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Improvement of growth and productivity of cotton (*Gossypium hirsutum* L.) through foliar applications of naphthalene acetic acid

Melhoria do crescimento e produtividade do algodão (*Gossypium hirsutum* L.) através de aplicações foliares do ácido naftaleno-acético

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Abstract

Plant growth regulators like naphthalene acetic acid (NAA) positively affect the growth and yield of crop plants. An experiment was conducted to check the foliar application of NAA on growth and yield components of cotton variety Bt.121 under field condition at research area of agriculture farm near Cholistan Institute of Desert Studies (CIDS), The Islamia University of Bahawalpur, Pakistan. The experiment was comprised of foliar application of NAA (1%) viz. T_0 (control), T_1 (One spray of NAA), T_2 (Two sprays of NAA), T_3 (Three sprays of NAA), T_4 (Four sprays of NAA). The first foliar spray was applied at 45 days after sowing (DAS) and later on it was continued with 15 days interval with skilled labour by hand pump sprayer. The experiment was laid out in randomized complete block design and each treatment was replicated three times. Data recorded on growth, chlorophyll contents, yield and yield components showed a significant increase with the application of NAA. Furthermore, earliness index, mean maturity date and production rate index were also influenced with foliar application of NAA. On the basis of growth and yield parameters it can be concluded that four spray of NAA (1%) can be applied commercially under field conditions.

Key words: Foliar spray. Growth regulator. NAA. *Gossypium hirsutum* L. Growth and yield.

Resumo

Reguladores de crescimento de plantas como ácido naftaleno acético (NAA) afetam positivamente o crescimento e o rendimento das plantas cultivadas. Um experimento foi conduzido para verificar a aplicação foliar de NAA nos componentes de crescimento e rendimento da variedade de algodão Bt.121 sob condições de campo em área de pesquisa do Instituto Cholistan de Estudos do Deserto (CIDS), Islamia University of Bahawalpur, Paquistão. O experimento foi composto de aplicação foliar de NAA (1%) viz. T0 (controle), T_1 (uma pulverização de NAA), T_2 (duas pulverizações de NAA), T_3 (três pulverizações de NAA), T_4 (quatro pulverizações de NAA). A primeira pulverização foliar foi aplicada aos 45 dias após a semeadura (DAS) e posteriormente a cada 15 dias de intervalo com pulverizador

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manual. O experimento foi desenvolvido em delineamento em blocos ao acaso e com três repetições. Os dados registrados sobre o crescimento, os teores de clorofila, os rendimentos e os componentes do rendimento mostraram aumento significativo com a aplicação de NAA. Além disso, o índice de precocidade, a maturidade média e a taxa de produção também foram influenciados pela aplicação foliar de NAA. Com base nos parâmetros de crescimento e rendimento, pode-se concluir que quatro pulverizações de NAA (1%) podem ser aplicadas comercialmente em condições de campo.
Palavras-chave: Pulverização foliar. Regulador de crescimento. NAA. *Gossypium hirsutum* L. Crescimento e rendimento.

Introduction

Cotton (*Gossypium hirsutum* L.) is subtropical, perennial plant belong to family Malvaceae, with 50 wild and cultivated species. It is one of the most important *Kharif* season cash crop, cotton occupies a significant place primarily towards agrarian economy of south western districts. Seeds produced by cotton plant used for a multiproduct base like hulls oil, lint and food for animal as well as in textile manufacturing (ARAGAO et al., 2005). Pakistan ranked 4th in cotton production but its yield is low raked at 10th position due to high prices of agricultural inputs (pesticides, fertilizers, etc.), higher intensity of insect and pest attacks, deficiency of water for irrigation, lack of advanced technologies and awareness, adulteration in pesticides and agro-professionalism (NEWS, 2009). Cotton is important for national economy because important fibre crop of Pakistan contributing raw materials to the textile industry and major role in earning foreign exchange. During July-March 2014-15, textile industry fetched foreign exchange of US$ 10.22 billion (ANONYMOUS, 2014).

The cotton crop production accounts for 1.5% in Gross Domestic Product (GDP) and 7.1% in agriculture value addition. Cotton (*Gossypium hirsutum* L.) is the queen of fibre and leading fibre crop of the world. In Pakistan it is grown over an area of 2961 thousand hectares with a production of 13983 thousand bales and average yield of 802 kg per hectare (ANONYMOUS, 2014). Bt. cotton is a type of cotton and developed through the transport of a gene from a soil bacterium, *Bacillus thuringensis* (Bt) by the production of cry protein, which is toxic for insects causing its death by disruption of its digestion process when they feed on plant. In 2009-2010, 70% of cotton crop planted was Bt and cultivation of Bt transgenic crop reduced the pesticide usage (CARROLL, 2009).

Plant growth regulators are also called plant hormones are the chemicals that are artificially synthesized having similar function as phytohormones. Plant hormones are not nutrients but chemicals that in small amount promote and influence the growth, development and differentiation of cells and tissues (GÜLLÜOĞLU, 2004). Growth regulators can improve the physiological efficiency including photosynthetic ability and can enhance effective partitioning of accumulates from source to sink in the field crops, thus considered as important component of cotton growth management to provide higher seed cotton yields (COPUR et al., 2010).

Application of NAA has good management effect on growth and yield of field crops by increasing fruit setting ratio and fruit dropping (RAOOFI et al., 2014). NAA positively affects the plant growth and improves the maturity of cotton (ABRO, 2004). In comparison with other natural auxin, NAA enhanced the weight and fiber elongation by hindering the secondary cell wall cellulose synthesis (SINGH, 2009). The objective of this study was to investigate the effect of foliar spray of different concentrations of NAA on growth and yield of cotton.

Materials and Methods

A field experiment was conducted to investigate the effect of foliar application of NAA on growth and yield of cotton crop at Cholistan Institute of

Desert Studies (CIDS), Baghdad-ul-Jadeed Campus, The Islamia University of Bahawalpur, Pakistan (longitude = 71° – 41'0" E, latitude = 29° – 24'0" N and altitude = 116 m) under irrigated conditions in the cotton-growing season during 2010-11. The experiment was laid out in Randomized Complete Block Design and replicated three times.

A cotton variety of Bt-121 was planted by drilling method at 75cm apart rows, while plant to plant distance was maintained of 30 cm by thinning just before the first irrigation and net plot size was plot measuring 36.45 m^2. Fertilizer i.e. 130 N, 60 P_2O_5 and 50 K_2O kg per hectare was applied in the form of urea, diamonium phosphate and sulphate of potash. All other agronomic practices were kept uniform for all the treatments.

The experiment was comprised of foliar spray of NAA applied at the rate of 1% with the treatments as T_0 (control), T_1 (one spray of NAA), T_2 (two sprays of NAA), T_3 (three sprays of NAA), T_4 (four sprays of NAA). Phytofix (Naphthalene acetic acid 4.5%) was applied with the help of skilled labour by hand pump sprayer. The solution (1%) of NAA was prepared by dissolving 0.045g in 100 liter water. The first spray was done at 45 days after sowing (DAS) and later on was applied at 15 days intervals. The spraying was done with a hand sprayer and first irrigation was applied at 35 DAS while the subsequent irrigations were applied according to the need of crop. All the agronomic practices were carried out uniformly as and when required.

The observations were recorded by randomly selection of four plants from each plot and tagged as A, B, C and D respectively, for recording various parameters during the course of study. Plant height was measured with the help of scale from the ground surface to the plant terminal. Number of leaves per plant were recorded by counting the total number of leaves of four taged plants in each plot and then average was calculated. The numbers of nodes present on the main stem of four tagged plants were counted and average was worked out. Leaf area of four taged plants in a plot was determined by the leaf area meter at different growth stages of crop. Chlorophyll contents (SPAD-502 value) in plant leaf were estimated by chlorophyll meter. To calculate the total number of seeds per boll, ten open bolls were picked from each plot in all treatments and seeds were recorded cautiously. For measuring the weight of seed cotton, ten open bolls picked from each net plot and then separated their locules, in all treatments and weighed seed cotton and locules was determined with the help of digital balance. Seed cotton yield was determined on plot basis. Earliness index was calculated with the help of following formula as proposed by Singh (2003).

$$\text{Earliness Index (\%)} = \frac{\text{Weight of seed cotton from first pick}}{\text{Total seed cotton weight from all picks}}$$

Mean maturity date (MMD) in cotton was calculated by the formula as proposed by Christidis and Harrison (1955).

$$\text{Mean Maturity Date (MMD)} = \frac{(W_1 \times H_1) + (W_2 \times H_2) + \ldots\ldots\ldots + (Wn \times Hn)}{W_1 + W_2 + \ldots\ldots + Wn}$$

Where W = weight of seed cotton, H = number of days from planting to harvest, 1, 2…n = consecutive periodic harvest number.

Saleem et al. (2010) calculated that production rate index was calculated from total seed cotton weight divided by the mean maturity date.

$$\text{Production Rate Index (g/day)} = \frac{\text{Total seed cotton weight (g)}}{\text{Mean maturity date (day)}}$$

Statistical analysis: Data collected during were statistically analyzed using Fisher's analysis of variance technique (ANOVA) and significant means were separated using least significant difference test (LSD) at 5% probability level (STEEL et al., 1997). Regression and correlation analysis was performed using MS Excel program against different variables.

Results and Discussion

Results regarding plant height in all the treatments continued to increase from 45 DAS towards the final harvest. At 54 DAS to onward highest plant height was recorded in T_4 treatment (four spray of NAA) and lowest was found in control treatment where no NAA was applied (Figure 1). Abro et al. (2004) also found similar beneficial effect of NAA on plant height, plant height, number of fruiting branches and yield in cotton. Number of leaves in all the treatments continued to increase up to 90 DAS and then gradually declines, however, it increased slightly at 108 DAS. At 54 DAS highest number of leaves per plant was recorded in T_4 treatment which is statistically at par ($p>0.05$) with the T_3 treatment and lowest was recorded in control treatment (T_0). At 63 DAS to onward maximum number of leaves per plant was found in T_4 treatment which differ significantly ($p<0.05$) from control treatment (Figure 2). Similar observation was recorded by Revanappa (1993) that the effectiveness of NAA in increasing growth was mainly due to increase in cell division, cell differentiation and cell expansion which enhance the growth of plant.

Number of nodes per plant in all the treatments continued to increase from 45 DAS towards the final harvest. At 63 DAS, highest number of nodes per plant was recorded in T_4 which is statistically at par ($p>0.05$) with T_3 treatment and lowest was recorded in control treatment. Number of nodes per plant at 117 DAS also showed statistically significant difference ($p<0.01$) among different treatments (Figure 3). Norton et al. (2005) also found a positive effect of foliar application of plant growth regulators on number nodes per plant in cotton. Leaf area per plant in all the treatments continued to increase from 45 DAS to 99 DAS and then gradually declined towards the final harvest. From 54 DAS to onward, leaf area differs significantly ($p<0.01$) from each other under different sprays of NAA (Figure 4). Similar results were found by Mir et al. (2010) that foliar applications of growth regulators significantly affect the leaf area per plant.

Figure 1. Effect of different foliar application of NAA on plant height (cm) in cotton.

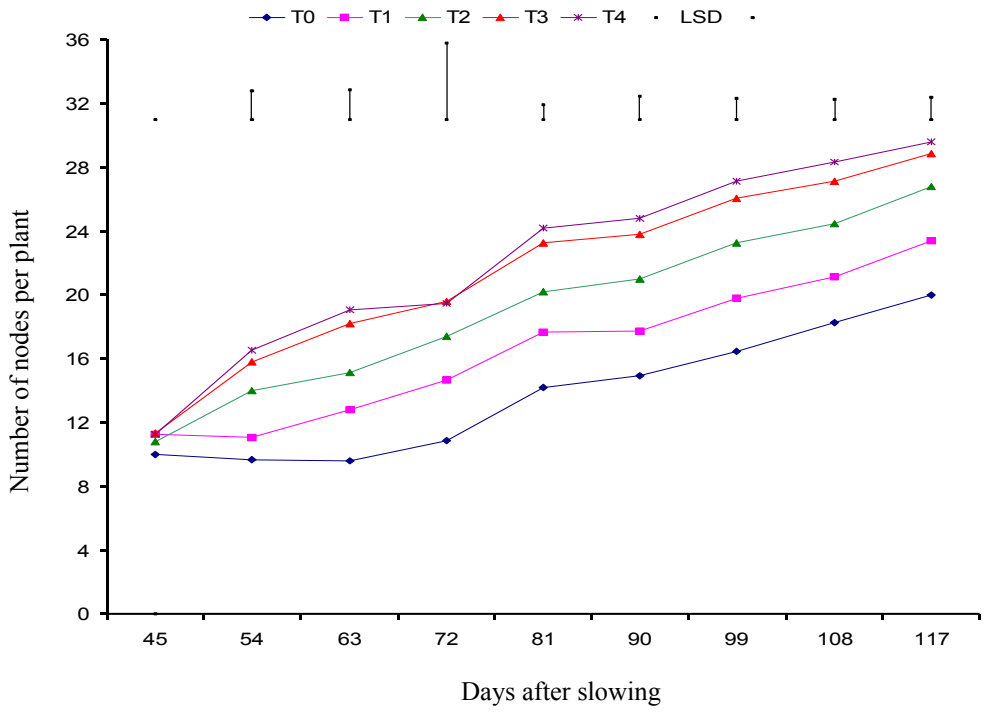
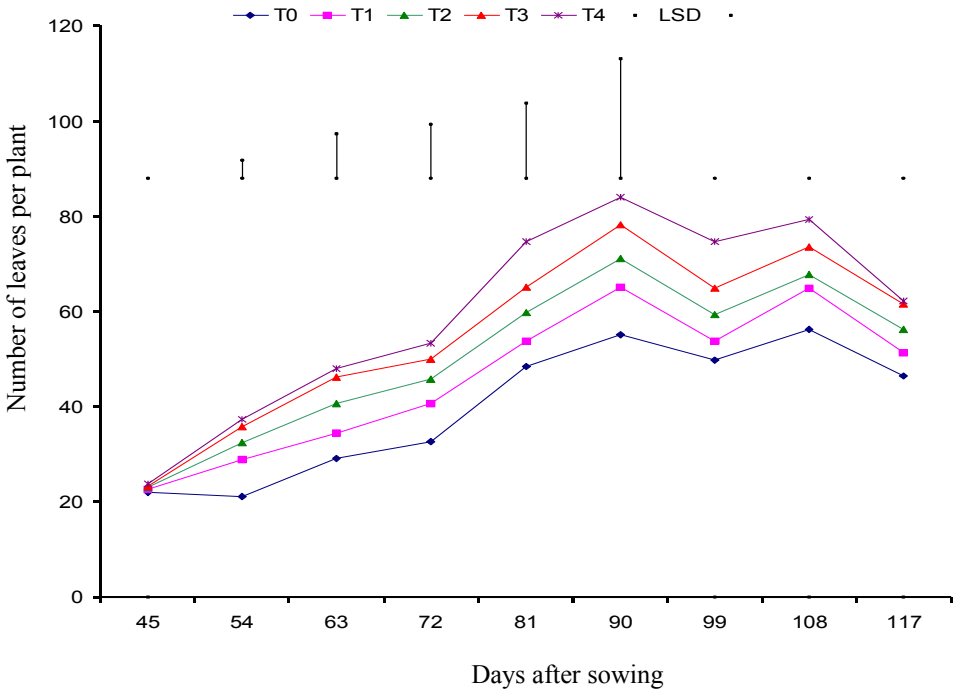


Figure 2. Effect of different spray of NAA on number of leaves per plant in cotton.



T_0: Control (no application) T_1: One spray of NAA (1%) T_2: Two sprays of NAA (1%)
T_3: Three sprays of NAA (1%) T_4: Four sprays of NAA (1%) LSD: Least significant difference.

Figure 3. Effect of different sprays of NAA on number of nodes per plant in cotton.

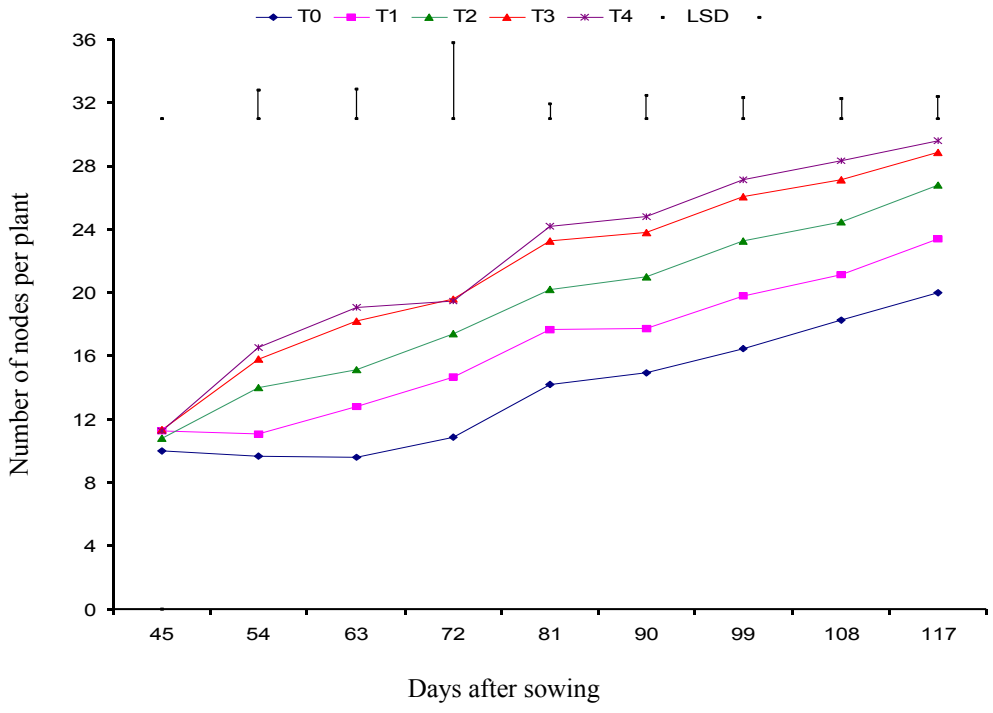
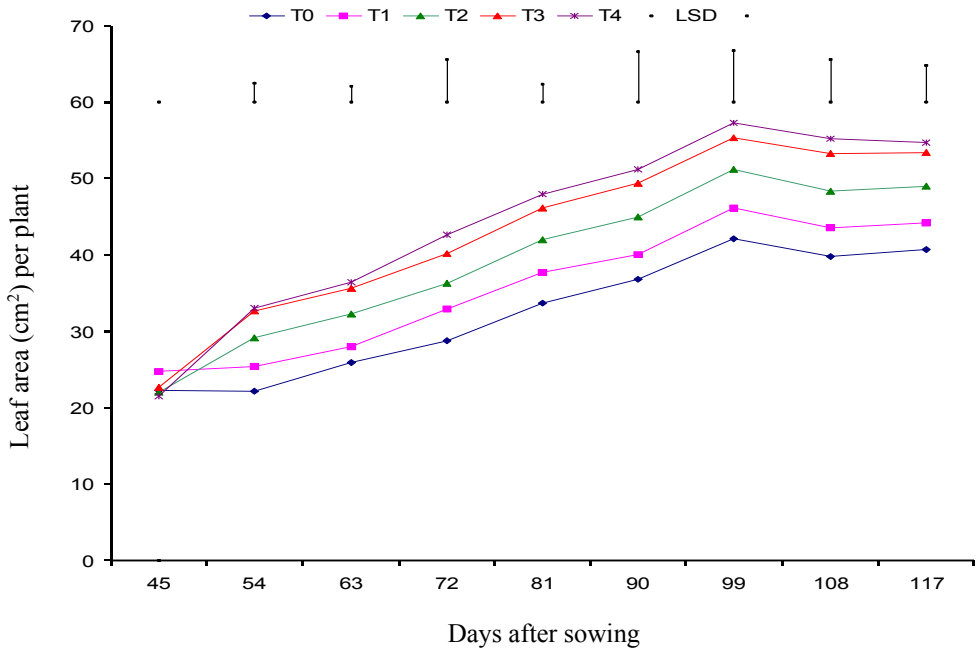


Figure 4. Effect of different sprays of NAA on leaf area (cm^2) per plant in cotton.



T_0: Control (no application) T_1: One spray of NAA (1%) T_2: Two sprays of NAA (1%)
T_3: Three sprays of NAA (1%) T_4: Four sprays of NAA (1%) LSD: Least significant difference.

Chlorophyll contents as influenced by different level of NAA increased progressively from 54 to 90 DAS and then decreased towards the final harvest. At 54 and 63 DAS the chlorophyll contents differ significantly ($p<0.05$) under different sprays of NAA. At 117 DAS maximum chlorophyll content was recorded in T_4 and lowest value was recorded in control, furthermore; T_4 treatment was statistically at par ($p>0.05$) with T_3 treatment and T_1 and T_2 treatments were also at par ($p>0.05$) with each other (Figure 5). Application of growth regulators causes variation in chlorophyll contents present in plant by increasing the chlorophyll synthesis and reduction in chlorophyll degradation. Senthil et al. (2003) investigated the effects of NAA at 40 ppm and IAA at 100 ppm supplied as foliar spray at 35 and 60 DAS on some biochemical and physiological aspects including total chlorophyll and soluble protein of soybean plant. Application of NAA was more economical as compared to control by recording maximum yield and yield components including photosynthesis (KIRAN KUMAR et al., 2002).

Number of bolls per plant in all the treatments also continued to increase from 62 DAS towards the final harvest. Maximum number of bolls per plant was recorded when four spray of NAA was applied (highest dose) which is followed by T_3 treatment and minimum was recorded in control treatment (Figure 6). Highest weight of seed cotton per open boll (3.46) were recorded with four sprays of NAA (highest dose) which is followed by treatment T_3 (3.26) and T_2 (3.18) and T_1 (2.94) and lowest was recorded in control (2.63) where no NAA was applied. There is 23.98% more weight of seed cotton per open boll in T_4 treatment than T_0 (control) was recorded (Table 1). Russell (2006) found that increase in yield is also due to higher number of leaves that provides the photo assimilates and as a result of delayed senescence of leaves for an extended period.

Figure 5. Effect of different sprays of NAA on chlorophyll contents (SPAD-502 values) in cotton.

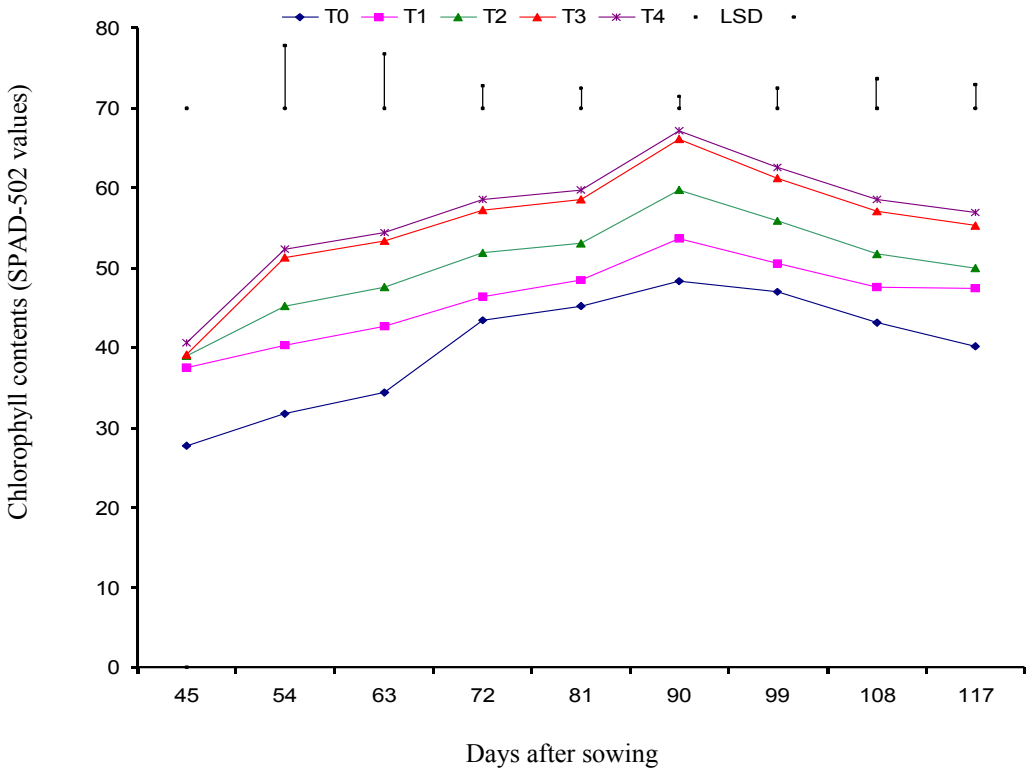
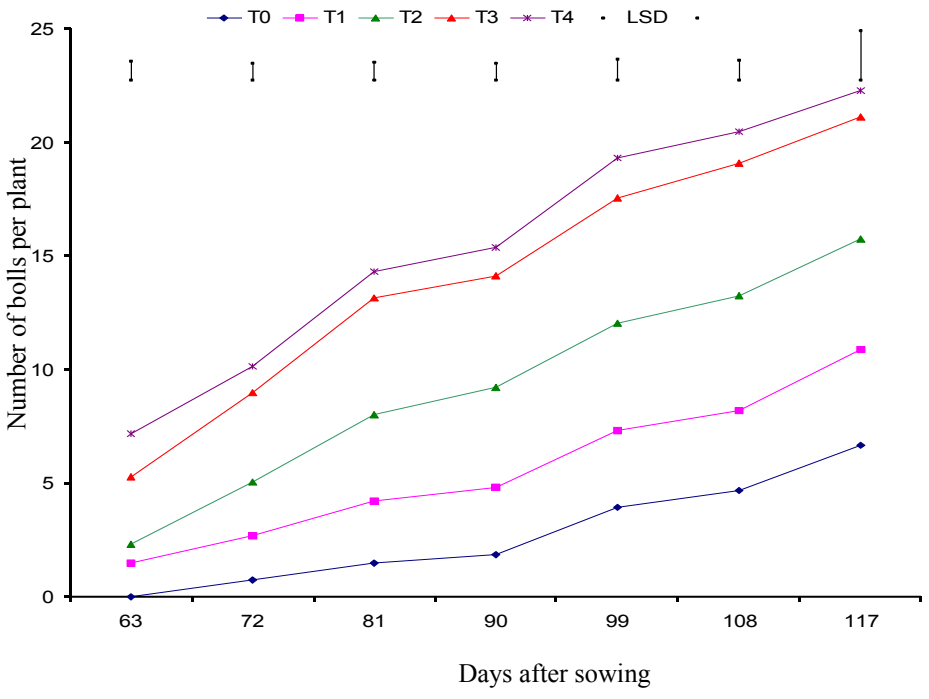


Figure 6. Effect of different sprays of NAA on number of bolls per plant in cotton.



T_0: Control (no application) T_1: One spray of NAA (1%) T_2: Two sprays of NAA (1%)
T_3: Three sprays of NAA (1%) T_4: Four sprays of NAA (1%) LSD: Least significant difference.

Highest weight of locules per open boll (1.73) was recorded with four sprays of NAA while the lowest was recorded in control (1.06) where no NAA was applied. Treatment T_2 and T_1 showed statistically at par ($p>0.05$) results with respect to weight of locules per open boll. Furthermore, it was observed that T_4 treatment has 38.72% more weight of locules per open boll than control treatment (Table 1). Maximum number of cotton seed per open boll was recorded in T_4 treatment which is statistically at par ($p>0.05$) with T_3 and minimum was in control treatment. Treatments T_0, T_1 are T_2 were statistically at par ($p>0.05$) with each other (Table 1). In study on Brinjil, Patil (2005) also reported that higher fruit weight and seed yield per plant was recorded with the application of NAA. Seed cotton yield also increased with the application of NAA and four sprays of NAA produced maximum seed cotton yield (2574) which is followed by T_3 (2516), T_2 (2461) and T_1 treatment (2369) respectively. There is 13.72% more yield in T_4 treatment than T_0 (Table 1). Similar results were observed by Gencsoylu, (2009) that foliar application of growth regulators significantly increased number of bolls per plant of cotton crop. Hallikeri et al. (2002) also stated that application of NAA with micronutrient significantly increased the seed cotton yield.

Results of present experiment showed that the maximum earliness index (68.20) was found in T_4 treatment (four spray of NAA) was applied and minimum (66.37) in T_0 treatment (control) **(**Table 1). Application of synthetic auxin like NAA may cause rapid cell division and cell elongation in the growing part of plants due to efficient translocation and utilization of photosynthetic metabolic product and also by enhancing the rate of photosynthesis (NATEH et al., 2005). Cothren (1999) in a study also investigated that plant growth regulators increased productivity and earliness by flowering, assimilation partitioning and yield enhancement.

Table 1. Effect of foliar application of NAA on earliness index, mean maturity date and production rate index, weight of seed cotton per boll, weight of locules per boll, number of cotton seeds per open boll and seed cotton yield.

Treatments	Weight of seed cotton per boll (g)	Weight of locules per boll (g)	Number of cotton seed per open boll	Seed cotton yield (Kg/ha)	Earliness index (%)	Mean maturity date (days)	Production rate index (g/day)
T_o	2.63c	1.06 d	15.2d	2220 a	66.37 b	160.10 a	25.78c
T_1	2.94bc	1.26 c	17.63 c	2369 ab	65.85 b	160.20 a	27.49bc
T_2	3.18ab	1.40 c	19.17 b	2461 ab	66.31 b	160.10 a	28.57ab
T_3	3.26ab	1.56 b	21.73 a	2516 bc	66.53 b	160.00 ab	29.23ab
T_4	3.46a	1.73 a	22.6 a	2574 c	68.20 a	159.70 b	29.95a
LSD at 5%	0.347	0.146	1.024	0.326	1.73	0.36	02.07

T_0: Control (no application) T_1 : One spray of NAA (1%) T_2: Two sprays of NAA (1%)
T_3: Three sprays of NAA (1%) T_4: Four sprays of NAA (1%).

Mean maturity date (MMD) was maximum (160.2) in T_1 treatment and minimum (159.7) in T_4 treatment. Treatment T_2 has MMD 160.2, T_3 has 160, T_4 has 159.7 and in T_0 MMD was 160.1 (Table 1). Tamas (1972) stated that yield of cotton seed influenced by the application of NAA and it was mainly due to stimulating effects of auxin on the photosynthetic capacity of chloroplast. Production rate index in treatment T_1 has 27.49, T_2 has 28.57 and T_3 has 29.23, maximum (29.95) in T_4 treatment and minimum (25.78) in T_0 (control) where NAA was not applied (Table 1). Richmond and Ray (1966) also found that MMD provided a more accurate measurement of earliness and NAA treatments show significant increase in earliness index and production rate index as compared to control treatment.

Correlations and regression analysis

The correlation analysis showed a positive and linear association between plant height and SCY ($r = 0.99$; $p<0.05$). Positive and linear correlation ($r = 0.99$) was observed between number of leaves per plant and SCY. Regression analysis also indicate the dependence of SCY on number of leaves per plant ($R^2 = 0.97$; $p<0.05$). Regression and correlation model shows the positive and linear relationship between leaf area and SCY ($R^2 = 0.96$; $r = 0.98$) as shown in table 2. The association between number of cotton seed per open boll and SCY is supported by regression model which showed the dependence of SCY on number of cotton seed per open boll ($R^2 = 0.96$; $p<0.05$). Regression analysis model indicate the positive and linear association between chlorophyll content and SCY ($R^2 = 0.98$; $p<0.05$) (Table 2). Sawan and Sakr (1998) also investigated the effect of the treatments of NAA on cotton growth, yield and yield components. The application of NAA increased the number of opened bolls, boll weight which positively contribute towards increasing in seed cotton yield.

Table 2. Regression equation, linear regression coefficients (R^2) and correlation coefficient between seed cotton yield and different parameters of cotton.

Characters	Regression equation	Linear regression coefficient (R^2)	Correlation coefficient (r)
SCY vs plant height	y = 32.108x + 684.57	0.97	0.99
SCY vs leaf area per plant	y = 27.24x + 1363.6	0.96	0.98
SCY vs Chlorophyll contents	y = 19.933x + 1437.1	0.98	0.99
SCY vs number of bolls per plant	y = 24.524x + 2195.4	0.93	0.97
SCY vs number of cotton seed per open boll	y = 45.075x + 1560.2	0.96	0.98
SCY vs weight of seed cotton per open boll	y = 432.01x + 1092	0.99	0.99
SCY vs number of leaves per plant	y = 17.771x + 1532.5	0.97	0.99

SCY= Seed cotton yield vs = versus.

Conclusions

Data recorded on growth, chlorophyll contents, yield and yield components showed a significant increase with the application of NAA. Furthermore, earliness index, mean maturity date and production rate index were also influenced with foliar application of NAA. On the basis of growth and yield parameters it can be concluded that four spray of NAA (1%) can be applied commercially under field conditions.

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