6 *Egypt. J. Agron.* **Vol. 45**, No. 1, pp. 81-97 (2023)

Egyptian Journal of Agronomy
http://agro.journals.ekb.eg/

Effect of Spraying Phosphoric acid and Ascorbic Acid on Cotton Productivity under Delayed Sowing Date

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COTTON sowing date is the main management procedure that controlled on yield and fiber quality. Delaying sowing date exposed cotton plants to high temperature during the whole growing seasons that due to shorter growth period and decrease yield. The experiment was conducted at Sakha Research Station of Plant Physiology Department, Cotton Research Institute, Agricultural Research Center, Kafr El-Sheikh, Egypt. The experiment design was split-plot with three replications, which main plots were included sowing date of early and delayed. The sub-plots were randomly of spraying phosphoric acid (PA) at 3000-6000 ppm and ascorbic acid (ASA) at 200-400ppm concentrations twice at squaring and flowering stages to cognition the effect of sowing date, foliar applications and their interaction effect on leaves chemical constituents, growth characteristics, yield and fiber properties of Giza 97 cotton cultivar during 2021 and 2022. The results examined that delayed cotton sowing date reduced chemical constituents, growth characteristics and yield components compared to early date. Spraying ASA and PA statically enhanced all studied parameters, which the best means recorded by sprayed ASA (400ppm) then PA (3000ppm) compared to untreated plants. The interaction between the two factors significantly improved almost studied parameters, which exogenous ASA (400ppm) gave the maximum values then PA (3000ppm) comparing to control plants with both sowing dates. Overall, the positive effects of ASA and PA due to their physiological roles in chlorophyll biosynthesis, enhancing photosynthesis rate and plant productivity.

Keywords: Ascorbic acid, Cotton, Delayed sowing date, Leaves chemical constituent, Growth and yield components, Phosphoric acid.

Introduction

Egyptian cotton (*Gossypium barbadense* L.) is known as extra-long staple and high fiber quality properties in the world. Cotton is use as animal's feed, food as oil and fiber in textile industry. The majority of Egyptian cotton growers accustomed to delay cotton sowing date after March for waiting winter crops harvesting that due to miss up the suitable cotton sowing date. Most annual areas of cotton in Egypt were sown over late May to early June cause of long duration interval of winter crops such as barseem and wheat (Abdalla & Abd-El-Zaher, 2012; Omar et al., 2018).

Cotton sowing date is a major management option to diminish the effects of abiotic factors such as high temperature, drought and oxidative conditions (Attia et al., 2016; Hassan et al., 2020). Early cotton sowing date confronts the hottest period only through bolls maturity stage that due to rapid loss of bolls moisture and opening naturally. However, delayed cotton sowing date exposes plants to high temperature during squaring, flowering and bolls maturity stages, due to shorter growth period and reduces cotton yield and quality (Huang, 2016; Iqbal et al., 2021). The optimum cotton sowing date had increased plants nutrition resources and improved its net assimilation in reproduction, growth and yield.

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Received 21/12/2022; Accepted 01/05/2023
DOI: 10.21608/AGRO.2023.182398.1352

In turn, early sowing date exposed cotton plants to suitable mean temperature and heat units that created a suitable balance between vegetative growth and fruiting development comparing with delay sowing date. Conversely, delayed sowing date plants had fastened growth, especially in a count of high temperature conditions, increased plants growth over respiration rate thus due to decrement leaves carbohydrate content and finally cotton yield (Mahdy et al., 2017). Moreover, early sowing date increased crops fruiting branches by 32% than the delayed date by allowing available resources to easily enter the plant early during the season (Khan et al., 2017; Sankaranarayanan et al., 2020). Ibrahim & Hamoda (2021) revealed that delayed sowing date of Egyptian cotton significantly reduced yield components (number of open bolls/plant, boll weight, lint % and cotton yield/fed). Elayan et al. (2015) mentioned that delayed sowing date pushed cotton plants for an early flowering and maturity, and also it decreased cotton yield and its components.

Temperature is also controlling cotton plant growth rate and development. The ideal temperature for cotton growth ranges from 27–29°C and 25.5°C. Cotton crop is generally sown under semiarid conditions, wherever maximum day temperature up to 48–50°C. Increasing temperature above optimum degree (30°C) stimulated the oxidative condition and its product of reactive oxygen species (ROS). High temperature conditions reduced several physiological processes such as carbon assimilation and leaves chlorophyll content (Lokhande & Reddy, 2014; Ibrahim et al., 2022). Cotton net photosynthesis was least either in higher or lower temperatures than at ideal (30°C). High temperature reduces net photosynthesis, whereas increases photorespiration rates that decrease net carbon gain in cotton (C3 species) (Loka & Oosterhuis, 2010). Consequently, cotton sowing date significantly affects stem carbohydrate content of cotton seedling, increase with early sowing date than delayed date. High night temperatures increase plant respiration and decrease carbohydrate content during cotton plant growth and decrease its yield. Moreover, high temperature above (35-40°C) decrease elongation of fruiting branch, cause male sterility in flowers and increase boll shedding in the late cotton fruiting season (Huang, 2016; Sarwar et al., 2018).

Exogenous application is an important crop managing strategy of delaying sowing date by maximizing growth and productivity. Foliar application of osmoprotectants can mitigate the harmful impacts of abiotic stresses and improve plant tolerance to stress conditions such as drought, salinity and high temperature.

Phosphorus (P) is a very important macro-element in cotton production after nitrogen (N), whereas its resources are limited worldwide. Cotton growth needs nutrients' availability and enduring supply during the growing season. Cotton yield increased significantly for available nutrients, especially P (Iqbal et al., 2020). Phosphorus has a life-limiting element in natural ecosystems cause of binding to insoluble compounds and becomes unavailable for plant uptake. Phosphorus is a very important element for several biological processes such as enzymes activity, cycles of biosynthesis and entering in the composition of nuclear acids, amino acids and fatty acids. Phosphorus enters in the formation of many important compounds in plant cells, includes photosynthesis, sugar phosphates shared in respiration, phospholipids of plant membranes, and enters in the formation of nucleotides used in molecules of DNA and RNA and in plant energy metabolism. Phosphorus is also an essential nutrient for chlorophyll biosynthesis as pyridoxal phosphate. Phosphorus is necessary for cell division and development of tissue. Phosphorus deficiency decrease leaf expansion rate and photosynthesis rate. The high $CaCO_3$ quantities and high soil pH (>7.6) result in sedimentation of P, which decrease the soluble P supply (Sawan et al., 2008; Saleem et al., 2010; Mai et al., 2018). Zewail et al. (2011) unveiled that phosphoric acid (PA) foliar application significantly improved chemical constituents (total carbohydrates, total free amino acids and crude protein), growth characteristics and yield components, whereas enzymes activity and total phenol content decrease compared to control of plant. Emara & Abd El-All (2017) observed that PA application improved relative water content, chlorophyll pigments, total sugars, and proline contents in cotton leaves. P significantly increased yield and yield components, while fiber quality generally insignificantly affected by PA application (El-Desouky et al., 2001).

Ascorbic acid (ASA) is an organic molecule that is necessary for sanitary plant metabolism and growth. Plant requires ASA in trace amount for flourish and different biological processes, which it acts as growth regulator, antioxidant, enzyme cofactor and redox buffer (Rehman & Wei, 2022).

ASA is existed in all plant cells; accumulate in the leaves and flowers, where the plant is actively growing. ASA is an essential molecule shared in osmotic regulation and cell division (Smirnoff, 2018). ASA effects on phyto-chormone mediated signaling processes through the reproductive transition, final stage of development and senescence. It is a critical component in electron transport system of plants (Gul et al., 2015; Desoky & Merwad, 2015; Kamal et al., 2017; Thomson et al., 2017). Exogenous application of ASA gave healthy plants, enhancing plant ability for elements uptake and improved cotton growth and productivity (Omar et al., 2018). Azoz et al. (2016) stated that spraying ASA (200 and 300ppm) significantly improved the growth characteristics and yield components of plant. Sarwar et al. (2018) revealed that exogenous of ASA (100ppm) improved chlorophyll content in plant under stress conditions.

The main objective of this study aim to recognize the effect of sowing date (early and delayed) and detect the positive effect of foliar application treatments of PA at (3000 and 6000ppm) and ASA at (200 and 400ppm) concentrations on leaves chemical constituents, growth characteristics, yield components and fiber properties of Giza 97 cotton cultivar during 2021 and 2022 seasons.

Materials and Methods

Experimental design and treatments

The experiment was conducted during two seasons 2021 and 2021 at Sakha Research Station of Plant Physiology Department, Cotton Research Institute, Agricultural Research Center, Kafr El-Sheikh, Egypt situated at 31° 6´N latitude, 30° 50´E longitude, and an elevation of about 6 meters above mean sea level. A split plot design with three replications was adopted; the main plots were randomly assigned to sowing dates including early sowing date (April 25), and delayed sowing date (May 25) in both seasons. The sub-plots were randomly assigned for five treatments as follows: untreated plants (control), phosphoric acid 3000ppm and 6000ppm, ascorbic acid 200ppm and 400ppm. The main objective of this study aim to recognize the effect of sowing date and detect the positive effect of foliar application treatments of PA and ASA on leaves chemical constituents, growth characteristics, yield components and fiber properties of Giza 97 cotton cultivar during 2021 and 2022 seasons.

Plots divided into two groups *i.e.*, the first one sowed at early date and the second one sowed at delayed date. Plants were sprayed with PA and ASA twice at squaring and flowering stages, beside the untreated plots in two sowing dates.

The experimental plot consisted of 7 rows, 3.5m long and 0.6 m width (plot area= 14.70m^2). Fertilization was carried out according to recommendation of Cotton Research Institute, all plots were fertilized at a rate of 60kg N/fed in the form of urea (46.5% N) in two equal doses, the first dose was added after thinning (before the first irrigation), while the second dose was applied before the second irrigation. Phosphorus fertilizer was applied during soil preparation in form of calcium superphosphate (15.5% P_2O_5) at a rate of 15.5kg P_2O_5/fed. Potassium fertilizer was applied after thinning at a rate of 24kg K_2O/fed in the form of the potassium sulphate (48% kg K_2O). All experimental plots received irrigation and pesticide as recommended by the Egyptian Ministry of Agriculture for cotton cultivation. The soil analysis was conducted according to Chapman & Pratt (1978). Soil physical and chemical properties of the experimental field are showed in Table 1.

Source of irrigation water

The source of irrigation water of the field experiments is a sub-canal of the Nile River. The chemical analysis of irrigation water showed in Table 2.

Mean temperature and heat unit accumulations

Mean temperature and heat unit accumulations were monitored by Department of Meteorology, Agricultural Research Center. Maximum and minimum and mean air temperature (°C) in Sakha station during 2021 and 2022 seasons are shown in Table 3. The data covered the period from the start of planting to harvesting stage. Average of air temperatures (°C) through the growing seasons recorded in order to calculate heat units (HU) according to Sutherland (2012) equation as follows:

Heat unit (HU)= Mean daily temperature – Base Temp. (Base Temp.= zero growth =15.6°C).

Monthly heat units (HU) during a six-month cotton growth period in Sakha station during 2021 and 2022 seasons are showed in Table 3.

TABLE 1. Physical and chemical properties of experimental soil during 2021 and 2022 seasons

Properties		2021	2022
pH		8.06	8.04
E.C. (dsm^{-1})		3.53	3.49
Soil mechanical analysis	Clay %	52.24	53.18
	Silt %	27.39	25.92
	Sand %	20.57	19.18
Soil texture		Clayey	Clayey
Available minerals (mg/kg soil)	N	17.12	17.09
	P	23.92	23.88
	K	216.42	215.85
	Cu	7.94	7.86
	Fe	42.43	42.17
	Mn	7.75	7.62
	Zn	14.17	14.02
Soluble anions (meq/L)	CO_3^{2-}	--	--
	HCO_3^-	4.78	4.73
	Cl^-	4.49	4.27
	SO_4^{2-}	7.84	7.79
Soluble cations (meq/L)	Ca^{2+}	6.60	6.57
	Mg^{2+}	3.75	3.72
	Na^+	7.55	7.54
	K^+	0.54	0.51

TABLE 2. Irrigation water chemical properties

Properties		2021	2022
pH		7.62	7.38
E.C. (dsm^{-1})		1.16	1.09
Soluble anions (meq/L)	CO_3^{2-}	--	--
	HCO_3^-	0.67	0.58
	Cl^-	1.85	1.64
	SO_4^{2-}	0.24	0.21
Soluble cations (meq/L)	Ca^{2+}	3.54	3.42
	Mg^{2+}	1.82	1.65
	Na^+	2.71	2.49
	K^+	0.64	0.60

TABLE 3. Monthly maximum, minimum, mean temperature and monthly heat units (HU) in Sakha location station during 2021 and 2022 seasons

Months	2021					2022				
	Temperature °C			Monthly heat units		Temperature °C			Monthly heat units	
	Max	Min	Mean	Early date	Delayed date	Max	Min	Mean	Early date	Delayed date
May	32.05	16.74	24.39	263.85	--	31.72	15.94	23.83	246.90	--
June	33.94	17.82	25.88	308.40	308.40	33.26	16.68	24.97	281.10	281.10
July	36.02	19.63	27.82	366.75	366.75	35.89	18.92	27.40	354.00	354.00
August	37.79	21.88	29.83	427.05	427.05	37.16	21.35	29.25	409.50	409.50
September	35.23	20.14	27.68	362.55	362.55	34.68	19.88	27.28	350.40	350.40
October	31.78	17.95	24.86	277.95	277.95	31.25	17.34	24.29	260.70	260.70
November	29.43	16.22	22.82	--	216.75	28.93	15.73	22.33	--	201.90

Chemical analysis

Cotton samples of 4th upper leaf/plant were taken randomly after 10 days from the last sprayed time (at flowering stage) with PA and ASA to determine the chemical analysis as follows:

Total chlorophyll and carotenoids contents

Total chlorophyll (mg/g, FW) estimated by the spectrophotometric method recommended by Arnon (1949) and carotenoids of Robbelen (1957). Leaf samples (0.3g from each replicate were homogenized in 50mL 80% (v/v) acetone and centrifuged at 10,000 × g for 10min. The absorbance of each acetone extract was measured at 665, 649, and 440nm using a UV-visible spectrophotometer.

Total soluble sugars content

Total soluble sugars were determined in ethanol extract of leaves by the phenol-sulfuric acid method according to Cerning (1975). A stranded curve was prepared using different concentration (10 to 100mg/mL) of pure glucose.

Total phenols content

Total phenols were determined in ethanol of leaves using Folin-Ciocalteau method according to Simons & Ross (1971). One milliliter of sample was mixed with 1mL of Folin and Ciocalten's phenol reagent, after 3min, 1mL of saturated Na_2CO_3 (14%) was added to the mixture and completed to 10ml by adding distilled water. The reaction was kept in the dark for 90min, after which its absorbance was read at 725nm. A calibration curve was constructed with different concentrations of gallic acid (0.01–1mM) as standard.

Total free amino acids content

Total free amino acids were determined in ethanol extract of cotton leaves by ninhydrin method according to Rosen (1957).

Total soluble protein content

Total soluble proteins were estimated according to the method of Lowry- Folin as described by Dawson et al. (1986). The results are expressed (total soluble protein) as mg/g of fresh weight.

Total antioxidant capacity

Total antioxidant capacity was determined in ethanol extract of cotton leaves using the phosphomolybdenum method of Prieto et al. (1999) as follows: A known volume (0.01mL) of extract was added to test tube then completed to a constant volume (0.3mL) with DW. 3.0mL of reagent solution (0.6M sulfuric acid, 28.0mM sodium phosphate and 4.0mM ammonium molybdate) were added to each tube and mixed well then incubated at 95°C for 90min. Blank was prepared by the same procedure without extract. After cooling to room, the absorbance of the solution was measured at 695nm using spectrophotometer against blank. Increased absorbance of the reaction mixture indicated increased total antioxidant capacity.

Growth characteristics

Plant samples (whole plant) were taken after 10 days from the last sprayed time with PA and ASA (at flowering stage), 4 plants were taken from each treatment. Growth characteristics of plants were recorded for this experiment as follows: plant height (cm), number of fruiting branches/plant, plant dry weight (g), leaf area (cm^2) (determined by leaf area meter Model L1 – 3100). In addition to, relative water content was determined according to the method of Schonfeld et al. (1988).

Yield and its components

At first pick, random sample of ten guarded plants was taken and labeled from each plot to determine the following characteristics , number of opened bolls/plant, boll weight, seed index (100-seed weight), lint % (weight of lint per plant/ weight of seed cotton plant*100) and seed cotton yield/fed (kentar, i.e 157.5kg) .

Fiber quality properties

Samples of lint cotton under different treatments were tested at the laboratories of the Cotton Technology Research Division, Cotton Research Institute in Giza to determine fiber properties, under controlled conditions of 65% ± 2 of relative humidity and 21º ± 2ºC temperatures. Fiber length, fiber strength and micronaire reading were determined on digital Fibrograph instrument 630, Pressley instrument and micronaire instrument 675 respectively, according to ASTM (2012) at the C.R.I. laboratories. Analysis of variance of the obtained data of each season was performed.

Statistical analysis

The measured variables were analyzed by ANOVA using M Stat-C statistical package Freed (1991). Mean comparisons were done using least significant differences (L.S.D) method at 5% level ($P \leq 0.05$) of probability to compare differences between the means according to the method described by Snedecor & Cochran (1988).

Results

Cotton leaves chemical constituents

Data in Table 4 unveiled the effect of cotton sowing date (early and delayed), foliar application treatments (PA and ASA at squaring and flowering stages) and their interaction on leaves chemical constituents.

TABLE 4. Effect of sowing date and foliar application of phosphoric acid, ascorbic acid and their interaction on total chlorophyll, carotenoids, total soluble sugar, total free amino acid, total phenol, total soluble protein contents and total antioxidant capacity in leaves of cotton plant

Sowing date (A)	Foliar application (ppm) (B)	Total Chl. (mg/g FW)	Carotenoids (mg/g FW)	Total soluble sugars (mg/g FW)	Total phenols (mg/g FW)	Total free amino acid (mg/g FW)	Total soluble protein (mg/g FW)	Total antioxidant capacity ($O.D_{695}$ nm)
Early date (April 25)	Control	6.73	0.706	23.68	15.95	18.72	23.24	0.963
	Phosphoric acid 3000	8.86	0.912	25.92	17.62	20.83	24.73	1.217
	Phosphoric acid 6000	7.05	0.785	24.47	16.76	19.64	23.86	0.995
	Ascorbic acid 200	7.76	0.839	25.03	17.29	20.24	24.24	1.042
	Ascorbic acid 400	9.22	0.964	26.58	18.39	21.45	25.04	1.463
Mean		7.92	0.841	25.13	17.20	20.17	24.22	1.136
Delayed date (May 25)	Control	4.26	0.415	19.02	10.27	12.85	21.12	0.506
	Phosphoric acid 3000	5.83	0.593	21.85	12.50	14.63	22.37	0.752
	Phosphoric acid 6000	4.92	0.483	19.62	11.74	13.59	21.65	0.573
	Ascorbic acid 200	5.34	0.537	20.78	12.09	14.18	21.94	0.681
	Ascorbic acid 400	6.18	0.629	22.36	13.68	15.23	22.68	0.794
Mean		5.30	0.531	20.72	12.05	14.09	21.95	0.661
General mean offoliar application (B)	Control	5.49	0.560	21.35	13.11	15.78	22.18	0.735
	Phosphoric acid 3000	7.34	0.752	23.89	15.06	17.73	23.55	0.985
	Phosphoric acid 6000	5.98	0.634	22.04	14.25	16.61	22.75	0.784
	Ascorbic acid 200	6.55	0.688	22.90	14.69	17.21	23.09	0.862
	Ascorbic acid 400	7.70	0.797	24.47	16.03	18.34	23.89	1.129
LSD at 0.05 of	A	0.064	0.007	0.073	0.216	0.179	0.063	0.079
	B	0.218	0.008	0.077	0.091	0.202	0.120	0.055
	A x B	0.309	0.012	0.109	0.128	N.S	N.S	0.077

With regard to cotton sowing date early and delayed affected significantly all leaves chemical constituents (Table 4). Delaying cotton sowing date significantly reduced leaves chemical constituents of total chlorophyll by 33.08%, carotenoids by 36.86%, total soluble sugars by 17.54%, total phenols by 29.94%, total free amino acids by 30.14%, total soluble protein by 9.37% and total antioxidant capacity by 41.81% compared to early sowing date.

Considering the effect of spraying cotton plants with PA and ASA treatments, the finding in Table 4 demonstrated that the foliar application treatments statistically improved leaves chemical constituents compared to untreated cotton plants. Spraying cotton plants with ASA at 400ppm concentration achieved the highest means, followed by spraying PA at 3000ppm concentration, then ASA at 200ppm and PA at 6000ppm comparing with untreated plants.

Exogenous ASA at 400ppm concentration registered the maximum results in all leaves chemical constituents of total chlorophyll by 40.25%, carotenoids by 42.32%, total soluble sugars by 14.61%, total phenols by 22.27%, total free amino acids by 16.22%, total soluble protein by 7.71% and total antioxidant capacity by 53.6% compared with untreated cotton plants.

In contrast, the interaction between cotton sowing date and foliar application treatments, results in Table 4 mentioned that the interaction statistically affected total chlorophyll, carotenoids, total soluble sugars, total phenols contents and total antioxidant capacity, whereas the content of total free amino acids and total soluble protein insignificantly affected.

Overall, the highest means of leaves chemical constituents obtained in cotton plants sprayed by ASA at 400ppm with early sowing date, followed by PA 3000ppm then ASA at 200ppm and PA 6000ppm, compared with the untreated cotton plants.

Growth characteristics

The results in Table 5 represent that the effect of cotton sowing date (early and delayed), foliar application treatments (PA and ASA twice at squaring and flowering stages) and their interaction on cotton growth characteristics during 2021 and 2022 seasons.

Regarding the main effect of cotton sowing date (early and delayed) treatments, data in Table 5 indicated that delaying cotton sowing date significantly decreased growth characteristics, number of fruiting branches/plant by 20.9% and 21.8%, plant dry weight by 18.02% and 17.33%, leaf area by 19.43% and 20.97% and relative water content by 15.5% and 11.89%, during 2021 and 2022 seasons respectively, compared to early sowing date in both studied seasons. However, delayed sowing date significantly increased plant height by 8.78% and 8.51%, during 2021 and 2022 seasons respectively, compared to early sowing date.

As for the effect of spraying PA and ASA treatments, findings in Table 5 pointed out that spraying PA and ASA significantly enhanced all cotton growth characteristics compared to untreated plants in both seasons. Spraying ASA at 400ppm concentration recorded the best results, followed by spraying PA at 3000ppm concentration compared to untreated plants under both sowing dates.

Foliar application at ASA at 400ppm achieved the highest values in growth characteristics of plant height (148.79cm and 153.14cm), number of fruiting branches/plant (11.83 and 12.77), plant dry weight (173.68g and 187.32g), leaf area (1209.7cm^2 and 1330.26cm^2) and relative water content (66.8% and 66.81%), during 2021 and 2022 seasons respectively, comparing to untreated cotton plants.

The interaction between cotton sowing date and spraying PA and ASA treatments, the data in Table 5 cited that all cotton growth characteristics significantly affected by the interaction between their treatments. Generally, the maximum means of growth characteristics obtained by spraying ASA at 400 ppm concentration under early and delayed sowing date in both seasons.

Yield and its component

Results in Table 6 showed the effect of cotton sowing date (early and delayed), spraying treatments (PA and ASA twice at squaring and flowering stages) and their interaction on growth characteristics during 2021 and 2022 seasons.

TABLE 5. Effect of sowing date and foliar application of phosphoric acid, ascorbic acid and their interaction on growth characteristics of cotton plant during 2021 and 2022 seasons

Sowing date (A)	Foliar application (ppm) (B)	Plant height (cm)		No. of fruiting branches/plant		Plant dry weight (g)		Leaf area (cm^2)		Relative water content (%)	
		2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Early date (April 25)	Control	122.09	126.45	11.23	11.83	103.45	112.52	768.03	799.08	60.62	62.95
	Phosphoric acid 3000	137.16	142.39	13.04	13.85	154.09	163.18	1075.27	1209.74	66.58	68.40
	Phosphoric acid 6000	133.70	135.71	11.75	12.31	125.36	136.35	835.28	875.62	65.02	66.52
	Ascorbic acid 200	136.63	139.62	12.35	12.94	144.11	151.94	1015.62	1166.93	65.80	67.16
	Ascorbic acid 400	142.23	146.85	13.86	14.42	181.84	196.23	1377.90	1476.78	70.55	71.38
Mean		134.36	138.20	12.44	13.07	141.77	152.16	1014.42	1105.63	65.71	67.28
Delayed date (May 25)	Control	130.40	135.33	8.62	9.04	97.26	102.78	607.56	645.74	45.44	50.23
	Phosphoric acid 3000	152.76	155.28	10.38	10.75	139.13	145.33	943.71	977.32	60.64	64.18
	Phosphoric acid 6000	140.43	146.15	9.71	9.96	112.74	126.54	715.90	746.17	50.98	56.06
	Ascorbic acid 200	151.93	153.61	9.87	10.22	123.86	134.16	777.68	815.91	57.52	59.73
	Ascorbic acid 400	155.36	159.43	10.62	11.13	165.53	178.42	1041.50	1183.75	63.05	66.24
Mean		146.17	149.96	9.84	10.22	127.70	137.44	817.27	873.77	55.52	59.28
General mean of foliar application (B)	Control	126.24	130.89	9.92	10.43	100.35	107.65	687.79	722.41	53.03	56.59
	Phosphoric acid 3000	144.96	148.83	12.12	12.30	146.61	154.25	1009.49	1093.53	63.61	66.29
	Phosphoric acid 6000	137.06	140.93	10.73	11.13	119.05	131.44	775.59	810.89	58.00	61.29
	Ascorbic acid 200	144.28	146.61	11.11	11.58	133.98	143.05	896.65	991.42	61.66	63.44
	Ascorbic acid 400	148.79	153.14	11.83	12.77	173.68	187.32	1209.70	1330.26	66.80	68.81
LSD at 0.05 of	A	0.127	1.757	0.101	0.129	1.953	5.300	66.68	19.512	0.501	0.055
	B	1.275	2.030	0.228	0.305	2.411	6.772	51.88	35.192	0.607	0.631
	A x B	1.389	2.871	0.322	0.432	3.410	9.392	73.38	49.769	0.858	0.893

TABLE 6. Effect of sowing date and foliar application of phosphoric acid, ascorbic acid and their interaction on yield and its components of cotton plant during 2021 and 2022 seasons

Sowing date (A)	Foliar application (ppm) (B)	Plant height (cm)		No. of fruiting branches/ plant		No. of open bolls/ plant		Boll weight (g)		Seed index (g)		Lint %		Seed cotton yield (k/fed)	
		2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Early date (April 25)	Control	145.71	147.28	12.38	13.64	14.04	14.53	1.95	2.04	9.48	9.63	40.72	40.56	5.95	6.23
	Phosphoric acid 3000	160.24	162.05	15.08	15.92	16.79	17.06	2.15	2.17	10.69	10.77	39.66	39.48	7.86	8.17
	Phosphoric acid 6000	153.85	156.14	13.54	14.73	15.33	15.82	2.03	2.08	9.93	10.18	40.33	40.17	6.68	6.93
	Ascorbic acid 200	157.63	159.26	14.62	15.45	16.34	16.71	2.10	2.15	10.14	10.35	40.05	39.92	7.49	7.73
	Ascorbic acid 400	163.34	164.83	15.41	16.38	17.29	17.55	2.18	2.21	10.85	10.92	39.26	39.05	8.14	8.34
Mean		156.15	157.91	14.20	15.22	15.96	16.33	2.08	2.13	10.21	10.37	40.00	39.83	7.22	7.48
Delayed date (May 25)	Control	156.55	158.21	10.65	11.12	12.34	12.74	1.68	1.71	8.25	8.46	41.73	41.63	4.43	4.59
	Phosphoric acid 3000	177.42	179.84	13.35	13.87	15.67	15.56	1.86	1.93	9.38	9.58	41.16	41.02	6.15	6.32
	Phosphoric acid 6000	164.79	167.52	11.23	11.74	14.20	14.55	1.76	1.82	8.63	8.85	41.52	41.40	5.31	5.61
	Ascorbic acid 200	171.83	174.35	12.74	13.26	14.35	14.82	1.84	1.89	8.92	8.13	41.42	41.26	5.64	5.87
	Ascorbic acid 400	180.65	183.16	13.98	14.35	15.24	15.98	1.90	2.02	9.74	9.91	40.95	40.78	6.32	6.67
Mean		170.24	172.61	12.39	12.86	14.36	14.73	1.80	1.87	8.98	9.18	41.35	41.21	5.57	5.81
General mean of foliar application (B)	Control	151.13	152.74	11.51	12.38	13.19	13.63	1.81	1.87	8.86	9.04	41.22	41.09	5.19	5.41
	Phosphoric acid 3000	168.83	170.94	14.21	14.89	16.23	16.31	2.00	2.05	10.03	10.17	40.41	40.25	7.00	7.24
	Phosphoric acid 6000	159.32	161.83	2.38	13.23	14.77	15.18	1.89	1.95	9.28	9.51	40.92	40.78	5.99	6.27
	Ascorbic acid 200	164.72	166.80	13.68	14.35	15.34	15.76	1.97	2.02	9.53	9.74	40.73	40.59	6.56	6.80
	Ascorbic acid 400	171.99	173.99	14.69	15.36	16.26	16.76	2.04	2.11	10.29	10.41	40.10	39.91	7.23	7.50
LSD at 0.05 of	A	0.540	2.851	0.120	0.272	0.278	0.193	0.010	0.014	0.114	0.039	0.236	0.111	0.053	0.175
	B	1.348	2.326	0.080	0.324	0.256	0.147	0.019	0.025	0.081	0.091	0.195	0.153	0.095	0.110
	A x B	1.907	3.289	0.113	0.459	0.363	0.208	0.023	0.035	0.098	0.128	0.277	0.217	0.134	0.156

Considering the cotton sowing date (early and delayed) treatments, data in Table 6 documented that delaying cotton sowing date had harmful effects on growth characteristics , yield and yield components comparing to early sowing date in both seasons. Delaying cotton sowing date significantly reduced growth characteristics of number of fruiting branches/plant by 12.74% and 15.5%, whereas plant height significantly increased by 9.02% and 9.3%, during 2021 and 2022 seasons respectively, compared to early sowing date in both seasons.

Furthermore, delaying cotton sowing date significantly reduced yield and its component of number of open bolls/plant by 10.02% and 9.79%, boll weight by 13.46% and 12.2%, seed index by 12.04% and 11.47% and seed cotton yield by 22.85% and 22.32%, during 2021 and 2022 seasons respectively, comparing to early sowing date in both studied seasons.

With regard the main effect of exogenous of PA and ASA treatments, results in Table 6 deduced that spraying ASA with 400ppm concentration gave the highest values, followed by spraying PA with 3000 ppm comparing to untreated cotton plants.

Exogenous of ASA at 400ppm concentration achieved the best results in growth characteristics and yield components of plant height by 13.8% and 13.91%, number of fruiting branches/plant by 27.62% and 24.07%, number of open bolls/plant by 23.24% and 22.99%, boll weight by 12.7 and 12.83%, seed index by 16.13% and 15.15% and seed cotton yield by 39.3 and 38.63%, respectively, comparing to untreated cotton plants in both seasons.

As for the effect of the interaction between cotton sowing date and exogenous treatments on growth characteristics and yield components, the results in Table 6 clearly showed that all growth characteristics and yield components significantly affected by the interaction between two treatments. In general, the maximum means recorded by spraying cotton plant by ASA at 400ppm under early and delay sowing dates in both seasons.

Fiber quality properties

The data in Table 7 stated the effect of cotton sowing date (early and delayed), foliar applications of PA and ASA treatments and their interaction on cotton fiber quality properties during 2021 and 2022 seasons.

Findings in Table 7 noticed that cotton sowing date (early and delayed) significantly affected on all fiber quality properties. Sowing cotton at delayed date significantly reduced fiber strength, while increased fiber length and micronaire reading compared to early sowing date in both seasons.

Regarding the main effect of exogenous of PA and ASA treatments, data in Table 7 confirmed that spraying ASA at 400 ppm concentration recorded the best values, followed by spraying PA at 3000 ppm concentration compared to untreated cotton plants.

Considering the interaction effect, finding in Table 7 indicted that the interaction between cotton sowing date and foliar application treatments insignificantly affected all cotton fiber quality properties in both seasons.

Discussion

Effect on sowing date and foliar application treatments on cotton leaves chemical constituents

Cotton sowing date affected drastically on all cotton leaves constituents, delayed sowing date reduced leaves constituents (total chlorophyll, carotenoids, total soluble sugars, total phenols, total free amino acids, total soluble protein contents and total antioxidant capacity) comparing with early sowing date (Table 4). This diminishing might be related to the main effect of high temperature and heat units predominate during lately sowing date, which accumulated heat units over than the zero point of cotton plant and then increased plants growth rate. Under high temperature conditions, photosynthesis loosed chlorophyll a to b ratio. Thereby, exposing cotton plant to higher temperature for long time during delayed sowing date than the optimum temperature (i.e.,<32°C), increased the oxidation stress conditions and effected passively on cotton plants during development stages (squaring, flowering and boll mutation). As such, cotton plants often grown in hot conditions that optimum temperature range is (20-30°C) for its normal growth and biomass accumulation. Also, the optimum temperature range for normal metabolic activities and biochemical processes limited between (23.5-32°C) with the ideal temperature for photosynthesis at (28°C). The effects of oxidation conditions on cotton plant due to increase ROS generation diminish metabolic and biochemical processes, excess respiration, photorespiration and chlorophyll degradation that caused to minimized photosynthesis rate and decrement carbohydrates content. Furthermore, Low carbohydrates capacity for expansion might be decreased phenols biosynthesis and antioxidant compounds. Besides, the passive effect on low contents of soluble proteins and free amino acids might be due to reduce photosynthesis and aggravate degradation of proteins. Similarly results obtained by Ali (2012), who pointed out that total soluble sugars tended to be reduced significantly with delaying cotton sowing date.

TABLE 7. Effect of sowing date and foliar application of phosphoric acid, ascorbic acid and their interaction on cotton fiber properties during 2021 and 2022 seasons

Sowing date (A)	Foliar application (ppm) (B)	Fiber length (mm)		Micronaire		Fiber strength	
		2021	2022	2021	2022	2021	2022
Early date (April 25)	Control	33.47	33.54	4.25	4.31	10.60	10.69
	Phosphoric acid 3000	33.58	33.65	4.39	4.43	10.78	10.84
	Phosphoric acid 6000	33.49	33.57	4.30	4.37	10.70	10.75
	Ascorbic acid 200	33.53	33.60	4.36	4.40	10.73	10.79
	Ascorbic acid 400	33.64	33.71	4.40	4.46	10.82	10.88
Mean		33.54	33.61	4.52	4.39	10.72	10.79
Delayed date (May 25)	Control	33.65	33.70	4.42	4.49	10.26	10.28
	Phosphoric acid 3000	33.78	33.82	4.58	4.61	10.48	10.52
	Phosphoric acid 6000	33.69	33.74	4.49	4.53	10.35	10.39
	Ascorbic acid 200	33.71	33.77	4.52	4.57	10.41	10.38
	Ascorbic acid 400	33.80	33.86	4.63	4.65	10.53	10.57
Mean		33.72	33.77	4.52	4.57	10.40	10.44
General mean of foliar application (B)	Control	33.56	33.62	4.33	4.40	10.43	10.48
	Phosphoric acid 3000	33.68	33.73	4.48	4.52	10.63	10.68
	Phosphoric acid 6000	33.59	33.65	4.39	4.45	10.52	10.57
	Ascorbic acid 200	33.62	33.68	4.44	4.48	10.57	10.63
	Ascorbic acid 400	33.72	33.78	4.51	4.55	10.67	10.72
LSD at 0.05 of	A	0.009	0.021	0.042	0.037	0.040	0.121
	B	0.021	0.080	0.049	0.089	0.063	0.122
	A x B	N.S	N.S	N.S	N.S	N.S	N.S

With respect to foliar application treatments (PA and ASA) affected drastically all cotton leaves chemical constituents, especially spraying ASA at 400ppm and PA at 3000ppm concentrations (Table 4). The favorable effect of ASA application might be related to its certain physiological and protective functional role as growth regulator and antioxidant, especially under high temperature and oxidative conditions with delaying sowing date. Exogenous of ASA energized the chlorophyll biosynthesis and increased the several photosynthesis pigments (i.e., Chl. a, Chl. b and carotenoids). That reflected on the improvement of carbohydrates biosynthesis and increased the contents of phenols, amino acid, proteins and antioxidant compounds with both early and delayed dates. These results supported with the finding of Dewdar & Rady (2013), Zhang (2013), Sarwar et al. (2018). Besides, Omar et al. (2018) investigated that spraying ascorbic acid stimulated the chlorophylls biosynthesis and lateness cotton leaf senescence.

The important role of PA foliar application might be attributed to phosphorus role in cotton plant physiological processes and its vital role during chlorophyll biosynthesis as pyridoxal phosphate, which increased photosynthesis rate and pigments content. Additionally, phosphorus has an important role in CO_2 development to sugars. Phosphorus plays main role in carbohydrates biosynthesis enzymatic reactions relied on phosphorylation. In turn, phosphorus had positive effects on photosynthesis rate and carbohydrates content that reflected on increscent of phenols and antioxidant compounds biosynthesis. Therefore, the increasing of amino acids and soluble proteins with spraying PA is causing to enhancement photosynthesis rate and efficiency. Spraying PA promoted digesting and translocation of carbohydrates and proteins and increased their concentrations in cotton leaves. These findings are in linked with those of Sawan et al. (2008), Saleem et al. (2010), Emara & Abd El-All (2017).

Results in Table 4 unveiled that the interaction between cotton sowing date and foliar application treatments improving significantly almost leaves chemical constituents. The affirmative effect of PA and ASA might be related to the activating of chlorophyll biosynthesis and antioxidant capacity of cotton plants, especially with delaying sowing date. These results are in agreement with those of Emara & Abd El-All (2017), Omar et al. (2017), Sarwar et al. (2018).

Effect on sowing date and foliar application treatments on cotton growth characteristics

It is clear from the date in Table 5 that delayed cotton sowing date increased drastically plant height than early sowing date. That might be attributed to high temperature and accumulated heat units (Table 3) through the whole growing season. There are a liner relationship between increasing temperature and height of cotton plant. However, high temperature during delaying sowing date significantly reduced the rest growth characteristics of number of fruiting branches/ plant, plant dry weight, leaf area and relative water content comparing to early sowing date in both seasons. Cotton required warm days and relatively cool night for good growth and development, whereas cotton seedlings were not sensitive for increasing temperature over to (40/32°C) through the first two weeks of cotton emergence. Conversely, after this period cotton seedlings were sensitive to high temperature conditions, which increasing temperature during delaying sowing date due to diminished plant biomass as compared to the ideal temperature during early sowing date. Sankaranarayanan et al. (2020) and Ibrahim et al. (2022) documented that cotton growth under high temperature conditions at (40/30°C) had not fruiting branches, lower fruiting branches at (35-27°C) and more fruiting branches at (30-22°C). Similar trend was observed by El-Hindi et al. (2006), Elayan et al. (2015), Huang (2016), Omar et al. (2018). Likewise, Iqbal et al. (2020), Iqbal et al. (2021) cited that early cotton planted date enhanced growth characteristics and gave cotton plants suitable period for ideal growth and development. Whereas, late cotton planted date growed faster because of the high temperature during the whole growing season.

Exogenous of PA and ASA significantly improved all cotton growth characteristics with early and delayed sowing dates in both studied seasons (Table 5). The benefit effects of spraying ASA on cotton growth characteristics mainly related to improve photosynthesis rate and increase carbohydrates content. Besides, ASA foliar application has physiological role in development cotton growth rate by promoting cell division, enlargement of cell and other plant organs. As well as, ASA treatment acted as antioxidant to evaluate the negative effects of oxidative conditions during delayed sowing date and stimulate plants growth and development. The results were consonance with the works of

Dewdar & Rady (2013), Omar et al. (2018) on cotton and Sarwar et al. (2018) on plant.

Exogenous of PA tended to diminish the exaggerated vegetative growth and divert cotton plants to development and productive stages, especially during sowing date. The benefits of phosphorus might be attributed to its vital role in cell elongation, cell division and improve meristematic tissue that due to promote early flowering stage and increase the number of flowers buds. Also, phosphorus is essential during chlorophyll biosynthesis, which it must be present as pyridoxal phosphate that due improve chlorophyll pigments and growth rate of cotton plants. Similar finding were obtained by Sawan et al. (2008), Saleem et al. (2010), Emara & Abd El-All (2017).

As shown in Table 5, the interaction between sowing date and foliar application treatments affected drastically on all cotton growth characteristics in both seasons. That explained the positive effects of spraying PA and ASA on cotton plants with different sowing dates especially during delayed sowing date, which they are alleviated the harmful effects of high temperature and oxidative conditions and then improved cotton growth rate in both seasons. These results are in agreement with those mentioned by Emara & Abd El-All (2017), Omar et al. (2018), who deduced that spraying PA and ASA enhanced the growth rate of cotton plants during late planting date.

Effect on sowing date and foliar application treatments on cotton yield and itscomponents

With respect to cotton sowing date (early and delayed) significantly affected on all yield and its components in both studied seasons (Table 6). Early sowing date have higher number of bolls, boll weight, seed index, and yield that might be attributed to the best environmental conditions of air temperature and heat units through flowering and boll development stages and also to the improvement of photosynthesis rate. In turn, the ultimate production of bolls happened at suitable mean air temperature (30°C) Also, early sowing date had enhanced boll size causing to accumulation of more assimilates and prolonged duration for boll development and maturity. Moreover, early sowing of cotton plants have the capacity to best recover via production new floral parts and transfer them into yield components compared to delay sowing date. Delayed sowing date drastically diminished yield components that might be related to high mean air temperature during peak flowering period and extremely effect on flower shedding and boll retention. Besides, delayed sowing had more delayed flowers and bolls during growing season under high temperature that shortened the duration from planting to boll opening by speedy boll maturity and decreased yield quantities and qualitative. Likewise, delayed cotton sowing date slowed the physiological maturity of boll and reduced carbohydrate content that due to diminish the number of bursted bolls. These finding are accordance with those outlined by Yeates et al. (2013), Elayan et al. (2015), Omar et al. (2018), Sankaranarayanan et al. (2020), Iqbal et al. (2021), Ibrahim et al. (2022).

Foliar application of PA and ASA significantly improved all cotton yield and its compounds with both early and delayed sowing date in 2021 and 2022 seasons (Table 6). The favorable effect of spraying ASA on yield components could be due to assured protective functional properties as growth hormone and antioxidant. Spraying ASA enhanced cotton yield components (number of opining bolls, boll weigh and seed index) on account of making increasing bloom and decreasing boll shedding on cotton plants. Moreover, exogenous of ASA with delaying date might be diminished the negative effects of high temperature and oxidative conditions such as decrement ROS generation that due to improving photosynthesis rate, carbohydrate content and finally cotton yield and its components. These results are in harmony with Dewdar & Rady (2013), Omar et al. (2018), Sarwar et al. (2018).

Spraying PA improved cotton yield components that cloud be attributed to vital and physiological role of phosphorus in chlorophyll formatting and provide to tissues like lateral buds and fruiting branches that led to increase cotton plant growth, development and thus yield. As well as, phosphorus increased squares initiation, diced flowering, enhanced boll set, improved boll maturity of set bolls and early senescence. Similar results are obtained by Sawan et al. (2008), Saleem et al. (2010), Emara & Abd El-All (2017).

As for the interaction between cotton sowing date and foliar application treatments, the results showed significantly effects in both seasons (Table 6). That might be due to the activation and productivity roles of ASA and PA as antioxidant and growth regulator, which increased photosynthesis rate and carbohydrate content, improved growth rate and divert cotton plants to development and productive phase especially through delayed sowing date. These finding in linked with those of Emara & Abd El-All (2017), Omar et al. (2018).

Effect on sowing date and foliar application treatments on fiber quality properties

Fiber quality properties are majorly affected by cultivars, whereas management procedures are the secondary one. Cotton sowing date significantly affected all fiber properties (fiber length, micronaire reading and fiber strength) in both seasons (Table 7). The high mean temperature through growing and fiber development stagesled to few increases in fiber length and higher micronaire reading in delayed sowing date comparing to early sowing date. The increasing of micronaire reading might be attributed to hot climate that causing thicker rings of cellulose and changing daily in fiber. Also, the augmentation in fiber length in delayedsowing date. Late sowing date reached to late maturity in the season and farmers harvest the immature cotton that has fiber strength and low dye uptake ability. These finding are in agreement with those of Emara (2012), Omar et al. (2018), Ibrahim & Hamoda (2021), Iqbal et al. (2021), who stated that early cotton planting had higher fiber strength comparing with late date.

Foliar application treatments significantly affected all fiber properties in both seasons (Table 7). ASA application improved fiber quality properties under optimal thermal conditions (early date) and under high temperature (delayed date). These results are in linked with those of Sarwar et al. (2018) and Omar et al. (2018), who depicted that spraying ASA as well as auxins, improved significantly cotton fiber properties.

Spraying PA had positively effects on fiber quality properties that might be related to its necessary effects on photosynthesis rate, carbohydrate biosynthesis and finally improved fiber properties. These finding are in linked with those of Sawan *et al.* (2008), Emara & Abd El-All (2017).

The interaction between cotton sowing date and foliar application treatments insignificantly affected in both studied season (Table 7). These finding are in agreement with those of Emara & Abd El-All (2017), Omar et al. (2018).

Conclusion

It could be recommended that the delayed sowing date exposed cotton plants to high temperature stress during development and production stages, which led to a significant decrease in cotton leaves chemical constituents, growth characteristics and yield components compared to early sowing date. The foliar application of ASA (200-400ppm) and PA (3000 and 6000ppm) statically improved all studied parameters, which spraying at ASA (400ppm) achieved the highest values followed by spraying PA (3000ppm) comparing to untreated cotton plants. The interaction between the two factors significantly enhanced almost studied parameters, which exogenous ASA (400ppm) recorded the best results then PA (3000ppm) compared to control plants with both sowing dates. Generally, the favorable effects of ASA and PA might be related to their certain physiological and protective functional role as growth regulator, antioxidant, enhancement photosynthesis rate and efficiency, especially under high temperature and oxidative conditions with delaying sowing date.

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تأثير الرش بحمض الفوسفوريك وحمض الاسكوربيك علي إنتاجية القطن تحت مواعيد الزراعة المتأخرة

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ميعاد زراعة القطن من الإجراءات الرئيسية التي تتحكم في جودة المحصول والألياف. تأخير ميعاد الزراعة يؤدي إلي تعرض نباتات القطن لدرجات الحرارة العالية خلال موسم الزراعة بأكمله مما أدي إلي تقليل فترة النمو وإنخفاض المحصول. أجريت التجربة بمحطة بحوث سخا لقسم الفسيولوجي – معهد بحوث القطن – مركز البحوث الزرعية – كفر الشيخ – مصر. كان تصميم التجربة قطع منشقة مره واحده مع ثلاث مكررات، حيت تضمنت القطع الرئيسية مواعيد الزراعة (مبكر – متأخر) وكانت القطع المنشقة عبارة عن معاملات الرش بحمض الفوسفوريك بتركيز (3000 – 6000 جزء في المليون) وحمض الأسكوربيك بتركيز (200 – 400 جزء في المليون) مرتين في مرحلتين الوسواس و التزهير بالإضافة إلي معاملة الكنترول، وذلك لمعرفة تأثير ميعاد الزراعة ومعاملات الرش وتفاعلتهما علي المكونات الكيميائية للأوراق وخصائص النمو والمحصول ومكوناته وجودة الألياف لصنف جيزة 97 خلال موسمي 2022-2021. أظهرت النتائج أن تأخر ميعاد زراعة القطن قلل من المكونات الكيميائية للأوراق وخصائص النمو والمحصول مقارنة بميعاد الزراعة المبكر. أدي الرش بحمض الفوسفوريك وحمض الاسكوربيك إلي تحسين جميع الصفات المدروسة إحصائيا، حيث سجلة معاملات الرش بحمض الأسكوربيك بتركيز 400 جزء في المليون أفضل النتائج يليها الرش بحمض الفوسفوريك بتركيز 3000 جزء في المليون مقارنة بالنباتات الغير معاملة (الكنترول). أدى التفاعل بين عاملي مواعيد الزراعة ومعاملات الرش إلي تحسين معنوي في معظم الصفات المدروسة, حيث أطت معالة الرش بحمض الأسكوربيك (400 جزء في المليون) أعلي النتائج يليها حمض الفوسفوريك (3000 جزء في المليون) مقارنة بالنباتات الكنترول في كل من ميعاد الزراعة المبكر والمتأخر. بشكل عام فإن التأثيرات الإيجابية لحمض الأسكوربيك و حمض الفوسفوريك بسبب دورهما الفسيولوجي في تخليق الكلورفيل وتعزيز معدل البنائج الضوئي ودفع النبات لزياده الأنتاج.