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EFFECT OF SOME FOLIAR ANTIOXIDANT TREATMENTS ON GROWTH AND PRODUCTIVITY OF COTTON GROWN IN UPPER EGYPT

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ABSTRACT

The present study was carried out at the Experimental Farm of Mallawi Agric. Res. Station , Minia, in 2005 and 2006 seasons, to investigate the responses of cotton cultivar Giza 83 grown in upper Egypt to some foliar treatments of ascorbic acid (vitamin C) and citric acid , both were applied twice , at the start and peak of flowering, at the concentrations of 250 , 500 and 1000 ppm, using tap water as control. The obtained results could be summarized as follows :

Foliar application of ascorbic acid (AA) at the concentration of 500 ppm resulted in significant increases in leaves content of chlorophyll a, b and carotenoids , plant height, number of open bolls /plant and seed cotton yield in both seasons, numbers of main stem nodes and fruiting branches /plant and boll weight in 2006 season, and it decreased fruit shedding % in 2005 season only in comparison with the control. Similar trend was obtained by 1000 ppm AA but the differences with the control were not always significant, and it significantly decreased earliness % in both seasons. The concentration of 250 ppm AA significantly increased leaves content of chlorophyll b and plant height in 2006 season only.

Citric acid (CA) at the concentrations of 500 and 1000 ppm significantly increased leaves content of chlorophyll a , number of open bolls /plant in the two seasons , plant growth parameters and boll weight in 2006 season, and seed cotton yield in 2005 season. Only 1000 ppm CA significantly increased seed cotton yield and decreased fruit shedding % in the two seasons, while 250 ppm CA exerted no significant effects on all studied traits in both seasons.

It could be concluded from results of this study that most used treatments of ascorbic acid and citric acid improved growth and fruiting performance of cotton plants grown under the naturally occurring climatic conditions of upper Egypt, however, the most consistently positive effects and the best results in general were obtained by spraying ascorbic acid at the concentration of 500 ppm or citric acid at the concentration of 1000 ppm.

INTRODUCTION

It is well accepted that cotton yield is largely dependent upon the environment in which it is grown and the management practices of the cropping systems . Under stressful environments , fruiting performance and yield of cotton plants are markedly limited . Recently , it has universally realized that the biosphere as a whole is becoming increasingly stressed , which would put more pressure on crop plants and researchers attempting to improve their productivity .

Cotton plants grown under the naturally occurring climatic conditions of upper Egypt are usually experience periods of high temperature, excess solar radiation and low relative humidity. Such high evapotranspirative demand conditions often further cause mid-day water stress even in wellwatered cotton plants. Sawan *et al*(2004) reported that fruit production and retention of Egyptian cotton were negatively correlated with high evaporation rate, long sunshine duration and low minimum humidity value. Although, cotton is a "sun loving" plant originated in hot climate , recent studies have shown that low cotton yield is strongly correlated with high air temperature above 36 C° (Bibi *et al* , 2008) and excess sunlight especially ultraviolet-B radiation(Kakani *et al* , 2003 and Zhao *et al*, 2005), both climatic variables are predicted to globally increase in the near future .

Irrespective to the varied negative effects for environmental stresses on plant at morphological and physiological levels, the major cause of reduced plant productivity under biotic or abiotic stresses is oxidative damage at the cellular level (Allen, 1995). Stress-mediated oxidative damage occurs via increasing level of cellular oxidants which are collectively known as reactive oxygen species (ROS) such as O^{-}_2 , $^1O_2$, OH^- and H_2O_2 (Noctor and Foyer , 1998 and Cothren , 1999) . ROS are extremely reactive and cytotoxic in plants and potentially damage all classes of biologically important cellular molecules (Alschar *et al*, 1997 and Baier and Dietz, 1999). Oxidative stress is a term commonly used to describe the adverse effects of ROS on plants (Mahan and Mauget, 2005). Oxidative stress is induced by a wide range of environmental stresses such as temperature extremes, intense solar radiation, water stress, pathogens and air pollutants(Cothren, 1999). Therefore, cotton plants grown in upper Egypt are prone to suffer from oxidative stress, which may be a cause for the frequently observed yield reduction in this region.

As immobile organisms that can not escape from various stresses, higher plants have evolved several stress-relif mechanisms including a network of antioxidants such as ascorbate, glutathione, tochopherol, carotene and many others, which considered the first line of defense against oxidative stress through metabolizing ROS and keeping them under control (Noctor and Foyer, 1998 and Anderson *et al*, 1997) . The term antioxidant describe any compound capable of quenching ROS with itself undergoing conversion to a destructive radical (Noctor and Foyer, 1998). However, exposing plants to adverse environmental conditions greatly increased ROS to reach the level that exceeds the scavenging capacity of the antioxidant system , causing oxidative damage (Alscher *et al* , 1997).

Under such situations enhancing the cellular antioxidant status could help balance the redox homeostasis in cells and, thereby minimize the oxidative damage under adverse environmental conditions(Alschar *et al*, 1997 and Baier and Dietz , 1999) . Zhao and Zou (2002) reported that the exogenous application of antioxidants might be a simple and effective way to increase the stress tolerance of plants . Also , Payton *et al* (2001) reported that enhancing chloroplastic antioxidant enzymes may improve cotton yield in temperate regions with large temperature diurnal fluctuations and high light intensity .

Ascorbic acid (AA) is an exceptional antioxidant that reacts with oxidizing agents much more readily than anything else and mops them up before they have a chance to damage anything(Foyer, 1993). It is a strong reductant that services in cells as electron doner , reducing and thus , running the risk of many different compounds including metal ions (Smirnoff, 1996). Under high irradiance stress, when the photon absorbed by leaves exceeds their utilizing capacity in CO_2 assimilation , AA plays an important role in photoprotection through its involvement in dissipating the excess exciting energy to heat by xanthophyll cycle (Smirnoff, 1996 and Baier and Dietz , 1999). Thus , many reports indicate that AA provides remarkable protective effects against various biotic and abiotic stresses (Foyer, 1993; Smirnoff, 1996 and Alschar *et al* 1997) . Furthermore , Arrigoni and De Tullio (2002) stated that AA is not just an antioxidant, but it much more than that . It acts as a co-factor for many enzymes. Much evidence has suggested that AA affects biosynthesis , levels and signalings of many phytohormones including ethylene , gibberellic acid and abscissic acid . Therefore , AA has a proposed roles in regulating many physiological and developmental processes including photosynthesis , cell division and growth , flowering and senescence (Barth *et a*l , 2006) . Many studies indicated that foliar application of AA exerted positive effects on leaves content of photosynthetic pigments , growth and yield of cotton (Dhopte, 1990; Ghourab and Wahdan, Gamalat, 2000 ; El-Shazly and El-Morsi , 2003 and Namich , Alia, 2006).

Citric acid is an organic compound belonging to the family of carboxylic acids which are known as plant growth stimulators, mainly through acting as nutrient absorption enhancers (Kinnersley *et al*, 1990) . Citric acid (CA), through its involving in the tricarboxylic acids cycle, has a role in the respiratory , nutritional and growth processes in plants. Organic acids, such as citrate, enhance nutrients uptake by plants, phosphorus in particular. They could chelate, forming stable complexes with, metal ions especially aluminium, and mitigate their toxicity (Meriga *et al*, 2003). Citric acid is found in large amounts in cotton plant especially in leaves with increasing its level under water stress, suggesting a role in osmoregulation (Timpa *et al*, 1986). CA as a natural and organic antioxidant has auxinic action. It was reported that foliar application of CA or AA improved growth and productivity of some legume crops (Abd-Allah *et al* , 2007). Also, external treatment of cotton plants with CA stimulated plant growth (Malic and Singh, 1982 and Saeed, 2000), and increased cotton yield and its components (Ghourab, 2000 and Saeed, 2000).

In the light of the above findings, the present study was carried out to explore the effect of foliar application of ascorbic acid and citric acid on growth and fruiting performance of the cotton cultivar Giza 83 grown under the naturally occurring climatic conditions of upper Egypt.

MATERIALS AND METHODS

Two field experiments were conducted at Mallawi Agric. Res. Station , Minia governorate , upper Egypt , in 2005 and 2006 seasons , to study the effect of foliar application of ascorbic acid and citric acid on leaves content of photosynthetic pigments, fruiting and yield of the cotton cultivar Giza 83 . A randomized complete block design in four replicates was used . Plot area was 13 m^2 , including 5 ridges , 4 m long and 65 cm apart . Sowing date was in the last week of March in both seasons . Ascorbic acid and citric acid were sprayed twice , at the start and peak of flowering, at the concentrations of 250 , 500 and 1000 ppm , using tap water as control . Standard agricultural practices were followed throughout the growing seasons .

In 2006 season , samples of the fourth leaves form the stem apex were collected 15 days after the second application of antioxidants to determine leaves content of the chlorophylls a and b (Arnon , 1949) and carotenoids (Roblen , 1957).

At harvest , 6 representative plants from the central ridge of each plot were chosen to estimate ; plant height , number of main stem nodes , number of fruiting branches per plant , numbers of aborted and total fruiting sites per plant . Fruit shedding % was calculated as (aborted fruiting sites ÷ total fruiting sites) x 100 . Earliness % was calculated as (1^{st} pick yield ÷ total yield) x100 . Seed cotton yield in kgms per plot was transformed to kentras per faddan . Samples of 25 harvestable bolls were randomly collected from each plot to estimate boll weight , lint % and seed index .

The collected data were subjected to statistical analysis according to Gomez and Gomez (1984) , using LSD in treatments comparison.

Table (1) :Averages of some climatic factors at Minia region in 2005 and 2006 seasons .

Month and days	2005					2006				
	Field air temperature (C)		Relative humidity (%)		Evaporation (mm/24 h)	Field air temperature (C)		Relative humidity (%)		Evaporation (mm/24 h)
	max.	main	min.	main		max.	main	min.	main	
May	43.2	28.1	24	68	11.1	46.0	31.1	31	54	11.3
June 1-10	44.9	31.0	26	51	13.3	46.9	31.8	28	53	12.8
June 11-20	46.7	32.3	23	46	12.7	44.2	32.0	28	56	11.2
June 21-30	45.2	31.8	26	54	13.0	47.7	34.0	28	51	15.0
July 1-10	46.7	32.8	27	58	10.8	47.5	33.0	26	58	11.8
July 11-20	45.1	32.7	32	65	11.6	46.9	32.7	26	59	11.5
July 21-31	49.2	34.3	29	57	10.5	50.6	35.7	27	58	10.2
August 1-10	48.5	34.6	30	64	10.2	45.7	32.1	32	64	10.3
August11-20	45.2	32.6	32	70	10.1	47.4	32.7	29	65	8.9
August 21-31	43.7	31.5	30	67	11.4	47.8	33.8	30	66	9.6
September	40.8	28.4	27	62	8.9	41.0	30.4	29	65	9.9

Source : Mallawi Meteorological Station .

RESULTS AND DISCUSSION

Results shown in Table (2) demonstrate that various antioxidant treatments improved leaves content of photosynthetic pigments in comparison with the control, however, the significant increases in chlorophyll a, b and carotenoids were obtained by the application of ascorbic acid (AA) at 500 and 1000 ppm only. Spraying 250 ppm ascorbic acid significantly increased leaves content of chlorophyll b only. Citric acid (CA) at the concentrations of 500 and 1000 ppm significantly increased chlorophyll a only.

With regard to effect of antioxidants on plant growth parameters (shown in Table 2), it is clear that most of antioxidant treatments positively affected plant growth as compared with the control. In 2005 season, only plant height was significantly increased by 500 and 1000 ppm ascorbic acid and 1000 ppm citric acid. In 2006 season, all used antioxidant treatments except for 250 ppm citric acid significantly increased plant height, number of main stem nodes and number of fruiting branches per plant in comparison with the control.

Table (2) : Effect of foliar application of ascorbic acid (AA) and citric acid (CA) on photosynthetic pigments (mg/g dry weight) and some plant growth parameters in 2005 and 2006 seasons.

Antioxidant treatments	Chlorophyll		Carotenoids	Plant height (cm)		No. of main stem nods		No. of fruiting branches/plant	
	a	b		2005	2006	2005	2006	2005	2006
Control	4.52	1.67	0.64	92.7	113.5	23.8	26.5	14.2	16.1
AA at 250 ppm	4.79	1.84	0.71	94.3	119.5	24.3	27.9	14.5	17.8
AA at 500 ppm	5.11	1.88	0.80	97.4	121.4	25.0	28.3	14.9	18.4
AA at 1000 ppm	4.88	2.13	0.84	96.9	122.3	24.8	28.0	14.5	18.0
CA at 250 ppm	4.64	1.75	0.62	95.9	118.3	23.5	27.5	14.5	17.0
CA at 500 ppm	4.91	1.80	0.69	96.2	121.9	24.5	28.5	14.9	18.1
CA at 1000 ppm	4.90	1.80	0.72	98.5	119.9	25.3	27.9	15.1	17.7
LSD 5%	0.31	0.15	0.09	4.1	5.7	N.S.	1.4	N.S.	1.5

Table (3) : Effect of foliar application of ascorbic acid (AA) and citric acid (CA) on cotton plant fruiting, yield and some yield components in 2005 season.

Antioxidant treatments	Open bolls /plant	Non-open bolls/ plant	Aborted fruiting sites/plant	Total fruiting sites/plant	Fruit shedding %	Boll weight (gm)	Seed cotton yield (ken./f)	Earliness %	Lint %	Seed index (gm)
Control	13.0	3.7	7.9	24.5	33.2	2.63	9.94	71.2	42.0	9.9
AA at 250 ppm	13.8	4.3	6.9	25.0	27.6	2.66	10.21	69.5	41.4	10.2
AA at 500 ppm	14.9	4.0	6.6	25.5	25.9	2.71	10.72	68.9	41.4	10.2
AA at 1000 ppm	14.3	4.4	7.5	26.2	28.6	2.71	10.42	66.5	41.5	10.8
CA at 250 ppm	13.8	3.5	6.8	24.1	28.2	2.73	10.15	72.2	41.8	10.0
CA at 500 ppm	14.6	4.0	6.9	25.5	27.1	2.72	10.51	70.7	41.4	10.2
CA at 1000 ppm	14.9	4.6	7.1	26.6	26.7	2.71	10.76	67.7	41.5	10.2
LSD 5%	1.2	N.S.	N.S.	N.S.	5.3	N.S.	0.51	4.5	N.S.	N.S.

Data presented in Tables (3 and 4) reveal that foliar application of 500 or 1000 ppm of either ascorbic acid or citric acid increased number of open bolls per plant and seed cotton yield per faddan in both seasons and boll weight in 2006 season only but decreased fruit shedding % in 2005 season, however, the significant differences were inconsistent in comparison with the control. The concentration of 250 ppm of both antioxidants exhibited no significant effects on plant fruiting and productivity in the two seasons. Earliness % was significantly decreased only by ascorbic acid at 1000 ppm only in both seasons. Various antioxidant treatments exerted no significant effects on numbers of non open bolls, aborted and total fruiting sites /plant, lint % and seed index in the two studied seasons.

Table (4) : Effect of foliar application of ascorbic acid (ASA) and citric acid (CA) on cotton plant fruiting, yield and some yield components in 2006 season.

Antioxidant treatments	Open bolls /plant	Non-open bolls/ plant	Aborted fruiting sites/plant	Total fruiting sites/plant	Fruit shedding %	Boll weight (gm)	Seed cotton yield (ken./f)	Earliness %	Lint %	Seed index (gm)
Control	13.3	5.1	9.0	27.4	32.8	2.56	10.28	58.9	41.2	10.5
AA at 250 ppm	14.3	4.9	8.4	27.6	30.4	2.63	11.05	55.0	41.0	10.6
AA at 500 ppm	15.3	6.6	8.6	30.5	28.2	2.68	11.64	54.7	41.2	10.5
AA at 1000 ppm	14.5	6.1	9.2	29.8	30.9	2.66	11.25	52.8	41.3	10.7
CA at 250 ppm	13.9	5.9	7.9	27.7	28.5	2.66	10.77	56.3	40.8	10.5
CA at 500 ppm	14.9	6.0	8.8	29.7	29.6	2.68	10.84	55.7	41.1	10.8
CA at 1000 ppm	15.5	5.8	8.8	30.1	29.2	2.70	11.43	54.3	40.9	10.7
LSD 5%	1.4	N.S.	N.S.	N.S.	N.S.	0.11	0.81	5.5	N.S.	N.S.

Summing up the results of this study, it could be concluded that most of the applied treatments of ascorbic acid and citric acid enhanced leaves content of photosynthetic pigments, plant growth , fruiting and yield. However, the most consistently positive effects and best results in general were obtained by the application of 500 ppm ascorbic acid and 1000 ppm citric acid . The climatic conditions under which the present study was performed are characterized by a frequent waves of high temperature, low relative humidity and high evaporation rate (Table 1) along with high light intensity, which all often accompany water stress. Fruiting of cotton plants subjected to such stressful conditions may be negatively affected. Similar results were obtained by Sawan *et al* (2004). Many reports indicate that high temperature causes leaf damage and premature senescence, and favors photooxidative carbon cycle (photorespiration) over photo-reductive one (photosynthesis), causing carbohydrate shortage (Hake and Silvertooth, 1990). It also adversely affects pollination, fertilization and seed set, resulting in reduced seed numbers and lower cotton yields (Bibi *et al*, 2008).

Also, high light intensity might result in damage to plants when the absorbed photon energy exceeds that utilized in carbon reduction, then, the surplus excitation energy , unless harmlessly dissipated, it could be transduced to destructive ROS(Baier and Dietz, 1999).The environmental stresses which limit photosynthesis such as temperature extremes and water stress, via increasing excess photon energy, can increase the damage caused by intense radiation . Much of the injury to plants under such stresses arises from oxidative damage at the cellular level through increasing the production of reactive oxygen species(ROS) which have the potential to generate a cascade of uncontrolled destructive oxidation (Allen,1995). These adverse effects may explain the lower photosynthetic pigments, growth and yield of the untreated control plants than those of antioxidants-treated cotton plants obtained in this study.

Numerous studies have shown that antioxidants are the first line in the defense against oxidative stress and enhancing the antioxidant status, by either genetic manipulation or exogenous application, can help in improving plants tolerance to various causes of oxidative stress, preserving the photosynthetic apparatus and other cellular biochemical and physiological activities under stress conditions(Foyer, 1993; Payton *et al*, 2001 and Zhao *et al*, 2005). Results of this study reveal that cotton plants treated with AA or CA exhibited higher leaves content of photosynthetic pigments than those of control plants. Many researchers obtained similar results using AA(Dhopte, 1990; Ghourab and Wahdan , Gamalat, 2000 and Namich, Alia, 2006) or using CA (Ghourab, 2000 and Saeed, 2000). This may be attributed to the well known role of antioxidants in providing the structural integrity of the photosynthetic apparatus under stressful conditions (Zhao and Zou 2002).

In relation to enhancing effects of both AA and CA on growth of cotton plants observed in the present study, it may be worth to mention that vitamins and organic acids are considered as non-hormonal plant growth promoters. More importantly, it is suggested that antioxidants , as environmentally friendly and cheap compounds ,could be beneficial in substituting the synthetic auxins in enhancing plant growth and productivity (Abd-Allah *et al*, 2007). AA through acting as antioxidant, enzyme co-factor and in electron transport, it plays a role in photosynthesis (Smirnoff, 1996), and cell division and elongation (Barth *et al*, 2006). Similar results indicated that AA promoted growth of cotton plant(Ghourab and Wahdan, Gamalat, 2000 and Namich, Alia, 2006). Similarly, citric acid, as organic antioxidant that has auxinic action, was reported to increase growth of cotton plant (Malic and Singh , 1982 and Saeed, 2000).

The increases in cotton yield and yield components obtained in this study by spraying ascorbic acid or citric acid could be a result of their responding increases in leaves content of photosynthetic pigments and growth parameters which may be reflected as improvements in plant fruiting performance and yield. It could be implied that the used antioxidant treatments minimize the damage of the prevailing unfavorable conditions at the cellular level leading to higher fruiting efficiency of plants. It was reported that cotton plants treated with ascorbic acid showed lower boll shedding % , and higher open bolls ,boll weight and seed cotton yield (El-Shazly and El-Morsi, 2003 and Namich , Alia, 2006). Meanwhile, Saeed (2000) and Ghourab (2000) found that foliar application of citric acid increased number of total and open bolls per plant , boll weight and seed cotton yield.

It could be concluded from the results of this study that most used treatments of ascorbic acid and citric acid improved growth and fruiting performance of cotton plants grown under the naturally occurring climatic conditions of upper Egypt, however, the most consistently positive effects and the best results in general were obtained by spraying ascorbic acid at the concentration of 500 ppm or citric acid at the concentration of 1000 ppm.

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تأثير المعاملة الخضرية ببعض معاملات مضادات الأكسدة على نمو وإنتاجية القطن تحت ظروف الوجه القبلي

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معهد بحوث القطن، مركز البحوث الزراعية، الجيزة، مصر

أقيمت تجربتان حقليتان بمحطة البحوث الزراعية بملوي خلال موسمي الزراعة ٢٠٠٥ و ٢٠٠٦، بهدف دراسة تأثير الرش بحمض الأسكوربيك وحمض الستريك على نمو وإنتاجية صنف القطن جيزة ٨٣ تحت الظروف المناخية للوجه القبلي. تم رش مضادى الأكسدة مرتين (الأولى عند بداية التزهير، والثانية عند قمة التزهير) بثلاثة تركيزات لكل منها (٢٥٠، ٥٠٠، ١٠٠٠ جزء فى المليون). وكانت أهم النتائج كما يلى:

أدى الرش بحمض الأسكوربيك بتركيز ٥٠٠ جزء فى المليون إلى زيادة معنوية فى كل من محتوى الأوراق من كلوروفيل أ ، ب ،والكاروتينات ، وطول النبات وعدد اللوز المتفتح للنبات ومحصول القطن الزهر للفدان فى كلا الموسمين ، وعدد عقد الساق الرئيسى وعدد الأفرع الثمرية للنبات ووزن اللوزة فى موسم ٢٠٠٦ فقط ، وإلى نقص معنوى فى ٪ لتساقط الثمار فى موسم ٢٠٠٥ فقط . كما أدى الرش بحمض الأسكوربيك بتركيز ١٠٠٠ جزء فى المليون إلى نفس التأثيرات السابقة ولكن الفروق مع معاملة المقارنة لم تكن معنوية دائماً ، كذلك أظهر هذا التركيز نقص معنوى فى٪ للتبكير فى كلا الموسمين . أعطى الرش بتركيز ٢٥٠ جزء فى المليون زيادة معنوية فى محتوى الأوراق من كلوروفيل ب وطول النبات فى موسم ٢٠٠٦ فقط.

أظهر الرش بحمض الستريك بتركيز ٥٠٠ أو ١٠٠٠ جزء فى المليون إلى زيادة جوهرية فى كل من محتوى الأوراق من كلوروفيل أ، وعدد اللوز المتفتح للنبات فى كلا الموسمين، وكل صفات النمو ووزن اللوزة فى موسم ٢٠٠٦ فقط ، ومحصول القطن الزهر للفدان فى موسم ٢٠٠٥ فقط ، بينما أعطى التركيز ١٠٠٠ جزء فى المليون فقط زيادة معنوية فى محصول القطن الزهر للفدان ونقص معنوى فى ٪ لتساقط الثمار فى كلا الموسمين . لم يكن للتركيز ٢٥٠ جزء فى المليون أى تأثير معنوى على كل الصفات تحت الدراسة فى كلا الموسمين.

يمكن أن نستخلص من نتائج هذه الدراسة أن معظم معاملات حمضي الأسكوربيك والستريك أظهرت تأثيراً إيجابيا علي نمو وإثمار نبات القطن تحت الظروف المناخية للوجه القبلي غير أن أفضل النتائج تم الحصول عليها بالمعاملة بحمض الأسكوربيك بتركيز ٥٠٠ جزء فى المليون أو بحمض الستريك بتركيز ١٠٠٠ جزء فى المليون.