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Effect of Water Stress and some Anti - Transpirants on Growth, Yield and Quality of Okra Plants (*Abelmoschus esculentus*)

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ABSTRACT

Two field experiments were conducted at private farm in Belqas, Dakahlia Governorate, Egypt during the two summer seasons of 2016 and 2017 to study the effect of irrigation intervals and foliar application of different antitranspirants *i.e.,* silicone in from of potassium silicate K_2SiO^3 (1000 ppm), chitosan (150 ppm) and glycine betaine (700 ppm) and their interactions on vegetative growth characters, pod yield, quality traits and chemical constituents of okra (Balady cultivar). The results showed that short irrigation intervals (10days) significantly increased number of leaves/plant, fresh and dry weight (g) as well as leaf area/plant, pod yield/plant, total pod yield (ton/feddan), pod length, chlorophylls a, b, total chlorophyll and chlorophyll a/b ratio of okra leaves and vitamin C, carbohydrate, protein, total sugars contents of okra pods compared with (irrigation at 20 days), except total soluble solids (TSS %) which had the highest significant values at 20 days irrigation intervals compared with 10 days irrigation intervals. Spraying with all foliar applications led to significant increase all the studied parameters compared with control treatment in both seasons. The superior application was chitosan in particular 150 ppm followed by glycine betaine followed by silicon while control treatment recoded the lowest values in both seasons, respectively, glycine betaine in particular 700 ppm gave the highest values of TSS of okra pods followed by chitosan followed by silicon while control treatment recoded the lowest value. From the obtained results, it could be concluded that Balady cultivar of okra plant which irrigated at 10 days interval and sprayed with chitosan at 150 ppm four times, *i.e.,* 20 days after sowing and repeated each 10 days interval, respectively recorded the highest values of all studied traits of okra plant compared to other treatments, except Total soluble solids (TSS %) which had the highest significant values of okra pods with the interaction between (irrigation every 20 days interval × foliar sprayed by 700 ppm of glycine betaine) during both seasons.

Keywords: okra (*Abelmoschus esculentus* L.), irrigation intervals, antitranspirants, silicon, chitosan, glycine betaine, growth, pod yield, quality.

INTRODUCTION

Okra (*Abelmoschus esculentus*) is an important summer vegetable crop in Egypt, which is consumed locally or exported abroad. The green pods of okra used fresh, frozen or as pickles.

Despite considerable resistance of okra to drought it requires large amounts of water during the growing, lack of water has deleterious effects on the yield. The maximum loss of yield happened when continuous water shortages continuously until the first harvest (Abd El-Kader *et al.,* 2010).

One of the most important strategies for increasing the productivity of okra under normal irrigation and drought stress using compounds of antitranspirants. These compounds should be harmless to humans and inexpensive.

Silicon is one of the most important antiperspirants used, and after oxygen the second most abundant element in the soil solution and in the earth's crust. Foliar spray of silicon reduces the negative effects of drought (Bukhari *et al.,* 2015).

Chitosan stimulate plant growth (Mondal *et al.,* 2012). Chitosan act as antitranspirant compound which effecte on many crops (Khan *et al.,* 2002).

Glycine betaine is amino acid which considers a vital tonic that is rapidly absorbed and transported within the plant parts. Exogenously applied glycine betaine can be used to increase the extent of plant height, chlorophyll (a and b), yield and yield components in drought stress condition and without drought stress (Miri and Armin, 2013).

This study designed to know the effect of water stress and spray some anti- transpirants such as silicon, chitosan, glycine betaine and their interactions on growth, yield and quality of okra plants (*Abelmoschus esculentus* L. Moench) which had grown under normal irrigation or drought stress conditions, without adversely affecting growth, quality and yield of okra.

MATERIALS AND METHODS

1- The experimental design and treatments

Split-plot design was the experimental layout with three replicates. These experiments included eight treatments which were the combination between 2 irrigation intervals and 4 foliar applications of antitranspirants. Two irrigation regimes (every 10 and 20 days intervals starting after 1st irrigation) were assigned in the main plots. The irrigation numbers were totally 18 and 9 times, respectively, while the foliar applications were randomly distributed in the sub-plots. The plot area was 12 m2 (4-ridges, each 5 m length, and 0.6 m width). Seeds were sown with 30 cm spacing between plants on one side of ridges at a rate of 3-5 seeds at hills by hand at the depth of 1-2 cm of soil and then covered with wet and dry soil. The seeds were sown on 20th March of 2016 and 2017. After germination plants were thinned on two plants/ hill.

Table 1. Mechanical and chemical analysis of the soil experimental.

Properties	Physical		Properties	Soluble anions (meq/100g soil)	
	Value			Value	
	2016	2017		2016	2017
Soil texture	Clay-loam	Clay-loam	$HCO3^-$	0.62	0.63
Sand (%)	16.22	15.74	$SO4^{--}$	0.05	0.07
Silt (%)	22.06	22.86	Soluble cations (meq/100g soil)		
Clay (%)	61.72	61.40		Value	
Organic matter %	1.34	1.50	Properties	2016	2017
	Chemical		Ca^{++}	0.61	0.62
	Value		Mg^{++}	0.31	0.33
	2016	2017	Na^{+}	0.22	0.21
pH value	7.80	8.20	Macro-elements (ppm)		
E C (mmohs/cm)	0.69	0.57		Value	
				2016	2017
			N	45.50	45.70
			P	11	11.30
			K	209	213

The treatments were arranged as follow

a. Irrigation intervals (main plot)

Normal irrigation at (10 days intervals), Drought stress at (20 days intervals).

b. Foliar applications of antitranspirants (sub plot)

Control (sprayed with tap water), Silicon in form of potassium silicate (K_2SiO_3) at 1000 ppm, Chitosan at 150 ppm and Glycine betaine at 700 ppm.

The plants were sprayed with foliar treatments four times, 20 days after sowing and repeated each 10 days interval. The normal agricultural practices of okra production were followed according to the recommendations of Egyptian Ministry of Agriculture. Pods harvesting was done according to the standard characteristics for exportation.

2- Data recorded were as follows

Vegetative growth characters

Five plants were marked randomly after 50 days of sowing from each plot for determining the following data: number of leaves/ plant, fresh weights/ plant (g), dry weights/ plant (g) and leaf area/ plant (cm2), it was estimated by drying each plant at 70°c to a constant weight, leaf area was recorded according to (Koller, 1972).

Pod yield and its components

In each harvest green pods were harvested of each plot at the proper maturing stage, counted and weighted and the following parameters were collected: average of pod length (cm), pod yield/plant (g) and total pod yield (ton/feddan) of okra pods.

Chemical composition of leaves: It was determined in leaves before the beginning of flowering and the following parameters were collected: chlorophylls a, b, total chlorophyll and chlorophyll a/b ratio of leaves were determined according to Lichtenthaler and Wellburn (1983).

Chemical composition of pods: Representative samples of 10 okra pods were randomly taken from each treatment to determine the quality parameters of okra pods vitamin C (mg/100gf.w.) was determined in in juice from fresh pods by titration with 2.6 diclorophenol indophenol blue dye according to the method reported in (AOAC, 1975), total carbohydrates was determined according to the method described by (Sadasivam and Manickam, 1996), protein was determined according to (AOAC, 2000), crude protein of each sample was calculated by multiplying the total nitrogen by the factor 6.25, Total sugars was determined according to the method described by Sadasivam and Manickam (1996) and total soluble solids (TSS) was estimated using Galli 110 refractometer according to (AOAC, 2000).

Statistical analysis

All statistical analyses were performed using analysis of variance technique by means of Costat computer software. Using the differences between individual pairs of treatment means were compared using Duncan Multiple Range Test at 5% according to Snedecor and Cochran (1989).

RESULTS AND DISCUSSION

1. Vegetative growth parameters

Effect of irrigation intervals

Table 2 show that the highest significant values of number of leaves/plant, fresh and dry weight/plant and leaf area/plant were recorded at 10 days from irrigation intervals during both seasons compared with irrigation intervals at 20 days. The differences between irrigation intervals could be suggested increasing water quantity applied to plant caused keeping higher moisture content in the soil and this in turn might the plant metabolism and thus leads to increase plant growth characters and produce higher dry matter. This result is in agreement with those of Saied (2000) on sugar beet. Such results are in agreement with Altaf *et al.* (2015) on okra.

Effect of foliar application of antitranspirants

Table 2 show that the highest significant values of number of leaves/plant, fresh and dry weight/plant and leaf area/plant were recorded with spraying plants by chitosan compared with glycine betaine, silicon meanwhile the control had the lowest values of mentioned growth parameters in both seasons. These results are in harmonious with Abbas *et al.* (2017) as for silicon, El-Sherbini (2015) as for chitosan, Ragab *et al.* (2015) as for glycine betaine.

The stimulative effect of silicon on vegetative growth might be due to that silicon improves protection against pathogens and enhances the growth. (Greger *et al.,* 2011).

Foliar application of chitosan increases photosynthesis, promotes and enhances plant growth, stimulates nutrient uptake and increases germination (Kim *et al.,* 2005).

Glycine betaine play important role in increase plant tolerance to some abiotic stresses such as salt, drought, and extreme temperatures. (Quan *et al.,* 2004).

Effect of the interactions:

Table 3 show that the highest significant values of number of leaves/plant, fresh and dry weight/plant and leaf area/plant of okra plant were obtained with irrigation every 10 days × foliar sprayed by 150 ppm of chitosan) followed by (irrigation every 10 days × foliar sprayed by 700 ppm of glycine betaine) and the lowest one was the interaction (irrigation every 20 days × control) in both seasons.

Similar results were harmonious with Farouk and Abd EL Mohsen (2011), Rakha (2014) and Raza *et al.* (2014).

Table 2 . Effect of irrigation intervals and foliar application of antitranspirants on number of leaves /plant, fresh and dry weight (g) as well as leaf area/plant (cm^2) of okra in the two seasons of 2016 and 2017.

Treatments		Number of leaves/plant		Fresh weight/plant (g)		Dry weight/plant (g)		Leaf area/plant (cm^2)	
		2016	2017	2016	2017	2016	2017	2016	2017
Irrigation intervals	Normal Irrigation at 10 days	27.55 a	29.33 a	493.84 a	499.09 a	63.08 a	65.68 a	4417.20 a	4600.27 a
	Drought Stresss at 20 days	20.17 b	20.79b	383.85 b	387.97 b	52.17 b	53.54 b	3405.17 b	3586.66 b
Foliar application	Control Tap water	19.66 c	21 c	384.48 d	390.66 d	51.90d	54.08 d	3453.61 d	3682.74 d
	Silicon 1000 ppm	24.16 b	25.41 b	443.95 c	447.55 c	57.53c	59.73 c	3790.92 c	3952.97 c
	Chitosan 150 ppm	26.30 a	27.50 a	470.85 a	475.78 a	61.81 a	63.46 a	4485.52 a	4581.66 a
	Glycine betaine 700 ppm	25.31 ab	26.33 b	456.11 b	460.13 b	59.26 b	61.16 b	3914.71 b	4156.50 b

Table 3. Effect of the interaction between irrigation intervals and foliar applications of antitranspirants on number of leaves/plant, fresh and dry weight as well as leaf area/plant of okra in the two seasons of 2016 and 2017.

Treatments		Number of leaves/plant		Fresh weight/plant (g)		Dry weight/plant (g)		Leaf area/plant (cm^2)	
		2016	2017	2016	2017	2016	2017	2016	2017
Normal Irrigation at 10 days	Control Tap water	22.33 c	24 d	438.53 d	442.66 d	57.42 d	59.43 d	3682.73 d	4084.82 c
	Silicon 1000 ppm	28 b	29.33 c	493.06 c	497.76 c	62.06 c	64.93 c	4143.67 c	4224.28 c
	Chitosan 150 ppm	30.66 a	33 a	531.16 a	538.73 a	68.33 a	70.73 a	5451.33 a	5470.66 a
	Glycine betaine 700 ppm	29.20 ab	31 b	512.60 b	517.20 b	64.53 b	67.63 b	4391.09 b	4621.33 b
Drought Stresss at 20 days	Control Tap water	17 d	18 f	330.43 h	338.66 h	46.38 f	48.73 g	3224.50 g	3280.66 e
	Silicon 1000 ppm	20.33 c	21.50 e	394.83 g	397.33 g	53 e	54.53 f	3438.16 f	3681.66 d
	Chitosan 150 ppm	21.93 c	22 e	410.53 e	412.83 e	55.30 de	56.20 e	3519.71 e	3692.66 d
	Glycine betaine 700 ppm	21.43 c	21.66 e	399.63 f	403.06 f	54 e	54.70 f	3438.33 f	3691.66 d

2. Pod yield and its components

Effect of irrigation intervals

Data in Table 4 show that irrigation intervals at 10 days had the highest values of pod length cm, the highest significant values of pod yield/plant and total pod yield ton/feddan in both seasons respectively compared with irrigation intervals at20 days.

Irrigation intervals at 20 days caused water stress to okra plant which considered as one of the most important limitations to photosynthesis and plant productivity (Tezara *et al.,* 2005). Similar results were obtained by Hussein *et al.* (2011) on okra.

Effect of foliar application of antitranspirants

It is obvious from the data in Table 4 that all foliar applications cause increase in all studied parameters compared with control. The highest values of pod length cm, the highest significant values of pod yield/plant and total pod yield ton/feddan were obtained when okra plants sprayed with chitosan followed by glycine betaine followed by silicon and the lowest application in all studied parameters was control.

There was insignificant difference between the effect of foliar application of chitosan and glycine betaine and there was insignificant difference between application of glycine betaine and silicon on pod length, pod yield/plant and total pod yield/feddan in both seasons. The foliar application chitosan, glycine betaine and silicon had a similar effect on pod length in second season. These results are in accordance with El-Sherbini (2015) as for silicon, El-Badawy (2014) as for chitosan, Ragab *et al.* (2015) as for glycine betaine.

Concerning silicon, the increase in yield from silicon treated plants is a result of deposition of the element under the leaf epidermis which caused a production of phenols, physical mechanism of defense, which reduces lodging, stimulates phytoalexin production, decreases transpiration losses and increases photosynthesis capacity of crop plants (Korndorfer *et al.,* 2004 and Ahmad *et al.,* 2012).

Foliar application of chitosan lead to stimulate leaves, shoots, roots, photosynthetic rate and chlorophyll content in plant (Khan *et al.,* 2002 and Gornik *et al.,* 2008) which caused in increment in the vigor growth followed by active translocation of photoassimilates from source to sink tissues followed by increase yield.

Concerning glycine betaine, the improveme in yield and yield components due to play an important role in increasing plant tolerance to abiotic stresses such as drought, extreme temperatures and salt (Quan *et al.,* 2004).

Effect of the interactions

Table 5 show that the highest significant values of all pod characters of okra plant were obtained with the interaction between (irrigation every 10 days × foliar sprayed with 150 ppm of chitosan) followed by (irrigation every 10 days × foliar sprayed with 700 ppm of glycine betaine) and the lowest one was the interaction between (drought stress irrigation every 20 days × control) in first and second season.

There was insignificant difference between interaction between (irrigation every 10 days × foliar sprayed with 150 ppm of chitosan) and (irrigation every 10 days × foliar sprayed with 700 ppm of glycine betaine) and There was insignificant difference between interaction between (irrigation every 10 days × foliar sprayed with 700 ppm of glycine betaine) and (irrigation every 10 days × foliar sprayed with1000 ppm of silicon) on pod yield/plant and total pod yield/feddan in both seasons.

Similar results were obtained by Farouk and Abd EL Mohsen (2011), Rakha (2014) and Noreen *et al.* (2015).

Table 4.Effect of irrigation intervals and foliar application of antitranspirants on pod length, pod yield/plant and total pod yield ton/feddan of okra in the two seasons of 2016 and 2017.

Treatments		The pod length (cm)		Pod yield/plant (g)		Total pod yield (ton/feddan)	
		2016	2017	2016	2017	2016	2017
Irrigation intervals	Normal Irrigation at 10 days	3.12a	3.21a	362.13a	365.28 a	8.04 a	8.11a
	Drought Stresss at 20 days	2.42 b	2.50 b	216.37 b	218.85 b	4.80b	4.86b
Foliar application	Control Tap water	2.61c	2.71 b	256.87 c	260.32 c	5.69c	5.78 c
	Silicon 1000 ppm	2.77b	2.87a	295.2 b	297.52 b	6.56 b	6.61 b
	Chitosan 150 ppm	2.88a	2.93a	305.55a	308.02a	6.79a	6.84a
	Glycine betaine 700 ppm	2.81ab	2.91a	299.4ab	302.4 ab	6.65ab	6.72ab

Table 5. Effect of the interaction between irrigation intervals and foliar applications of antitranspirants on pod yield/plant, total pod yield/feddan and pod length of okra plant in the two seasons of 2016 and 2017.

Treatments		The pod length (cm)		Pod yield/plant (g)		Total pod yield (ton/feddan)	
		2016	2017	2016	2017	2016	2017
Normal Irrigation at 10 days	Control Tap water	2.93 c	3.03c	321c	324.45 c	7.11 c	7.21c
	Silicon 1000 ppm	3.1 b	3.2 b	369.3 b	372 b	8.20 b	8.26b
	Chitosan 150 ppm	3.26a	3.30 a	383.1a	385.95 a	8.51a	8.57a
	Glycine betaine 700 ppm	3.20a	3.30 a	375.15ab	378.75 ab	8.33ab	8.41ab
Drought Stresss at 20 days	Control Tap water	2.30 e	2.39 e	192.75e	196.2 e	4.28 e	4.36 e
	Silicon 1000 ppm	2.44 d	2.54d	221.1 d	223.05 d	4.91 d	4.95d
	Chitosan 150 ppm	2.50d	2.56 d	228 d	230.1 d	5.06 d	5.11 d
	Glycine betaine 700 ppm	2.43 d	2.53 d	223.65d	226.05 d	4.97 d	5.02d

3. Chemical composition of plants

Chemical composition of leaves

Effect of irrigation intervals

Data in Table 6 show that the highest significant values of chlorophylls a, b, total chlorophyll and chlorophyll a/b ratio of okra leaves were recorded at 10 days intervals during both seasons compared with irrigation intervals at 20 days which had the lowest significant values of the studied parameters. Similar results were obtained by Maghsoudi *et al.* (2015).

Chemical composition of okra leaves was lower at the longer regime at 20 days intervals compared with irrigation intervals at 10 days because the nutrient mobility in the soil is towered and the nutrients flow to root absorption zone rate decreased when soil moisture decreased, the results obtained by (Mahmoud and Hafiz, 2002).

Effect of foliar application of antitranspirants

Table 6 show that the highest values of chlorophylls a, b, total chlorophyll and chlorophyll a/b ratio of okra leaves were obtained when okra plants sprayed with chitosan followed by glycine betaine and silicon which had a similar effect meanwhile the lowest application in all studied parameters was control.

The results are agreed with Maghsoudi *et al.* (2016) as for silicon, Abu-Muriefah (2013) as for chitosan, Miri and Armin (2013) as for glycine betaine.

Concerning the possible mechanisms of silicon is supplementation of silicon led to increase production of skeleton of carbon and increased the demand for N for the synthesis of amino acids and other N compounds and photosynthetic activity (Lima Filho and Abdalla, 2008).

Meanwhile, the possible mechanisms of chitosan, its favorable effect on chemical composition of leaves might be referred to chitosan increased photosynthetic rate (Khan *et al.,* 2002).

Concerning the possible mechanisms of glycine betaine on chemical composition of leaves might be referred to the beneficial effect of glycine betaine on metabolism and growth and its role as osmoprotectant (Ragab *et al.,* 2015).

Effect of the interactions

Data in Table 7 show that the highest significant values of chlorophylls a, b and total chlorophyll and chlorophyll a/b ratio of okra leaves were obtained with (irrigation every 10 days × foliar sprayed by 150 ppm of chitosan) followed by (irrigation every 10 days × foliar sprayed by 700 ppm of glycine betaine) and the lowest significant values of the studied parameters was the interaction between (drought stress irrigation every 20 days × control) in first and second season. Same results were obtained by Farouk and Abd El Mohsen (2011), Miri and Armin (2013) and Maghsoudi *et al.* (2016).

Table 6. Effect of irrigation intervals and foliar applications of antitranspirants on chlorophylls a, b, total chlorophyll and chlorophyll a/b ratio of okra leaves in the two seasons of 2016 and 2017.

Treatments		Chlorophyll a (mg/ gf w)		Chlorophyll b (mg/ gf w)		Total. Chlorophyll (mg/ gf w)		Chlorophyll a/b ratio	
		2016	2017	2016	2017	2016	2017	2016	2017
Irrigation intervals	Normal Irrigation at 10 days	0.62 a	0.67a	0.42 a	0.45 a	1.04a	1.13a	1.48a	1.46 a
	Drought Stresss at 20 days	0.55b	0.62 b	0.39 b	0.44b	0.95 b	1.06 b	1.39b	1.39b
Foliar application	Control Tap water	0.55 c	0.62 c	0.39 c	0.44 c	0.95 c	1.07c	1.39 c	1.40c
	Silicon 1000 ppm	0.58 b	0.64 b	0.40b	0.45 b	0.99b	1.09b	1.42 bc	1.42b
	Chitosan 150 ppm	0.62a	0.66a	0.41a	0.45a	1.04 a	1.12a	1.48 a	1.46 a
	Glycine betaine 700 ppm	0.59b	0.64b	0.41b	0.45b	1.00b	1.10 b	1.44b	1.43b

Table 7. Effect of the interaction between irrigation intervals and foliar applications of antitranspirants on Chlorophylls a, b, Total chlorophyll and Chlorophyll a/b ratio of okra leaves in the two seasons of 2016 and 2017.

Treatments		Chlorophyll a (mg/ gf w)		Chlorophyll b (mg/ gf w)		Total. Chlorophyll (mg/ gf w)		Chlorophyll a/b ratio	
		2016	2017	2016	2017	2016	2017	2016	2017
Normal Irrigation at 10 days	Control Tap water	0.57 e	0.64c	0.40cd	0.45 bc	0.97 d	1.09 c	1.42cde	1.42c
	Silicon 1000 ppm	0.61 c	0.67 b	0.42 b	0.45 b	1.03b	1.12 b	1.47bc	1.46 b
	Chitosan 150 ppm	0.68 a	0.70a	0.43a	0.46a	1.11 a	1.17 a	1.56 a	1.51 a
	Glycine betaine 700 ppm	0.63b	0.67b	0.42ab	0.45 ab	1.05 b	1.13b	1.48 b	1.46b
Drought Stresss at 20 days	Control Tap water	0.54 i	0.61e	0.39 d	0.44d	0.93 g	1.05 e	1.37e	1.38e
	Silicon 1000 ppm	0.55h	0.62de	0.39 d	0.44cd	0.94 fg	1.06de	1.38 e	1.39 e
	Chitosan 150 ppm	0.56 f	0.63 d	0.39cd	0.44cd	0.96 de	1.07 cd	1.41 cde	1.41 cd
	Glycine betaine 700 ppm	0.55 g	0.62 d	0.39 d	0.44cd	0.95ef	1.07 de	1.40 de	1.39 de

Chemical composition of pods

Effect of irrigation intervals

Table 8 show that the highest significant values of vitamin C, carbohydrate, Protein, total sugars contents were at irrigation intervals at 10 days during both seasons compared with irrigation intervals at 20 days which had the lowest significant values of the studied parameters, except TSS which had the highest significant values at 20 days irrigation intervals compared with 10 days irrigation intervals. Similar results are obtained by Farouk and Abd EL Mohsen (2011), Farouk and Ramadan (2012) and Rashed and Moursi (2016).

Chemical composition of okra pod was lower at irrigation intervals at 20 days during both seasons compared with irrigation intervals at 10 days because Water stress is one of the most important limitations to photosynthesis (Tezara *et al.,* 2005).

Water stress reduces total carbohydrates because it's inhibitory effect on photosynthetic pigment concentrations, photosynthetic activities or Rubisco enzyme activity which decreases all sugar fractions (Stibrova *et al.,* 1986).

Effect of foliar application of antitranspirants

Data shown in Table 8 show that application of chitosan gave the highest values of content of vitamin C, carbohydrate, Protein, total sugars contents of okra pods followed by glycine betaine followed by silicon while control treatment recoded the lowest values. Application of chitosan and glycine betaine had a similar effect on Protein contents in second season. Spraying okra plants with glycine betaine gave the highest values of TSS of okra pods followed by chitosan followed by silicon while control treatment recoded the lowest values of TSS.

These results are agreed with EL-Sherbini (2015) as for silicon, Abdel-Mawgoud *et al.* (2010) as for chitosan and Aldesuquy *et al.* (2012) as for glycine betaine.

The positive effect of silicon might be due to silicon enhance the stressful conditions resistance of and improves nutrition supply coordination and supply of micronutrient (Jia *et al.,* 2011).

The positive effect of chitosan on chemical composition of okra pods might be due to greater availability of amino compounds released from it (Chibu and Shibayama, 2001) and increase the uptake and availability of water and essential nutrients (Guan *et al.,* 2009).Chitosan increased photosynthetic rate (Khan *et al.,* 2002) and therefore, increase the accumulation of photosynthesis output compounds in pods.

Concerning glycine betaine, its favorable effect on chemical composition of pods

might be referred to the beneficial effect of it on growth and metabolism and its role as osmoprotectant (Ragab *et al.* 2015).

Effect of the interactions

Data in Table 9 show that the highest significant values of vitamin C, carbohydrate, protein and total sugars (%) contents of okra pods were obtained with the interaction between (irrigation every 10 days × foliar sprayed by 150 ppm of chitosan) in both seasons followed by (irrigation every 10 days × foliar sprayed by 700 ppm of glycine betaine) and the lowest one was the interaction between (drought stress irrigation every 20 days × control) in first and second season.

The highest significant values of TSS contents of okra pods were obtained with (irrigation every 20 days × foliar sprayed by 700 ppm of glycine betaine) in both seasons followed by (irrigation every 20 days × foliar sprayed by 150 ppm of chitosan) and the lowest one was the interaction between (irrigation every 10 days × control). Same results were obtained by Farouk and Abd EL Mohsen (2011), Aldesuquy *et al.* (2012) and Maghsoudi *et al.* (2016).

From the obtained results, it could be concluded that Balady cultivar of okra plant sprayed with chitosan at 150 ppm four times, i.e., 20 days after sowing and repeated each 10 days interval, respectively collected the highest total yield /feddan.

Table 8.Effect of irrigation intervals and foliar applications of antitranspirants on Vitamin C, Carbohydrate, Protein, Total sugars (%) and Total soluble solids (TSS %) contents of okra pods in the two seasons of 2016 and 2017.

Treatments		Vitamin C (mg/100gf w)		Carbohydrate (%)		Protein (%)		Total sugars (%)		TSS (%)	
		2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Irrigation intervals	Normal Irrigation at 10 days	36.70a	40.15a	27.18a	29.21a	11.64 a	12.05a	2.80a	3.11a	10.34 b	10.39b
	Drought Stresss at 20 days	32.35b	36.30b	25.41 b	28 b	10.52 b	10.89b	2.33 b	2.59b	11.65a	11.69a
Foliar application	Control Tap water	32.6d	36.7 d	25.57 d	28.16d	10.75d	11.09 c	2.32d	2.58 d	10.41 d	10.49d
	Silicon 1000 ppm	33.86 c	37.9 c	26.10 c	28.44c	11.00c	11.44b	2.50c	2.79 c	10.77c	10.79 c
	Chitosan 150 ppm	36.35a	39.82 a	26.94a	29.06a	11.33a	11.69 a	2.79a	3.11a	11.21 b	11.23 b
	Glycine betaine 700 ppm	35.3 b	38.48 b	26.57b	28.74 b	11.24b	11.67 a	2.66b	2.94b	11.59a	11.66a

Table 9. Effect of the interaction between irrigation intervals and foliar applications of antitrranspirants on Vitamin C, Carbohydrate, Protein, Total sugars (%) and Total soluble solids (TSS %) contents of okra pods in the two seasons of 2016 and 2017.

Treatments		Vitamin C (mg/ 100gf w)		Carbohydrate (%)		Protein (%)		Total sugars (%)		TSS (%)	
		2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Normal Irrigation at 10 days	Control Tap water	34.36 d	38.66 d	26.54d	28.78 d	11.25 d	11.62 d	2.44d	2.65 d	9.73 g	9.87g
	Silicon 1000 ppm	36.03c	39.8c	27.02 c	29.06 c	11.45c	11.91 c	2.68c	2.96c	9.95 f	9.97f
	Chitosan 150 ppm	38.93a	41.64a	27.76a	29.66a	12a	12.35a	3.17a	3.58 a	10.6 e	10.61 e
	Glycine betaine 700 ppm	37.5 b	40.5 b	27.42 b	29.34 b	11.87 b	12.33b	2.94b	3.26 b	11.1d	11.11 d
Drought Stresss at 20 days	Control Tap water	30.83 f	34.73h	24.61h	27.55h	10.25 g	10.56 h	2.21 f	2.51e	11.1d	11.11 d
	Silicon 1000 ppm	31.7 f	36 g	25.19 g	27.82 g	10.56f	10.97 g	2.33e	2.62d	11.6 c	11.61 c
	Chitosan 150 ppm	33.76 de	38.01 e	26.13 e	28.47e	10.67e	11.03 e	2.42d	2.63d	11.83b	11.85 b
	Glycine betaine 700 ppm	33.1 e	36.47 f	25.72 f	28.15f	10.62 e	11.01 f	2.37de	2.63d	12.09a	12.21a

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تأثير الاجهاد المائى وبعض مضادات النتح على نمو وانتاج وجودة نبات الباميا

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أجريت تجربتين حقليتين في مزرعة خاصة في بلقاس بمحافظة الدقهلية ، مصر خلال الموسمن الصيفيين لعامى ٢٠١٦ و ٢٠١٧ لدراسة تأثير فترات الري والرش الورقى بمضادات النتح المختلفة مثل السيليكون فى شكل سيليكات البوتاسيوم (١٠٠٠ جزء في المليون) ، الشيتوزان (١٥٠جزء في المليون) والجليسين بيتين (٧٠٠ جزء في المليون) وتفاعلاتهم على خصائص النمو الخضري ، المحصول , صفات الجودة و المحتوى الكيماوى للباميا (الصنف البلدى).أظهرت النتائج أن فترات الري القصيرة كل (١٠ أيام) زادت بشكل ملحوظ عدد الأوراق / النبات والوزن الطازج والجاف , المساحة الورقية / النبات ، محصول النبات الواحد ، محصول القرون للفدان وطول القرون وكلوروفيل أ ، ب والكلوروفيل الكلي ، نسبة كلوروفيل أ / ب فى أوراق الباميا. وفيتامين ج ، الكربوهيدرات الكليه ، المحتوى البروتينى و محتوى السكريات الكلية فى قرون الباميا مقارنة مع (الري كل ٢٠ يوم). باستثناء المواد الصلبة الذائبة الكلية حيث سجلت أعلى قيم معنوية خلال فترات الري كل ٢٠ يوم مقارنة بفترات الري كل١٠ أيام.أدى الرش بجميع انواع الرش الورقى إلى زيادة كبيرة في جميع الصفات المدروسه مقارنة مع الكنترول. وكان تطبيق الشيتوزان بتركيز ١٥٠ جزء في المليون افضل انواع معاملات الرش الورقى يليه الجليسين بيتين يليه السيليكون بينما سجلت معاملة الكنترول اقل القيم للصفات المذكورة. رش نبات الباميا بالجليسين بيتين بتركيز ٧٠٠ جزء فى المليون اعطى اعلى القيم لمحتوى القرون بالمواد الصلبة الذائبه الكلية يليه الشيتوزان يليه السيليكون فى حين اعطى الكنترول اقل القيم المذكورة .يمكن أن نستنتج أن الصنف البلدى لنبات الباميا الذي تم ريه كل ١٠ أيام وتم رشه بالشيتوزان بتركيز (١٥٠ جزء في المليون) أربع مرات بعد ٢٠ يوما من الزراعه وتكرار الرش كل ١٠ أيام ، سجل أعلى القيم لجميع الصفات المدروسة من نبات الباميا مقارنة مع المعاملات الاخرى باستثناء المواد الصلبة الذائبة الكلية حيث سجلت أعلى القيم فى قرون الباميا عند التفاعل بين الرى كل ٢٠ يوم والرش الورقى بالجليسين بيتين بتركيز (٧٠٠ جزء فى المليون) خلال كلا الموسمين .