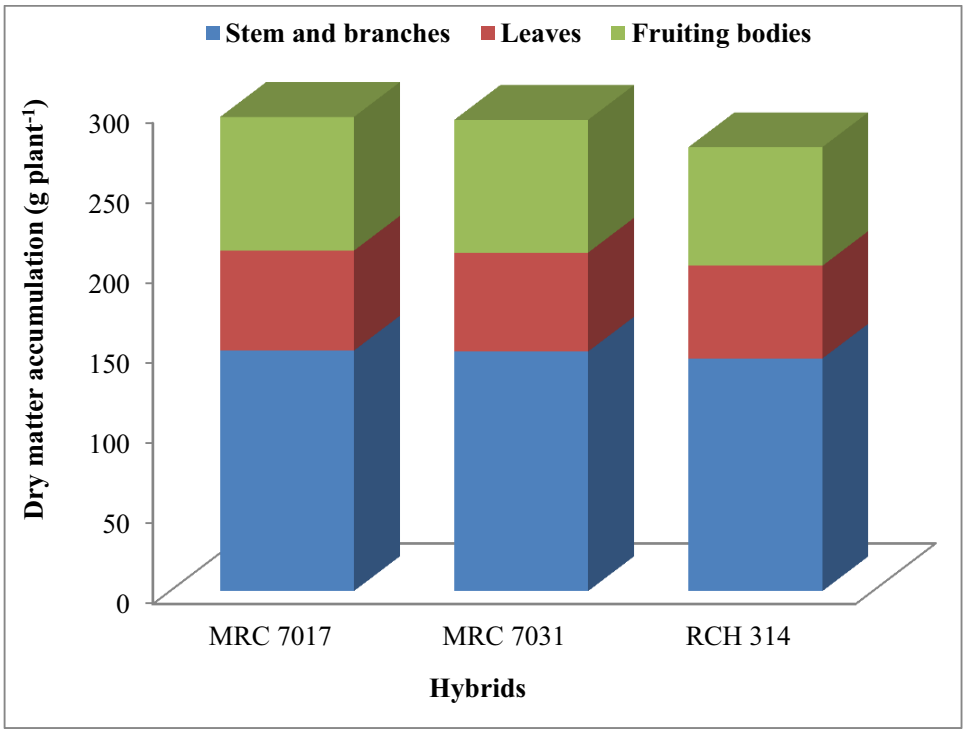
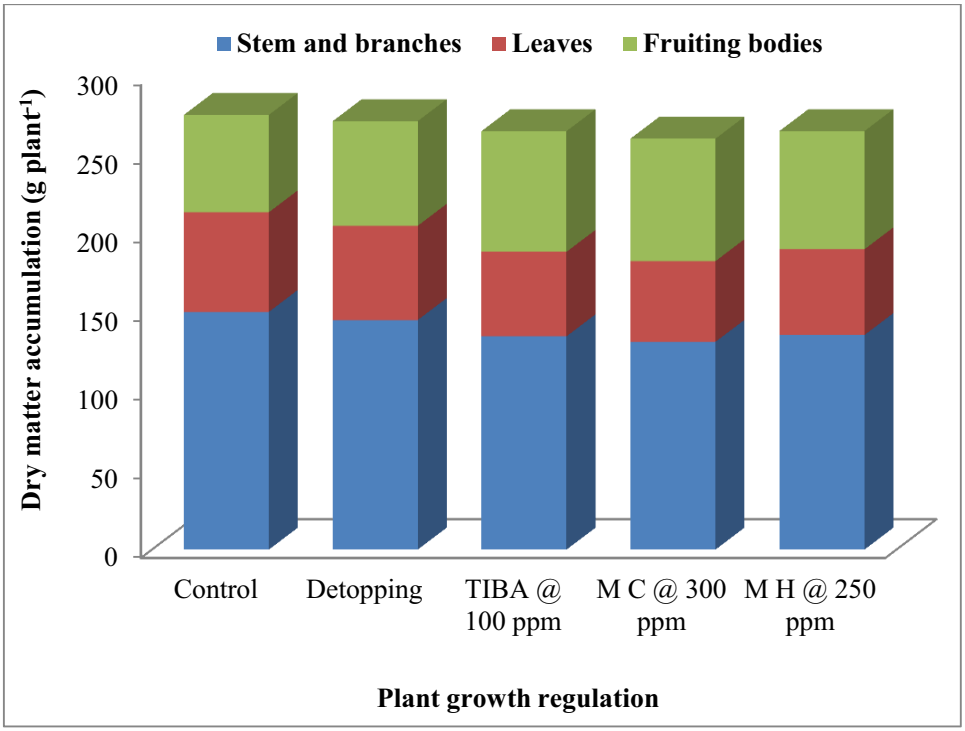


Fig 4.27: Dry matter accumulation (g plant^{-1}) of different hybrids at maturity during 2011 (a) and 2012 (b)

(a)



(b)

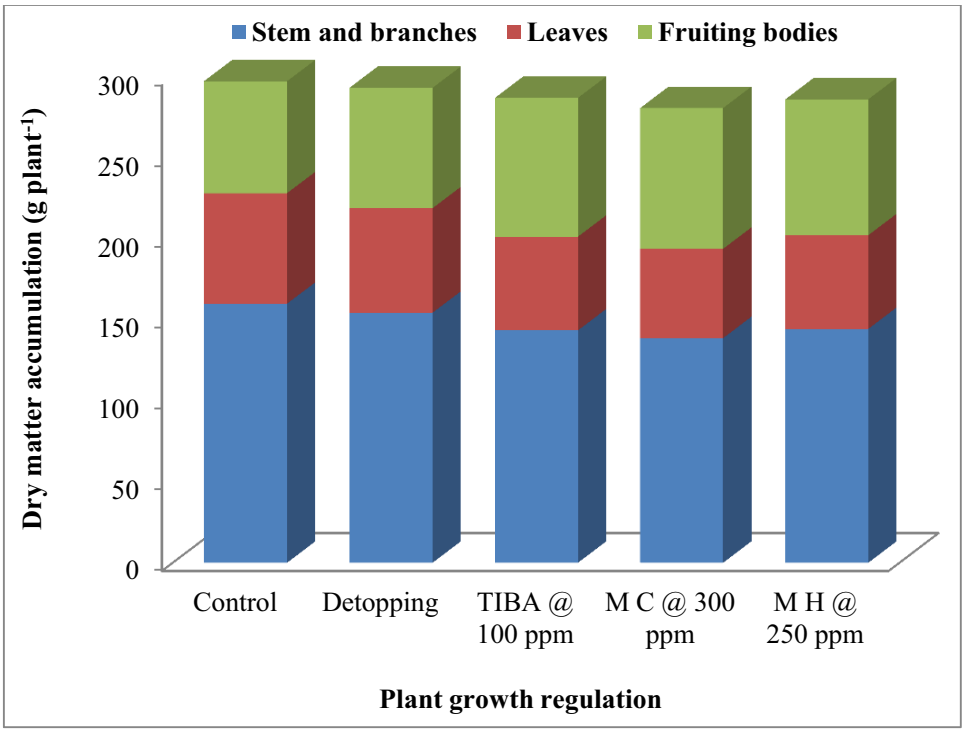


Fig 4.28: Dry matter accumulation (g plant^{-1}) of different hybrids as affected by plant growth regulation treatments at maturity during 2011 (a) and 2012 (b)

TDMA was reduced by application of growth retardants due to inhibitory effect on vegetative growth and leaf area of the plant. MC, TIBA and MH application exerted a significant influence on partitioning of dry matter into fruiting bodies as it resulted in significantly less dry matter allocation towards vegetative plant parts but more of it towards the fruiting bodies. Kerby (1985) also found that MC inhibitting the excessive vegetative growth by reducing the transfer of photosynthates to stem, branches and leaves and divert more of them towards fruiting structures. Similar results have also been reported by Wang *et al* (1985), Fernandez *et al* (1998) and Prakash and Prasad (2000). Rahman *et al* (2004) reported a significant reduction in plant height with MH application and also observed more partitioning of assimilates to the fruiting bodies rather than the vegetative parts. All the interaction effects were non significant for the DMA at all the growth stages during both the years.

4.3.4 Crop Growth Rate

Crop growth rate (CGR) reflects the dry matter gained by a unit area of crop in unit time. The data presented in Table 4.38 reveals that CGR of all the hybrids did not differ significantly at all the crop growth stages during both the years. However, at initial periods of crop growth i.e. 30-60 DAS a marginal increase in CGR was observed due to less dry matter accumulation, thereafter CGR attained its maxima and value ranges from 6.28 to 6.73 during 2011 and 6.86 to 7.27 during 2012 at 60-90 DAS but after that the CGR again showed a decreasing trend till maturity because the rate of crop growth was slow at later stages due to the initiation of reproductive stage that crop diverts more of its assimilates towards the reproductive parts rather than the vegetative parts.

Similarly, all the plant growth regulation treatments failed to influence the CGR of crop during both the years. The interaction between hybrids and plant growth regulation treatments was non significant in both the years.

4.3.5 Relative Growth Rate

Relative growth rate (RGR) is an efficiency index because it expresses the rate of growth per unit of existing dry matter in a day. Normally RGR is expressed as gram of dry matter produced by a gram of existing dry matter in a day. At initial stages of crop growth (30-60 DAS), RGR was found to be higher and after that a declining trend was observed in RGR, because the rate of increase in dry matter was slow after 60 DAS as this is a grand growth period of crop. As data was examined for RGR, all the hybrids showed statistically similar results during both the years (Table 4.39).

Different plant growth regulation treatments also failed to influence the RGR during both the crop growth seasons. All the interaction effects for RGR were also statistically uniform throughout the two crop growth seasons.

Table 4.38: CGR of *Bt* cotton hybrids as affected by different plant growth regulation treatments

Treatment	Crop growth rate (g m^{-2} day^{-1})							
	30-60 DAS		60-90 DAS		90-120 DAS		120-150 DAS	
	2011	2012	2011	2012	2011	2012	2011	2012
Hybrids								
MRC 7017	2.87 a	2.91 a	6.72 a	7.24 a	5.09 a	5.45 a	2.67 a	3.17 a
MRC 7031	2.80 a	2.84 a	6.57 a	7.09 a	5.25 a	5.60 a	2.66 a	3.14 a
RCH 314	2.72 a	2.75 a	6.28 a	6.86 a	4.84 a	5.06 a	2.41 a	2.87 a
SEm	**0.09**	**0.09**	**0.33**	**0.33**	**0.23**	**0.21**	**0.07**	**0.08**
F(p)	**0.29**	**0.32**	**0.16**	**0.30**	**0.45**	**0.27**	**0.006**	**0.01**
Plant growth regulation*								
Control	2.76 a	2.79 a	6.73 a	7.27 a	5.50 a	5.82 a	2.51 a	3.01 a
Detopping	2.82 a	2.88 a	6.55 a	7.11 a	5.17 a	5.49 a	2.66 a	3.15 a
TIBA @ 100 ppm	2.78 a	2.81 a	6.49 a	7.05 a	4.86 a	5.21 a	2.67 a	3.08 a
M C @ 300 ppm	2.82 a	2.81 a	6.35 a	6.99 a	4.88 a	4.97 a	2.43 a	3.03 a
M H @ 250 ppm	2.80 a	2.86 a	6.50 a	6.89 a	4.89 a	5.36 a	2.62 a	3.04 a
SEm	**0.08**	**0.09**	**0.21**	**0.22**	**0.29**	**0.30**	**0.07**	**0.09**
F(p)	**0.97**	**0.95**	**0.78**	**0.79**	**0.46**	**0.38**	**1.00**	**0.82**
Interaction F(p)	**0.99**	**0.99**	**0.99**	**0.99**	**1.00**	**1.00**	**1.00**	**0.99**

* Applied at 80 days after sowing

Table 4.39: RGR of *Bt* cotton hybrids as affected by different plant growth regulation treatments

Treatment	Relative growth rate (g g^{-1} day^{-1})							
	30-60 DAS		60-90 DAS		90-120 DAS		120-150 DAS	
	2011	2012	2011	2012	2011	2012	2011	2012
Hybrids								
MRC 7017	0.139 a	0.139 a	0.063 a	0.067 a	0.0167 a	0.0169 a	0.0057 a	0.0064 a
MRC 7031	0.140 a	0.141 a	0.063 a	0.068 a	0.0177 a	0.0178 a	0.0058 a	0.0064 a
RCH 314	0.138 a	0.139 a	0.063 a	0.068 a	0.0169 a	0.0166 a	0.0055 a	0.0062 a
SEm	**0.006**	**0.005**	**0.004**	**0.004**	**0.001**	**0.0009**	**0.0001**	**0.0001**
F(p)	**0.97**	**0.95**	**0.97**	**0.97**	**0.73**	**0.60**	**0.38**	**0.54**
Plant growth regulation*								
Control	0.141 a	0.137 a	0.066 a	0.070 a	0.0182 a	0.0181 a	0.0055 a	0.0060 a
Detopping	0.138 a	0.144 a	0.063 a	0.067 a	0.0174 a	0.0174 a	0.0058 a	0.0065 a
TIBA @ 100 ppm	0.137 a	0.138 a	0.063 a	0.068 a	0.0164 a	0.0166 a	0.0060 a	0.0065 a
M C @ 300 ppm	0.139 a	0.139 a	0.061 a	0.067 a	0.0167 a	0.0160 a	0.0056 a	0.0065 a
M H @ 250 ppm	0.139 a	0.139 a	0.063 a	0.065 a	0.0166 a	0.0174 a	0.0058 a	0.0064 a
SEm	**0.005**	**0.006**	**0.003**	**0.003**	**0.001**	**0.001**	**0.0001**	**0.0002**
F(p)	**0.99**	**0.94**	**0.89**	**0.90**	**0.82**	**0.75**	**0.05**	**0.40**
Interaction F(p)	**0.99**	**0.99**	**0.97**	**0.94**	**0.99**	**0.99**	**1.00**	**1.00**

* Applied at 80 days after sowing

4.3.6 Net Assimilation Rate

Net assimilation rate (NAR) indirectly indicates the rate of net photosynthesis. The data presented in Table 4.40 depict that NAR was statistically similar for all the hybrids at all growth stages of crop. However, it was higher during the period of 30-60 DAS and afterwards a declining trend was observed for NAR. The decreasing trend for NAR after 60 days of crop was due to the reason that the rate of crop growth was slow due to the initiation of reproductive stage as the demand for photosynthates was more by reproductive parts as compared to vegetative parts at later stages hence, the increase in leaf area over the existing leaf area was also less as the crop reaches towards maturity. However, most of leaves abscised when crop turns toward maturity due to senescence which also lowered leaf area as evident from the less LAI at later stages (Table 4.33).

All the plant growth regulation treatments failed to influence the NAR at the initial growth stages of crop during both the years while, it showed a significant effect during the period of 120-150 DAS (Table 4.40). All PGRs recorded significantly higher NAR as compared to untreated control during both the years. Higher NAR was recorded in the treatment where 100 ppm TIBA was applied (0.074 and 0.075 mg cm^{-2} day^{-1}) and it was statistically at par with MC 300 ppm which recorded 0.072 and 0.075 mg cm^{-2} day^{-1} of NAR and MH 250 ppm where 0.073 and 0.073 mg cm^{-2} day^{-1} of NAR was recorded during 2011 and 2012, respectively. TIBA @ 100 ppm recorded significantly higher NAR than control during both the years. However, TIBA @ 100 ppm showed significant difference with detopping for NAR only during 2011 while, it was statistically similar with detopping during 2012. Higher values for NAR in PGR application was due to reduction of plant height and its anti polar transport nature for auxin which caused apical dominance and resulted in more translocation of assimilates towards the vegetative parts i.e. leaves and stems at earlier stages but when fruiting bodies started developing, maximum amount of assimilates were translocated towards them and eventually enhanced its total dry weight that helped in increasing the NAR of PGRs as compared to control. Ravichandran and Ramaswami (1991) also studied that TIBA application @ 50 ppm at pre flowering stage helped in increasing the NAR of soybean. Similarly Rahman *et al* (2004) studied that MH @ 100 and 200 ppm increased the NAR of soybean by increasing the dry matter of fruiting bodies. All the interactions for NAR were non significant at different growth stages during both the years.

4.3.7 Specific Leaf Area

Specific leaf area (SLA) is an index of the leafiness of the leaf, a measure of density or relative thickness, which involves an assessment of the leaf's area in relation to its dry weight. Specific leaf area was not influenced by the hybrids at all the crop growth stages during 2011 and 2012 (Table 4.41). At 150 DAS, the SLA for the hybrids varied between 265.7 to 282.8 cm^2 g^{-1} and 266.5 to 284.0 cm^2 g^{-1} during 2011 and 2012 respectively.

Table 4.40: NAR of *Bt* cotton hybrids as affected by different plant growth regulation treatments

Treatment	Net assimilation rate (mg cm^{-2} day^{-1})							
	30-60 DAS		60-90 DAS		90-120 DAS		120-150 DAS	
	2011	2012	2011	2012	2011	2012	2011	2012
Hybrids								
MRC 7017	0.88 a	0.48 a	0.44 a	0.43 a	0.19 a	0.16 a	0.071 a	0.073 a
MRC 7031	0.84 a	0.46 a	0.43 a	0.43 a	0.20 a	0.17 a	0.071 a	0.073 a
RCH 314	0.09 a	0.50 a	0.42 a	0.42 a	0.19 a	0.16 a	0.067 a	0.069 a
SEm	**0.05**	**0.02**	**0.02**	**0.02**	**0.01**	**0.009**	**0.003**	**0.002**
F(p)	**0.44**	**0.50**	**0.78**	**0.89**	**0.78**	**0.76**	**0.04**	**0.18**
Plant growth regulation*								
Control	0.89 a	0.48 a	0.45 a	0.44 a	0.20 a	0.17 a	0.063 c	0.066 b
Detopping	0.87 a	0.49 a	0.43 a	0.42 a	0.19 a	0.17 a	0.068 bc	0.070 ba
TIBA @ 100 ppm	0.86 a	0.48 a	0.43 a	0.43 a	0.19 a	0.16 a	0.074 a	0.075 a
M C @ 300 ppm	0.88 a	0.47 a	0.42 a	0.43 a	0.19 a	0.16 a	0.072 a	0.075 a
M H @ 250 ppm	0.87 a	0.48 a	0.43 a	0.42 a	0.18 a	0.17 a	0.073 a	0.073 a
SEm	**0.05**	**0.02**	**0.01**	**0.01**	**0.01**	**0.01**	**0.001**	**0.002**
F(p)	**0.99**	**0.99**	**0.85**	**0.89**	**0.89**	**0.96**	**0.0007**	**0.04**
Interaction F(p)	**0.97**	**0.99**	**0.99**	**0.97**	**0.99**	**0.99**	**0.99**	**1.00**

* Applied at 80 days after sowing

Table 4.41: SLA of *Bt* cotton hybrids as affected by different plant growth regulation treatments

Treatment	Specific leaf area (cm^{-2} g^{-1})					
	90 DAS		120 DAS		150 DAS	
	2011	2012	2011	2012	2011	2012
Hybrids						
MRC 7017	261.8 a	301.4 a	281.7 a	305.6 a	265.7 a	266.5 a
MRC 7031	262.5 a	301.0 a	283.9 a	308.0 a	266.9 a	267.4 a
RCH 314	267.7 a	299.3 a	299.1 a	324.5 a	282.8 a	284.0 a
SEm	**10.98**	**11.81**	**12.68**	**13.31**	**10.74**	**11.38**
F(p)	**0.83**	**0.98**	**0.31**	**0.32**	**0.20**	**0.20**
Plant growth regulation*						
Control	267.3 a	301.1 a	271.8 a	294.9 a	264.3 a	254.5 b
Detopping	267.9 a	302.1 a	283.7 a	307.7 a	271.3 a	261.2 ba
TIBA @ 100 ppm	259.4 a	296.5 a	293.9 a	318.9 a	272.5 a	281.4 ba
M C @ 300 ppm	261.8 a	297.1 a	301.1 a	326.6 a	280.9 a	286.5 a
M H @ 250 ppm	263.5 a	306.0 a	290.7 a	315.4 a	270.0 a	279.4 ba
SEm	**9.86**	**10.95**	**11.13**	**12.25**	**9.56**	**9.85**
F(p)	**0.96**	**0.97**	**0.42**	**0.43**	**0.81**	**0.11**
Interaction F(p)	**0.99**	**0.99**	**1.00**	**1.00**	**1.00**	**1.00**

* Applied at 80 days after sowing

Plant growth regulation treatments also failed to influence the SLA at all the growth stages except at 150 DAS during 2012. MC applied @ 300 ppm showed significantly higher SLA (286.5 cm^2 g^{-1}) as compared to untreated control. All other PGRs and detopping were statistically at par with both control and MC (300 ppm) during 2012. It might be due to the fact that MC produced shorter plants due to its anti-gibberellin activity and the photosynthates were efficiently utilized by the existing sinks i.e. leaves and increased the leaf thickness by reducing leaf expansion as evident from its higher NAR (Table 4.40) and leaf chlorophyll content (Table 4.43). Interaction between hybrids and plant growth regulation treatments was non significant during both the years.

4.3.8 Main Stem Internodes

Scrutiny of the data presented in Table 4.42 reveals that different hybrids did not differ significantly for the number of main stem internodes before the application of plant growth regulation treatments however, the range varied from 13.3 to 14.0 and 15.8 to 16.5 during both the years.

At maturity the number of main stem internodes also did not show any significant difference among the hybrids. The number of main stem internodes recorded in MRC 7017 was 20.2 and 26.3 followed by MRC 7031 which recorded 20.0 and 26.0 during 2011 and 2012, respectively. RCH 314 attained 19.4 and 24.8 number of main stem internodes during both the years respectively.

At maturity all the PGRs and detopping showed a significant effect on number of main stem internodes during both the years (Table 4.42). The number of main stem internodes in detopping was 17.3 and 22.5 significantly lower than control and all the PGRs during 2011 and 2012, respectively. Detopping modifies the cotton crop canopy by reducing its spread and height that eventually resulted in significant reduction of number of main stem internodes as reported by Ahmed *et al* (1989). The number of main stem internodes produced by MC (300 ppm) were 19.5 and 25.3 followed by TIBA @ 100 ppm (19.9 and 25.9) and MH @ 250 ppm (20.3 and 25.7) however, all these growth regulators performed statistically similar with each other for the number of main stem internodes but attained significantly lower number of main stem internodes than control (22.3 and 29.0) during 2011 and 2012, respectively. The decrease in number of main stem internodes in plant growth regulator treatments as compared to control was due to the anti gibberellin nature of MC, auxin polar transport inhibitor nature of TIBA and antimitotic activity of MH as evident by shorter plant height (Table 4.32). Nichols *et al* (2003) and Jonathan and Alexander (2006) also reported that application of MC reduced the number of main stem internodes in cotton. Similarly, Dastur and parkash (1954)

Table 4.42: Effect of *Bt* cotton hybrids and plant growth regulation treatments on main stem internodes and height to node ratio

Treatment	Main stem internodes before spray		Main stem internodes at final picking		Height to node ratio	
	2011	2012	2011	2012	2011	2012
Hybrids						
MRC 7017	14.0 a	16.5 a	20.2 a	26.3 a	6.42 a	5.48 a
MRC 7031	13.3 a	15.8 a	20.0 a	26.0 a	6.43 a	5.49 a
RCH 314	13.8 a	16.3 a	19.4 a	24.8 a	6.05 a	5.22 a
SEm	**0.35**	**0.41**	**0.58**	**0.71**	**0.23**	**0.19**
F(p)	**0.33**	**0.33**	**0.42**	**0.20**	**0.23**	**0.42**
Plant growth regulation*						
Control	14.2 a	16.8 a	22.3 a	29.0 a	6.39 b	5.45 b
Detopping	13.8 a	16.3 a	17.3 c	22.5 c	7.66 a	6.55 a
TIBA @ 100 ppm	13.6 a	16.0 a	19.9 b	25.9 b	5.82 b	4.96 b
M C @ 300 ppm	13.7 a	16.1 a	19.5 b	25.3 b	5.86 b	4.99 b
M H @ 250 ppm	13.3 a	15.7 a	20.3 b	25.7 b	5.77 b	5.03 b
SEm	**0.41**	**0.48**	**0.58**	**0.77**	**0.23**	**0.20**
F(p)	**0.61**	**0.62**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**
Interaction F(p)	**0.84**	**0.86**	**0.99**	**0.99**	**0.99**	**0.99**

* Applied at 80 days after sowing

observed a significant reduction of internodes in cotton when TIBA was applied at different concentrations (0, 50, 100 and 150 ppm) as compared with control. The interaction between hybrids and plant growth regulation treatments was non significant in both the years.

4.3.9 Height to Node Ratio

Height to node ratio indicates the internodal length of the plant. The hybrids failed to influence height to node ratio during both the years (Table 4.42).

Data presented in Table 4.42 depict that plant growth regulation treatments had a significant effect on height to node ratio during both the years. Detopping exhibited significantly higher height to node ratio (7.66 and 6.55) as compared to all other plant growth regulation treatments and control during 2011 and 2012, respectively. However, all the growth regulators *viz*. MC (300 ppm), TIBA (100 ppm) and MH (250 ppm) and control showed statistically similar height to node ratio during both the years.

The higher height to node ratio in detopping was due to significantly lesser number of main stem internodes in comparison to PGRs as apparent from Table 4.42. The interaction between different hybrids and plant growth regulation treatments was non significant during both the years.

4.3.10 SPAD value

SPAD meters are reliable alternatives to traditional tissue analysis of plant chlorophyll content and also used as nutritional diagnostic tools. Higher levels of chlorophyll content in leaves indicates enhanced photosynthetic efficiency of the crop which influences the crop growth and yield. The data pertaining to chlorophyll content which is indicating as SPAD value is presented in Table 4.43. The hybrids failed to influence the SPAD value at all the crop growth stages during both the years.

A perusal of data presented in Table 4.43 reveal that the SPAD value were similar at 90 DAS, as the plant growth regulation treatments were applied 10 days before the taking readings of leaf chlorophyll content. Whereas, the growth regulation treatments showed significant effect at 120 DAS and higher SPAD value was recorded with MC @ 300 ppm (29.2 and 30.4) statistically at par with TIBA @ 100 ppm (28.5 and 29.7) and MH @ 250 ppm (27.8 and 28.9) but significantly higher than control (22.6 and 24.6) and detopping (23.2 and 25.3) during 2011 and 2012, respectively. Higher SPAD value in MC @ 300 ppm, TIBA @ 100 ppm and MH @ 250 ppm as compared to control and detopping might be due to the lesser plant height (Table 4.32) that caused translocation of assimilates towards the leaves and increased the leaf thickness which was apparent from higher SLA (Table 4.41).

Table 4.43: Effect of *Bt* cotton hybrids and plant growth regulation treatments on SPAD value

Treatment	SPAD value			
	90 DAS		120 DAS	
	2011	2012	2011	2012
Hybrids				
MRC 7017	32.9 a	36.2 a	26.6 a	28.2 a
MRC 7031	32.6 a	35.8 a	26.8 a	28.4 a
RCH 314	31.8 a	35.0 a	25.3 a	26.8 a
SEm	**0.82**	**1.06**	**0.67**	**0.89**
F(p)	**0.56**	**0.54**	**0.16**	**0.11**
Plant growth regulation*				
Control	31.5 a	34.6 a	22.6 b	24.6 b
Detopping	31.8 a	35.0 a	23.2 b	25.3 b
TIBA @ 100 ppm	33.3 a	36.6 a	28.5 a	29.7 a
M C @ 300 ppm	33.0 a	36.3 a	29.2 a	30.4 a
M H @ 250 ppm	32.5 a	35.8 a	27.8 a	28.9 a
SEm	**0.96**	**1.02**	**0.77**	**0.74**
F(p)	**0.63**	**0.60**	**<0.0001**	**<0.0001**
Interaction F(p)	**0.99**	**0.99**	**0.99**	**0.99**

* Applied at 80 days after sowing

Kumar *et al* (2005) and Brar *et al* (2000) reported significantly higher total chlorophyll content with the application of growth retardant i.e. MC. Similarly, an increase in chlorophyll content with the application of MH on leaves of oats was observed by Sangeeta and Varshney (1992). The increase in chlorophyll content in soybean leaves was also found by Pravin *et al* (2001) with the application of TIBA at 50 and 100 ppm. Interaction between hybrids and plant growth regulation treatments was non significant at both 90 and 120 DAS during both the years.

4.3.11 Days Taken to Initiation of Squaring

Plant growth regulation treatments did not significantly influenced all the *Bt* cotton hybrids for square initiation and it was initiated after 55 days of crop in both the years (Table 4.44). The interaction between hybrids and plant growth regulation treatments was non significant in 2011 and 2012.

4.3.12 Days Taken to 50 % Squaring

Hybrids and plant growth regulation treatments took 64-67 days to complete 50 % squaring during both the years. Different hybrids and growth regulation treatments did not vary among themselves for the days taken to 50% squaring. All the interactions for days taken to 50 % squaring were non significant in both the years (Table 4.44).

4.3.13 Days Taken to Flower Initiation

Flowering initiated at 72-73 and 73-74 DAS in all the hybrids and different regulation treatments during 2011 and 2012, respectively. Hybrids and plant growth regulation treatments did not differ significantly for the days taken to flower initiation during both the years.

4.3.14 Days Taken to 50% Flowering

Hybrids and plant growth regulation treatments showed non significant variation for 50 % flowering during both the years (Table 4.44). To complete 50 % flowering different hybrids and plant growth regulation treatments took 82-83 days during 2011 and 86-87 days during 2012. Interaction between hybrids and plant growth regulation treatments was non significant during both the years.

4.3.15 Days Taken to Initiation of Boll Formation

Data presented in Table 4.45 depict that hybrids and plant growth regulation treatments did not differ significantly for the days taken to initiation of boll formation and they took 83-84 days and 90-91 days to complete boll initiation during both the crop growth seasons (Table 4.45). Interaction between hybrids and plant growth regulation treatments was not significant in both the years.

4.3.16 Days Taken to 50 % Boll Formation

As evident from Table 4.45 different hybrids did not differ significantly for 50 % boll formation and they took 105-106 days in 2011 and 107-108 days in 2012. Similarly, all the growth regulators and detopping failed to significantly influence the days taken to 50 % boll formation and they took 105-106 days in 2011 and 106-108 days in 2012 to complete 50 % boll formation. No interaction was observed for the days taken to 50 % boll formation in any of the two years.

Table 4.44: Effect of *Bt* cotton hybrids and plant growth regulation treatments on days taken to square initiation, 50 % squaring, days taken to flower initiation and 50 % flowering

Treatment	Days to square initiation		Days to 50% squaring		Days to flower initiation		Days to 50% Flowering	
	2011	2012	2011	2012	2011	2012	2011	2012
Hybrids								
MRC 7017	55 a	55 a	65 a	66 a	72 a	74 a	82 a	86 a
MRC 7031	55 a	55 a	65 a	66 a	72 a	73 a	82 a	87 a
RCH 314	55 a	55 a	65 a	66 a	73 a	74 a	83 a	87 a
SEm	**0.60**	**0.92**	**1.18**	**1.20**	**1.09**	**1.11**	**1.17**	**1.67**
F(p)	**0.97**	**0.83**	**0.91**	**0.96**	**0.76**	**0.76**	**0.71**	**0.77**
Plant growth regulation*								
Control	56 a	55 a	64 a	66 a	72 a	73 a	82 a	87 a
Detopping	56 a	55 a	65 a	66 a	73 a	74 a	82 a	87 a
TIBA @ 100 ppm	55 a	55 a	65 a	66 a	72 a	74 a	83 a	86 a
M C @ 300 ppm	54 a	55 a	65 a	66 a	72 a	74 a	82 a	87 a
M H @ 250 ppm	55 a	55 a	65 a	67 a	72 a	74 a	82 a	87 a
SEm	**0.87**	**0.80**	**1.05**	**1.09**	**1.22**	**1.25**	**1.16**	**1.73**
F(p)	**0.73**	**0.94**	**0.89**	**0.99**	**0.97**	**0.99**	**0.99**	**0.99**
Interaction F(p)	**0.88**	**0.88**	**0.99**	**0.99**	**0.99**	**0.99**	**0.97**	**0.99**

* Applied at 80 days after sowing

Table 4.45: Effect of *Bt* cotton hybrids and plant growth regulation treatments on days taken to boll initiation, 50 % boll formation, days taken to boll open initiation and 50 % boll opening

Treatment	Days to boll initiation		Days to 50% boll formation		Days to boll open initiation		Days to 50% boll opening	
	2011	2012	2011	2012	2011	2012	2011	2012
Hybrids								
MRC 7017	83 a	90 a	105 a	107 a	128 a	133 a	145 a	145 a
MRC 7031	83 a	90 a	105 a	107 a	127 a	133 a	145 a	145 a
RCH 314	84 a	91 a	106 a	108 a	128 a	134 a	144 a	145 a
SEm	**1.12**	**1.84**	**1.19**	**1.13**	**1.59**	**1.20**	**1.55**	**1.25**
F(p)	**0.47**	**0.78**	**0.93**	**0.81**	**0.91**	**0.87**	**0.91**	**0.93**
Plant growth regulation*								
Control	83 a	90 a	105 a	106 a	127 a	132 a	144 a	145 a
Detopping	83 a	90 a	105 a	107 a	127 a	133 a	144 a	145 a
TIBA @ 100 ppm	84 a	91 a	106 a	108 a	128 a	134 a	145 a	146 a
M C @ 300 ppm	83 a	91 a	106 a	108 a	128 a	134 a	145 a	146 a
M H @ 250 ppm	84 a	90 a	106 a	107 a	128 a	134 a	145 a	145 a
SEm	**1.28**	**1.91**	**1.04**	**1.07**	**1.19**	**1.36**	**0.87**	**0.92**
F(p)	**0.87**	**0.97**	**0.97**	**0.76**	**0.97**	**0.59**	**0.85**	**0.96**
Interaction F(p)	**0.99**	**0.99**	**0.99**	**1.00**	**0.99**	**1.00**	**1.00**	**1.00**

* Applied at 80 days after sowing

4.3.17 Days Taken to Initiation of Boll Opening

A perusal of data presented in Table 4.45 show that a non significant difference was recorded for hybrids during both the years and 127-128 days (2011) and 133-134 days (2012) were taken to initiate boll opening.

Growth regulation treatments did not differ significantly for days taken to initiation of boll opening and they took 127-128 days (2011) and 132-134 days (2012). The interaction effects were non significant for all the treatments during both the years.

4.3.18 Days Taken to 50 % Boll Opening

The scrutiny of data presented in Table 4.45 depict that the hybrids and growth regulation treatments show non significant effect for the time taken to complete 50 % boll opening. Hybrids took 144-145 days and 145 days to complete 50 % boll opening during 2011 and 2012 respectively. Different growth regulation treatments required 144-145 days during 2011, to complete 50 % boll opening and 145-146 days during 2012 to complete 50 % boll opening.

4.3.19 Monopodial Branches per Plant

Monopodial branches are the vegetative branches which arise from the lower nodes of the plant. As evident from data presented in Table 4.46, hybrids did not differ significantly for the number of monopodial branches plant^{-1}. Hybrid MRC 7017, MRC 7031 and RCH 314 produced 3.87, 3.80 and 3.72 monopods plant^{-1}, respectively during 2011 and 4.41, 4.33 and 4.20 monopods plant^{-1}, respectively during 2012. These three hybrids have same morphological behaviour to produce monopodial branches which was attributed to their similar genetic make up. Heitholt *et al* (1992) and Brar (1997) also confirmed that similar genetic make up of hybrids resulted in almost same growth pattern of the plant.

Data presented in Table 4.46 show the effect of foliar application of PGRs on number of monopodial branches plant^{-1}. Plant growth regulation treatments failed to influence the number of monopodial branches plant^{-1} significantly in any of the two years because PGRs were applied either at maximum vegetative growth stage or thereafter, whereas the monopodial branches arise from the lower nodes of the plant during the earlier stages of crop growth. These results were in conformity with the findings of Wallace *et al* (1993) and Rajni (2010). The interaction between hybrids and plant growth regulation treatments were non significant in both the years.

4.3.20 Sympodial Branches per Plant

Sympodial branches arise from monopodial branches and are the reproductive branches on which fruiting bodies develop. Hybrids differed significantly among themselves for the number of sympodial branches plant^{-1} during both the crop growth seasons (Table 4.46). Hybrid MRC 7017 produced significantly higher number of sympodial branches plant^{-1} (24.5 and 27.5), than RCH 314 and were 12.9 and 8.3 per cent more than hybrid RCH 314 during 2011 and 2012, respectively. Hybrid MRC 7031 produced 24.2 and 27.2 number of sympodial branches plant^{-1} which statistically at par with hybrid MRC 7017 during 2011 and 2012, respectively. Hybrid RCH 314 which produced 21.7 and 25.4 number of sympodial branches plant^{-1} which was significantly lower than both MRC 7017 and MRC 7031 during 2011 and 2012, respectively. The variation in number of sympodial branches plant^{-1} recorded by different cotton hybrids could be attributed to their respective genetic constitution.

As evident from the data presented in Table 4.46, different growth regulation treatments had a significant influence on the number of sympodial branches plant^{-1}. The application of MC @ 300 ppm resulted in significantly higher number of sympodial branches plant^{-1} than control and detopping during both the years of study.

Foliar application of MC (300 ppm) produced maximum number of sympodial branches plant^{-1} (25.5 and 29.0) which were statistically at par with TIBA @ 100 ppm (25.0 and 28.5) and MH @ 250 ppm (24.4 and 27.8) but proved significantly better than control (20.9 and 23.8) and detopping (21.4 and 24.4) during 2011 and 2012, respectively. This significant increase in number of sympodial branches plant^{-1} with application of MC could be contributed to its anti-gibberellin activity by which it restricts the growth of main stem thus stimulating the growth of lateral branches. These results also confirm the findings of Singh (1999), Brar *et al* (2001) and Kumar *et al* (2006). The increase in number of sympodial branches plant^{-1} with TIBA was due to the fact that TIBA suppresses the activity of endogenous auxin and inhibits both internode elongation and apical dominance which helped lateral branches to develop (Galston 1947). Similarly, MH application helps in increasing the number of sympodial branches plant^{-1} by inhibiting the cell division in apical region of the plant which resulted smaller plants with more lateral branches. Pandya and Dixit (1997) also confirmed that MH application resulted in more number of shoots plant^{-1} in *L. siceraria*. No interaction was observed for sympodial branches plant^{-1} during both the years.

Table 4.46: Effect of different *Bt* cotton hybrids and plant growth regulation treatments on monopodial and sympodial branches per plant

Treatment	Monopodial branches plant^{-1}		Sympodial branches plant^{-1}	
	2011	2012	2011	2012
Hybrids				
MRC 7017	3.87 a	4.41 a	24.5 a	27.5 a
MRC 7031	3.80 a	4.33 a	24.2 a	27.2 a
RCH 314	3.72 a	4.20 a	21.7 b	25.4 b
SEm	**0.11**	**0.12**	**0.68**	**0.72**
F(p)	**0.50**	**0.31**	**0.28**	**0.32**
Plant growth regulation*				
Control	3.69 a	4.19 a	20.9 b	23.8 b
Detopping	3.70 a	4.20 a	21.4 b	24.4 b
TIBA @ 100 ppm	3.80 a	4.32 a	25.0 a	28.5 a
M C @ 300 ppm	3.97 a	4.51 a	25.5 a	29.0 a
M H @ 250 ppm	3.81 a	4.33 a	24.4 a	27.8 a
SEm	**0.11**	**0.11**	**0.66**	**0.83**
F(p)	**0.39**	**0.32**	**<0.0001**	**<0.0001**
Interaction F(p)	**0.99**	**0.99**	**1.00**	**1.00**

* Applied at 80 days after sowing

4.3.21 Flowers per Plant

Flowers are the reproductive parts which develop into bolls and ultimately contribute to the seed cotton yield. Flower production in cotton is dependent on the production of buds and squares which in turn depends upon the production of new fruiting points and ultimately the growth of plant (Cathey and Meredith 1988). The number of flowers produced plant^{-1} differed significantly among the hybrids in both the years (Table 4.47 and Fig. 4.29). Hybrid MRC 7017 produced the maximum number of flowers (129.7 and 168.6) followed by hybrid MRC 7031(127.1 and 162.7) in 2011 and 2012, respectively. However, both MRC 7017 and MRC 7031 produced statistically similar number of flowers plant^{-1} during both the years. Hybrid RCH 314 produced significantly less number of flowers (114.8 and 151.6) as compared to hybrid MRC 7017 during 2011 and 2012, respectively. The variation in number of flowers produced plant^{-1} can be explained by the differences in genetic makeup of the plants and their capacity to produce more number of sympodial branches plant^{-1} (Table 4.46) which resulted in more fruiting points plant^{-1}. The variation in number of flowers plant^{-1} showing genetic differences among cultivars have also been reported by Wankhade *et al* (1992) and Puri (2001).

Maximum number of flower production in hybrid MRC 7017 was due to the higher genetic potential of hybrid to develop superior plants in terms of height, sympodial branches plant^{-1} which resulted in more fruiting points plant^{-1}.

A perusal of the data presented in Table 4.47 and depicted in Fig. 4.30 reveal that various growth regulation treatments had a significant influence on the total number of flowers plant^{-1} during both the crop growth seasons. MC @ 300 ppm produced significantly higher number of flowers (128.9 and 167.5) than control and detopping and the percentage increase of flowers by MC @ 300 ppm was 9.31 and 9.33 over control during 2011 and 2012, respectively. However, MC applied @ 300 ppm was statistically at par with TIBA @ 100 ppm (127.5 and 165.6) and MH @ 250 ppm (126.1 and 163.9) for the total number of flowers plant^{-1} during both the years. TIBA (100 ppm) and MH (250 ppm) was statistically at par with detopping and control during 2011 and with detopping only during 2012, for the number of flowers plant^{-1}. Higher flower production in the treatment where MC @ 300 ppm was applied might be because of MC decreased the vegetative growth of plant and translocated assimilates towards the growing points which resulted in higher sympodial branches plant^{-1} (Table 4.46) and hence it increased the number of flowers plant^{-1}.

No interaction effect was shown by hybrids and plant growth regulation treatments for flowers plant^{-1} in both the years.

Table 4.47: Flowers per plant and setting percentage of *Bt* cotton as affected by different hybrids and plant growth regulation treatments

Treatment	Total Flowers		Setting (%)	
	2011	2012	2011	2012
Hybrids				
MRC 7017	129.7 a	168.6 a	41.7 a	43.5 a
MRC 7031	127.1 a	162.7 ba	41.1 a	43.1 a
RCH 314	114.8 b	151.6 b	40.6 a	43.0 a
SEm	**2.80**	**3.43**	**1.07**	**0.81**
F(p)	**0.0002**	**0.001**	**0.63**	**0.87**
Plant growth regulation*				
Control	117.9 b	153.2 c	39.2 b	41.4 b
Detopping	118.8 b	154.4 bc	39.2 b	41.5 b
TIBA @ 100 ppm	127.5 ba	165.6 ba	42.6 a	44.4 ba
M C @ 300 ppm	128.9 a	167.5 a	43.2 a	44.9 a
M H @ 250 ppm	126.1 ba	163.9 bac	41.6 ba	43.8 ba
SEm	**3.08**	**3.89**	**1.07**	**0.97**
F(p)	**0.04**	**0.03**	**0.03**	**0.04**
Interaction F(p)	**1.00**	**1.00**	**1.00**	**0.99**

* Applied at 80 days after sowing

4.3.22 Setting Percentage

Setting percentage is one of the important parameter which determines the seed cotton yield. In a crop like cotton higher setting percentage of bolls means more economic yield per unit biomass. Different hybrids did not vary significantly for the setting percentage during both the years (Table 4.47). However, relatively higher setting percentage was recorded in MRC 7017 (41.7 and 43.5) than MRC 7031 (41.1 and 43.1 per cent) and RCH 314 (40.6 and 43.0 per cent) but failed to reach the level of significance during 2011 and 2012, respectively.

Amongst the growth regulation treatments, foliar application of MC @ 300 ppm resulted in maximum setting percentage of 43.2 and 44.9 which was significantly higher than control (39.2 and 41.4 %) and detopping (39.2 and 41.5 %) but statistically at par with TIBA application @ 100 ppm (42.6 and 44.4 %) and MH @ 250 ppm (41.6 and 43.8 %) in 2011 and 2012, respectively. The significant improvement in the setting percentage with MC application might be due to better partitioning of metabolites towards the fruiting bodies due to growth retardation by MC (Wallace *et al* 1993) thereby exerting a favorable effect on retention of fruiting bodies by preventing their shedding (Table 4.34 to 4.37). Interaction between hybrids and plant growth regulation treatments was non significant during both the years.

4.3.23 Total Bolls per Plant

Hybrids had a significant influence on the total number of bolls produced plant^{-1} (Table 4.48 and Fig. 4.29). Hybrid MRC 7017 produced higher number of bolls plant^{-1} (53.9 and 73.2) which was statistically at par with hybrid MRC 7031 (52.0 and 70.0 bolls plant^{-1}) but significantly higher than RCH 314 (46.5 and 64.9 bolls plant^{-1}) during 2011 and 2012, respectively. It could be due to the reason that MRC 7017 produced more number of sympodial branches plant^{-1} (Table 4.46) and flowers plant^{-1} than both the hybrids (Table 4.47). The differential ability of cultivars to produce bolls has also been reported by Heitholt *et al* (1992).

Data presented in Table 4.48 and illustrated in Fig. 4.30 reveal that application of MC @ 300 ppm recorded the maximum number of bolls plant^{-1} (55.6 and 75.1) and statistically at par with TIBA @ 100 ppm (54.0 and 73.2) during both the years but it was significantly higher than MH @ 250 ppm (52.0) during 2011 whereas, during 2012, it did not vary significantly with MH @ 250 ppm (71.3). Total bolls plant^{-1} were significantly higher in MC @ 300 ppm as compared to control (46.0 and 63.3) and detopping (46.5 and 64.0) during 2011 and 2012, respectively. The increase in number of bolls plant^{-1} with foliar application of MC was due to better partitioning of metabolites and photosynthates towards the fruiting bodies and retardation of excessive vegetative growth resulted in higher number of sympodial branches plant^{-1} (Table 4.46) and improved setting percentage (Table 4.47). El-shshway

(1999), Mekki (1999) and Gormus (2006) also reported that MC decreased the vegetative growth of plant and in-turn reproductive growth was enhanced by shifting assimilates towards the fruiting points. Higher number of total bolls in MH and TIBA was also due to their decreased plant height which resulted in assimilate translocation towards other plant parts and resulted in higher sympodial branches plant^{-1} which ultimately increased the total bolls plant^{-1}. Sharma *et al* (2005) also reported an increase in pod set in soybean when MH (100 ppm) was applied. The application of TIBA @ 25 ppm increased in number of pods plant^{-1} in cowpea as compared to control had also been reported by Ganiger *et al* (2002a) The interaction effect of different treatments was non significant during both the crop growth seasons.

4.3.24 Total Picked Bolls per Plant

The most important character which directly contributes towards seed cotton yield is the number of picked (opened) bolls plant^{-1}. Data presented in Table 4.48 and Fig. 4.29 it was observed that hybrid MRC 7017 produced maximum number of picked bolls plant^{-1} (48.6 and 66.1) which was statistically at par with hybrid MRC 7031 (46.9 and 63.4) but was significantly higher than RCH 314 (41.2 and 58.7) during 2011 and 2012, respectively. However, during 2011, Hybrid MRC 7031 produced more number of bolls plant^{-1} as compared to RCH 314 while, during 2012, it was statistically at par with hybrid RCH 314. However, hybrid RCH 314 produced least number of total picked bolls plant^{-1} in both the years. Higher number of total picked bolls plant^{-1} was recorded in hybrid MRC 7017 could be due to the reason that it produced more number of sympodial branches plant^{-1} (Table 4.46), total flowers and total bolls plant^{-1} as compared to both the hybrids and as apparent from the Table 4.47 and 4.48, respectively.

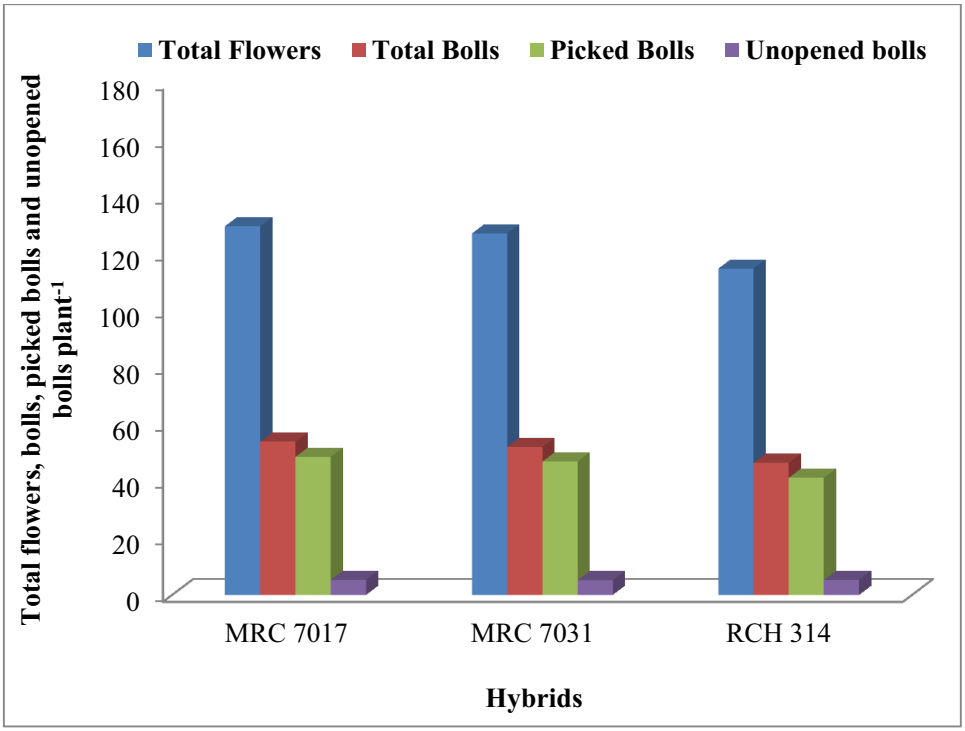
As evident from the Table 4.48 and Fig. 4.30, different growth regulator treatments had a significant influence on number of picked bolls plant^{-1} during both the years. The foliar application of MC @ 300 ppm recorded maximum number of picked bolls plant^{-1} (50.3 and 68.3) statistically at par with TIBA @ 100 ppm (48.7 and 66.4) and also with MH @ 250 ppm (46.9 and 64.6) during 2011 and 2012, respectively. All the PGR treatments were significantly better than control and detopping during both the years. The increase in number of picked bolls plant^{-1} with MC application was due to improved source-sink relationship and setting percentage (Table 4.47). The decrease in number of picked bolls plant^{-1} with detopping was due to decrease in number of sympodial branches plant^{-1} (Table 4.46) and reduced setting percentage (Table 4.47), which might be due to less suppression of branch primordia and retardation of vegetative growth, thereby lowering the mobilization of photosynthates into fruiting bodies and retention of fruiting bodies (Owen and Craig 2003). MH and TIBA application also suppressed plant height which helped in initiation of more lateral branches and improving the mobilization of assimilates into fruiting bodies as evident from higher number of total bolls plant^{-1} (Table 4.48).

Table 4.48: Effect of different hybrids and plant growth regulation treatments on total bolls, picked bolls, unopened bolls per plant and boll opening percentage

Treatment	Total Bolls		Picked Bolls		Unopened bolls		Boll opening (%)	
	2011	2012	2011	2012	2011	2012	2011	2012
Hybrids								
MRC 7017	53.9 a	73.2 a	48.6 a	66.1 a	5.33 a	6.95 a	90.1 a	90.3 a
MRC 7031	52.0 a	70.0 ba	46.9 a	63.4 ba	5.15 a	6.65a	89.9 a	90.4 a
RCH 314	46.5 b	64.9 b	41.2 b	58.7 b	5.27 a	6.6 0 a	88.6 a	90.4 a
SEm	**1.26**	**1.45**	**1.07**	**1.38**	**0.18**	**0.17**	**0.85**	**0.70**
F(p)	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**0.73**	**0.58**	**0.41**	**0.99**
Plant growth regulation*								
Control	46.0 c	63.3 b	40.7 b	56.7 b	5.25 a	7.08 a	88.2 a	89.6 a
Detopping	46.5 c	64.0 b	41.2 b	57.6 b	5.31 a	6.83 a	88.5 a	89.8 a
TIBA @ 100 ppm	54.0 ba	73.2 a	48.7 a	66.4 a	5.30 a	6.66 a	90.1 a	90.6 a
M C @ 300 ppm	55.6 a	75.1 a	50.3 a	68.3 a	5.27 a	6.50a	90.5 a	90.9 a
M H @ 250 ppm	52.0 b	71.3 a	46.9 a	64.6 a	5.11 a	6.58a	90.5 a	90.8 a
SEm	**1.17**	**1.34**	**1.14**	**1.37**	**0.20**	**0.19**	**1.11**	**1.11**
F(p)	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**0.94**	**0.35**	**0.41**	**0.89**
Interaction F(p)	**0.99**	**0.99**	**0.99**	**0.99**	**0.96**	**0.99**	**0.99**	**0.99**

* Applied at 80 days after sowing

(a)



(b)

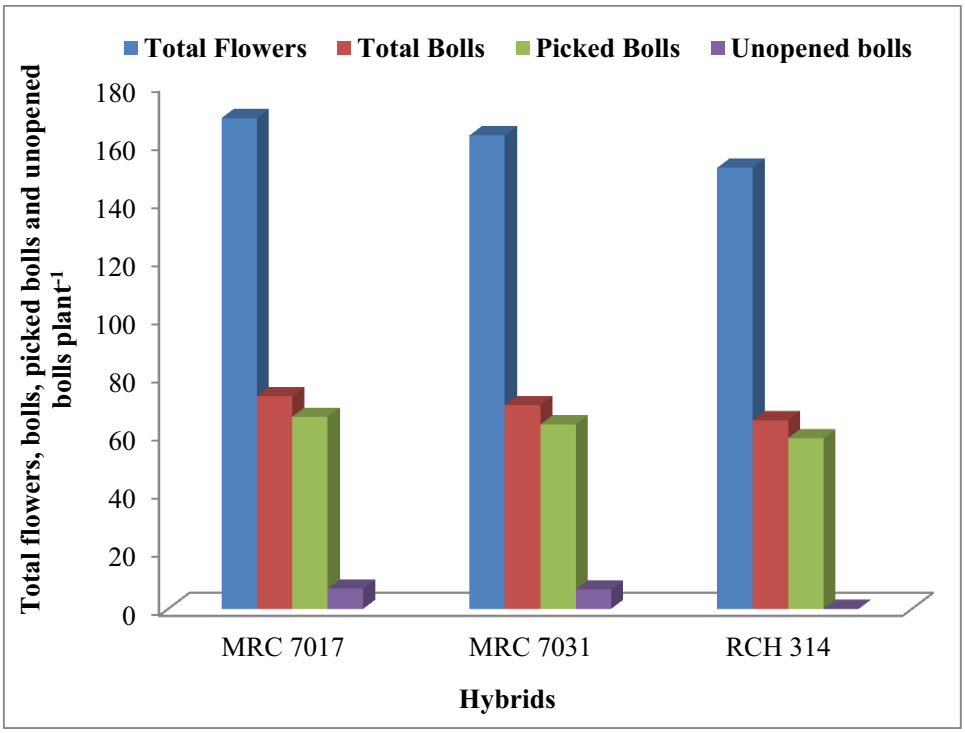
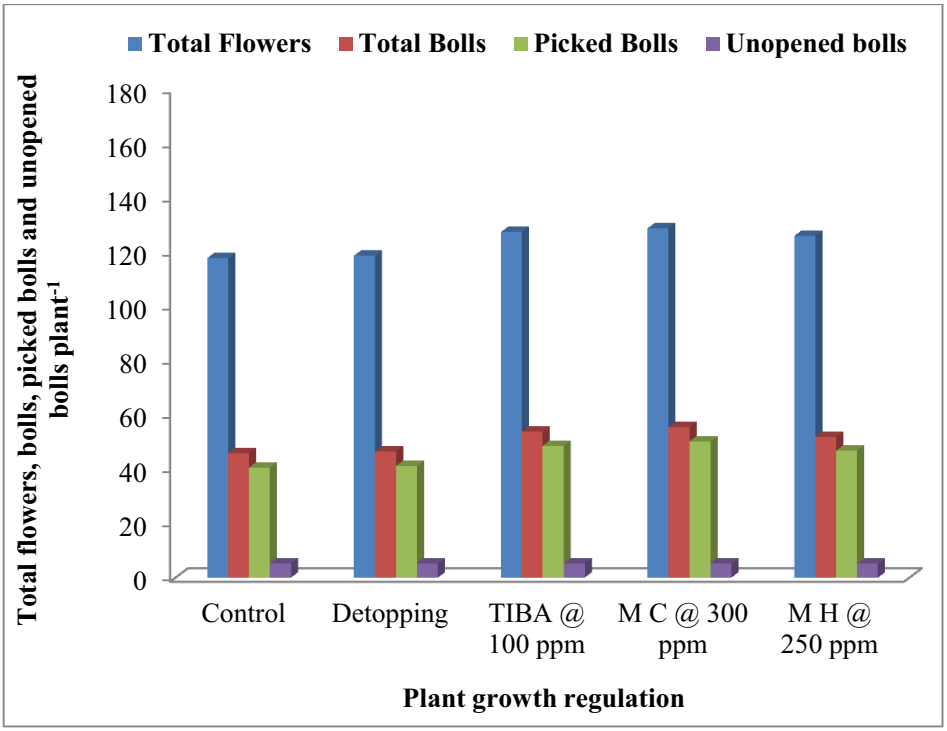


Fig 4.29: Total flowers, bolls, picked bolls and unopened bolls per plant of different hybrids during 2011 (a) and 2012 (b)

(a)



(b)

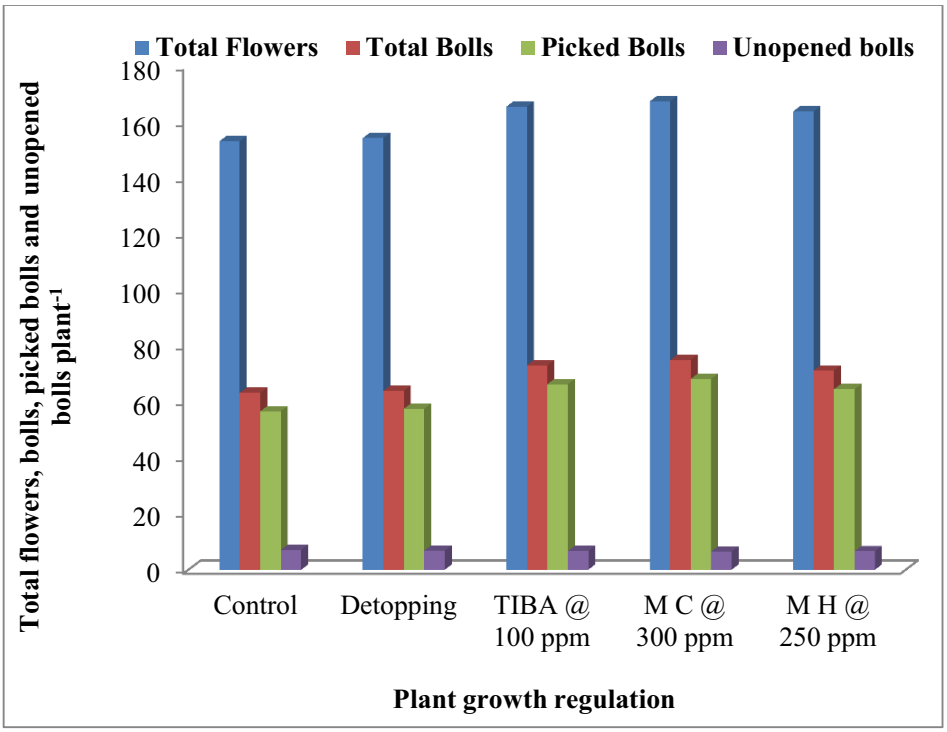


Fig 4.30: Total flowers, bolls, picked bolls and unopened bolls per plant of hybrids as influenced by different plant growth regulation treatments during 2011 (a) and 2012 (b)

Dastur (1959) reported an increase in number of bolls in cotton when TIBA was applied. An increase in fruit load in flax with MH application was reported by Norton *et al* (2005). Interactive effect of various growth regulation treatments and hybrids was non significant during both the years.

4.3.25 Number of Unopened Bolls per Plant

Different hybrids and growth regulation treatments did not vary among themselves for the number of unopened bolls plant^{-1} in both the years (Table 4.48 and Fig. 4.29 and 4.30). The interaction effect for number of unopened bolls plant^{-1} was also non significant during both the years.

4.3.26 Boll Opening Percentage (BOP)

Data presented in Table 4.48 show that different hybrids and growth regulation treatments did not vary significantly among themselves for the boll opening percentage during both the years. The interaction effect of different plant growth regulation treatments with hybrids also was non significant during both the years.

4.3.27 Boll Weight

It is the weight of seed cotton in each boll that directly influences the total seed cotton yield. Data presented in Table 4.49 reveal that the hybrids failed to exert any significant influence on boll weight during both the crop growth seasons. It is evident from the allocation of similar amount of assimilates to the bolls which in turn produced same amount of lint and seeds in each boll as manifested through non significant variations in lint and seed indices (Table 4.51) of the hybrids.

A perusal of data presented in Table 4.49 reveal that different plant growth regulation treatments significantly influenced the boll weight in both the years of study. Maximum boll weight of 3.46 and 4.08 g was obtained with foliar application of MC @ 300 ppm which was statistically at par with TIBA @ 100 ppm (3.44 and 4.06 g) and MH 250 ppm (3.42 and 4.04 g) but significantly better than control (3.11 and 3.68 g) and detopping (3.13 and 3.69 g) during 2011 and 2012, respectively. TIBA and MH were statistically at par with detopping during 2011 and attained significantly higher boll weight than control while, during 2012 both the growth regulators had significantly higher boll weight than detopping and control. Siddique *et al* (2002) reported that the increase in boll weight with application of MC was because of improved source-sink relationship and better translocation of metabolites towards reproductive sinks (fruiting bodies) due to retardation of excessive vegetative growth. TIBA and MH also reduced the vegetative growth of plant which helped in better translocation of assimilates towards the bolls. York (1983), Brar *et al* (2000) and Kumar *et al* (2006) had also reported a significant increase in boll weight with MC application. The interactive effect of different plant growth regulation treatments with hybrids was non significant in both the years.

Table 4.49: Effect of hybrids and plant growth regulation treatments on boll weight (g)

Treatment	Boll weight (g)	
	2011	2012
Hybrids		
MRC 7017	3.34 a	3.94 a
MRC 7031	3.33 a	3.93 a
RCH 314	3.27 a	3.86 a
SEm	**0.07**	**0.11**
F(p)	**0.78**	**0.76**
Plant growth regulation*		
Control	3.11 c	3.68 b
Detopping	3.13 bc	3.69 b
TIBA @ 100 ppm	3.44 ba	4.06 a
M C @ 300 ppm	3.46 a	4.08 a
M H @ 250 ppm	3.42 bac	4.04 a
SEm	**0.10**	**0.11**
F(p)	**0.03**	**0.02**
Interaction F(p)	**1.00**	**1.00**

*Applied at 80 days after sowing

4.3.28 Seed Cotton Yield of First Pick

Yield is the ultimate result of the interaction of various factors and is a valid criterion for comparing the efficiency of different treatments. Data presented in Table 4.50 and illustrated in Fig. 4.31 depict that hybrids differed significantly with each other for the seed cotton yield in the first picking. Hybrid MRC 7017 recorded maximum first picking seed cotton yield (9.90 and 12.37 q ha^{-1}) and was statistically at par with hybrid MRC 7031 which yielded 9.66 and 12.02 q ha^{-1} during 2011 and 2012, respectively. Whereas, hybrid RCH 314 with yield of 8.49 and 10.61 q ha^{-1} recorded significantly lower seed cotton yield than both MRC 7017 and MRC 7031 during 2011 and 2012, respectively. Higher yield by the hybrid MRC 7017 can be explained by the better growth and development due to its higher genetic potential as evident from the better plant height (Table 4.32) which resulted in increased

number of sympodial branches plant^{-1} (Table 4.46), flowers plant^{-1} (Table 4.47), total bolls and picked bolls plant^{-1} (Table 4.48) as recorded by the hybrid.

The results on effect of application of different plant growth regulation on seed cotton yield of first pick are depicted in Table 4.50 and presented in Fig. 4.32. Different growth regulation treatments had a significant effect on the seed cotton yield obtained in the first picking during both the years. MC @ 300 ppm recorded maximum seed cotton yield of 9.72 and 12.15 q ha^{-1} which was 8.8 and 8.9 per cent higher than untreated control during 2011 and 2012, respectively. MC applied @ 300 ppm though statistically at par with TIBA @ 100 ppm, MH @ 250 ppm and control but was significantly better than detopping during both the years. However, all the growth regulator treatments proved to be significantly higher seed cotton yield than detopping during both the years. Kerby *et al* (1986) also reported that early season boll load is stimulated by MC. The higher seed cotton yield in MC was due to the reason that MC, TIBA and MH decreases plant height but increased the reproductive growth of the plant as evident from higher number of flowers, total bolls and picked bolls plant^{-1}. Greer and Anderson (1965) also confirmed that yield was increased with the application of TIBA in soybean by reducing the vegetative growth thereby photosynthetic rate enhanced that helped in producing more fruiting points plant^{-1} which resulted in higher yield over control. Kumar *et al* (2003) also observed higher yield in chickpea with MH application. A non significant influence on seed cotton yield and lint yield per hectare was observed by Siddique *et al* (2002) by detopping plants at 90 DAS. It was also observed that detopping in *G hirsutum* was not advantageous in terms of seed cotton yield Turkhede *et al* (2003). The interaction between all the hybrids and plant growth regulation treatments was non significant during both the years.

4.3.29 Seed Cotton Yield of Second Pick

Data presented in Table 4.50 and represented in Fig. 4.31 reveal that hybrids yielded significantly different amounts of seed cotton yield per hectare in second picking. Hybrid MRC 7017 yielded the highest i.e. 6.41 and 8.22 q ha^{-1} while hybrid RCH 314 yielded the minimum seed cotton yield of 5.72 and 7.12 q ha^{-1} in 2011 and 2012, respectively. Both the hybrids MRC 7017 and MRC 7031 were statistically at par with each other for the amount of seed cotton obtained from second picking during 2011. However, during 2012, hybrid MRC 7017 produced significantly higher seed cotton yield as compared to MRC 7031 and RCH 314 and both the hybrids i.e. MRC 7031 and RCH 314 were statistically at par with each other for the amount of seed cotton produced during 2012**.** Higher yield by the hybrid MRC 7017 can be explained by the better growth and development as evident from the better plant height resulted in increased number of flowers, total bolls and picked bolls plant^{-1} as recorded

by the hybrid. Blaise *et al* (2003) also reported that a significant difference was observed between the *Bt* hybrids for seed cotton yield. Singh *et al* (2003) also reported a yield difference between hybrids and it was due to the higher number of bolls plant^{-1}.

Different plant growth regulation treatments had a significant effect on the seed cotton yield obtained from second picking in both the years (Table 4.50 and Fig. 4.32). Maximum seed cotton yield was obtained with application of MC @ 300 ppm (6.71 and 8.86 q ha^{-1}) and was statistically at par with TIBA 100 ppm (6.50 and 8.35 q ha^{-1}) and MH 250 ppm (6.37 and 8.34 q ha^{-1}) but significantly better than control (5.50 and 6.18 q ha^{-1}) and detopping (5.62 and 6.41 q ha^{-1}) during 2011 and 2012, respectively. The higher yield in PGR treatments was due to the reason that all the PGRs decreased plant height (Table 4.32) and the photosynthates were translocated towards the lateral branches which resulted in more number of sympodial branches plant^{-1} (Table 4.46), flowers, total bolls and picked bolls plant^{-1} as compared to control. No interaction was observed for seed cotton yield of second pick during both the years.

4.3.30 Seed Cotton Yield of Third Pick

The data depicted in Table 4.50 and presented in Fig. 4.31 show that different hybrids differed significantly for the seed cotton yield obtained from the third picking. Hybrid MRC 7017 recorded significantly higher seed cotton yield of 5.87 and 10.10 q ha^{-1} as compared to the hybrid RCH 314 (5.07 and 9.10 q ha^{-1}) during 2011 and 2012, respectively.

Hybrid MRC 7031 which recorded the seed cotton yield of 5.39 and 9.94 q ha^{-1} was statistically at par with both MRC 7017 and RCH 314 during 2011 and 2012, respectively. Higher yield production by the hybrid MRC 7017 can be explained by the better growth and development as evident from the better plant height (Table 4.32), number of sympodial branches plant^{-1} (Table 4.46), total flowers plant^{-1} (Table 4.47), total bolls and picked bolls plant^{-1} (Table 4.48).

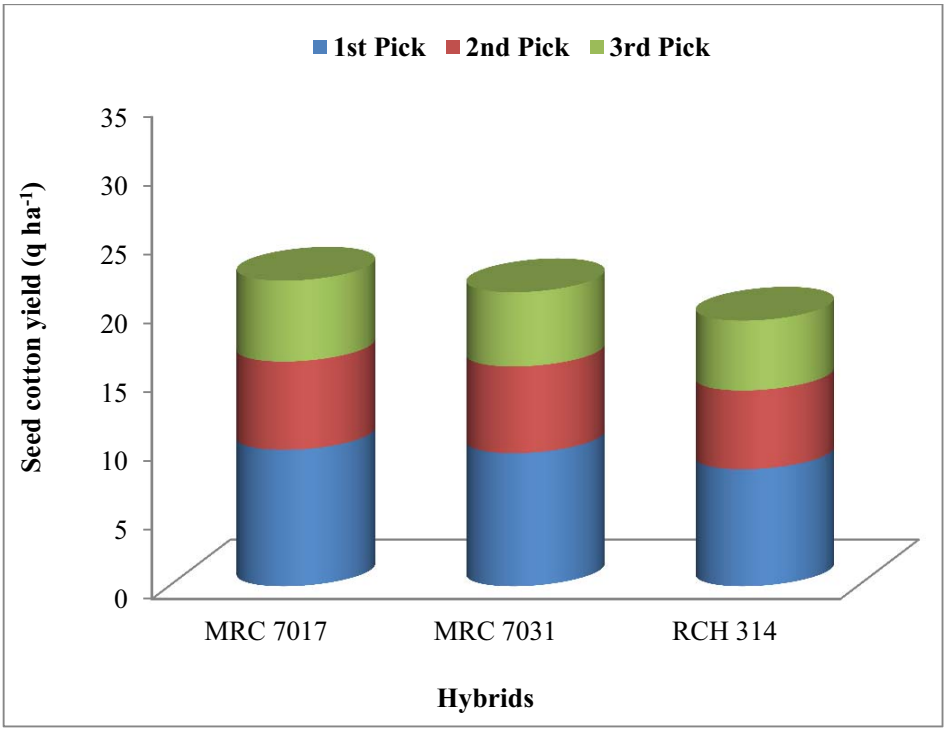
Data illustrated in Table 4.50 and presented in Fig. 4.32 reveal that MC @ 300 ppm yielded maximum seed cotton yield of 6.33 and 10.61 q ha^{-1} which was statistically at par with TIBA @ 100 ppm (5.96 and 10.27 q ha^{-1}) and MH @ 250 ppm (5.94 and 10.12 q ha^{-1}) but produced significantly higher yield than detopping (4.57 and 8.88 q ha^{-1}) and control (4.41 and 8.70 q ha^{-1}) during 2011 and 2012, respectively. The increase in seed cotton yield in MC (300 ppm) was 43.5 and 21.9 per cent over control during 2011 and 2012, respectively. Brar *et al* (2000) also reported that application of MC at 80 DAS had beneficial effect on seed cotton yield. The interaction between hybrids and fruiting form removal treatments was non significant during both the years.

Table 4.50: Effect of plant growth regulation treatments on seed cotton yield (q ha^{-1}) of *Bt* cotton hybrids

Treatments	Seed cotton yield (q ha^{-1})							
	1st Pick		2nd Pick		3rd Pick		Total	
	2011	2012	2011	2012	2011	2012	2011	2012
Hybrids								
MRC 7017	9.90 a	12.37 a	6.41 a	8.22 a	5.87 a	10.10 a	22.18 a	30.70 a
MRC 7031	9.66 a	12.02 a	6.29 a	7.55 b	5.39 ba	9.94 ba	21.35 a	29.52 a
RCH 314	8.49 b	10.61 b	5.72 b	7.12 b	5.07 b	9.10 b	19.30 b	26.85 b
SEm	**0.22**	**0.28**	**0.14**	**0.17**	**0.12**	**0.22**	**0.31**	**0.42**
F(p)	**<0.0001**	**<0.0001**	**0.001**	**<0.0001**	**<0.0001**	**0.002**	**<0.0001**	**<0.0001**
Plant growth regulation*								
Control	8.93 ba	11.16 ba	5.50 b	6.18 b	4.41 b	8.70 b	18.86 b	25.97 b
Detopping	8.77 b	10.97 b	5.62 b	6.41 b	4.57 b	8.88 b	18.97 b	26.34 b
TIBA @ 100 ppm	9.67 a	12.09 a	6.50 a	8.35 a	5.96 a	10.27 a	22.13 a	30.71 a
M C @ 300 ppm	9.72 a	12.15 a	6.71 a	8.86 a	6.33 a	10.61 a	22.79 a	31.62 a
M H @ 250 ppm	9.65 a	11.98 a	6.37 a	8.34 a	5.94 a	10.12 a	21.97 a	30.46 a
SEm	**0.25**	**0.32**	**0.16**	**0.19**	**0.13**	**0.25**	**0.32**	**0.44**
F(p)	**0.02**	**0.03**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**
Interaction F(p)	**0.66**	**0.64**	**0.98**	**0.66**	**0.69**	**0.99**	**0.88**	**0.92**

* Applied at 80 days after sowing

(a)



(b)

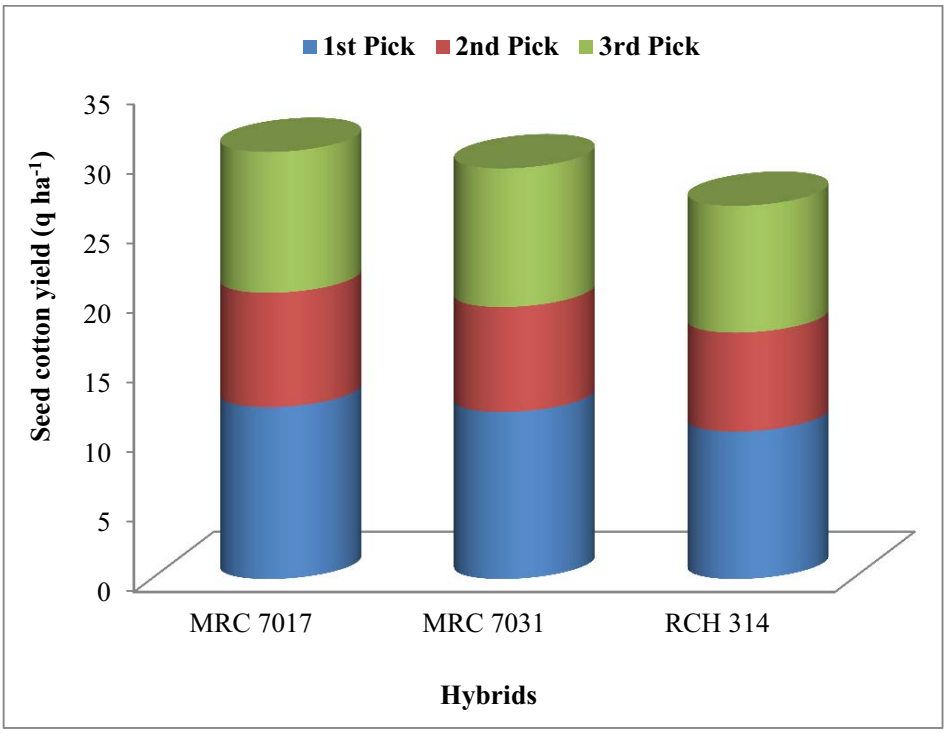
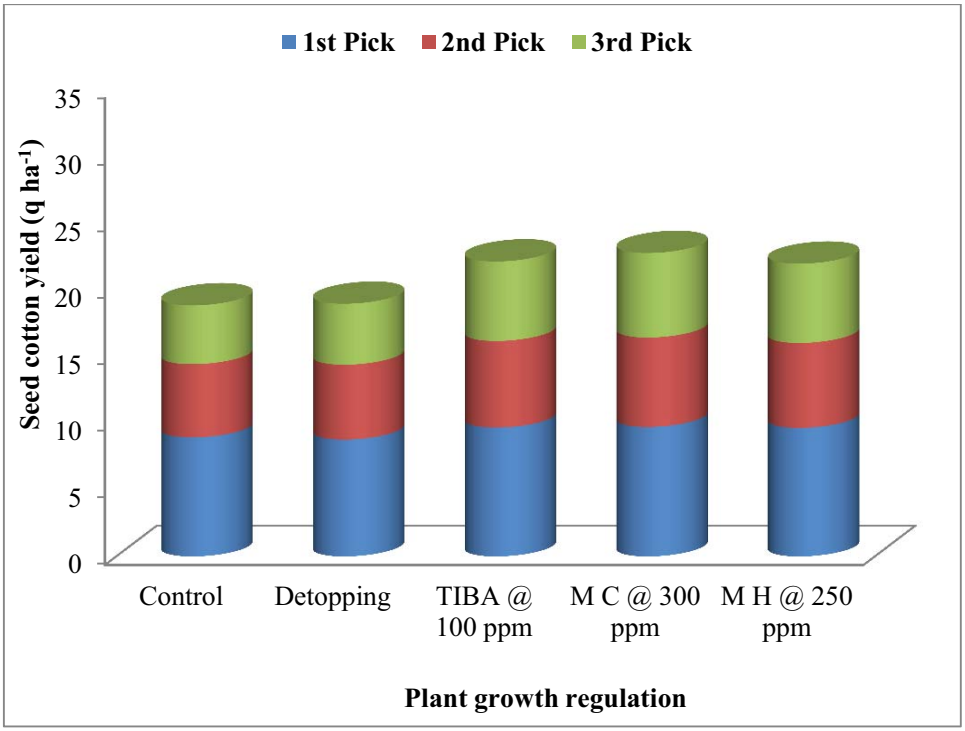


Fig 4.31: Seed cotton yield (q ha^{-1}) as affected by different during 2011 (a) and 2012 (b)

(a)



(b)

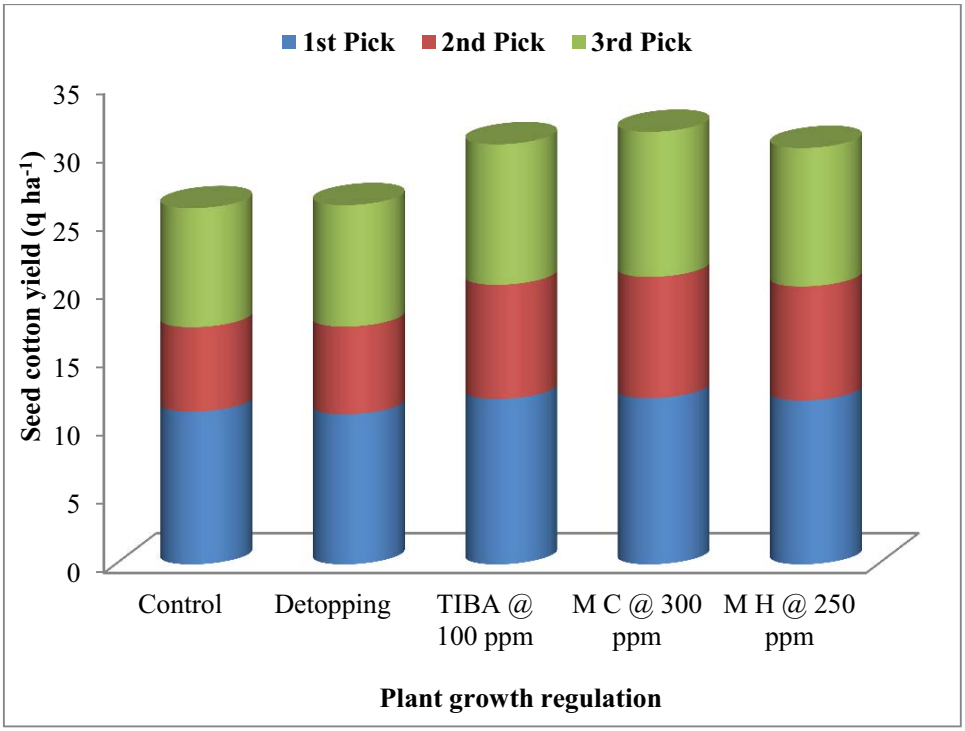


Fig 4.32: Seed cotton yield (q ha^{-1}) of *Bt* cotton hybrids as affected by different plant growth regulation treatments during 2011 (a) and 2012 (b)

4.3.31 Total Seed Cotton Yield

All the hybrids had a significant impact on total seed cotton yield during both the years. Data presented in Table 4.50 and represented in Fig. 4.31, show that hybrid MRC 7017 recorded maximum seed cotton yield of 22.18 and 30.70 q ha^{-1} which was statistically at par with hybrid MRC 7031 which yielded 21.35 and 29.52 q ha^{-1} during 2011 and 2012, respectively. Hybrid RCH 314 recorded significantly lower seed cotton yield than MRC 7017 and MRC 7031 which was 14.9 and 14.3 per cent lower than MRC 7017 and 10.6 and 9.9 per cent lower than MRC 7031 during 2011 and 2012, respectively. Higher yield by the hybrid MRC 7017 can be explained by the better growth and development due to its higher genetic potential as evident from the better plant height (Table 4.32) which resulted in increased number of sympodial branches $plant^{-1}$ (Table 4.46), flowers $plant^{-1}$ (Table 4.47), total bolls and picked bolls $plant^{-1}$ (Table 4.48) as recorded by the hybrid MRC 7017. The yield advantage enjoyed by the hybrid MRC 7017 in the three pickings enabled it to produce the highest total seed cotton yield. The yield obtained in all the hybrids was less in the year 2011 as compared to the year 2012. It was due to the heavy rainfall that caused shedding of fruiting structures and resulted in less flower and boll production during the year 2011 and more rainfall than normal also resulted in favourable conditions for pest buildup (Appendix II).

Different growth regulation treatments had a significant effect on total seed cotton yield. Data presented in Table 4.50 and depicted in Fig. 4.32 reveal that maximum total seed cotton yield of 22.79 and 31.62 q ha^{-1} was recorded where MC @ 300 ppm applied, which was significantly better than detopping and untreated control during 2011 and 2012, respectively. However, the percentage yield reduction in detopping was 16.6 and 16.7 over MC @ 300 ppm during 2011 and 2012, respectively. The application of TIBA @ 100 ppm produced seed cotton yield of 22.13 and 30.71 q ha^{-1} and was statistically at par with MC @ 300 ppm during 2011 and 2012, respectively. The minimum total seed cotton yield was obtained from untreated control which was statistically at par with detopping during both the years of experimentation. Growth regulation treatments where TIBA @ 100 ppm and MH @ 250 ppm were applied also showed non significant difference with each other in both the years. Foliar application of MC @ 300 ppm improved the seed cotton yield as it exerted a favourable effect on various physiological processes leading to improvement in yield attributing characters like open bolls $plant^{-1}$ (Table 4.48), hence increased the yield. MC application is supposed to increase CO_2 uptake and fixation in cotton leaves (Gausman *et al* 1980), resulting in increased assimilate production. Further MC restricts the vegetative growth of plants and increases the partitioning of assimilates towards fruiting bodies (Kaur 1998). The beneficial effect of MC on seed cotton yield had also been reported by Brar *et al* (2000) and Siddique *et al* (2002). The increase in seed cotton yield with TIBA application was also reported by Djanaguiraman *et al* (2005) and they found that TIBA at 100 ppm

significantly reduced plant height and increased the enzyme activity and yield of cotton and the increase in yield was due to the increase in number of bolls plant^{-1} over control. The increase in yield with MH application was also observed and it was due to the reduced plant height which helped in translocation of assimilates towards the reproductive parts and increased total bolls and picked bolls in cotton. The increase in yield with application of MH @ 200 ppm in bitter gourd was also reported by Rai *et al* (2003). The interaction effects of various treatments were non significant during the two years.

4.3.32 Bartlett Index

Bartlett index is an important indicator of maturity period of the crop. The higher value of the Bartlett index indicates early maturity. Different hybrids and growth regulator treatments did not exert any significant influence on the Bartlett index in any of the two years as evident from Table 4.51. No interaction was found for the Bartlett index in both the years.

4.3.33 Ginning Outturn (GOT)

Ginning out turn is an important quality character which influences the price of cotton in the market. It indicates the amount of lint presented in seed cotton. Perusal of the data presented in the Table 4.51 reveal that various hybrids and growth regulation treatments did not differ significantly for ginning-outturn in any of the two years. Dippenaar and Meyer (1994), Mert and Caliskan (1998), Deol and Brar (2003), Iqbal *et al* (2004) also reported that growth regulators do not have any adverse effect on the ratio of lint to seed. The interaction between hybrids and plant growth regulation treatments was non significant during both the years.

4.3.34 Seed Index

Seed index is an important component of seed cotton yield and is expressed as the weight of 100 seeds in grams. A lower value of seed index indicates more immature seeds which deteriorates the industrial value of the cotton seed. A scrutiny of the data given in the Table 4.51 indicates that different hybrids and plant growth regulator treatments did not influence the seed index significantly in both the years. Boman and Westerman (1994), Singh (1996), Singh (1999) and Ghourab *et al* (2000) reported results on similar lines. Interactive effect of plant growth regulation treatments on hybrids was non significant during both the years.

4.3.35 Lint Index

Lint index is a measure of surface area and density of fibres on the seed. It is directly related to seed index and ginning out turn. Data presented in the Table 4.51 reveal that a non significant effect on lint index was observed in different hybrids and various growth regulation treatments during both the years. Athayde and Lamas (1999) and Ghourab *et al* (2000) also reported that percentage fibre was not affected by application of PGRs. No interaction was observed for lint index during both the years.

Table 4.51: Effect of different hybrids and plant growth regulation treatments on seed index, lint index, ginning out turn and Bartlett index

Treatment	Seed Index		Lint index		GOT (%)		Bartlett Index	
	2011	2012	2011	2012	2011	2012	2011	2012
Hybrids								
MRC 7017	8.58 a	8.66 a	4.33 a	4.61 a	33.35 a	34.49 a	0.72 a	0.69 a
MRC 7031	8.58 a	8.67 a	4.32 a	4.60 a	33.43 a	34.57 a	0.73 a	0.69 a
RCH 314	8.50 a	8.60 a	4.40 a	4.83 a	34.03 a	35.87 a	0.72 a	0.68 a
SEm	**0.21**	**0.21**	**0.22**	**0.25**	**0.83**	**0.96**	**0.004**	**0.004**
F(p)	**0.89**	**0.92**	**0.90**	**0.44**	**0.66**	**0.17**	**0.47**	**0.45**
Plant growth regulation*								
Control	8.63 a	8.72 a	4.30 a	4.50 a	33.26 a	34.04 a	0.74 a	0.69 a
Detopping	8.59 a	8.68 a	4.34 a	4.55 a	33.44 a	34.23 a	0.73 a	0.69 a
TIBA @ 100 ppm	8.51 a	8.61 a	4.35 a	4.77 a	33.67 a	35.47 a	0.72 a	0.68 a
M C @ 300 ppm	8.54 a	8.63 a	4.41 a	4.88 a	33.95 a	35.99 a	0.71 a	0.68 a
M H @ 250 ppm	8.50 a	8.63 a	4.36 a	4.70 a	33.70 a	35.16 a	0.72 a	0.68 a
SEm	**0.18**	**0.18**	**0.16**	**0.18**	**0.74**	**0.73**	**0.004**	**0.004**
F(p)	**0.98**	**0.98**	**0.99**	**0.57**	**0.97**	**0.29**	**0.0002**	**0.16**
Interaction F(p)	**1.00**	**1.00**	**1.00**	**0.99**	**1.00**	**0.99**	**0.71**	**0.35**

*Applied at 80 days after sowing

CHAPTER V

SUMMARY

Cotton (*Gossypium hirsutum* L.), also known as "white gold" is an immensely important cash crop for sustaining agrarian economy and livelihood of the Indian farming community. Punjab, a leader in cotton production till recent times has trailed behind other states in average productivity. The major factors for low productivity of cotton in Punjab are attributed to poor plant stand, excessive vegetative growth, shedding of young fruiting bodies like buds, flowers and bolls and failure of pest control measures. The low productivity of cotton was the reason for shifting the area from cotton-wheat to rice-wheat cropping system in south-western districts of Punjab. Introduction of *Bt* cotton hybrids have evoked a considerable enthusiasm in farming and scientific community for boosting cotton productivity at reduced cost of production and environmental pollution because of less pesticide load. Under optimum growing conditions, cotton crop produce excess vegetative biomass that is often associated with reduced yield. Excessive vegetative growth often occurs at the expense of reproductive growth and a large fraction of squares and small bolls on the lower sympodia are shed resulting in late maturing and low yielding crop. All squares produced by the plant do not contribute to yield as some of the squares do not develop into bolls because of shedding.

Loss of reproductive organs from cotton can be induced by numerous causes. Manual removal of squares is similar to actual pest damage which can elicit many morphological and physiological responses, including compensatory growth. It has been noticed that fruit loss can enhance photosynthetic rate in cotton. The removal of fruiting forms from different positions on the sympodial branches has marked influence on yielding behaviour of the cotton plant. As fruiting structures (squares and bolls) are shed from the sympodium, a redistribution of assimilates destined for these structures must occur and natural shedding of upland cotton bolls also had a significant effect on adjacent bolls. Fruiting forms at different positions on the sympodial branches have a marked influence on yielding behaviour of the cotton plant. Under normal field conditions, more lint is harvested from cotton bolls on proximal fruiting sites than from the distal fruiting sites on sympodial branches. It is due to the presence of more bolls with higher retention on first fruiting position than on the second, third or lateral positions.

Plant growth regulators (PGRs) have emerged as magic chemicals that could increase agricultural production at an unprecedented rate and help in removing and circumventing many of the barriers imposed by genetics and environment. PGRs include a broad category of compounds that promote, inhibit or modify plant's physiological or morphological behaviour. They have the potential to promote crop earliness, improve square, flower and boll retention, increase nutrient uptake and keep harmony between vegetative and reproductive growth thus

improving lint yield and quality. Removing the terminal main stem bud (detopping) is also considered an important adjustment in cotton plants to modify the plant architecture on irrigated fertile soils. Detopping decreases plant height and number of main-stem nodes but increases boll retention and cotton yield.

Effect of fruiting form removal and plant growth regulation may differ with hybrids in view of their profound impact on canopy structure, phenological behaviour, growth and fruiting pattern. It is therefore necessary to study the interactive influence of growth regulation and fruiting form removal on different *Bt* hybrids.

In view of aforementioned, the present investigation entitled "Studies on source sink relationship for realization of higher productivity in *Bt* cotton (G*ossypium hirsutum* L)" was undertaken with the following objectives:

- To quantify the effects of fruiting form removal at selected fruiting sites on yield and yield components of *Bt* cotton.
- To study the effect of fruiting form removal on within-plant yield distribution of *Bt* cotton.
- To characterize the growth and development of *Bt* cotton hybrids by topping and use of plant growth retardants for improving cotton productivity.

To meet these objectives, the present investigation entitled "Studies on source sink relationship for realization of higher productivity in *Bt* cotton (G*ossypium hirsutum* L)"comprising of two field experiments and one pot experiment were carried out at the Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana, during *kharif* seasons of 2011 and 2012. The soil of experimental field was loamy sand in texture, slightly high in pH and normal in soluble salt content. Soil tested low in organic carbon and available nitrogen and high in available phosphorus and potassium. Recommended cultural practices and plant protection measures were followed throughout the crop growth season. The entire investigation consisted of three experiments and was laid out in split plot design with four replications. Three *Bt* cotton hybrids i.e. MRC 7017, MRC 7031 and RCH 314 were kept in main plots. The sub plot treatments in Experiment I consisted of 0 % (No square removal), 25 % removal (25 % squares removed for a period of month at pin head stage), 50 % removal (50 % squares removed for a period of month at pin head stage), P1 (fruits retained at first position), P2 (fruits retained at second position) and P1, 2 (fruits retained at first and second position). The Experiment II was a pot experiment comprising similar treatments as in Experiment I. The sub plot treatments in Experiment III consisted of control, detopping (removal of 5 to 7 cm apical portion of the main stem), MC application @ 300 ppm, TIBA @ 100 ppm and MH @ 250 ppm. Growth retardants and detopping treatments were applied at maximum vegetative growth stage i.e. 80 days after sowing (DAS).

Experiment I: Reproductive compensation behaviour of different cotton cultivars in response to fruiting form removal.

Plant growth characters like, height and dry matter accumulation (TDMA) did not differ significantly for the hybrids at 60 and 90 DAS while these were significantly affected at 120 DAS to maturity with maximum being recorded in MRC 7017 followed by MRC 7031 and RCH 314 during both the years. The three *Bt* cotton hybrids did not differ significantly for the leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR), specific leaf area (SLA) and net assimilation rate (NAR) at all the growth stages during both the years of experimentation. Main stem internodes plant^{-1}, height to node ratio and monopodial branches also showed non significant variation among the hybrids. Whereas, hybrids had a significant effect on sympodial branches plant^{-1} and higher number of sympodial branches plant^{-1} were recorded in hybrid MRC 7017 which was statistically at par with MRC 7031 but significantly higher than RCH 314.

The phenological characters like square initiation, 50 % squaring, flower initiation, 50 % flowering, initiation of boll formation, 50 % boll formation, boll open initiation and 50 % boll opening showed non significant differences among the hybrids.

Significantly higher production of total flowers, bolls and picked bolls plant^{-1} were recorded in MRC 7017 as compared to RCH 314 but it was statistically at par with MRC 7031 during both the years. Whereas, hybrids MRC 7017, MRC 7031 and RCH 314 did not differ significantly for the number of unopened bolls plant^{-1}, setting percentage, boll opening percentage and boll weight during both the crop growth seasons. Higher seed cotton yield was obtained in hybrid MRC 7017 which was statistically at par with hybrid MRC 7031 and both the hybrids produced significantly higher seed cotton yield than hybrid RCH 314. The percentage increase in yield in MRC 7017 was 17.9 and 19.6 per cent over RCH 314 during 2011 and 2012, respectively.

Fruiting form removal treatments had a significant influence on plant height, LAI and TDMA at all the crop growth stages except at 60 DAS during both the years. Significant increase in plant height, LAI and TDMA was recorded in 50 % square removal treatment at 90 DAS whereas, at 120 DAS, P2 attained more plant height and LAI as compared to other fruiting form removal treatments. However, accumulation of dry matter in vegetative parts was significantly higher in P2 while dry matter accumulation in fruiting bodies was significantly higher in 0 and 25 % square removal treatments at 120 and 150 DAS during both the years of study. Total number of main stem internodes plant^{-1} were higher in fruiting form removal treatments than that of undamaged control. Different fruiting form removal treatments failed to influence the height to node ratio and monopodial branches plant^{-1} during both the years. While, sympodial branches plant^{-1} were significantly influenced by fruiting form removal treatments and higher number of sympodial branches plant^{-1} were recorded in

P2 than all other fruiting form removal treatments during both the years. SPAD value was significantly affected by all the fruiting form removal treatments at 90 DAS and they had higher SPAD value than control. While, at 120 DAS, maximum SPAD value was recorded in P1 which was statistically at par with P2 and P1, 2 but significantly higher than 0, 25 and 50 % square removal treatments.

Different phenological parameters like square initiation, days taken to 50 % squaring, flower initiation, 50 % flowering, initiation of boll formation and 50 % boll formation showed non significant difference among all the fruiting form removal treatments. Whereas, removal of fruiting forms delayed boll open initiation and 50 % boll opening by 4-11 days than control during both the years.

Flowers, total bolls and picked bolls plant^{-1} were significantly affected by fruiting form removal treatments and maximum were produced in 0 and 25 % square removal treatments as compared to all other treatments. While, among the treatments where fruits were retained at specific positions P1, 2 attained maximum number of flowers, total bolls and picked bolls plant^{-1} which were significantly more than P1 and P2 during both the years. However, P1 produced significantly higher number of total bolls and picked bolls plant^{-1} than P2 during both the years.

The variation among fruiting form removal treatments for setting percentage and boll opening percentage was not significant during both the years. However, fruiting form removal treatments showed significant variation for unopened bolls plant^{-1} and significantly less number of unopened bolls were found in P1 and P2 than all other fruiting form removal treatments. Boll weight was significantly improved in fruiting form removal treatments as higher boll weight was observed in P1 (3.43 and 4.05 g) than all other fruiting form removal treatments during both the years. Higher amount of total seed cotton yield was obtained in 0 and 25 % square removal treatments as compared to all other fruiting form removal treatments, as it was a combined effect of all the three pickings. P1 recorded significantly higher seed cotton yield than P2 and it was 25.2 and 25.3 per cent higher than P2 during 2011 and 2012, respectively.

Experiment II: Reproductive compensation behaviour of different cotton cultivars in response to fruiting form removal.

The hybrids differed significantly for plant height among themselves from the period of 90 DAS to maturity in both the years. At 90, 120 and 150 DAS maximum plant height was recorded in hybrid MRC 7017 which was statistically at par with hybrid MRC 7031 and both were significantly higher than hybrid RCH 314 during both the years. Hybrids did not differ significantly for the number of main stem internodes plant^{-1} but height to node ratio differed significantly in all the hybrids which was maximum in MRC 7031 and was significantly higher by 8.8 and 9.7 per cent than RCH 314 during 2011 and 2012 respectively. Monopodial

and SPAD value did not differ significantly for the hybrids but sympodial branches plant^{-1} were significantly influenced by the hybrids and maximum number of sympodial branches were recorded in MRC 7017 (24.9 and 26.9) followed by MRC 7031 and RCH 314 during 2011 and 2012, respectively.

All the phenological characters like days to square initiation, flower initiation, initiation of boll formation and boll open initiation showed non significant difference among all the *Bt* cotton hybrids.

MRC 7017 produced maximum number of total flowers plant^{-1} which were statistically at par with hybrid MRC 7031 and significantly higher than RCH 314 during both the years. Square abscission in RCH 314 was significantly higher as compared to the other two hybrids and it was 14.0 and 14.6 per cent higher than MRC 7017 and 15.5 and 16.1 per cent higher than MRC 7031 during 2011 and 2012, respectively. Abscission of flowers plant^{-1} were maximum in MRC 7017 which was statistically at par with MRC 7031 but significantly higher than RCH 314 during both the years. Total number of bolls and picked bolls plant^{-1} were significantly influenced by the hybrids. MRC 7017 and MRC 7031 obtained significantly higher number of bolls and picked bolls plant^{-1} as compared to RCH 314 during both the years of experimentation. Hybrids MRC 7017, MRC 7031 and RCH 314 did not differ significantly for the number of unopened bolls plant^{-1}, setting percentage and boll opening percentage during both the crop growth seasons. Boll weight was also not significantly influenced by the hybrids during both the years. Hybrid MRC 7017 yielded maximum amount of total seed cotton (99.4 and 103.4 g plant^{-1}) as well as those obtained from the first and second pick than the other two hybrids during 2011 and 2012, respectively. The lower seed cotton yield was produced by the hybrid RCH 314 which was 86.4 and 89.9 g plant^{-1} during 2011 and 2012, respectively.

During both the years, fruiting form removal treatments had a significant influence on plant height at all the growth stages except at 60 DAS. At 90 DAS, maximum plant height was recorded in 50 % square removal treatment which was statistically at par with P1 and P2 but significantly higher than all other fruiting form removal treatments. Whereas, at 120 and 150 DAS, P2 attained more plant height as compared to other fruiting form removal treatments but was statistically at par with P1 and P1, 2 during both the years. Mean number of main stem internodes plant^{-1} were higher in fruiting form removal treatments than that of undamaged control and 25 % square removal treatment. Fruiting form removal treatments also significantly influenced the height to node ratio during both the years and maximum height to node ratio was recorded in the treatment where fruits were retained at second position (P2) which was statistically at par with all the fruiting form removal treatments except for control and 50 % square removal treatments during both the years. Removal of fruiting forms failed to influence the number of monopodial branches plant^{-1} but sympodial

branches plant^{-1} were significantly affected during both the years. Maximum number of sympodial branches were recorded in the crop where fruits were retained at second position (P2), and statistically at par with P1, P1, 2, 25 % and 50 % fruiting form removal treatments, but attained significantly more number of sympodial branches plant^{-1} than control during both the years of investigation. SPAD value was significantly affected by all the fruiting form removal treatments at 90 DAS as all the fruiting form removal treatments had higher SPAD value than control. While, at 120 DAS, only P2 exhibited significant influence on SPAD value over all other fruiting form removal treatments.

Square and flower initiation showed non significant differences for all the fruiting form removal treatments whereas, boll initiation and days taken to boll open initiation were delayed by the removal of fruiting forms except for 0 and 25 % square removal treatments during both the years.

Higher number of total squares and flowers plant^{-1} were produced in 0 and 25 % square removal treatments which were statistically at par with each other but significantly higher than all other fruiting form removal treatments. Among the site specific fruit retention treatments, P1, 2 attained more number of flowers plant^{-1} than P1 and P2 during both the years. Maximum abscission of squares and flowers was recorded in 0 % square removal treatment than all the other fruiting form removal treatments. Whereas, the abscission of squares and flowers plant^{-1} was significantly less in P1 and P2 as compared to all other fruiting form removal treatments and both were statistically at par with each other during both the years. Fruiting form removal treatments significantly influenced the setting percentage during both the years. Significantly higher setting percentage was recorded in P1 as compared to all the other fruiting form removal treatments during both the years which were 28.8 and 28.9 per cent higher than control during 2011 and 2012, respectively. Total bolls and picked bolls plant^{-1} were significantly higher in 0 and 25 % square removal treatments as compared to all other fruiting form removal treatments during both the years. Among the site specific fruit retention treatments P1 produced significantly higher total bolls and picked bolls plant^{-1} than P2 during both the years. Unopened bolls plant^{-1} were significantly reduced in P1 by 48.9 and 48.7 per cent than 0 % square removal treatment during 2011 and 2012, respectively. Boll opening percentage was non significant during both the years of experimentation while, boll weight improved in fruiting form removal treatments as higher boll weight of 3.64 and 3.97 g was observed in P1 as compared to all other fruiting form removal treatments during 2011 and 2012, respectively. Significantly higher total seed cotton yield was obtained in 0 and 25 % square removal treatments as compared to all the other fruiting form removal treatments. Among various site specific fruit retention treatments P1 recorded significantly higher seed cotton yield than P2 (24.6 and 24.7 per cent during 2011 and 2012, respectively).

Different quality parameters such as seed index, lint index, ginning out-turn and bartlett index were not significantly influenced by various fruiting form removal treatments.

Experiment III: Productivity of cotton as influenced by detopping and growth retardants.

All the hybrids recorded statistically same plant height at 90 DAS thereafter, significant difference in plant height was observed in the hybrids during both the years. At 120, 150 and 180 DAS, maximum plant height was recorded in MRC 7017 which was statistically at par with MRC 7031 but significantly higher than RCH 314 during both the years. Hybrids failed to significantly influence the LAI during both the years of study. Whereas, MRC 7017 recorded a relatively higher LAI than MRC 7031 and RCH 314 at all the growth stages but failed to reach the level of significance during both the years. TDMA did not differ significantly among the hybrids during both the years but dry weight of fruiting bodies differed significantly among all the hybrids at 120 and 150 DAS and maximum was recorded in MRC 7017 which was statistically at par with MRC 7031 but significantly higher than RCH 314 during both the years of experimentation.

CGR, RGR, SLA and NAR of all the hybrids did not differ significantly at all the crop growth stages during both the years. Different hybrids did not differ significantly for the number of main stem internodes plant^{-1} and height to node ratio during both the years of experimentation. Monopodial branches plant^{-1} also showed non significant variation among the hybrids during both the years. Whereas, higher number of sympodial branches plant^{-1} were recorded in MRC 7017 (24.5 and 27.5) which were statistically at par with MRC 7031 and both the hybrids produced significantly higher number of sympodial branches plant^{-1} than RCH 314 during both the years.

All the phenological parameters like days taken to square initiation, 50 % squaring, flower initiation, 50 % flowering, initiation of boll formation, 50 % boll formation, boll open initiation and 50 % boll opening showed non significant difference among all the hybrids.

Higher number of flowers, total bolls and picked bolls plant^{-1} were obtained in MRC 7017 which were statistically at par with MRC 7031 but were significantly higher than RCH 314 during both the years. All the three hybrids did not differ significantly for the number of unopened bolls plant^{-1}, setting percentage, boll opening percentage and boll weight during both the crop growth seasons. Hybrid MRC 7017 produced significantly higher seed cotton yield (22.18 and 30.70 q ha^{-1}) as compared to hybrid RCH 314 whereas, it was statistically at par with hybrid MRC 7031 during both the years.

Application of MC (300 ppm), TIBA (100 ppm) and MH (250 ppm) resulted in significant reduction in plant height, LAI and total dry matter accumulation from the control in both the years. Detopping treatment also showed significant reduction in plant height than control but attained more plant height than all the PGRs. Application of all the PGRs resulted in

significantly higher dry matter allocation to the fruiting bodies and less of it towards the vegetative plant organs. Higher SPAD value was observed with MC application (300 ppm) followed by TIBA (100 ppm) and MH (250 ppm), which was significantly higher than control and detopping.

All the PGRs and detopping did not significantly affect the CGR and RGR during different periods of crop growth. The SLA was not significantly affected by the plant growth regulation treatments during both the years whereas, during 2012 SLA at 150 DAS was significantly higher when MC @ 300 ppm applied than control. However, TIBA @ 100 ppm and MH @ 250 ppm showed non significant variation with control and MC (300 ppm) for SLA during 2012. All PGRs attained higher NAR as compared to control and detopping during the period of 120-150 DAS whereas, at initial periods of growth PGRs failed to significantly influenced the NAR during both the years.

Days taken to 50 % squaring, flower initiation, 50 % flowering, initiation of boll formation, 50 % boll formation, boll open initiation and 50 % boll opening were not significantly affected by the PGRs applied. Different PGR treatments failed to have any significant influence on the number of monopodial branches plant^{-1}, while the number of sympodial branches plant^{-1} were highest with application of MC @ 300 ppm followed by TIBA (100 ppm), MH (250 ppm) detopping and control. Total number of flowers plant^{-1} were significantly higher in MC @ 300 ppm than control and detopping during both the years. Similarly higher setting percentage was recorded in MC @ 300 ppm (43.2 and 44.9) as compared to all other PGRs and control during both the years. During 2011 MC @ 300 ppm produced maximum number of bolls plant^{-1} and were statistically at par with TIBA @ 100 ppm but significantly higher than all other plant growth regulation treatments. While during 2012, application of MC (300 ppm), TIBA (100 ppm) and MH (250 ppm) significantly improved the total number of bolls plant^{-1} while, detopping failed to exhibit any influence on total number of bolls plant^{-1}. Maximum number of picked bolls plant^{-1} were recorded with MC application @ 300 ppm followed by TIBA @ 100 ppm and MH @ 250 ppm as compared to control and detopping during both the years. Application of PGRs showed a non significant effect on unopened bolls plant^{-1} and boll opening percentage. However, boll weight was significantly affected by the application of PGRs. Maximum boll weight of 3.46 g and 4.08 g was recorded with MC application @ 300 ppm during 2011 and 2012, respectively. All other PGRs like TIBA (100 ppm) and MH (250 ppm) were statistically at par with MC (300 ppm) for boll weight. Application of MC @ 300 ppm significantly increased total seed cotton yield (22.79 and 31.62 q ha^{-1}) as well as that obtained from the three pickings. TIBA (100 ppm) and MH (250 ppm) were statistical similar with MC (300 ppm) for the seed cotton yield obtained in all the pickings as well as for total seed cotton yield. Detopping failed to significantly influenced the seed cotton yield during both the years. Different quality parameters such as seed index, lint index, Bartlett

index and ginning out-turn were not significantly influenced by application of various PGR treatments.

Conclusions

- Among different *Bt* cotton hybrids MRC 7017 yielded higher seed cotton yield as compared to MRC 7031 and RCH 314.
- Treatment where squares were removed upto 25% for one month period compensated for the early removal of squares and produced statistically same seed cotton yield as in undamaged control.
- 50% square removal treatment did not compensate for the square removal. Moreover, a significant reduction in yield was observed as a result of higher loss of fruiting forms.
- Fruiting form removal at selected fruiting sites illustrated that position one (P1) had a higher retaining capacity for total bolls and picked bolls than position two (P2).
- Foliar application of MC (300 ppm) yielded more seed cotton by improving the setting percentage and therefore increasing the number of picked (open) bolls per plant without exhibiting any adverse effect on quality traits.
- All other PGRs also proved beneficial in enhancing total seed cotton yield and yield contributing characters.

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APPENDIX – I

Normal meteorological data during the months of May to November

Standard weeks	Weekly interval	Average air temperature (^{0}C)			Average relative humidity (%)	Weekly rainfall (mm)	Weekly evaporation (mm)
		Max.	Min.	Mean	Mean		
18	30.04.11-06.05.11	37.5 (34.2)	20.1 (16.9)	28.2 (25.5)	36 (47)	2.2 (18.3)	68.2 (213.0)
19	07.05.11-13.05.11	38.2	21.3	29.8	38	6.4	65.6
20	14.05.11-20.05.11	38.5	21.7	30.1	39	5.5	71.2
21	21.05.11-27.05.11	39.5	23.5	31.6	40	4.0	75.7
22	28.05.11-03.06.11	40.3 (38.6)	24.1 (21.9)	32.2 (30.3)	36 (39)	20 (21.6)	80.2 (312.1)
23	04.06.11-10.06.11	40.7	25.4	33.1	39	8.8	76.9
24	11.06.11-17.06.11	39.1	25.7	32.4	47	9.2	67.6
25	18.06.11-24.06.11	39.1	26.1	32.6	51	18.3	66.5
26	25.06.11-01.07.11	37.6 (38.9)	27.7 (25.6)	32.7 (32.3)	60 (49)	28.0(66.4)	54.3 (293.4)
27	02.07.11-08.07.11	36.3	25.9	31.1	64	54.5	62.7
28	09.07.11-15.07.11	34.0	25.7	29.9	70	58.2	39.1
29	16.07.11-22.07.11	33.6	25.7	29.7	73	53.2	35.9
30	23.07.11-29.07.11	33.6	25.7	29.7	76	47.9	31.0
31	30.07.11-05.08.11	33.4 (34.4)	25.7 (25.8)	29.6 (30.1)	77 (71)	56 (232.1)	30.0 (171.2)
32	06.08.11-12.08.11	33.3	25.4	29.4	79	55	25.9
33	13.08.11-19.08.11	33.5	25.1	29.3	78	38.3	31.3
34	20.08.11-26.08.11	33.7	24.9	29.3	78	44.3	31.4
35	27.08.11-02.09.11	33.7 (33.4)	24.4 (25.2)	29.1 (29.3)	74 (78)	34.2(179.7)	33.9 (133.1)
36	03.09.11-09.09.11	33.7	23.9	28.8	74	42.2	32.1
37	10.09.11-16.09.11	32.7	23.0	27.9	72	25.8	32.0
38	17.09.11-23.09.11	34.2	21.9	28.1	68	27.3	32.8
39	24.09.11-30.09.11	33.7 (33.7)	20.5 (22.1)	27.1 (27.9)	64 (70)	16.0(101.8)	30.6 (132.7)
40	01.10.11-07.10.11	33.7	18.7	26.2	60	3.3	32.5
41	08.10.11-14.10.11	33.7	18.7	26.2	60	3.3	32.5
42	15.10.11-21.10.11	31.8	15.4	23.6	57	2.3	29.2
43	22.10.11-28.10.11	31.0	14.2	22.6	57	0.5	25.8
44	29.10.11-04.11.11	29.5 (31.9)	12.8 (16.1)	21.2 (24.0)	60 (59)	3.8 (6.0)	24.8 (126.8)
45	05.11.11-11.11.11	28.1	11.3	19.7	59	0.7	22.4
46	12.11.11-18.11.11	27.1	10.3	18.7	62	0.9	20.4
47	19.11.11-25.11.11	25.3	8.8	17.1	62	2.5	8.1
48	26.11.11-02.12.11	23.8 (26.7)	7.4 (10.1)	15.6 (18.4)	64 (61)	1.6 (9.4)	15.7 (83.4)

Figures in parenthesis are average monthly normal values

APPENDIX – II

Meteorological data during the months of May to November, 2011

Standard weeks	Weekly interval	Average air temperature (^{0}C)			Average relative humidity (%)	Weekly rainfall (mm)	Weekly evaporation (mm)
		Max.	Min.	Mean	Mean		
18	30.04.11-06.05.11	38.9 (33.8)	24.3 (17.6)	31.6 (25.7)	39.4 (50.0)	1.8 (26.5)	61.4 (187.0)
19	07.05.11-13.05.11	39.6	24.0	31.8	39.6	0.0	60.2
20	14.05.11-20.05.11	41.9	26.2	34.0	39.9	0.0	68.8
21	21.05.11-27.05.11	37.4	24.4	30.9	54.4	22.4	57.6
22	28.05.11-03.06.11	36.3 (39.4)	24.1 (25.0)	30.2 (32.2)	59.4 (44.7)	32.8 (34.4)	62.1 (277.1)
23	04.06.11-10.06.11	38.7	26.5	32.6	49.0	2.0	69.3
24	11.06.11-17.06.11	36.7	26.1	31.4	65.5	148.6	42.8
25	18.06.11-24.06.11	35.2	25.4	30.3	74.1	75.1	25.5
26	25.06.11-01.07.11	31.0 (35.4)	25.0 (25.3)	28.0 (30.3)	86.3 (79.8)	104.6 (352.9)	21.8 (180.5)
27	02.07.11-08.07.11	34.3	26.5	30.4	77.2	26.8	37.8
28	09.07.11-15.07.11	34.1	27.2	30.7	73.9	24.0	33.2
29	16.07.11-22.07.11	33.7	26.3	30.0	78.5	45.4	32.4
30	23.07.11-29.07.11	32.8	27.2	30.0	80.9	18.0	27.1
31	30.07.11-05.08.11	34.6 (33.7)	26.7 (26.8)	30.7 (30.2)	77.4 (77.9)	27.1 (114.2)	29.7 (143.2)
32	06.08.11-12.08.11	32.4	27.2	29.8	82.5	443.8	22.4
33	13.08.11-19.08.11	29.9	24.0	27.3	88.6	32.1	23.5
34	20.08.11-26.08.11	32.9	26.1	29.5	82.0	4.0	25.8
35	27.08.11-02.09.11	33.0 (32.4)	26.9 (26.0)	29.9 (29.3)	83.1 (82.7)	7.4 (513.4)	22.7 (106.9)
36	03.09.11-09.09.11	31.5	25.3	28.4	87.2	52.5	18.1
37	10.09.11-16.09.11	32.0	25.1	28.7	86.7	123.6	23.2
38	17.09.11-23.09.11	31.8	22.9	27.3	82.0	0.0	26.9
39	24.09.11-30.09.11	31.5 (31.8)	22.2 (24.1)	26.8 (27.0)	77.5 (80.9)	0.0 (177.1)	28.0 (103.2)
40	01.10.11-07.10.11	32.9	22.3	27.6	72.2	0.0	28.0
41	08.10.11-14.10.11	33.6	19.1	26.4	67.9	0.0	28.0
42	15.10.11-21.10.11	32.8	15.8	24.3	62.6	0.0	25.0
43	22.10.11-28.10.11	30.4	14.6	22.5	63.5	0.0	22.9
44	29.10.11-04.11.11	29.8 (32.1)	14.0 (17.5)	21.9 (24.8)	69.7 (67.1)	0.0 (0.0)	17.1 (113.0)
45	05.11.11-11.11.11	28.3	14.1	21.2	67.1	0.0	16.8
46	12.11.11-18.11.11	28.3	12.4	20.3	66.6	0.0	17.1
47	19.11.11-25.11.11	27.2	12.4	19.8	76.9	0.0	12.1
48	26.11.11-02.12.11	24.6 (27.6)	9.8 (12.5)	17.2 (20.1)	73.1 (70.4)	0.0 (0.0)	10.4 (61.2)

Figures in parenthesis are average monthly normal values

Meteorological data during the months of May to November, 2012

Standard weeks	Weekly interval	Average air temperature (^{0}C)			Average relative humidity (%)	Weekly rainfall (mm)	Weekly evaporation (mm)
		Max.	Min.	Mean	Mean		
18	30.04.12-06.05.12	34.8 (32.8)	17.8 (17.6)	26.3 (25.3)	31.0 (51.0)	7.4 (38.6)	51.8 (173.9)
19	07.05.12-13.05.12	38.8	23.7	31.3	33.0	0.0	63.2
20	14.05.12-20.05.12	39.3	23.1	31.2	34.9	0.0	63.7
21	21.05.12-27.05.12	41.0	23.1	32.0	30.6	1.6	71.0
22	28.05.12-03.06.12	43.5 (39.6)	25.6 (22.6)	34.5 (31.1)	26.6 (31.8)	0.0 (1.6)	80.6 (295.9)
23	04.06.12-10.06.12	39.3	25.7	32.5	44.6	0.0	66.8
24	11.06.12-17.06.12	41.9	25.3	33.6	41.7	1.5	85.4
25	18.06.12-24.06.12	41.0	28.9	34.9	44.9	0.4	76.4
26	25.06.12-01.07.12	39.4 (39.4)	28.3 (26.4)	33.9 (32.9)	43.5 (41.9)	1.6 (3.5)	70.6 (320.2)
27	02.07.12-08.07.12	37.7	29.0	33.4	58.6	9.5	68.5
28	09.07.12-15.07.12	35.0	27.3	31.1	67.7	10.6	44.8
29	16.07.12-22.07.12	36.1	27.5	31.8	62.9	1.6	47.0
30	23.07.12-29.07.12	35.2	28.3	31.8	73.0	44.8	40.8
31	30.07.12-05.08.12	33.9 (35.7)	27.6 (28.0)	30.7 (31.8)	64.1 (64.5)	10.4 (76.9)	34.0 (212.1)
32	06.08.12-12.08.12	34.4	27.0	30.7	77.2	17.5	27.5
33	13.08.12-19.08.12	33.7	26.5	30.1	80.1	61.6	27.3
34	20.08.12-26.08.12	31.6	26.4	29.0	84.6	42.8	23.2
35	27.08.12-02.09.12	32.6 (33.2)	25.7 (26.6)	29.1 (29.9)	68.9 (77.0)	39.1 (160.4)	22.8 (120.2)
36	03.09.12-09.09.12	32.8	26.4	29.6	76.6	20.4	27.5
37	10.09.12-16.09.12	34.2	25.8	30.0	75.8	38.6	26.8
38	17.09.12-23.09.12	31.0	22.8	26.9	80.6	82.1	19.3
39	24.09.12-30.09.12	32.9 (31.8)	20.9 (23.3)	26.6 (27.5)	61.4 (71.6)	0.0 (141.7)	28.1 (109.3)
40	01.10.12-07.10.12	33.9	20.1	27.0	68.1	0.0	28.0
41	08.10.12-14.10.12	33.4	17.4	25.4	65.4	0.0	28.0
42	15.10.12-21.10.12	31.2	16.4	23.8	66.1	0.0	24.0
43	22.10.12-28.10.12	29.3	13.1	21.8	68.4	1.0	21.2
44	29.10.12-04.11.12	29.7 (31.6)	13.3 (16.2)	21.5 (24.1)	56.6 (64.6)	0.0 (1.0)	18.8 (108.4)
45	05.11.12-11.11.12	28.9	12.7	20.8	65.1	0.0	14.6
46	12.11.12-18.11.12	26.4	10.7	18.6	70.4	0.0	11.0
47	19.11.12-25.11.12	25.5	9.3	17.4	63.4	0.0	14.0
48	26.11.12-02.12.12	24.0 (25.8)	7.8 (10.3)	15.9 (18.1)	64.4 (64.3)	0.0 (0.0)	13.4 (60.6)

Figures in parenthesis are average monthly normal values

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