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The Performance of Globe Artichoke Plants as Affected by Spraying with Chitosan and Salicylic Acid

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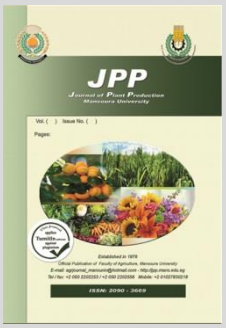

ABSTRACT

Globe artichoke is one of the most important vegetable crops in the countries bordering the Mediterranean basin including Egypt. Globe artichoke cv. 'Balady' is the most preferred by Egyptian farmers, but due to lateness of its flowering, lowering its yield capacity it is facing extinction among the Egyptians. Therefore, two field experiments were carried out during the seasons of 2019/2020 and 2020/2021 as an attempt to improve its yield and quality. The experiments were executed in a private farm located at Abou El-Matameer city, in Behiera Governorate, Egypt. Three chitosan concentration were used, included control, 150 and 300 mg/l. Also, four concentrations of salicylic acid were used in the present study (0, 50, 75 and 100 mg/l) as a foliar spraying individual or in combination. The spraying was applied twice; the first one was carried out after 65 days from planting, the second application was 20 days after the first one. The untreated plants were sprayed with tap water. The layout experimental was factorial experiments in a Randomized Complete Blocks Design with three replications.The obtained results indicated, generally, that the higher concentration of chitosan (300 mg/l) and salicylic acid (75 mg/l) separately or in mixture recorded the highest average values and might be considered as an optimal treatment for the production of high yield and good quality of 'Balady' cv. globe artichoke plants under the environmental conditions of Behiera Governorate and other similar regions.

Keywords: globe artichoke, 'Balady' cv., chitosan, salicylic, foliar application.

INTRODUCTION

Globe artichoke is considered as one of the most important vegetable crops in the countries bordering the Mediterranean basin including Egypt (Ryder *et al*., 1983). Egypt is ranked the second world producer of Globe artichoke with the highest productivity per unit area in the world. The total area grown with artichoke in Egypt was 16546 hectares, which produced about 179439 tons with an average yield of 7.95 ton/fed (FAO, 2019). The globe artichoke is an attractive source of natural antioxidants since it is rich in polyphenols mainly phenolic acids and Flavonoids (Pandino *et al*., 2012; Dabbou *et al*., 2017). Plant polyphenols are dietary antioxidants in human health and disease might protect against oxidative damage. Besides, the inulin physiological effect as dietary fiber improves the intestinal flora and increased intestinal absorption of calcium and magnesium, it reduces lipid and cholesterol levels in blood. It, also, has a variety of functions as a source of carbohydrates for ethanol production in non-food industrial application, and acts as a fat replacer and prebiotic agent, and in yoghurt and ice cream preparations, it forms a gel that is similar as texture to fat, but with much lower Calories (Raccuia and Melilli, 2010; Sharaf-Eldin, 2002).

Chitosan is an N-acetylated derivative of the polysaccharide chitin and it is a natural polymer with a poly-cationic nature, which has several applications in agriculture, e.g., soil modifier, films coating, fungicide, and elicitor (Deepmala *et al*., 2014). It also increases photosynthesis, promotes and enhances plant growth, stimulates nutrient uptake, and increases germination (Kim *et al*., 2005). It is mainly composed of glucosamine, 2-amino-2- deoxy-β-D-glucose (Freepons, 1991) and can be extracted from the marine crustaceans such as crabs and shrimps (Bautista-Baños *et al*., 2006; El-Miniawy *et al*., 2013). It supplies to stimulation of plants immunity against microorganisms (Patkowska *et al*., 2006; Gornik *et al*., 2008; Sharma *et al*., 2019). Elsharkawy and Ghoneim (2019) found that spraying chitosan at 300 ppm significantly increased plant growth characters (leaf dry matter, leaf length and width and plant height), head yield and its components (number of heads/plant, early and total plant yield). Also, Saif Eldeen *et al*. (2014) reported that foliar application of chitosan on globe artichoke plants cv. French, at 2 ml/l caused significant increases in vegetative growth characters (plant height, number and dry weight of leaves/ plant), yield distribution (early, medium and late yields), head quality characteristics (head weight, diameter, receptacle fresh and dry weight as well as TSS), dry receptacle N, P, K, protein and total sugars contents. There are no more available studies regarding the effect of chitosan on growth, yield, earliness and quality of artichoke. Many reports mentioned that using chitosan as a foliar spray increased vegetative growth, yield and quality of some vegetable crops (Abdel-Mawgoud *et al*., 2010; Kamal and Ghanem, 2011; Fawzy *et al*., 2012; Morovvat *et al*., 2021). Foliar applications of chitosan at concentration of 75 mg/l on Indian spinach caused an increase in plant height, leaf number, branch number, leaf area, and fresh and dry weight.

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Oppositely, higher chitosan concentrations were required for the optimal growth development of okra (*Abelmoshus esculentus* L.). Foliar application of 100–125 mg/l chitosan every15 days increased okra fruit production, in addition to plant height, leaf number, relative growth rate, and photosynthesis rate, but had no effect on the chlorophyll content (Mondal *et al*., 2012). The foliar spraying of chitosan on tomato plants increased the fruit weight and yield (El-Tantawy, 2009). Sugiyama *et al*. (2001); Yumin *et al*. (2013) stated that the application of chitosan to some herbs can increase their phenolic contents.

Salicylic acid (SA) is one of the classes of plant hormones for growth and development and the incidence of both abiotic and biotic stresses. It is a phenolic derivative, distributed in a wide range of plant species. It is a natural product of phenylpropanoid metabolism. However, decarboxylation of trans-cinnamic acid to benzoic acid and its subsequent 2- hydroxylation; results in salicylic acid (SA). According to Hayat *et al.* (2010), the word salicylic acid was derived from a Latin word '*Salix*' averaging willow tree, and a plant phytohormone. Likewise, salicylic acid (SA) acts as an endogenous hormone-like plant growth regulator, which has abroad, but also had different roles on stress adjustment and appears to be an effective agent for the plant to overcome different stresses (Canakci and Munzuroglu, 2007; Amanullah *et al*., 2010; Vicente and Plasencia, 2011). It is an endogenous hormone and can be used as plant growth regulator with phenolic nature which participate in regulation of several physiological processes in plants, such as stomata closure, ion uptake, inhibition of ethylene biosynthesis and transpiration (Khan *et al*., 2002; Shakirova *et al*., 2003). There are available studies regarding the effect of salicylic acid on growth, yield, earliness and quality of artichoke. Many reports mentioned that using salicylic acid as a foliar spray increased vegetative growth, yield and quality of some vegetable crops (Javaheri *et al*., 2012; Flores-López *et al*., 2016; AL-Jeboori *et al*., 2017; Omar, 2017).

Therefore, the objectives of this paper are endeavor to test various levels of chitosan and salicylic acid singly or mixture as foliar application to improve growth, yield and quality of globe artichoke 'Balady' cv. under Egyptian environment.

MATERIALS AND METHODS

Experimental conditions

Two field experiments were carried out during the two successive seasons of 2019/2020 and 2020/2021. The experiments were executed in a private farm located at Abu El-Matamir district, in Behiera Governorate, Egypt, under open field conditions. This site located between latitude 30.92° N, and longitude 30.18° E with an elevation of about 7 m above sea level. Soil samples of 0-30 cm depth were collected and analyzed for some soil's physical and chemical properties of the experimental site during both seasons was using the methods described by Page *et al*. (1982). Soil texture of the experimental field was sandy loam. The soil salinity, pH, and organic matter were found to be 1.63-1.60 (dS/m), 8.0-8.10, 1.6-1.9% respectively. The inorganic elemental concentrations of N, P, and K were 90 - 95, 11 - 15 and 360 - 380 ppm in the first and second seasons, respectively.

Planting and agronomic practices

Stumps cuttings (crown pieces) produced from the old crowns of the previous globe artichoke plants, cv. Balady were used. Stumps were disinfected by the fungicide thiophanate methyl 70% at the rate of 2 g/ l for 20 minutes, and planted on one side of the ridge on August 15th, in both seasons. Each explant was of the same constant weight, more or less, *ca*. 160 g /explant. It was planted at 1.0 m apart and 1.0 m width of ridge. So, the total number of plants/ feddan were approximately 4200 plants. The recommended agricultural practices for commercial globe artichoke production were followed when it was necessary.

Chitosan and salicylic acid application

A pure commercial product of chitosan (2-amino-2-deoxy-ˇ-d-glucosamine) namely Chito-Care® with a degree of deacetylation of 85% was used. Chitosan was dissolved in acetic acid and final targeted concentration was reached with tap water. Three concentrations of chitosan were used, control (0), 150 and 300 ppm and four concentrations of salicylic acid were used in the present study (0, 50, 75 and 100 mg/l) singly or in mixture. The control plants were sprayed with tap water. Salicylic acid was purchased from Algomhoria Company for Chemicals, Alexandria, Egypt. The spraying was applied twice; the first one was carried out after 65 days from planting (at the stage when the plants had approximately 12-15 leaves), the second application was 20 days after the first one (or when plants had approximately 20 leaves). Bio-films wetting agents were applied at the rate of 0.5 ml/liter of the solution. The plants were sprayed until drop-off by using a hand-sprayer at early morning.

Experimental design

The used experimental layout was factorial experiments system in a Randomized Complete Blocks Design with three replications. Each replicate consisted of twelve treatment combinations, the combinations among the three chitosan levels and the four salicylic acid foliar spraying levels. Each experimental plot consisted of two ridges; each ridge was 7.00 m length and 1 m width.

Data recorded

Growth attributes' records

Five plants from each experimental unit were randomly chosen and tagged for growth measurements after one hundred and fifteen days from planting, plant height, length of the fifth leaf and number of leaves per plant characters were determined. Number of offshoots per plant was determined at the end of season. Leaves dry matter content (%) was conducted in an electrical oven at 75˚ C till obtaining a constant weight, then determined as (%).

Yield and its component measurements

Heads were harvested when they had attained maximum size, but before the lowest bract began to open with 10 cm of the stalk. Early yield was calculated for the first 12 pickings over 88 days (from December 2nd till February 28th) and total yield was calculated for all pickings during both seasons. The following criteria were determined for early and total yield: number of heads/ plant, number of heads/feddan, yield/plant, yield/feddan, average head fresh weight, and head dry matter content (%).

Heads quality characters

At the peak of harvesting period (March), Crude protein (%) and Total soluble solids content (TSS %), were estimated according to A.O.A.C. (2000). Total phenols (%,

f.w.) were determined using the method described by Khalifa *et al.* (1968). Head inulin content (%) was estimated according to a simplified spectrophotometric method described by Araya and Suporn (2011). Total sugars (%, d.w.) were determined according to the method described by Malik and Singh (1980).

Statistical Analysis

All obtained data of the present study were, statistically, analyzed according to the design used by the Costat computer software program. Duncan's multiple range test at 0.05 level of probability was used to compare the differences among the means of the various treatment combinations as illustrated by Duncan (1955).

RESULTS AND DISCUSSION

Vegetative growth characters:

Results presented in Table (1) exhibited clearly that foliar application with chitosan at 300 mg/l level showed significantly ($p \leq 0.05$) the highest average values of plant height, length of the fifth leaf, number of leaves per plant, number of offshoots per plant, and leaves dry matter content (%) characters during both seasons compare to the lowest level (150 mg/l) and control plants. These results might be explained by the chitosan role as key of enzyme activities of nitrogen metabolism (nitrate reductase, glutamine synthetase and protease) and its effect on photosynthesis which enhanced the plant growth (Gornik *et al*., 2008; Mondal *et al*., 2012). In addition, chitosan induces syntheses of plant hormones such as gibberellins. Furthermore, it enhances growth by some signaling pathways related to auxin biosynthesis *via* a tryptophan independent pathway (Sugiyama *et al*., 2001; Yumin *et al*., 2013). Also, the stimulating effects of vegetative growth might be due to that chitosan application enhanced the increase of water and essential minerals availability and uptake through adjusting cell osmotic pressure, and the reduction of the accumulation of harmful free radicals by increasing antioxidants and enzyme activities (Khan *et al*., 2002). The enhancement of artichoke growth traits by foliar application of chitosan is in agreement with those findings by Saif Eldeen *et al*. (2014) and Elsharkawy and Ghoneim (2019) on artichoke, El-Tantawy (2009) on tomato, Abdel-Mawgoud *et al*. (2010) and El-Miniawy *et al*. (2013) on strawberry, Fawzy *et al*. (2012) on garlic, Mondal *et al*. (2013) on mungbean and Ibrahim and Mohsen (2015) on summer squash.

Table 1. Average values of some vegetative growth-related characters of globe artichoke plants cv. 'Balady' as affected by foliar application with chitosan, salicylic acid (SA) and their combination during the winter seasons of 2019/2020 and 2020/2021.

Treatments		Plant height (cm)		The fifth leaf length (cm)		No. leaves /plant		No. offshoots /plant		Leaves dry matter (%)	
		2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021
Chitosan (mg/l)											
Control		79.90 b	79.90 c	70.50 b	71.70 b	15.01 b	15.20 c	5.60 b	5.60 c	17.60 b	17.90 c
150		80.15 b	81.20 b	70.40 b	71.60 b	15.50 b	15.60 b	5.80 ab	5.80 b	17.70 b	18.10 b
300		88.90 a	88.80 a	72.70 a	73.90 a	16.30 a	16.50 a	6.20 a	6.30 a	17.90 a	18.30 a
Salicylic acid (SA) mg/l											
Control		61.10 d	59.40 d	63.20 d	64.20 d	10.40 d	10.50 d	5.10 c	5.10 d	16.90 d	17.20 d
50		77.10 c	79.85 c	68.80 c	70.10 c	15.00 c	15.10 c	5.40 bc	5.40 c	17.50 c	17.90 c
75		89.50 b	87.50 b	75.20 b	77.50 b	16.70 b	16.80 b	6.90 b	6.00 b	18.10 b	18.40 b
100		104.50 a	106.50 a	77.60 a	78.80 a	20.50 a	20.70 a	7.10 a	7.10 a	18.60 a	18.97 a
Combination effects (mg/l)											
Chitosan	SA										
Control	Control	55.90 l	54.60 l	62.30 g	63.30 j	9.20 g	9.35 j	4.70 d	8.80 h	16.70 g	17.00 k
	50	75.30 h	79.40 h	69.40 d	70.90 g	15.10 de	15.40 f	5.30 cd	5.30 f	17.50 e	17.80 h
	75	85.10 f	85.90 f	74.20 c	75.40 e	16.20 c-e	16.40 e	5.80 b-d	5.90 d	17.80 d	18.20 f
	100	103.40 b	99.80 c	76.10 b	77.10 c	19.60 b	19.70 c	6.50 b	6.60 b	18.40 bc	18.80 c
150	Control	59.70 k	57.40 k	62.70 g	63.70 j	10.60 fg	10.70 i	5.20 cd	5.30 g	16.90 fg	17.20 j
	50	72.90 i	75.60 i	66.40 e	67.60 h	14.60 e	14.60 g	5.30 cd	5.30 f	17.50 e	17.83 h
	75	87.70 e	87.40 e	75.40 bc	76.70 d	16.60 cd	16.60 e	6.00 bc	6.10 c	18.00 d	18.40 e
	100	100.30 c	104.50 b	76.90 b	78.40 b	20.20 ab	20.50 b	6.60 b	6.60 b	18.60 ab	18.97 b
300	Control	67.50 j	66.20 j	64.60 f	65.60 i	11.20 f	11.40 h	5.30 cd	5.30 f	17.10 f	17.40 i
	50	83.10 g	84.50 g	70.60 d	71.70 f	15.20 de	15.40 f	5.60 b-d	5.60 e	17.60 e	17.95 g
	75	95.50 d	89.20 d	76.00 b	77.40 cd	17.30 c	17.40 d	6.10 bc	6.10 c	18.30 c	18.60 d
	100	109.70 a	115.30 a	79.60 a	81.00 a	21.70 a	21.90 a	8.00 a	8.10 a	18.80 a	19.20 a

- Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using Duncan's multiple range test at 0.05 level of probability.

With reference to the main effect of salicylic acid (SA), it exerted significant ($p \leq 0.05$) effect on the characteristics under the study, in general. It is noticeable that there is a direct proportionate relationship between the foliar application of SA and the given traits. In other words, as SA level increases; the given traits' average values increase and *vice versa*; whereas, the highest level of SA (100 mg/l) brought about the highest average values for plant height, the fifth leaf length, number of leaves/plant, number of offshoots/plant, and leaves' dry weight (%), compare to the control (untreated) plants, which recorded the lowest average values of the various studied traits. The positive effects of SA on vegetative growth-related characters in the present study could be attributed to SA mode of action in regulating and modulating the physiological processes on growth and development of artichoke plants under the study *via* ion uptake and transport, photosynthetic rate, membrane permeability and transpiration (Bhupinder and Usha, 2003; Wang *et al*., 2006).

The combination between both variables practiced significant effect ($p \leq 0.05$) on the traits under the study. Notably, the interaction between any chitosan levels and SA at its higher level (100 mg/l) recorded the highest average values for plant height, the fifth leaf length, number of leaves/plant, number of offshoots/plant and leaves dry matter, during both seasons

consecutively, compare to various untreated plants with SA. Foliar application with the combination 300 mg/l chitosan plus 100 mg/l SA gave highest significant values of artichoke vegetative growth characters.

Head yield and its components

Early yield

Pertaining the main effect of chitosan foliar application (Table 2), the highest level (300 mg/l) differed significantly ($p \leq 0.05$) from the lowest level (150 mg/l) and control plants. Foliar application with the highest chitosan level recorded the highest average values for early yield traits as number of heads/plant, number of heads/feddan, early yield /plant, early yield/feddan, and average head weight, consecutively compare to the other treatments. Such findings may be explained as chitosan role in, exhibition different regulatory and defensive roles through elicitation and signaling of different physiological and metabolically processes. Previous studies showed that chitosan can, directly or indirectly, influence the physiological activities of the plants (Kamal and Ghanem, 2011; Shehata *et al*., 2012). In this regard, the obtained results are consistent with those of Elsharkawy and Ghoneim (2019) who showed that spraying globe artichoke plants with chitosan at various levels (150 and 300 ppm) resulted in a highly significant improvement in yield potential compared with the control (untreated), during both seasons. High level of chitosan 300 ppm increased significantly number of heads/plant and early plant yield. These findings could be taken place due to the switching from vegetative to reproductive growth, as known as the floral transition which is controlled by both endogenous and exogenous cues, such as physiological age of propagation methods, temperature, photoperiod, hormones, and set of floral–promoting genes (Lee and Lee, 2010; Srikanth and Schmid, 2011). Concerning the main effect of SA concentrations, it exerted significant ($p \leq 0.05$) effect on the traits under the study, and it was in direct proportionate relationship with the characters under investigation, and *vice versa* is true, too. When SA was sprayed at 100 mg/l; brought about the highest average values for early yield traits as number of heads/plant, number of heads/feddan, early yield/plant, early yield/feddan, average head weight, respectively compare to control (untreated) plants, despite of the other two concentration of SA (50 and 75 mg/l), were different statistically ($p \leq 0.05$) from the control plants, too. The earliness of globe artichoke plant yield may be taken place owing to SA treatments which increases number of leaves and promotes vegetative growth (as reported earlier) and thus there is a translocation of the synthesized assimilates to other plant parts and might have facilitate early flowering (produced heads). Also, the obtained results could be attributed to the role of salicylic acid (SA) in enhancing the plant defense in plant against phytoplasma attack, reduces infection symptoms, favors photosynthetic translocation and improves the yield and quality of fruits (Lopez-Delgado *et al*., 2018).

Table 2. Average values of early yield characters of globe artichoke plants cv. 'Balady' as affected by foliar application with chitosan, salicylic acid (SA) and their combination during the winter seasons of 2019/2020 and 2020/2021.

Treatments		No. of heads /plant		No. of heads/feddan ($\times 10^3$)		Early yield/plant (kg)		Early yield/feddan (ton)		Average head weight (g)	
		2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021
Chitosan (mg/l)											
Control		6.93 b	7.20 c	29.11 b	30.24 c	1.219 b	1.284 c	5.121 b	5.393 c	175.95 c	178.35 c
150		7.45 ab	7.68 b	31.29 ab	32.29 b	1.323 b	1.381 b	5.557 b	5.802 b	177.61 b	179.88 b
300		8.08 a	8.24 a	33.94 a	34.61 a	1.472 a	1.519 a	6.181 a	6.380 a	182.15 a	184.35 a
Salicylic acid (SA) mg/l											
Control		5.60 d	5.88 d	23.52 d	24.70 d	0.899 d	0.959 d	3.777 d	4.028 d	160.57 d	163.10 d
50		6.87 c	7.08 c	28.85 c	29.74 c	1.201 c	1.238 c	5.045 c	5.199 c	174.83 c	174.83 c
75		7.74 b	7.88 b	32.51 b	33.10 b	1.432 b	1.475 b	6.016 b	6.196 b	185.07 b	187.20 b
100		9.73 a	9.97 a	40.87 a	41.87 a	1.906 a	1.977 a	8.004 a	8.304 a	195.87 a	198.30 a
Combination effects (mg/l)											
Chitosan	SA										
Control	Control	4.60 i	5.05 l	19.32 i	21.21 l	0.721 i	0.806 l	3.029 i	3.387 l	156.80 k	159.70 l
	50	6.80 fg	7.03 h	28.56 fg	29.53 h	1.174 e-g	1.230 h	4.932 e-g	5.164 h	172.70 gh	174.90 h
	75	7.41d-f	7.60 f	31.12 d-f	31.92 f	1.341 c-e	1.392 f	5.633 c-e	5.845 f	181.00 ef	183.10 f
	100	8.90 bc	9.10 c	37.38 bc	38.22 c	1.720 b	1.781 c	7.226 b	7.480 c	193.30 bc	195.70 c
150	Control	5.90 h	6.10 k	24.78 h	25.62 k	0.947 h	0.996 k	3.977 h	4.181 k	160.50 jk	163.20 k
	50	6.60f-h	6.80 i	27.72 gh	28.56 i	1.113 f-h	1.159 i	4.676 f-h	4.869 i	168.70 hi	170.50 i
	75	7.70 de	7.90 e	32.34 de	33.18 e	1.425 cd	1.478 e	5.983 cd	6.208 e	185.00 de	187.10 e
	100	9.60 b	9.90 b	40.32 b	41.58 b	1.884 b	1.967 b	7.915 b	8.262 b	196.30 ab	198.70 b
300	Control	6.30 gh	6.50 j	26.46 gh	27.30 j	1.036 gh	1.082 j	4.350 gh	4.543 j	164.40 ij	166.40 j
	50	7.20 ef	7.40 g	30.24 ef	31.08 g	1.274 d-f	1.325 g	5.352 d-f	5.556 g	177.00 fg	179.10 g
	75	8.10 cd	8.15 d	34.02 cd	34.23 d	1.533 c	1.560 d	6.437 c	6.552 d	189.20 cd	191.40 d
	100	10.70 a	10.90 a	44.94 a	45.78 a	2.119 a	2.185 a	8.898 a	9.179 a	198.00 a	200.50 a

The interaction among various combinations exerted significant ($p \leq 0.05$) effects on the tested characteristics, especially when the plants treated with the highest concentration of chitosan (300 mg/l) and GA_3 (100 mg/l) compare with the other concentrations and control plants. The combination gave rise to the highest average values for artichoke early yield traits as number of heads/plant, number of heads/feddan, early yield /plant, early yield/feddan, and average head weight compare with the other combinations, during both seasons.

Total yield

Results outlined in Table (3) exhibited that both foliar application of chitosan and SA concentrations, either individually or their combination showed significant ($p \leq 0.05$) effects on total yield characters of globe artichoke plants during both seasons. In relation to the main effect of chitosan, the presented results declare that the given variable exerted significant ($p \leq 0.05$) effect on the total yield characters. It is obvious that the highest chitosan level (300 mg/l) exhibited significantly ($p \leq 0.05$) the highest average values compare to

the other levels for artichoke total yield characters as number of heads/plant, number of heads/feddan, total yield/plant, total yield/feddan, average head weight and head dry matter (%) during both growing seasons. Such findings may be explained as chitosan role in, exhibition different regulatory and defensive roles through elicitation and signaling of different physiological and metabolically processes. The obtained results are consistent with those of Elsharkawy and Ghoneim (2019) who showed that spraying globe artichoke plants with chitosan at various levels (150 and 300 ppm) resulted in a highly significant improvement in yield potential compared with the control (untreated), during both seasons. High level of chitosan 300 ppm increased significantly number of heads/plant and total plant yield.

Respecting the main effect of SA, foliar application showed significant ($p \leq 0.05$) effect on the given traits of the variable. Further, there is a direct proportionate relationship between SA concentration and the traits under the study especially upon using SA at 100 mg/l. The increases were for number of heads/plant, number of heads /feddan, total yield/plant, total yield /feddan, average head weight, and head dry weight, compare to control (untreated) plants which recorded the lowest average values. The obtained results could be attributed to the role of salicylic acid (SA) in enhancing the plant defense in plant against phytoplasma attack, reduces infection symptoms, favors photosynthetic translocation and improves the yield and quality of fruits (Lopez-Delgado *et al*., 2018). However, treating the combined foliar application with 300 mg/l chitosan and 100 mg/1 SA exhibited the highest average values for total yield characters as number of heads/plant, number of heads /feddan, total yield/plant, total yield /feddan, average head weight, and head dry weight compared to the other treatments during both seasons of the study.

Table 3. Average values of total yield characters of globe artichoke plants cv. 'Balady' as affected by foliar application with chitosan, salicylic acid (SA) and their combination during the winter seasons of 2019/2020 and 2020/2021.

Treatments		No. of heads /plant		No. of heads/feddan ($\times 10^3$)		Total yield/plant (kg)		Total yield/feddan (ton)		Average head weight (g)		Head dry matter (%)	
		2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021	2019/ 2020	2020/ 2021
Chitosan (mg/l)													
Control		9.68 c	9.96 c	40.66 c	41.83 c	1.556 c	1.625 c	6.535 c	6.824 c	160.75 b	163.13 c	24.20 a	24.81 c
150		10.25 b	10.50 b	43.05 b	44.10 b	1.661 b	1.728 b	6.976 b	7.256 b	162.05 b	164.53 b	24.40 a	24.90 b
300		11.10 a	11.38 a	46.62 a	47.80 a	1.547 a	1.922 a	7.759 a	8.072 a	166.43 a	168.88 a	24.60 a	25.20 a
Salicylic acid (SA) mg/l													
Control		7.77 d	8.01 d	32.63 d	33.64 d	1.154 d	1.207 d	4.845 d	5.069 d	148.47 d	150.67 d	23.10 c	23.60 d
50		9.33 c	9.60 c	39.19 c	40.32 c	1.475 c	1.541 c	6.196 c	6.474 c	158.13 c	160.57 c	24.30 b	24.90 c
75		10.60 b	9.83 b	44.52 b	45.49 b	1.752 b	1.846 b	7.482 b	7.754 b	168.07 b	170.47 b	24.60 b	24.19 b
100		13.76 a	14.00 a	57.79 a	58.80 a	2.444 a	2.525 a	10.266 a	10.603 a	177.63 a	180.33 a	25.50 a	26.10 a
Combination effects (mg/l)													
Chitosan	SA												
Control	Control	6.70 i	7.13 l	28.14 i	29.95 l	0.975 k	1.052 l	4.094 k	4.420 l	145.50 l	147.60 l	22.70 h	23.30 k
	50	9.30 ef	9.50 h	39.06 ef	39.90 h	1.470 gh	1.524 h	6.175 gh	6.400 h	158.10 h	160.40 h	24.40 c-f	24.90 f
	75	10.00 de	10.30 f	40.00 de	43.26 f	1.649 ef	1.722 f	6.926 ef	7.233 f	164.90 f	167.20 f	24.20 d-f	24.80 g
	100	12.70 b	12.90 c	53.34 b	54.18 c	2.216 c	2.287 c	9.308 c	9.606 c	174.50 c	177.30 c	25.40 ab	26.00 b
150	Control	8.10 h	8.20 k	34.02 h	34.44 k	1.202 j	1.236 k	5.049 j	5.190 k	148.40 k	150.70 k	23.10 gh	24.60 j
	50	9.00 fg	9.30 i	37.80 g	39.06 i	1.394 hi	1.465 i	5.855 hi	6.152 i	154.90 i	157.50 i	23.90 e-g	24.50 h
	75	10.50 d	10.70 e	44.10 d	44.94 e	1.764 e	1.823 e	7.409 e	7.658 e	168.00 e	170.40 e	24.60 b-e	25.20 e
	100	13.40 b	13.80 b	56.28 b	57.96 b	2.370 b	2.477 b	9.956 b	10.404 b	176.90 b	179.50 b	25.80 a	26.50 a
300	Control	8.50 fg	8.70 j	35.70 gh	36.54 j	1.288 ij	1.337 j	5.409 ij	5.616 j	151.50 j	153.70 j	23.50 f-h	24.00 i
	50	9.70 d-f	10.00 g	40.74 def	42.00 g	1.566 fg	1.638 g	6.575 fg	6.880 g	161.40 g	163.80 g	24.80 b-e	25.30 e
	75	11.30 c	11.50 c	47.46 c	48.30 d	1.936 d	1.999 d	8.130 d	8.395 d	171.30 d	173.80 d	25.00 a-d	25.50 d
	100	14.90 a	15.30 a	62.58 a	64.26 a	2.704 a	2.818 a	11.358 a	11.837 a	181.50 a	184.20 a	25.20 a-c	25.80 c

- Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using Duncan's multiple range test at 0.05 level of probability.

Head quality characteristics

Results depicted in Table (4) express the average values of head (*capitulum*) chemical quality characters of globe artichoke plants cv. 'Balady' as affected by foliar application of chitosan and salicylic acid concentrations and their combinations. The effects were significant ($p \leq 0.05$) for various characters except for total phenols of the tested chitosan foliar application. With reference to the main effect of chitosan, the highest level (300 mg/l) recorded the highest average values of crude protein, TSS (%), inulin (%) and total sugars (%) compared to the other treatments, during both seasons. These increments may be explained as a result of favorable stimulatory effects of all treatments on vegetative growth characters and enhanced photosynthetic apparatus. The significant effect of foliar spray of chitosan might be explained as the effect of chitosan a new plant growth promoter. Also, chitosan may have effect on the plant growth and yield (El-Bassiony *et al*., 2003). Similar results were also obtained by Elsharkawy and Ghoneim (2019) on artichoke, Farouk *et al*. (2008) on cucumber, Ghoname *et al*. (2010) on sweet pepper, Abu-Muriefah (2013) on common bean. They found that, foliar applications with chitosan improved fruit quality of plants. Abdel-Mawgoud *et al*. (2010) on strawberry found that total soluble solids increased in response to chitosan application. Concerning the total phenol content (%, f.w.), despite the absence of the significant ($p > 0.05$) differences among chitosan levels justifies the richness of globe artichoke's heads, generally, in polyphenolic acids and flavonoids (Pandino *et al*., 2012).

Table 4. Averages values of head quality characters of globe artichoke plants cv. 'Balady' as affected by foliar application with chitosan, salicylic acid (SA) and their combination during the winter seasons of 2019/2020 and 2020/2021.

Treatments		Head chemical quality contents									
		C-Protein (%)		Total phenols (%)		TSS (%)		Inuline (%)		Total sugars (%)	
		2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021
Chitosan (mg/l)											
Control		10.50 b	10.94 c	0.213 a	0.216 a	7.43 c	7.56 c	11.99 c	12.28 c	14.99 c	15.32 c
150		10.75 b	11.19 b	0.214 a	0.216 a	7.50 d	7.61 b	12.16 b	12.40 b	15.18 b	15.61 b
300		11.38 a	11.75 a	0.214 a	0.216 a	7.66 a	7.77 a	12.54 a	12.81 a	15.67 a	15.99 a
Salicylic acid (SA) mg/l											
Control		8.31 d	8.63 d	0.201 d	0.203 d	6.98 d	7.19 d	10.81 d	11.00 d	13.75 d	14.10 d
50		10.13 c	10.58 c	0.211 c	0.214 c	7.35 c	7.46 c	11.73 c	12.04 c	14.57 c	14.93 c
75		11.63 b	11.94 b	0.218 b	0.221 b	7.70 b	7.82 b	12.71 b	13.01 b	15.78 b	16.11 b
100		13.38 a	14.13 a	0.225 a	0.228 a	8.09 a	5.21 a	13.66 a	13.94 a	17.03 a	17.41 a
Combination effects (mg/l)											
Chitosan	SA										
Control	Control	7.81 k	8.13 i	0.203 fg	0.206 j	6.85 l	6.95 k	10.54l	10.82 k	13.44 k	13.58 i
	50	10.25 h	10.81 f	0.211 c-f	0.214 h	7.63 h	7.55 g	11.72 h	12.04 h	14.53 i	14.91 g
	75	11.06 f	11.38 e	0.216 b-d	0.219 f	7.59 f	7.73 e	12.34 f	12.64 f	15.37 f	15.71 e
	100	12.81 c	13.50 b	0.223 ab	0.226 c	7.96 c	8.08 c	13.34 c	13.61 c	16.63 c	17.07 c
150	Control	8.38 j	8.69 h	0.205 ef	0.206 j	6.97 k	7.07 j	10.82 k	10.91 k	13.71 j	14.31 h
	50	9.50 i	9.81 g	0.209 d-f	0.211 i	7.25 i	7.37 h	10.44 i	11.73 i	14.22 j	14.54 h
	75	11.63 e	11.94 d	0.218 a-c	0.221 e	7.68 e	7.79 e	10.75 e	13.01 e	15.78 e	16.17 d
	100	13.50 b	14.31 a	0.225 ab	0.227 b	8.09 b	8.21 b	13.65 b	13.95 b	17.02 b	17.42 b
300	Control	8.69 j	8.94 h	0.195 g	0.197 k	7.13 j	7.23 i	11.08 j	11.27 j	14.10 i	14.43 h
	50	10.63 g	11.06 f	0.213 c-e	0.215 g	7.46 g	7.56 f	12.04 g	12.34 g	14.97 g	15.33 f
	75	12.19 d	12.56 c	0.221 a-c	0.228 d	7.82 d	7.92 d	13.05 d	13.38 d	16.18 d	16.47 d
	100	13.88 a	14.50 a	0.227 a	0.230 a	8.21 a	8.35 a	13.98 a	14.27 a	17.44 a	17.74 a

-Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using Duncan's multiple range test at 0.05 level of probability.

Pertaining the main effect of SA concentrations on chemical quality characters of globe artichoke plants' head [crude protein %, total phenols (%), TSS (%), inulin (%), and total sugars (%)]. The results declare that concentrations of SA affected significantly ($p \leq 0.05$) traits under study. Also, it is obvious that there is a direct proportionate relationship between SA level and the given traits. Foliar application of SA at 100 mg/l, brought about the highest average values for crude protein, total phenols, TSS, inulin, and total sugars compare to the other treatment, especially the control (untreated) plants. The obtained results could be attributed to the role of salicylic acid (SA) in enhancing the plant defense in plant against phytoplasma attack, reduces infection symptoms, favors photosynthetic translocation and improves the yield and quality of fruits (Lopez-Delgado *et al*., 2018). Also, SA either directly or indirectly influences the activity of certain enzymes as described for sucrose-p-synthesis, sucrose synthase and amylases. These metabolic effects, such as changing carbohydrate metabolism in plants and so that soluble sugar, especially non-reducing sugars accumulated to function as osmotic regulators (osmolytes).

In addition, the accumulated reducing sugars (e.g. glucose and fructose) could be used as the initial precursors for the synthesis of other osmolytes such as proline and polyamines (Tari *et al*., 2002; Szepesi *et al*., 2005), hence support the plant protection against a biotic and/or abiotic stresses, and enhance plant characteristics. Notably, the activity of SPS (sucrose-p-syntheses), the major enzyme involved in sucrose synthesis was regulated by SA treatment in leaves. However, after SA treatment, the levels of sucrose decreased in leaves, but increased in roots, indicating the distinct fate of sucrose in leaves and roots after SA treatment (Poor *et al*., 2011). It should be realized that the recorded results of foliar application of SA concentration on head chemical quality contents (crude protein %, total phenols %, TSS %, inulin %, and total sugars %) may be related to the mode of action of it in lowering the respiration rate (Riederer and Schreiber, 2001), its function in delaying senescence, increasing the content of cuticle and sustain the integrity of membranes which reduce the water loss and cell wall thickness that protect the capitulum (head) physical and chemical properties from abiotic and/or biotic stresses adverse effects (Marzouk and Kassem, 2011). With regard to the combination effect of both chitosan and SA concentrations, results of Table (4) revealed such significant ($p \leq 0.05$) differences among the various tested combinations. the combination between any chitosan foliar application levels and foliar application of SA at 100 mg/l, brought about the highest average values of the tested traits individually; nevertheless, the combination between highest chitosan level (300 mg/l) and SA at (100 mg/l) recorded the highest average values of chemical quality characters for globe artichoke plants' head as [crude protein %, total phenols (%), TSS (%), inulin (%), and total sugars (%)] compare to the other treatments.

This study recommends, generally, that the foliar application of globe artichoke plants 'Balady' cv. with chitosan at higher level (300 mg/l) and salicylic acid at (100 mg/l) separately or in combination resulted in the highest average values and might be considered as an optimal treatment for the production of high yield and good quality of globe artichoke plants 'Balady' cv. under the environmental conditions of Behiera Governorate and other similar regions.

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سلوك نباتات الخرشوف متأثراً بالرش الورقي بالشيتوسان وحمض السالسيلك

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يعتبر الخرشوف أحد أهم محاصيل الخضر في البلدان المجاورة لحوض البحر الأبيض المتوسط بما في ذلك مصر. ويعتبر صنف الخرشوف "البلدي" الأكثر زراعة لدى المزارعين، ولكن نتيجة تأخير إزهاره وانخفاض القدرة الإنتاجية يؤدي إلى العزوف عنه. لذلك أجريت تجربتان ميدانيتان خلال الموسمين المتتاليين 2020/2019 و2021/2020 كمحاولة لتحسين إنتاجيته وجودته. نفذت التجارب فى مزرعة خاصة تقع فى مدينة أبو المطامير بمحافظة البحيرة بمصر تحت ظروف الحقل المفتوح. تم إستخدام ثلاثة تركيزات من الشيتوزان متضمنة، الكنترول، 150 و300 ملجم / لتر. كذلك، تم إستخدام أربعة تركيزات من حمض الساليسيليك (0، 50، 75 و100 ملجم / لتر) مفردة أو مختلطة رشا على الأوراق. وقد تم الرش مرتين وتم تنفيذ المعاملة الأولي بعد 65 يومًا من الزراعة (في المرحلة التي كانت فيها النباتات تحتوي على ما يقرب من 12-15 ورقة)، وكانت المعاملة الثانية بعد 20 يومًا من الأولي (أو عندما كان للنباتات حوالي 20 ورقة). تم رش معاملات الكنترول بماء الصنبور. كان تصميم التجربة عبارة عن تجربة عامليه في تصميم القطاعات العشوائية الكاملة بثلاث مكررات. تم دراسة تأثير كلاً من المتغيرين ومخاليطهما على الصفات المرتبطة بالنمو الخضري والمحصول ومكوناته وجودة الرأس. أشارت النتائج المتحصل عليها، بشكل عام، إلى أن التركيز الأعلى للشيتوزان (300 ملجم / لتر) وحمض الساليسيليك (75 ملجم / لتر) بشكل منفصل أو في الخليط سجل أعلى متوسط القيم للصفات المدروسة. ويمكن اعتبارها المعاملة الأمثل للإنتاجية وصفات الجودة لصنف الخرشوف البلدي في ظل الظروف البيئية لمحافظة البحيرة والمناطق المماثلة الأخرى.