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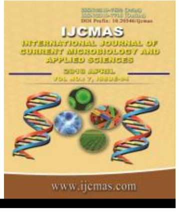

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Production Potential of Cotton (*Gossypium hirsutum*) as Affected by Plant Growth Regulators (PGRs)

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ABSTRACT

Cotton (*Gossypium hirsutum* L.) is the most important fibre crop of the world with significant role in Indian agriculture, industrial development, employment generation and contribution to the national income. It is mainly grown for textile fibre, feed, fuel and edible oil. Despite a firm competition from synthetic fibres, cotton continues to enjoy a place of prime importance in the textile industry. Under optimum growing conditions as a result of maximizing inputs for cotton production, particularly nitrogen and irrigation water, plants often become excessively tall and vegetative (Nichols *et al.*, 2003). Thus, vigorous plant 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 (Kerby *et al.*, 1987) and a large fraction of squares and small bolls on the lower sympodia may shed and result in late maturity and often a lower yielding crop (Fowler and Ray, 1977). All squares produced by the plant do not grow into bolls and not contribute to yield (Sudararaj and Thulsidas, 1993). Cotton can shed upto 70 % of all initiated fruiting structures from sympodial branches during reproductive stage of development (Peoples and Mathews, 1981) but its extent in recently released *Bt* hybrids is still unknown and needs immediate attention. According to Heitholt and Schmidt, (1994), whole plant boll retention i.e. total bolls per total flowers are 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), decreased defoliation and reduced yield (Zhao and Oosterhuis, 2000). Thus, the plant must have a balance between vegetative and reproductive growth, where there is enough vegetative growth to provide adequate carbohydrate supply for fruit development, but not excessive vegetative growth that inhibits fruit development (Kerby *et al.*, 1997). Kaur *et al.*, (2015) also reviewed the importance of PGR's in order to overcome some production constrains in direct seeded rice (DSR) and reported that certain plant growth regulators (PGRs) can prove as effective measure to ensure enhanced germination, better early seedling growth, improved root length and higher yield in DSR.

Keywords

Cotton (*Gossypium hirsutum* L.), Plant growth regulators (PGRs)

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Introduction

Managing the equilibrium between vegetative and reproductive growth is thus, an important part in cotton production. Modifying plant growth has become an essential element of cotton production, whether by making adjustments in fertility, water management or the use of plant growth regulators (PGRs). Applying plant growth regulators 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 organic compounds that promote, inhibit or modify physiological and/or morphological behavior of the plant. 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 improve lint yield and quality.

Growth promoters like auxins, gibberellins and cytokinins have been widely used to reduce abscission and to increase boll number and seed cotton yield (Brar *et al.*, 2001) whereas, growth retardants like mepiquat chloride (MC) and cycocel (CCC) 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).

Effect of Mepiquat Chloride (MC) on growth, yield and quality parameters of cotton

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. Maximum setting percentage, picked bolls per plant, boll weight and seed cotton yield was observed with MC application (Table 1). MC 300 ppm produced maximum total seed cotton yield of 30.28 and 27.00 q ha^{-1} which was 37.20 and 33.07 %higher than control (22.07 and 20.29 q ha^{-1}) during 2008 and 2009 respectively, but was statistically at par with MC 200 ppm (Rajni, 2010). Similarly, Sawan *et al.*, (2007) at Giza (Egypt) observed that number of opened bolls per plant, boll weight, seed index, seed cotton yield per plant, seed cotton and lint yield hectare^{-1} increased with foliar application of mepiquat chloride on cotton at 48 g ha^{-1} (75 DAS) + 24 g ha^{-1} (90 DAS). Increase in average number of bolls per plant and seed cotton yield with MC application was also reported by Gencsoylu, (2009). In a three year study (2001-03), Nuti *et al.*, (2006) found that

MC caused more bolls to set in the fruiting profile as compared to untreated control. McCarty *et al.*, (1989) also observed that MC increased yield and the percentage of total bolls at the first position on sympodial branches.

Application of MC 50 ppm sprayed at 90 DAS was most effective in reducing plant height and leaf area, resulted in higher boll weight (5.58 g boll^{-1}) and significantly higher seed cotton yield of 1040 kg ha^{-1}, which was 12 %more than control in hybrid *Bt* cotton 'DDH-11' (Kumar *et al.*, 2006). Reduction of vegetative growth with application 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 (Kerby *et al.*, 1997). Siebert and Stewart (2006), MC reduced plant height by 14.6 and 10.0% as compared to control in 2004 and 2005, respectively, although yield responses to MC application were inconsistent. Similarly, 9% reduction in plant height and 4% 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. Significantly shorter plants were also observed by Brar *et al.*, (2001) with MC 250 ppm at 60 DAS. MC had the tendency to dwarf cotton plants ranging from 22 to 24 % when it was applied at 60 DAS as compared to 14 to 17 % when applied at 80 DAS as compared to control. Higher number of harvested bolls per plant was observed with MC 250 ppm applied at 80 DAS and the increase in total seed cotton yield was reported to be 33.9% during 1996 and 26.5% during 1997 over control, whereas early application of MC (60 DAS) reduced both the seed cotton yield and number of harvested bolls/plant.

Gormus (2006) reported that MC application at the rate of 0.15 l ha^{-1} at first flowering and 2 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 % over control) was also reported with MC application at 2 weeks after first flower. 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 %reduction in plant height over control, respectively (Deol and Brar, 2003). 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 % more over control, while its application at 125 ppm (60 and 80 DAS) resulted in 9.5% reduction in seed cotton yield over control. Spraying of MC on cotton cv. Giza 80 at the initiation start of flowering and found that it significantly reduced plant height and length of internodes, increased number of open bolls per plant and seed cotton yield while seed index and lint percentage were not significantly affected (Ghourab *et al.*, 2000). Cook and Kennedy (2000) also observed reduction in plant height and height to main stem node ratio with MC application. The low rate multiple (LRM) treatment that consisted of four weekly application of 12.25 g MC ha^{-1} initiated at pin head square stage with moderate early bud loss produced 10% greater yield than control. 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).

Application of MC and PGR-IV increased the rate of flowering, boll number/plant and seed cotton yield. MC increased seed cotton yield by 23 and 10 % than control and PGR-IV, respectively whereas, the lint yield was 18 % greater than the untreated control (Biles and Cothren, 2001). Sawan *et al.*, (2001) reported highest seed, oil and protein yield ha^{-1} with MC 288 g ha^{-1} followed by cycocel. During a 3 year study under different tillage systems, Kennedy and Hutchinson (2001) observed that higher yield was related to faster, early season crop growth, which can be promoted by mepiquat chloride.

Application of Mepiquat Chloride (Pix) 1000 ml/500 litres of water at bud formation resulted in maximum plant height (137 cm), monopodial branches/plant (1.9), symonopodial branches/plant (23.0), opened bolls/plant (30.1), un-opened bolls/plant (4.0), seed cotton yield/plant (97.4 g), seed cotton yield (3074.0kg ha^{-1}) and ginning out-turn (34.5%). It is also observed that Pix at 1500 ml/500 litres of water at bud formation is more effective for obtaining more number of bolls/plant and maximum seed cotton yield/plots as well as seed cotton yield kg ha^{-1} (Vistro *et al.,* 2017). Zhao *et al.,* (2017) opined that cotton yield responses to the MC, are associated with climate, cultivar, and plant population and showed that MC application at the seedling, early bloom, and full bloom stages significantly increased the cotton yields by 5.6, 5.0, and 6.1%, respectively. Late MC application of 45.0-90.0 g ha^{-1} at the post-topping stage is necessary for vigorous cotton cultivars to facilitate the balance of vegetative and reproductive growth.

The application of PGRs would be a useful practice for improving K nutrition and lowering the cost of K fertilizer input in cotton production. Foliar application of the PGRs, mepiquat chloride (MC) and Miantaijin [MTJ, a combination of MC with diethyl aminoethyl hexanoate (DA-6)] during squaring and flowering period significantly increased the lint yield and K uptake in most situations at Beijing and had a consistent tendency to increase lint yield across K fertilizers and years at Hebei. The partial factor productivity and agronomic efficiency of K were also enhanced by the application of the PGRs in most situations in Beijing. The application of PGRs can increase the uptake of N and P in cotton plants, although to a lower magnitude than K uptake (Yang *et al.*, 2014).

Effect of Cycocel (CCC) on growth, yield and quality parameters of cotton

Cycocel or Chlormequat chloride [(2-chloroethyl) trimethyl ammonium chloride] also known as CCC, was first introduced by Tolbert in 1960 as a growth retarding substance. It is an antigibberellin and results in more diversion of biological yield into economic yield. It delayed senescence, helps in increasing photosynthesis and mobilization of photosynthates towards reproductive sink. It was observed by Thomas (1964) and Gabar *et al.,* (1979) that CCC imparts dark green colour to the cotton plant by increasing chlorophyll and carotenoid contents. The influence of CCC (cycocel) on plant growth, yield and quality of late-seeded (mid-December) cotton was studied in northwest Argentina (1998-2001) by Mondino *et al.,* (2004) and it was observed that cycocel reduced plant height and node number as well as the total production of aerial biomass, thus increasing the harvest index. Due to increase in the boll weight and boll number/plant, the yield of treated plots increased by an average of 35% in comparison with control. Similar increase in seed cotton yield was also observed by Srivasankaran *et al.,* (1995) at Coimbatore with application of cycocel at 40 ppm alone or alternated with 1.0% DAP (diammonium phosphate) as compared to untreated control.

Application of CCC at 375 ppm at 90 DAS resulted in significantly higher total chlorophyll content (1.693 and 1.595 mg g^{-1} fresh weight at 120 and 150 DAS, respectively) but lower photosynthetic rate (due to reduction in leaf diffusion resistance and decreased CO_2 uptake) and reduction in seed cotton yield (37 %) was observed with CCC @ 500 ppm applied at 45 DAS over control due to reduced growth and increased boll shedding (Kumar *et al.,* 2005). Foliar application of cycocel on Egyptian cotton cv.

Giza 75 at the rate of 250, 500 and 750 ppm at 105 DAS increased the number of opened bolls/plant, boll weight, seed and lint indices, seed cotton yield/plant and both seed cotton and lint yield/hectare (Sawan *et al.*, 2008). Chlormequat chloride (CCC) applied at 50 ppm gave significantly more bolls/plant, boll weight and seed cotton yield than those of 0 and 100 ppm, whereas, its application @ 50 and 100 ppm significantly reduced plant height, LAI and dry matter accumulation compared to control. A maximum of 9.1 and 8.2 q ha^{-1} reduction in plant dry matter was observed with 100 ppm than control during 1994 and 1995, respectively (Prakash and Prasad, 2000).

A reduction of 18.5 % in plant height was reported by Wankhade *et al.*, (2002). A decrease in plant height, leaf area and number of bolls/plant but an increase in chlorophyll content was reported with CCC application @ 50 ppm at 30, 60 and 90 DAS (Prasad and Prasad, 1994). More *et al.*, (1993) also observed significant reduction in plant height, number of branches/plant, number of leaves/plant, number of internodes and internodal length when plants were treated with 100, 150 and 200 ppm of CCC. Significantly higher seed cotton yield of 2.81 t ha^{-1} was observed with CCC application at 100 ppm applied at 70 DAS.

Similarly, Singh and Chouhan (1993) while working with cotton cv. Ganganagar Ageti in Rajasthan observed that two foliar sprays of CCC @t 80 ppm at flower initiation and 20 days later reduced plant height and increased the boll weight significantly and seed cotton yield was increased by 7.56 % compared to control. According to Mahmoud *et al.*, (1994), CCC when applied at rates of 500 and 5000 ppm at early growth stages decreased plant height, while it's late application increased plant height and leaf abscission but decreased the number of nodes/plant and number of leaves/plant. Karoddi *et al.,* (1993) reported that application of 60 ml CCC per hectare at 90, 105 and 120 DAS increased mean seed cotton yield. While, Pipolo *et al.*, (1993) observed that single and double applications of CCC @ 25 g ha^{-1} resulted in yield increase of 11.5 and 11.6 per cent, respectively.

Effect of kinetin on growth, yield and quality parameters of cotton

Kinetin (6-furfurlamino-purine) is a member of the cytokinin group of plant growth substances that are known to promote cell division and enlargement of stems, leaves and fruits. They also delay senescence, stimulate mobilization of metabolites allowing longer photosynthetic activity. Although, specific modes of action have not been elucidated, but these compounds theoretically promote fruit set and retention and increase the ability of the plant to fill existing fruit (sinks).

Cotton plants were sprayed twice with different kinetin concentrations at 60 and 75 DAS during square initiation and the beginning of boll development stage and significant increase was recorded in the number of open bolls/plant, boll weight, lint and seed indices and seed cotton yield/plant (Sawan *et al.*, 2000). Deng (1996), reported that when cotton was sprayed with 4PU-30 (synthetic cytokinin) at the square and flower stages, seed cotton and lint yield were not significantly increased but spraying with a mixture of 4PU-30 and DPC (MC) increased lint yield by 16.3-17.3 % compared with control. Hofmann and Else, (1989) treated cotton with several rates of kinetin (Burst Yield Booster, BYB) in single and multiple applications at various growth stages and observed non-significant differences in cotton lint yield and no measurable differences in plant height or flower and boll production. They also reported a non-significant effect of kinetin on fibre quality parameters.

Table.1 Yield and yield attributes of Bt cotton as affected by various plant growth regulation treatments (Rajni, 2010)

Treatment	Setting percentage		Picked bolls per plant		Boll weight (g)		Total Seed cotton yield (q ha^{-1})	
	2008	2009	2008	2009	2008	2009	2008	2009
Control	39.24	38.41	45.3	42.9	2.95	2.90	22.07	20.29
Detopping	37.48	37.76	44.7	42.5	2.95	2.82	21.41	19.46
MC 200ppm	45.13	43.46	52.8	48.7	3.42	3.18	29.73	25.24
MC 300ppm	46.01	44.37	54.2	50.4	3.45	3.25	30.28	27.00
CCC 250ppm	39.62	39.40	45.3	44.1	3.00	2.95	22.19	21.26
CCC 500ppm	36.99	35.71	40.5	37.7	2.73	2.64	17.26	15.41
Kinetin 25ppm	38.57	38.29	44.2	42.3	2.95	2.95	21.23	20.27
Kinetin 50ppm	40.12	39.17	46.1	44.2	3.15	2.97	23.54	21.39
GA_3 25ppm	40.55	39.42	47.6	44.2	3.16	2.97	24.42	21.35
GA_3 50ppm	38.77	37.00	44.7	41.8	3.12	2.80	21.84	19.01
NAA 25ppm	39.37	38.70	45.9	44.1	3.05	2.95	22.75	21.29
NAA 50ppm	41.16	39.34	49.2	45.4	3.18	3.03	25.51	22.40
($P <0.05$)	3.93	4.65	4.67	4.90	0.23	0.26	4.58	4.30

Application of kinetin either to intact buds or bolls or to boll explants, i.e. other than the abscission zones, promoted abscission, but when applied directly to the abscission zone it reduced shedding, thus confirming the ‘directed transport of metabolites’ concept. Kinetin applied to intact buds or bolls or to boll explants counteracted to some extent the promotive effect of abscisic acid (ABA) on abscission (Varma, 1978).

Effect of Gibberellic Acid (GA_3) on growth, yield and quality parameters of cotton

Gibberellic acid (GA_3) is one of the most wide spread plant growth promoters associated with stem elongation and leaf enlargement, but have been shown to increase fruit retention in cotton and were first discovered in Japan in 1930’s from the fungus *Fujikuroi.* Thind *et al.,* (2007) studied the effect of GA_3 (50 mg l^{-1}) on *G. arboreum* L. cv. LD 694 and *G. hirsutum* L. hybrids LHH 144 and LHH 1128 at flower initiation stage and found that maximum plant height, number of nodes/plant, number of leaves/plant, average internodal length, canopy area and boll number/plant were recorded with GA_3 treated plants. GA_3 at 50 and 100 ppm resulted in increased shoot length, number of leaves/plant, total leaf area, fresh and dry shoot and root weight of cotton (Haroun *et al.,* 2004). While, Kapoor *et al.,* (2004) found that 50 ppm GA_3 + 100 ppm NAA increased boll setting in cotton and maximum boll setting of 74.5 % was observed with GA_3 + NAA. He-XunHong *et al.*, (2002) treated cotton buds with 0, 25, 50, 75, 100, 150 and 200 ppm GA_3 solutions and observed that GA_3 reduced the shedding rates of flowers and bolls while boll-setting was increased with increasing GA_3 concentration from 0 to 200 ppm. Application of GA_3 at 50 ppm during the fruiting period was most effective in improving the fruit retention with 24.4 % boll retention as compared to only 4.4 % of untreated control plants (Sandhu and Brar, 1983).

GA_3 at the rate of 0.001 % reduced shedding of buds, ovaries and bolls and increased boll weight and seed cotton yield (Pak and Kuznetsova, 1983). An increase in plant height, moisture content of bolls and seed cotton yield with the foliar application of GA_3 was reported by He *et al.*, (1983). Contrary, Xu and Zheng (1981) observed a decrease in growth and development of bolls and especially of seeds and fibres with the foliar application of GA_3 at 250 ppm. Dippenaar, (1988) suggested that application of GA_3 at 25 g ha^{-1} under field conditions increased plant height and reduced seed cotton yield by 28 %. Similarly, Ebaid *et al.*, (1984) were of the view that GA_3 application increased bud and boll abscission but decreased the boll setting percentage, number of open bolls/plant and seed cotton yield. They also found that GA_3 did not affect the number of fruiting branches and flowers/plant. However, non-significant differences in seed cotton yield with application of GA_3 were reported by Hedin and McCarty, (1994).

Chlorophyll levels of cotton leaves were high, 287.914 µmol m^{-2} to 468.796 µmol m^{-2} being the treatments without and sprayed with 0.06 mg L^{-1} gibberellic acid (GA_3), with 62.82% increase. The application of 0.06 mg L^{-1} GA_3 generally promotes increased levels of photosynthetic pigments and relative water content in cotton leaves. However, different cultivars respond differently to the application of plant growth regulators (da Costa *et al.*, 2017). Enhancing IAA and ABA contents in the fiber of brown and green cotton by spraying GA_3 and ABA improved fiber quality. Application of GA_3 @ 20 ppm improves the IAA content (at 20 days post-anthesis) in the brown and green-fibered cottons by 51.07 and 64.33%, fiber ABA content by 38.96 and 24.40%, and fiber length by 8.13 and 13.96%, respectively. Fiber strength, micronaire and maturation were also enhanced at boll opening (Zhang *et al.*, 2017).

Effect of Naphthalene Acetic Acid (NAA) on growth, yield and quality parameters of cotton

Auxin is the first plant hormone to be discovered and affects a number of plant functions such as cell and stem elongation, leaf expansion, increased rooting and decreased fruit abscission. Naphthalene acetic acid (NAA) is a synthetic auxin that maintains ongoing physiological and biochemical functions, mobilizes nutrients to cotton bolls by attracting assimilates to storage sinks and is known to increase fruit set leading to increased seed cotton yield (Bhatt and Date, 1955; Negi and Singh,1956; Bhardwaj *et al.*, 1963). Kumar *et al.*, (2006) reported that application of NAA (20 ppm) at 90 DAS recorded higher plant height, number of main stem nodes, number of sympodia, number of bolls/plant, boll weight, and seed cotton yield compared to control. Foliar application of 20 ppm NAA resulted in maximum seed cotton yield (1331 kg ha^{-1}), which was 43 % higher than control (930 kg ha^{-1}). This was because of higher number of bolls/plant (27.8) and higher mean boll weight (5.56 g $boll^{-1}$).

Sharma and Dungarwal, (2004) found that foliar spray of NAA 10 ppm significantly increased the crop growth rate, relative growth rate, sympodial branches/plant and seed cotton yield during both the years (1996 and 1997). Application of NAA 10 ppm gave 19.7 % higher seed cotton yield over control. More squares, flowers, number of picked bolls, total number of bolls/plant and boll setting percentage were recorded, while dropped bolls per plant, shedded squares/plant, number of shedded flowers/plant and % dropped flowers/plant decreased significantly with application of NAA (Sharma and Dungarwal, 2003). Relatively higher seed cotton yield (12.3%) over control was obtained with foliar application of 20 ppm NAA at flowering and boll development stage (Turkhede *et al.*, 2003). Brar *et al.*, (2001) observed that application of NAA (30 ppm) at 60 and 80 DAS significantly increased the seed cotton yield by 25.2 and 27.2 % during 1996 and 21.4 and 23.5 % during 1997, respectively, over control. Highest boll setting was observed (32.4 and 33.9%) when NAA was applied at 60 DAS during both the years. Sawan *et al.*, (1998) sprayed NAA once (after 90 days), twice (90 and 105 days) or thrice times (90, 105, 120 DAS) at concentrations of 5, 10, 15, 20 or 25 mg l^{-1}, respectively and found that lint yield ha^{-1} increased with application of NAA compared with control. Highest yield was achieved when NAA was applied at the rate of 20 ppm (22.13%) followed by 15, 25, 10 and 5 ppm (17.28, 16.84, 12.97 and 7.25%) than control. Similarly, Jadhav and Kalbhor, (1981) at Pune reported that application of NAA twice i.e. at square formation and 30 days after square formation stage, increased number of bolls/plant, reduced boll shedding and consequently increased yield (35.74 q ha^{-1}) as compared to one application at square formation stage (33.63 q ha^{-1}). Maximum seed yield of 38.22 q ha^{-1} was recorded with 45 ppm NAA concentration and the % increase in yield with 15, 30 and 45 ppm of NAA was 7.60, 15.57 and 15.89 % respectively as compared to control. Swamy, (1991) while studying the effects of NAA at 10, 20 or 30 ppm applied at 60, 60+90 or 60+90+120 days after planting found that boll shedding was reduced and boll weight and seed cotton yield were increased with application of NAA. Mehetre *et al.*, (1990) also found that two foliar sprays of 20 ppm NAA at square formation and 50 % flowering stages gave significantly higher seed cotton yield than control. Significantly higher seed cotton yield and increased boll weight with foliar application of NAA 40 ppm at 45, 60 and 75 DAS over control was observed by Pothiraj *et al.*, (1995). Similar findings were reported by Venkatakrishnan, (1994). Application of NAA at 10 ppm resulted in reducing shedding percentage of fruiting forms and increase in seed cotton yield (Patel, 1992).

Different growth parameters, chlorophyll levels, yield and yield components of cotton showed a significant increase with the four spray of 1% NAA solution (the 1st spray was done at 45 DAS and remaining at 15 days intervals). Furthermore, earliness index (68.20%), mean maturity date (159.70 days) and production rate index (29.95 g/day) were also significantly influenced with foliar application of NAA. Weight of seed cotton per open boll was 23.98% more with the four spray of 1% NAA solution (Parveen *et al.*, 2017).

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