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RESPONSE OF COTTON GROWTH AND YIELD TO FOLIAR APPLICATION WITH THE GROWTH REGULATORS INDOLE ACETIC ACID (IAA) AND KINETIN

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ABSTRACT

Two field experiments were carried out at Sids Agric. Res. Station, Beni-Suef Governorate, in 2007 and 2008 seasons, to study response of growth, fruiting and yield of the Egyptian cotton cultivar Giza 80 (*G. barbadense L.*) to foliar application with indole acetic acid (IAA) and Kinetin (a synthetic cytokinin). Besides the control treatment, two concentrations of each of IAA (25 and 50 ppm) and kinetin (10 and 20 ppm) and their combinations were application twice, at the start and peak of flowering stages. Results revealed that, cotton plants treated with various treatments of IAA and/or kinetin showed higher leaves content of chlorophyll a, b and total chlorophylls than those of untreated ones. However, only some treatments of IAA and/or kinetin significantly increased plant height, numbers of fruiting branches/plant and open bolls/plant in both seasons; number of main stem nodes and seed cotton yield/fad., in 2007 season only; and total fruiting sites/plant and seed index in 2008 season only, but they significantly decreased fruit shedding% and earliness% in 2007 season only. Application 50 ppm IAA alone significantly decreased earliness% in 2007 season, and either alone or with kinetin at both levels gave the highest values of plant growth parameters, but their effects on fruit shedding and yield did not reach the significant level. In general, the most consistently positive effects on plant fruiting and seed cotton yield were given by application 25 ppm IAA alone or 20 ppm kinetin alone or both.

Keywords: Cotton, Growth regulators, IAA, Kinetin, Fruit shedding and Yield.

INTRODUCTION

Cotton plant is characterized by high shedding rate of fruiting forms owing to many internal and external factors. Significant cotton yield potential is lost by premature shedding of squares and young bolls (Cothren, 1999). Boll retention is the more important factor in determining cotton yield (Boquet & Moser, 2003).Two physiological theories have been put forth to explain fruit shedding; **a)** The nutritional theory demonstrates that cotton plant retains only as many bolls as it can supply with carbohydrates and nutrients. Accordingly, any condition decreases the available assimilates supply increases bud and boll abscission, and **b)** The hormone balance theory stated that fruit shedding increases when hormone balance changes in favor of ABA and ethylene and any stress increases their levels usually increases fruit shedding (Guinn & Brummett, 1987 and Cothren, 1999). However, the nutritional and hormonal theories are not contradictory or mutually exclusive; they just represent different parts of the overall control system involving a complex set of interacting factors including genetics, physiology, nutrition and environment (Guinn, 1998). Therefore, it is believed that fruit shedding in cotton is inevitable and could not be completely avoided, but its magnitude could be reduced by optimizing crop management practices (Oosterhuis *et al*, 1990 and Guinn, 1998).

From the physiological point of view, fruit shedding in cotton is considered a physiological disorder and cotton yield could be considerably increased by reducing it, which could be approached via ensuring regular supply of photosynthesis and nutrients to the developing fruits (Prakash & Perumal, 2001). Otherwise, the supply of assimilates during boll development stage is restricted by poor synchronization between carbon production and its utilization by developing bolls since leaf photosynthesis and carbon production in cotton peak prior to maximum carbon demand by bolls. Several studies have indicated that photosynthetic activity of a single leaf and canopy peaks at the ban thesis of its subtending fruit and soon after flowering, respectively, then markedly declines with age during boll filling period (Wallschleger & Oosterhuis, 1990; Peng & Krieg, 1991 and Doma *et al*, 2000). It was suggested that enhancing leaf photosynthesis and/or leaf longevity during boll filling stage could substantially increase cotton yield (Wallschleger & Oosterhuis, 1990 and Faver & Gerik, 1996). According to a simulation study, an increase of cotton photosynthesis rate by 15% could result in >50% yield increase, provided N and water are adequate (Landivar *et al*, 1983). In this respect, the growth regulators auxins and cytokinins have been reported to delay leaf senescence and enhance photosynthesis and retard the abscission response in cotton (Guinn & Brummett, 1987, Gan & Amasino, 1995 and Cothren, 1999).

Auxins are one of the important classes of signaling molecules transcribed in plants. From embryonic patterning to fruit dehiscence, every plant process has some involvement with auxins as hormonal signals. Indole acetic acid (IAA), the major active form of the naturally occurring auxins in plant, usually delays abscission in cotton (Guinn & Brummett, 1987). The decline in photosynthetic activity of cotton leaf is correlated with a decrease in its content of free IAA (Guinn & Brummett, 1993). Boll content of IAA is positively correlated with boll retention (Guinn & Brummett, 1987), and abscising bolls contained much less IAA than retained bolls (Rodgers, 1981). Wahdan, (2000) reported that application IAA mediated hormonal changes in cotton leaves in favor of growth promoting substances which led to enhancing chlorophyll content and plant growth and productivity. Also, exogenously applied IAA positively influenced plant growth, boll setting and yield and yield components (El-Sayed & El-Menshawi, 2006 and El-Menshawi, 2008).

Cytokinins are key regulators of many aspects of plant growth and development. It is well established that cytokines ordinarily stimulate chloroplast development and chlorophyll synthesis and delay leaves senescence, allowing longer photosynthetic activities (Gan & Amasino, 1995 and Arteca, 1996). Kinetin, a synthetic cytokinin, is regarded a stable antioxidant that has powerful anti-aging effects as well as anti-stress responses in plants (Gadallah, 1999). The external application of kinetin on cotton plants exerted promoting effects on leaves content of chlorophyll and plant height (Zayed *et al*, 2005 a), boll setting, yield and yield components (El-Aggory *et al*, 1982; Sawan *et al*, 2000 and Zayed *et al*, 2005 b).

The aim of this work was to investigate the effect of foliar application with the growth regulators IAA and kinetin on growth, fruiting and productivity of Giza 80 cotton cultivar.

MATERIALS AND METHODS

Two field experiments were conducted at Sids Agric. Res. Station, Beni-Suef governorate, Middle Egypt, in 2007 and 2008 growing seasons, using the Egyptian cotton cultivar Giza 80 (*G. barbadense L.*). Two concentrations of each of Indole acetic acid (IAA) (25 and 50 ppm) or/and kinetin (10 and 20 ppm) and their combinations as well as control (without spraying) were sprayed twice, at the start and peak of flowering periods. Plot area was $12m^2$, (5 ridges, 4m long and 60cm apart). Distance between hills was 25 cm with leaving two plants per hill at thinning time (after five week form sowing). Sowing date was in the last week of March in both seasons. Treatments were arranged in the randomized complete blocks design in four replicates. Normal agricultural practices were followed during the growing seasons.

The following measurements were determined:

1) **Leaves content of chlorophyll;** In 2008 season, samples of the upper fourth leaves were collected at 15 days after the second application of growth regulators to determine leaves content of chlorophyll a and b according to Arnon (1949).
2) **Plant Growth Parameters;** Final plant height (cm), number of main stem nodes and number of fruiting branches per plant.
3) **Plant Fruiting Characteristics;** Number of open bolls per plant, number of non-open bolls per plant, numbers of aborted and total fruiting sites per plant, fruit shedding % was calculated as (aborted fruiting sites ÷ total fruiting sites) x 100.
4) **Yield and Yield Components;** Boll weight (gm), seed cotton yield in kg per plot was transformed into Kentars per faddan, earliness % was calculated as (1st pick yield ÷ total yield) x 100, lint percentage and seed index (gm).

The obtained data were subjected to statistical analysis according to Gomez and Gomez (1984), and L.S.D. values at 5% level of significance were used for comparison between means.

RESULTS AND DISCUSSION

1- Effect on leaves content of chlorophyll:

Data present in Table (1) reveal that various foliar treatments of IAA and kinetin either separately or in combination significantly increased leaves content of chlorophyll a, b and total chlorophylls in comparison with the control. The highest chlorophyll concentration was given by application the lower kinetin level (10 ppm) alone or with application 25 ppm IAA.

It is well recognized that cotton leaves, typically, have a limited productive life and their photosynthetic activity decreases with age (Oosterhuis *et al*, 1990), correlating with decreasing their content of free IAA (Giunn& Brummett, 1993). Also, during boll filling period, roots activity declines and their production of cytokinins is likely to be reduced (Cothren, 1999). Therefore, the exogenous application of auxins or cytokinins during this critical period, as done in the present study, is believed to replenish the leaves and plant content of such juvenility promoting substances, which could help in maintaining leaves chlorophyll and giving them longer active life.

Table (1): Effect of foliar application with IAA and kinetin on leaves content of chlorophyll in 2008 season and some growth parameters of cotton plant in 2007 and 2008 seasons.

Treatments	Chlorophyll (mg/g dry weight)			Plant height (cm)		No. of main stem nodes		No. of fruiting branches/plant	
	Chl. a	Chl. B	total	2007	2008	2007	2008	2007	2008
Control	3.26	1.67	4.93	124.2	135.8	23.8	25.3	13.1	14.7
25 ppm IAA	3.67	1.80	5.47	126.8	139.4	24.5	26.4	13.9	15.5
50 ppm IAA	3.48	1.83	5.31	130.2	140.4	25.6	26.6	14.6	16.2
10 ppm kinetin	4.02	1.81	5.83	126.2	135.6	24.2	25.5	13.7	14.7
20 ppm kinetin	3.66	1.93	5.59	125.8	137.1	24.6	26.0	14.0	15.3
25 ppm IAA + 10 ppm kinetin	3.77	1.89	5.66	128.8	137.6	25.4	26.1	14.8	15.9
25 ppm IAA + 20 ppm kinetin	3.69	1.94	5.63	129.4	140.4	26.0	26.6	14.8	16.3
50 ppm IAA + 10 ppm kinetin	3.48	2.00	5.48	132.9	141.3	26.1	26.9	15.1	16.6
50 ppm IAA + 20 ppm kinetin	3.68	1.87	5.55	131.1	140.1	25.7	27.0	14.7	16.3
L.S.D. at 5%	**0.21**	**0.10**	**0.36**	**4.8**	**3.9**	**1.3**	**NS**	**1.3**	**1.1**

IAA is known to stimulate photosynthetic rate through enhancing chlorophyll content and stomatal opening (Arteca, 1996). External application of cytokinins delays leaves senescence (Gan& Amasino, 1995). Cytokinins (kinetin) have been shown to stimulate the conversion of proplastide into chloroplast and induce grana formation, chlorophyll synthesis and thereby photosynthetic rate (Arteca, 1996). Kinetin is identified as strong anti-aging compound that could maintain chlorophyll stability under stress conditions and enhance its content in leaves (Gadallah, 1999). Similar results were reported by Wahdan, (2000), Zayed *et al.* (2005 a) and El-Menshawi (2008).

2- Effect on plant growth parameters:

It is clear from results in Table (1) that application 50 ppm IAA alone and as combined with the two levels of kinetin significantly increased plant height and number of fruiting branches in both seasons and number of main stem nodes in 2007 season only in comparison with the control. The combined application of 25 ppm IAA + 10 or 20 ppm kinetin gave similar trend but the differences with the control were not always significant. The separately applied IAA at 25 ppm and kinetin at both concentrations exhibited slight insignificant increases in plant growth parameters. It is clear that the higher IAA concentration (50 ppm) surpassed the lower one (25 ppm) in promoting plant vegetative growth, while kinetin at both levels showed little effects on plant growth compared with either IAA or the control.

These results could be explained on the basis of the fact that growth regulators have the potential to affect the amount, type and direction of plant growth. Auxins (IAA) have long been recognized as growth promoters that can enhance stem elongation through stimulating cell division and elongation. However, though cytokinins stimulate cell division, they increase growth by swelling rather than elongation (Arteca, 1996). Wahdan, (2000) found an increase in cotton plant growth with increasing the level of IAA.

3- Effect on plant fruiting characteristics:

Results illustrate in Table (2) show that various treatments of IAA and kinetin exhibited no significant effects on number of non-open bolls per plant and number of aborted fruiting sites per plant in the two studied seasons. However, in comparison with the control, most of IAA and kinetin treatments significantly increased number of open bolls/plant in both seasons. In 2008 season only, number of total fruiting sites per plant was significantly increased only by 50 ppm IAA alone or with 10 ppm kinetin and by 25 ppm IAA + 20 ppm kinetin. In 2007 season only, fruit shedding % was significantly increased by only the combined application of 25 ppm IAA with 10 or 20 ppm kinetin.

Table (2): Effect of foliar application with indole acetic acid (IAA) and kinetin on some fruiting characteristics of cotton plant in 2007 and 2008 seasons.

Treatments	No. of open bolls/plant		No. of non-open bolls/plant		No. of aborted fruiting sites/plant		Total fruiting sites/plant		Fruit shedding%	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Control	11.2	9.6	5.1	5.6	7.6	8.9	22.9	24.1	33.2	36.9
25 ppm IAA	13.0	11.2	4.7	6.2	7.3	8.2	23.9	25.6	30.5	32.0
50 ppm IAA	12.8	11.0	5.9	6.8	7.3	9.5	25.0	27.3	30.4	34.8
10 ppm kinetin	12.5	11.1	5.2	5.5	7.1	8.0	23.8	24.6	29.8	32.5
20 ppm kinetin	13.1	11.5	5.3	6.1	7.2	8.7	24.6	26.3	29.3	33.1
25 ppm IAA + 10 ppm kinetin	13.0	10.7	5.9	6.5	7.0	9.0	24.9	26.2	28.1	34.4
25 ppm IAA + 20 ppm kinetin	13.3	12.0	6.0	6.0	6.8	9.3	25.1	27.3	27.1	34.1
50 ppm IAA + 10 ppm kinetin	12.6	11.4	6.9	6.9	7.6	9.2	25.1	27.5	30.3	34.7
50 ppm IAA + 20 ppm kinetin	12.4	10.8	5.8	6.3	7.9	9.5	25.1	26.6	31.5	35.7
L.S.D. at 5%	1.2	1.5	NS	NS	NS	NS	NS	3.1	4.3	NS

Such positive effects for IAA and kinetin on plant fruiting performance could be a result of their effects on maintaining higher and longer photosynthetic activity of leaves as indicated by the obtained increase in leaves chlorophyll content (Table 1), which might increase assimilates availability for developing bolls. In addition, both auxins and cytokinins are known to enhance assimilates mobilization from sources to sinks via inducing the development of vascular tissues, phloem loading and unloading, and enhancing sink strength (Arteca, 1996). Increasing assimilates production and supply may increase boll retention (Giunn, 1998).

High content of IAA in bolls retard their shedding since IAA directly may inhibit the synthesis or activities of cellulase and pectinase, the enzymes which digest cell walls and middle lamella of cells in the abscission zone, resulting in separation (Giunn, 1998). Cytokinins could reduce fruit abscission indirectly since they can establish local metabolic sinks capable of attracting carbohydrates and nutrients, which may make fruits more competitor for assimilates and reduce their abortion (Giunn, 1998 and Cothren, 1999). Accordingly, auxins and cytokinins are quite effective in retarding the abscission response in cotton (Cothren, 1999). Several studies indicated that number of open bolls and boll retention was significantly increased by application IAA (El-Menshawi, 2008) or kinetin (Sawan *et al*, 2000 and Zayed *et al*, 2005 b).

4- Effect on yield and yield components:

Results in Table (3) indicate that foliar application of IAA and kinetin exerted no significant effects on boll weight and lint % in the two growing seasons but it significantly affected earliness% and seed cotton yield per faddan in 2007 season only, and seed index in 2008 season only. Application 50 ppm IAA alone was the only treatments that cause a significant reduction in earliness % in 2007 season only. While 25 ppm IAA alone was the only treatment that gave a significant increase in seed index in 2008 season only. In 2007 season only, seed cotton yield (kentar/fad.) was significantly increased by the application of 25 ppm IAA or as combined with 10 or 20 ppm kinetin, or by the application of 20 ppm kinetin alone. The highest seed cotton yield was obtained by applied 25 ppm IAA + 20 ppm kinetin, 25 ppm IAA alone or 20 ppm kinetin alone, respectively.

Table (3): Effect of foliar application with indole acetic acid (IAA) and kinetin on cotton yield and some yield components in 2007 and 2008 seasons.

Treatments	Boll weight (gm)		Seed cotton yield (kentar/fad.)		Earliness %		Lint %		Seed index (gm)	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Control	2.54	2.61	8.11	7.01	61.5	63.8	40.11	40.77	10.1	10.6
25 ppm IAA	2.58	2.57	9.09	7.56	58.9	64.8	39.87	40.55	10.4	11.0
50 ppm IAA	2.56	2.77	8.65	7.76	57.1	61.1	39.72	40.23	10.3	10.8
10 ppm kinetin	2.66	2.79	8.62	7.72	62.0	65.9	40.21	39.83	10.0	10.9
20 ppm kinetin	2.65	2.73	8.83	7.79	63.9	66.1	40.12	39.79	10.2	10.3
25 ppm IAA + 10 ppm kinetin	2.59	2.66	8.98	7.42	60.4	62.2	40.07	39.66	10.3	10.5
25 ppm IAA + 20 ppm kinetin	2.56	2.72	9.15	7.89	61.6	61.8	39.82	39.86	10.4	10.5
50 ppm IAA + 10 ppm kinetin	2.66	2.67	8.74	7.65	60.1	64.6	39.64	39.14	10.2	10.6
50 ppm IAA + 20 ppm kinetin	2.55	2.74	8.69	7.36	58.1	63.0	39.75	39.89	10.4	10.3
L.S.D. at 5%	**NS**	**NS**	**0.66**	**NS**	**4.2**	**NS**	**NS**	**NS**	**NS**	**0.4**

The significant reduction in earliness% obtained by the treatment of 50 ppm IAA could be a result of its enhancing effect on plant vegetative growth which might delay crop maturity. However, Wahdan, (2000) reported that IAA at high concentrations (75 and 100 ppm) enhanced vegetative growth at the expense of fruiting growth, but it increased earliness%. The obtained increase in seed cotton yield and seed index could be attributed to the positive effects of IAA and Kinetin on reducing bud and boll shedding likely through increasing the supply of photosynthesis and nutrients to the developing bolls during boll filling stage. Boll retention is important for cotton yield since it may determine number of open bolls, the most important yield component in cotton. In this connection, maximum cotton yield is associated with management practices that provide healthy and better functioning leaves during the critical boll filling period; and growth regulators could be used to keep leaves as strong sources at the same time that plant builds up the fruiting sinks (Oosterhuis *et al,* 1990). Several investigators reported that seed cotton yield and some yield components were significantly increased by foliar application of IAA (El-Sayed & El-Menshawi, 2006 and El-Menshawi, 2008) or kinetin (El-Aggory *et al*, 1982; Sawan *et al*, 2000 and Zayed *et al*, 2005 b).

It could be concluded from results that treatments of IAA and/or kinetin induced some improvement in cotton growth and productivity with the most consistently positive responses were given by the application of 25 ppm IAA and 20 ppm kinetin either separately or combined.

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إستجابة نمو ومحصول القطن للرش بمنظمي النمو إندول حمض الخليك و الكينيتين

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أقيمت تجربتان حقليتان بمحطة البحوث الزراعية بسدس، محافظة بني سويف، في موسمي ٢٠٠٧ و ٢٠٠٨، بهدف دراسة إستجابة نمو وإثمار ومحصول القطن صنف جيزة ٨٠ للرش بإندول حمض الخليك أو الكينيتين أو كلاهما. شملت الدراسة تسعة معاملات نتجت من رش إندول حمض الخليك بمفرده بتركيزيين (٢٥ و ٥٠ جزء في المليون) والكينيتين بمفرده بتركيزيين (١٠ و ٢٠ جزء في المليون) وكذلك التوافيق بينهما، بالإضافة لمعاملة المقارنة (بدون رش)، و تم رش هذه المعاملات مرتين (عند بداية وقمة التزهير)، وكان التصميم التجريبي المستخدم هو القطاعات الكاملة العشوائية في أربعة مكررات.

ويمكن تلخيص أهم النتائج فيما يلي:

أظهرت جميع معاملات إندول حمض الخليك والكينيتين زيادة معنوية في محتوى الأوراق من كلوروفيل أ ، ب والكلوروفيل الكلى مقارنة بمعاملة المقارنة. إلا أن بعض هذه المعاملات أعطت زيادة معنوية في طول النبات و عدد الأفرع الثمرية للنبات وعدد اللوز المتفتح للنبات في كلا الموسمين، و في عدد عقد الساق الرئيسي ومحصول القطن الزهر/فدان في موسم ٢٠٠٧ فقط، و في عدد المواقع الثمرية الكلية للنبات و معامل البذرة في موسم ٢٠٠٨ فقط، وكذلك إلى نقص معنوي في النسبة المئوية للتبكير وتساقط الأعضاء الثمرية في موسم ٢٠٠٧ فقط. أدى الرش بإندول حمض الخليك بتركيز ٥٠ جزء في المليون بمفرده إلى نقص معنوي في النسبة المئوية للتبكير، سواء بمفرده أو مع رش الكينيتين بأي من التركيزيين أعطى أعلى قيم لصفات النمو الخضري للنبات و لكنه أظهر زيادة غير معنوية في محصول القطن الزهر/فدان.

وبشكل عام تم الحصول على أفضل النتائج من رش إندول حمض الخليك بتركيز ٢٥ جزء في المليون بمفرده أو رش الكينيتين بتركيز ٢٠ جزء في المليون أو رش كلاهما معاً حيث أعطت هذه المعاملات أقل نسبة مئوية لتساقط الأعضاء الثمرية وأعلى عدد للوز المتفتح للنبات و أعلى محصول للقطن الزهر/فدان خلال موسمي الدراسة.