Egypt. J. Hort. **Vol. 46**, No. 1, pp. 95 - **106** (2019)

Effect of Chitosan and Gibberellic Acid Applications on Yield, Quality and Yield Pattern of Globe Artichoke (*Cynarascolymus* L.)

Gehan A. Elsharkawy and Ibrahim M. Ghoneim
Vegetable Crops Department, Faculty of Agriculture, Alexandria University , Egypt.

A TWO-YEAR study was carried out in Alexandria, Egypt to investigate the potential compensation of thermal requirement for artichoke flowering by gibberellic acid (GA_3) treatment and to evaluate the effect of combined treatment of GA_3 and chitosan. The experiment comprised twelve treatments, four treatments of GA_3 at 0 (control), and25 ppm, sprayed once, twice or three times at one month interval between treatment and three levels of chitosan at 0, 150 or 300 ppm. The effect of these treatments was evaluated on plant growth, earliness, productivity, quality and yield pattern of globe artichoke of the improved local El-Baladycultivar. The results showed that plants sprayed once or twice with GA_3 gave the highest values of vegetative growth, early yield and edible part fresh weight. However, spraying artichoke plants three times with GA_3 resulted in the highest number of heads / plant, total yield, average head weight, head diameter and edible part diameter. Moreover, spraying chitosan at 300 ppm significantly increased plant growth characters, head yield and its components. In addition, the interaction treatments between spraying artichoke plants two times with GA_3 and chitosan at 150 ppm gave the highest values for early yield. However, total yield favored spraying plants three times with GA_3 and 300 ppm of chitosan. The results showed that the percentage of yield pattern distribution for the plants treated three times with GA_3 as average of both seasons, were 27.9 and 29.4 % compared to 25.6 and 27.4 % for the non-treated plants in both seasons, respectively. On the other hand, applying chitosan at 300 ppm gave 27.4 and 36.3 % compared to 24.2 and 26.7% for the control plants in both seasons.

Keywords: Globe artichoke, Gibberellic acid, Chitosan, Yield pattern.

Introduction

Globe artichoke is an important vegetable crop grown in the Mediterranean territories,Italy, Spain and France, producing over than 80% of the world crop production (Ryder et al., 1983). Artichoke is considered of high nutritional value due to its high content of phenolic compounds, flavonoids, inulin, fiber and mineral salts, as well ascynarin. In Egypt, farmers planted artichoke for its nutritional and medicinal properties. The majority of globe artichoke production in Egypt is usually obtained in March and April, while the optimum time for exportation to European countries is December up to February. The early production in this period is considered of great importance, because of the great demand and high prices. Shifting the yield pattern would be of great interest to meet the exportation demands. Artichoke productivity and earliness of heads areinfluenced by various factors including environmental conditions, cultivars characteristics, soil management practices, nutrition practices, propagation methods and plant population. Artichoke production requires low temperature and long photoperiod to form generative stem and bloom (Mauromicale and Ierna, 1995). It was reported that most suitable temperature for vernalizationranged from 2 to 7°C (Harwood and Markarian, 1968). Basnizki and Goldschmidt (1994) found that gibberellic acid initiated generative stems for artichoke plants in the unfavorable photoperiod conditions. Also, gibberellic acid shortened period from planting to harvest and increased yield (Calabrese and Bianco, 2000). In addition, various studies reported the effect of gibberellic acid (GA_3) on globe artichoke growth, yield, and quality (Schrader, 1992, Elia et al., 1994, Mauromicale & Irena, 1995 and 2000, Foury, 2003 and Garcia et al., 2004). Applications of GA_3 are considered common practice to achieve globe artichoke earliness and flowering process.

Corresponding author: Gehan Abdelaziz Elsharkawy, e-mail: gehanelsharkawy@yahoo.com
DOI: 10.21608/ejoh.2018.6604.1091

Chitosan is an N-acetylated derivative of the polysaccharide chitin and it is a natural polymer with a poly-cationic nature, which has numerous applications in agriculture, e.g., soil modifier, films, 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, and El-Miniawy et al., 2013). It contributes to stimulation of plants immunity against microorganisms (Patkowska et al., 2006,and Gornik et al., 2008). 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 &Ghanem 2011 and Fawzy et al., 2012). It was also observed that the addition of 1.0% (w/v) of high MW (600–900 kDa) chitosan to the soil enhanced plant heights, canopy diameters and leaf areas of strawberry (El-Ghaouth et al., 1991). Foliar applications of chitosan at concentration of 75 mg/l on Indian spinach (Basellaalba L.) resulted in an increase in plant height, leaf number, branch number, leaf area, and fresh and dry weight. On the other hand, higher chitosan concentrations were required for the optimal growth enhancement of okra (Abelmoshus esculentus L.). Foliar application of 100–125 mg/l chitosan every15 days increased okra fruit production, as well as 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) and Yumin et al. (2013) stated that the application of chitosan to some herbs can increase their phenolic contents. There are no available studies regarding the effect of chitosan on growth, yield, earliness and quality of artichoke.

The present study investigates the effect of multiple foliar sprays with gibberellic acid and chitosan concentrations on vegetative growth, earliness, yield, quality and yield pattern of globe artichoke heads, for both exportation and local consumption.

Materials and Methods

Experimental conditions

Two field experiments were conducted in the seasons of 2014/2015 and 2015/2016 to study the effect of applications number of gibberellic acid and chitosan concentrations on growth, earliness and yield potential of artichoke cv. Balady. The experiments were conducted at the Agriculture Research Station Farm (Abies) of the Faculty of Alexandria University, Egypt. This site located between latitude 31.2^{o}N, and longitude 29.6^{o} E with an elevation of about 2.5 m below sea level. Soil texture of the experimental field was clay. Soil chemical analysis was measured using the methods described by Page et al. (1982). The soil pH**,** and organic matter were found to be 7.6-7.0, 1.6-2.2% respectively. The inorganic elemental concentrations of N, P, and K were 220 - 198, 20 - 26 and 740 - 463 ppm in the first and second seasons, respectively.

Planting and agronomic practices

Seed pieces (stumps) produced from the old crowns of the previous globe artichoke plants, cv. Balady were used. Stumps were disinfected by the fungicide Topsin M-70 at the rate of 2 g/ lfor 20 minutes, and planted ononeside of the ridge on August 15th, in both seasons. Each experimental unit consisted of an area of 9 m^{2}, 3 rows of 3 meter long and 1meter wide, with a plant spacing of 1m between plants. Two guard ridges were left as buffering between each two adjacent main and sub- plots. All the recommended cultural practices for growing artichoke were performed when it was necessary.

Gibberellic acid (GA_3) application

Aqueous solutions of 25 ppm of GA_3 (Berelex, ICI Soplant) was used. The applications were done early in the morning when plants were turgid. Single, double or triple applicationswere done by using a hand-sprayer on leaves until run-off. According to the different plant dimensions, the spray volumes were 100, 300 and 400 ml plant^{-1} when the plants were at the stage of the 8th, 15th and 25th expanded leaf, respectively. The control plants were sprayed with tap water. The first application of $GA_3$was done after one month of planting while the second and third sprays were given at 30 days intervals.

Chitosan 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 (0.0), 150 and 300 ppm. The control plants were sprayed with tap water. Foliar spray applications were done twice after one month from planting and repeated after another month. Bio-films wetting agents were applied at the rate of 0.5 ml liter^{-1}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 split plot system in a randomized complete blocks design (RCBD) with three replicates. Each replicate consisted of twelve treatment combinations, the combinations among the three GA_3number of sprays beside control and the three chitosan foliar spraying levels. The GA_3 were considered as the main plots and the different chitosan foliar spraying treatments were the sub-plots.

Data recorded

*Plant growth parameters:*A randomly chosen sample of 5 plants plot^{-1} was marked after 120 days from planting date to determine plant height, leaf dry matter content,average leaf length and width of the fifth true leaf and leaf dry matter.

Yield potential: All heads of all plants in each plot were harvested, counted and weighted during the period from December till the end of January (as an early yield) and to the end of the season to determine total yield per plant in kg .

Yield pattern distribution/plant: it is expressed as the number and percentage of harvested heads produced each month relatively to the total harvested heads throughout the entire harvesting season.

*Head quality characteristics:*At the peak of harvesting period (March), head quality characters were considered. The average head weight and diameter, receptacle fresh and dry weights and diameter of the edible portion were recorded. TSS of receptacles was recorded using a hand refractometer.

Statistical analysis

Collected data were statistically analyzed by analysis of variance using SAS program (SAS, 1985) with means separated by revised Least Significant Difference (LSD) test according to Snedecorand Cochran (1980).

Results and Discussion

Vegetative growth

Results in Table 1 indicated that leaf length and width plant height, and leaf dry matter significantly increased compared to the unsprayed control generally in most of the cases. The best values of GA_3sprayings ranged from one time for leaf length and two times for leaf width and leaf dry matter, compared to the lowest values which recorded from untreated plants.The stimulating effect of GA_3 on vegetative growth characters is related to its effect on cell elongation and division. GA_3positive effects were previously reported by Bekhit et al. (1985), ElGreadly (1994) and Sharaf-Eldin (2002).

As for the chitosan foliar applications at different levels, obtained results in Table 1 indicated that increasing chitosan concentration to 300 ppm caused a successive and significant increase in leaf dry matter, while 150 ppm gave the best for leaf length and leaf width. For plant height, either of the chitosan levels of 150 or 300 ppm gave a significant effect in the two seasons as compared with the control. 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., 2008and 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 and 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 characters by foliar application of chitosan is in agreement with those findings by 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 mung bean and Ibrahim et al. (2015) on summer squash.

The statistical comparisons listed in Table 2 illustrated significant interaction effects between GA_3 application number and various chitosan concentrations on leaf length and width of

TABLE 1. Vegetative growth characters of globe artichoke as affected by gibberellicacid applications and chitosan concentrations in 2014 and 2015 seasons.

Treatments		Leaf length (cm)		5th Leaf width (cm)		Plant height(cm)		Leaf dry matter(%)	
GA_3 number of applications	Chitosan concentrations(ppm)	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control (without GA_3)		63.38d	60.80c	23.94d	22.96d	80.80b	81.60b	18.47c	21.02b
25 ppm GA_3 (once)		68.00a	64.73a	24.71c	23.64c	85.70ab	86.04a	19.42b	22.31ab
25 ppm GA_3 (twice)		64.59c	61.60bc	25.72a	24.53a	84.94ab	81.49b	20.46a	23.74a
25 ppm GA_3 (thrice)		66.58b	63.59ab	25.30b	24.20b	87.43a	82.99ab	19.7 5b	22.99ab
	0	63.19C	60.64B	23.51C	22.49C	78.89B	80.90B	18.20B	21.21C
	150	68.37A	65.03A	26.14A	24.97A	86.28A	82.93AB	20.06A	22.83B
	300	65.36B	62.30B	25.10B	24.04B	88.99A	85.26A	20.32A	23.51A

Means into every group within a column followed by the same letter (s)do not differ significantly by revised LSD ($P = _{0.05}$).

artichoke plants. The combination of gibberellic acid at one or two applications plus 150 ppm chitosan gave the highest mean values of leaf length and width. Moreover, spraying GA_3 three times along with the chitosan at 150 ppm gave the highest plant height in the first season. For leaf dry matter the results showed that spraying chitosan at 150 or 300 ppm combined with two or three applications of GA_3increased the accumulation of dry matter in leaves.

Yield potential

Data in Table 3 shows the effect of multiple applications of gibberellic acid or different levels of chitosan on artichoke yield. The results clearly show significant and positive effect on yield characters compared to the untreated control in the two tested seasons. Double applications of GA_3 application gave the best results for early yield per plant where, the increased percentages were 19 and 51% over the control in both seasons, respectively. The positive effect of GA_3 on early yield may be attributed to its induction effect on early blooming and flowering stimulation (AbdElhamied et al., 2008).Firpo et al. (2005) noticed that using gibberellin in cultivation of artichoke cv. 'Violet de Provence' plants increased early yield of artichoke buds by 115%. Gibberellic acid (GA_3) treatment caused earlier harvest in vegetative propagated cultivars (Foti and La Malfa, 1981andMangano and Signorelli, 1981). Studies performed on seed-grown varieties of artichoke indicated that GA_3 effectiveness on earliness depends on sowing dates, the sensitivity of each cultivar to GA_3 and the number of GA_3 treatments (Elia et al., 1994). On the other hand, application of gibberellic acid (GA_3) for artichoke sown directly into the ground in warm climate conditions enforced it to flower and yield in the same year (López et al., 2007), and to obtain earlier harvest of buds by 20 days (Miguel et al., 2004). Sharaf-Eldin et al. (2003) reported that exogenous GA_3 treatment, if misapplied can negatively affect plant vigor, caused elongation of early buds and produced brittle leaves that easily break. These negative impacts became apparent if GA_3 is applied early in the season. Also, the application of high doses and existence of excessive heat during or immediately after application may contribute to the previous effects.

The foliar sprays with GA_3 at 25ppm three times resulted in the highest mean values for number of heads, and total plant yield. The increment

TABLE 2. Vegetative growth characters of globe artichoke as affected by interaction of gibberellic acid applications and chitosan concentrations in 2014 and 2015 seasons.

Treatments		Leaf length (cm)		5th Leaf width (cm)		Plant height(cm)		Leaf dry matter (%)	
GA_3 number of applications	Chitosan concentrations (ppm)	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control (without GA_3)	0	57.00h	55.80f	23.20c	22.40bc	73.10e	71.50e	17.08c	19.97c
	150	65.56d-f	62.00b-d	24.41bc	23.32a-c	81.16cd	88.16ab	19.22b	21.26bc
	300	67.60b-d	64.6a-d	24.21bc	23.18a-c	88.16a-c	85.16b-d	19.11b	21.84bc
25 ppm GA_3 (once)	0	72.00a	69.00a	23.20c	22.10c	84.30bc	91.30a	18.27bc	21.02bc
	150	68.80bc	65.00a-c	26.05ab	24.96a-c	84.31bc	81.33cd	19.95b	22.29b
	300	63.20f	60.20d-f	24.90bc	23.86a-c	88.50a-c	85.50a-c	20.04ab	23.61ab
25 ppm GA_3 (twice)	0	60.16g	57.16ef	23.16c	22.09c	82.33cd	79.33d	18.92bc	22.35b
	150	69.43ab	66.43ab	27.50a	26.10a	84.50bc	80.10cd	20.77ab	24.10a
	300	64.20ef	61.22c-e	26.50ab	25.40ab	88.00a-c	85.06b-d	21.70a	24.78a
25 ppm GA_3 (thrice)	0	63. 60ef	60.63c-e	24.51bc	23.40a-c	75.83de	81.50cd	18.52bc	21.48bc
	150	69.70ab	66.70ab	26.60ab	25.50a-c	95.16a	82.16cd	20.32ab	23.67a
	300	66.46c-e	63.46b-d	24.86bc	23.72a-c	91.30ab	85.33bc	20.42ab	23.82ab

Mean values in each column with the same letter do not differ significantly by revised LSD ($P = _{0.05}$).

TABLE 3. Yield potential characters of globe artichoke as affected by gibberellicacid applications and chitosan concentrations in 2014 and 2015 seasons.

Treatments		Number of heads/ plant		Early yield/plant(kg)		Total yield/plant (kg)		Head fresh weight (g)	
GA_3 number of applications	Chitosan concentrations (ppm)	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control (without GA_3		8.56d	4.89d	1.56c	0.47c	3.23d	1.47c	334.5b	287.90b
25 ppm GA_3 (once)		9.37b	5.48c	1.70b	0.54b	3.42c	1.85b	355.6a	327.50a
25 ppm GA_3 (twice)		9.24c	5.98b	1.86a	0.71a	3.77b	1.80b	345.8 ab	322.97a
25 ppm GA_3 (thrice)		10.10a	6.53a	1.78b	0.53b	4.00a	2.25a	350.2a	317.13a
	0	8.55C	5.17B	1.18B	0.43C	3.10C	1.57C	332.3B	287.50B
	150	9.23B	5.76C	2.03A	0.56B	3.75B	1.90B	365.9A	338.88A
	300	10.16A	6.24A	1.97A	0.69A	3.96A	2.06A	341.4A	315.22A

Means into every group within a column followed by the same letter (s) do not differ significantly by revised LSD ($P = _{0.05}$).

reached18% and 33% for number of heads/plant and 24 and 53% for plant yield over the control treatment in both studied seasons, respectively. However, for average head weight, there is no clear significant difference noticed between the numbers of GA_3 applications. The present study demonstrated that exogenous GA_3 applications can replace cold requirements in Balady cultivar of artichoke. This result is in an agreement with the findings of Sharaf-Eldin et al. (2003) and Abd-Elhamied et al. (2008) whoreported that GA_3 application has insignificantly affected the number of heads per plant and total late yield of globe artichoke. Also stimulating effect of gibberellins at levels ranged at 20-30 ppm on artichoke plants was reported by Paradiso et al. (2007). High concentration of gibberellic acid stimulated flowering of late flowering cultivars, and low concentration stimulated flowering of early flowering cultivars (Baixauli et al., 2007). Calbrese and Bianco (2000) stated that GA_3 treatment increased the yield of heads.

The effects of chitosan treatment on yield potential are illustrated in Table 3. Results showed that spraying globe artichoke plants with chitosan at various levels (150 and 300ppm) 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 andearly and total plant yield. However, using 150 ppm of chitosan gave the highest average head weight with a significant difference in the first season. 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. Mondal et al. (2012) reported that most of the morphological characters in okra were enhanced with increasing chitosan concentration up to 25 ppm. In addition, Abu-Muriefah (2013) stated that foliar-applied chitosan, in particular 200 mg/l, increased the common bean plant growth as compared to the control plants. Previous studies showed that chitosan can, directly or indirectly, influence the physiological activities of the plants (Kamal, and Ghanem, 2011 and Shehata et al., 2012). In this regard,the obtained results are consistent with those of El-Tantawy (2009) who reported that plant growth and development were enhanced by the application of chitosan in tomato.

Data presented in Table 4 show the effect of interaction between GA_3 and chitosan levels on yield and its components of artichoke. It was noticed that application of GA_3 at 25 ppm three times together with chitosan at the rate of 300 ppm produced the best interaction which had significant effect on number of heads / plant and total plant yield. However, the highest value for early yield and average head weight was obtained when artichoke plants were treated with GA_3 two times and 150 ppm chitosan.

Head quality

Results in Table 5 showed that GA_3number of applications has a significant effect on head diameter, receptacle fresh weight, receptacle diameter and head dry matter, in both seasons. Spraying artichoke plants three times with GA_3 resulted in the highest head diameter and highest value for receptacle diameter especially in the second season. In addition it seems that spraying artichoke plants with any number of GA_3 increased dry matter of head in both studied seasons. The lowest values were obtained from the control plants. However, TSS decreased significantly by increasing number of treatments with GA_3in both studied seasons. Mauromicale and Irena (2000) found that GA_3 application generally decreased the head weight. Such results revealed that head weight, head length, head diameter and edible part fresh weight were significantly decreased with increasing the concentration of GA_3 compared to the control. The advantageous influence of gibberellin (GA_3) on equality of artichoke buds and their even maturing on plants was observed (Halter et al., 2005). The use of GA_3 can raise higher gross revenue (Garcia et al., 2004). It seems that the significant enhancement of the rate of yield by GA_3 application is due to the larger number of buds rather than the increase in other bud characteristics (weight, length and diameter).

Data recorded in Table 5 show that foliar spraying with chitosan at both levels (150 and 300ppm) caused significant improvements on head quality characteristics, expressed as head weight, diameter, and receptacle fresh and dry weight compared to the control. Meanwhile, TSS and head dry matter were not significantly affected in both seasons. The highest head quality characteristics were recorded by plants foliarly sprayed with chitosan at 300 ppm followed by 150 ppm. However, the lowest mean values were recorded by the untreated control. 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. Similar to GA_3 effect, such effectmay have effect on the plant growth and yield (El-Bassiony et al., 2003). Similar results were also obtained by 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.

As for the interaction,data presented in Table 6show that spraying artichoke two times by GA_3 at 25 ppm along with chitosan at 150 ppm gave the highest values of receptacle fresh weight in both seasons as well as receptacle diameter in the first season. It could be observed that GA_3 is the limiting factor for dry matter whereas, spray GA_3 with any number of sprays increased dry matter significantly under any concentrations of chitosan.

Yield pattern

The results in Fig. 1 illustrated the effect of number of GA_3 treatments and chitosan concentrations on yield pattern distribution of globe artichoke heads throughout the harvesting period, expressed as percentage of total number of heads/plant/month, in the two growing seasons of 2014/2015 and 2015/2016. The results indicated that the major peaks of the head yield of globe artichoke were found to be concentrated in March and April months. Also, the application of GA_3 at any number of applications increased the earliness of the artichoke plants in December and January compared to the control in both growing seasons. Meanwhile, chitosan concentrations of 150 or 300ppm increased the earliness pronouncedly comparing to control plants.

In both seasons, GA_3 and chitosan multiple treatments produced a generally higher rate of head production in an earlier date December to March instead of April and May compared with the control. The results showed that the percentage of yield pattern distribution for the plants which treated three times with GA_3 as average of both seasons in the first three months (December to February), were 27.9 and 29.4% compared to 25.6 and 27.4% for the non-treated plans in both studied seasons, respectively. On the other hand, applying chitosan at 300 ppm gave 27.4 and 36.3% compared to 24.2 and 26.7% for the control plants in both seasons.

TABLE 4.Yield potential characters of globe artichoke as affected by interaction of gibberellic acidapplications and chitosan concentrations in 2014 and 2015 seasons.

Treatments		Number of heads/ plant		Early yield/plant(kg)		Total yield/plant (kg)		Head fresh weight (g)	
G.A. No. of applications	Chitosan concentrations (ppm)	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control (without GA_3	0	7.83h	4.26j	0.88e	0.38f	2.60h	1.51fg	313.0c	211.1g
	150	8.36g	4.83i	1.90c	0.40ef	3.51f	1.41g	366.4a	341.6c
	300	9.50d	5.02h	1.92c	0.64bc	3.60ef	1.50fg	324.bc	311.1d-f
25 ppm GA_3 (once)	0	7.95h	5.58f	1.21d	0.40ef	2.97g	1.59ef	316.6de	316.6de
	150	9.58cd	5.80e	2.01bc	0.51c-f	3.68de	1.87d	368.2a	318.8c-e
	300	10.58b	5.50f	1.90c	0.71ab	3.61ef	2.11c	335.2b	347.2b
25 ppm GA_3 (twice)	0	9.00f	5.44fg	1.32d	0.51c-f	3.07g	1.50fg	332.2bc	288.8f
	150	9.70c	6.00d	2.27a	0.79a	4.04c	1.94d	369.2a	387.4a
	300	9.02f	6.58b	2.00bc	0.82a	4.20b	1.97cd	336.2b	292.7f
25 ppm GA_3 (thrice)	0	9.43de	5.30g	1.31d	0.46d-f	3.79d	1.68e	320.4bc	333.8b-d
	150	9.30e	6.43c	1.96c	0.54c-e	3.78d	2.39d	360.2a	307.7ef
	300	11.57a	7.88a	2.09b	0.59b-d	4.45a	2.69a	370.2a	309.9ef

Mean values in each column with the same letter do not differ significantly by revised LSD ($P = _{0.05}$).

TABLE 5. Head quality characters of globe artichoke as affected by gibberellic acid Number of applications and chitosan concentrations in 2014 and 2015 seasons.

Treatments		Head diameter (cm)		Receptacle fresh weight (g)		Edible part diameters(cm)		Head dry matter (%)		TSS (%)	
GA_3 Number of applications	Chitosan concentrations (ppm)	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control (without GA_3		8.21b	8.06c	106.05b	111.83c	6.76a	5.82d	14.92b	14.56b	11.65a	11.40a
25 ppm GA_3 (once)		8.30b	8.30b	124.12a	134.80a	6.78a	6.16b	22.05a	21.69a	11.48b	11.24b
25 ppm GA_3 (twice		8.47a	8.36b	123.21a	141.93a	6.90 a	6.23c	21.54a	21.18a	11.49b	11.25b
25 ppm GA_3 (thrice		8.41a	8.40a	122.90a	121.66b	6.80 a	6.58a	21.45a	21.09a	11.25c	11.01c
	0	8.33B	8.08C	109.40C	116.70C	5.89 B	6.01C	19.55A	19.19A	11.37B	11.13A
	150	8.33B	8.30B	130.40A	136.87A	7.38 A	6.36A	20.13A	19.77A	11.48A	11.24A
	300	8.43A	8.45A	117.40B	128.90B	7.16 A	6.18B	20.29A	19.93A	11.66A	11.42A

Mean values in each column with the same superscript(s) do not differ significantly by revised LSD(P = 0.05).

TABLE 6. Head quality characters of globe artichoke as affected by interaction betweengibberellic acid Number of applications and chitosanconcentrations in 2014 and 2015 seasons.

Treatments		Head diameter(cm)		Receptacle fresh weight (g)		Edible part diameters (cm)		Head dry matter (%)		TSS (%)	
GA_3 Number of applications	Chitosan concentrations ppm	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control (without GA_3	0	8.11a	7.44g	89.13i	102.7f	5.84b	5.86e	15.3b	14.96 b	11.86a	11.62a
	150	8.62a	8.46b	133.1b	115.61e	7.48a	6.04cd	15.03b	14.67b	11.74a	11.48a
	300	8.10a	8.28c	95.93h	117.2e	7.1a	5.58f	14.42b	14.06b	11.36a	11.12a
25 ppm GA_3 (once)	0	8.32a	8.16c-e	126.0cd	130.0cd	5.94b	6.18c	21.55a	21.19a	11.48a	11.24a
	150	8.11a	8.12de	126.2cd	143.8ab	7.43a	6.03d	22.62a	22.26a	11.55a	11.31a
	300	8.5 a	8.62a	120.16e	130.1cd	7.33a	6.10cd	21.98a	21.62a	11.40a	11.16a
25 ppm GA_3 (twice	0	8.40a	8.02e	106.0g	119.9de	6.00b	5.98de	20.67a	20.31a	11.60a	11.36a
	150	8.50a	8.43b	139.3a	153.3a	7.21a	6.54b	21.21a	20.85a	11.28a	11.04a
	300	8.51a	8.63f	124.1d	152.7a	7.15a	6.18c	22.74a	22.38a	11.59a	11.35a

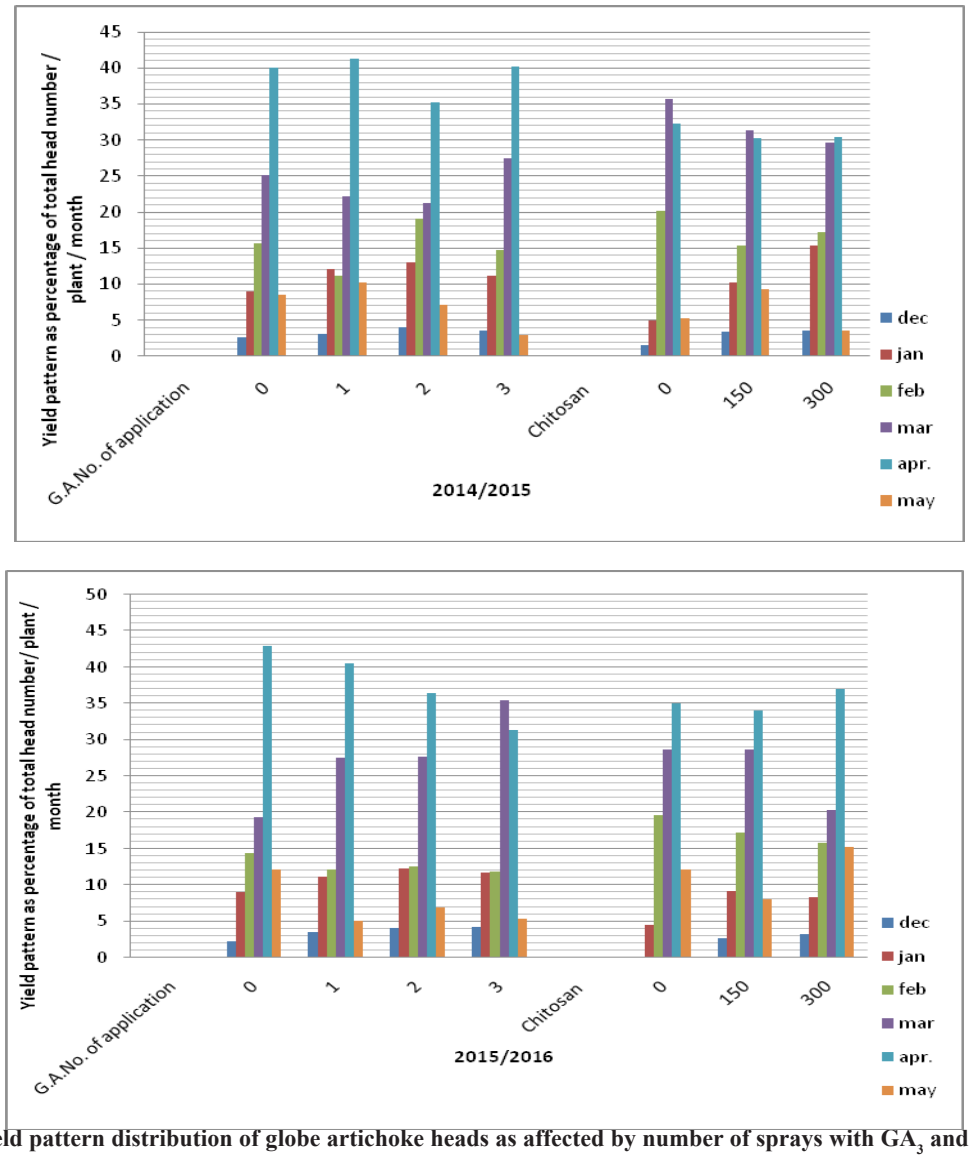

Fig. 1. yield pattern distribution of globe artichoke heads as affected by number of sprays with GA_3 and chitosan concentrations during the seasons of 2014/2015 and 2015/2016.

In conclusion, the results would contribute to knowledge on the ability of exogenous GA_3 and chitosan application to stimulate flowering and increase earliness in globe artichoke.

Acknowledgment

My sincere gratitude to Alexandria University, Egypt for introducing all facilities needed for this study. I sincerely appreciate all kind of the help supported by Mr. Abdel Menam,The agricultural engineer in AbiesStation for helping in applying the treatments and collecting the data.

Funding statement

The present work was partially supported by Faculty of Agriculture, Alexandria University, Egypt.

Conflict of interest

The authors declared that there is no conflict of interest.

References

Abd-Elhamied,Afaf, A.M. Kassim, T. and El-Zoheiry, S.S. (2008) Effect of vernalization and gibberelic acid on earliness, total yield and quality of globe artichoke. *Annals Agric. Sc., Moshtohor,* **46** (4), 511-523.

Abdel-Mawgoud, A.M.R., Tantawy, A.S., El-Nemr, M.A. and Sassine, Y.N. (2010) Growth and yield Responses of strawberry plants to Chitosan application. *European J. Sci. Res.,* **39** (1), 170-177.

Abu-Muriefah, Sharifa S. (2013) Effect of chitosan on common bean (*Phaseolus vulgaris* L.) plants grown under water stress conditions. Inter. *Res. J. Agric. Sci. Soil Sci.,* **3** (6),192-199.

Baixauli, C., Giner, A., Miquel, A., López, S., San Bautista, A. and Maroto, J.V. (2007) Interaction between cultivar and gibberellic acid concentration in seed propagated artichoke. *Acta Hort.,* 630, 165–170.

Basnizki, Y. and Goldschmidt, E.E. (1994) Further examination of gibberellin GA_3 effects on flowering of globe artichokes (*Cynarascolymus* L.) under controlled environment and field condition. *Isr. J. Plant Sci.,* **42**, 159–166.

Bautista-Baños, S., Hernández-Lauzardo, A.N., and Velázquez-del Valle, M.G. (2006) Chitosan as a potential natural compound to control pre and postharvest diseases of horticultural commodities. *Crop Protection*, **25**, 108-118

Bekhit, R.S., El-Fadaly, K.A. and Abou-ElHassan, E.A. (1985) Effect of gibberellic acid and some nutritional treatments on growth, yield and quality of globe artichoke (*Cynarascolymus*L.). *J. Agric. Sci., Mansoura Univ*. **11** (2), 745-751.

Calabrese, N. and Bianco, V.V. (2000) Effect of gibberellic acid on yield and quality of seed grown artichoke (*Cynaracardunculus* L. var. scolymus (L.) Fiori). *Acta Hort.*, **514**, 25–32.

Deepmala, K., Hemantaranjan, A. and Bharti S., et al. (2014) A future perspective in crop protection: chitosan and its oligosaccharides. *Adv. Plants Agric. Res*., **1** (1), 23–30. DOI: 10.15406/ apar.2014.01.00006

El Ghaouth, A., Arul, J. Ponnampalam, R. and Boulet, M. (1991) Chitosan coating effect on storability and quality of fresh strawberries. *J. Food Sci*., **56**, 1618-20

El-Bassiouny, R.E. and Hassan, M.A. (2003) Effect of gibberellic acid and mixture of micronutrients (nutarmine) on earliness, head yield, pre, and post-harvest quality of globe artichoke (*Cynarascolymus* L.) *J. Agric. Sci. Mansoura Univ.,* **28** (3), 1949-1967.

El-Greadly, N.H.M. (1994) Effect of some chemical substances on earliness, productivity and endogenous substances of globe artichoke, *Ph.D. Thesis,* Fac. of Agric., Cairo Univ.

Elia, A., Calabrese, N. and Bianco, V.V. (1994) Sowing Time, Gibberellic Acid Treatments and Cultivars of "Seed" Propagated Artichoke. *Acta. Hort.*, **371**, 347-354.

El-Miniawy, S.M., Ragab, M.E., Youssef, S.M. and Metwally, A.A. (2013) Response of Strawberry Plants to Foliar Spraying of Chitosan.*Res. J. Agric. & Biol. Sci.*, **9** (6), 366-372.

El-Tantawy, E.M. (2009) Behaviour of tomato plants as affected by spraying with chitosan and aminofort as natural stimulator substances under application of soil organic amendments. *Pakistan J. Biol. Sci.*, **12**, 1164-1173.

Farouk, S., Mosa, A.A., Taha, A.A., Ibrahim, Heba M. and EL- Gahmery, A.M. (2011) Protective effect of humic acid and chitosan on radish (*Raphanussativus*L.var.sativus) plants subjected to cadmium stress. *J. Stress Physiol. and Biochem.*, **7** (2), 99-116.

Fawzy, Z.F., El-Shal, Z.S., Li Yunsheng, Ouyang Zhu and Sawan, Omaima, M. (2012) Response of Garlic (*Allium Sativum*, L.)Plants to Foliar Spraying of Some BioStimulants under Sandy Soil Condition. *Journal of Applied Sciences Research,* **8** (2), 770-776, 2012.

Firpo, I.T., García, S.M., Cointry, E.L., LópezAnido, F.S., Cravero, V.P. (2005) Evaluation of the performance of different cultivars in offseason production. *Acta Hort.,* **681**, 89–93.

Foti, S., La Malfa, G. (1981) Influenza di fattoritermici, luminosi e chimicisullaemissione del capolino in *Cynarascolymus* L. In: Atti 3° CongrIntCarciofo, Bari, Laterza, Bari, Italy, 207-217

Foury, C. (2003) Common vegetables for seed and fruit. Chapter: Artichoke or globe artichoke and cardoon. http://gears.tucson.ars.ag.gov. (03.05.2008).

Freepons, D. (1991). Chitosan, does it have a place in agriculture? Proceedings of the Plant Growth Regulation Society of America, pp 11-19.

García, S.M., Cointry, E.L., Firpo, I.T., LópezAnido, F.S., Cravero, V.P., Asprelli, P. (2004) Vernalization of seed-grown artichoke. *Acta Hort*., **660**, 443–445.

Ghoname, A.A., El-Nemr, M.A., Abdel-Mawgoud, A.M.R. and El Tohamy, W.A. (2010) Enhancement of sweet pepper crop growth and production by application of biological, organic and nutritional solutions. *Res. J. Agric. and Biol. Sci.*, **6** (3), 349-355.

Gornik, K., Grzesik, M. and Duda, B.R. (2008) The effect of chitosan on rooting of gravevine cuttings and on subsequent plant growth under drought and temperature stress. *J. Fruit Ornamental Plant Res*., **16**, 333-343.

Halter, L., Habegger, R., Schnitzler, W.H. (2005) Gibberellic acid on artichoke (*Cynarascolymus*L.) cultivated in Germany to promote earliness and to increase productivity.*Acta Hort.,* **681**, 75–81.

Harwood, R.R., Markarian, D. (1968) Annual culture of globe artichoke (*Cynarascolymus* L.). I. Preliminary report. Proc. Amer. Soc. *Hort. Sci.*, **92**, 400–409.

Ibrahim, S. Kh. A. and Mohsen, A. A. M. (2015) Effect of chitosan and nitrogen rates on growth and productivity of summer squash plants. *Middle East J. Agric. Res.*, **4** (4), 673-681.

Kamal, A. M. and Ghanem, K.M. (2011) Response of cape gooseberry plants (*physalisPeruviana*, L.) To some organic amendments and foliar spray with chitosan.*J. Plant Production, Mansoura Univ*., **2** (12), 1741 – 1759.

Khan, W.M., Prithiviraj, B. and Smiyh, D.L. (2002) Effect of foliar application of chitin oligosaccharides on photosynthesis of maize and soybean.*Photosynthetica*,**40**, 621-624.

Kim, H.J., Chen, F., Wang, X. and Rajapakse, N.C. (2005) Effect of chitosan on thebiological properties of sweet basil (*Ocimumbasilicum* L.).*Journal of Agriculturaland Food Chemistry*, **53**, 3696-3701.

López, J., González, A., Vicente, F.E., Condés, L.F., Fernández, J.A. (2007) Artichoke production in the province of Murcia (SE Spain). *Acta Hort.,* **630**, 223–227.

Mangano, G., Signorelli, P. (1981) Azione di trattamenti con acidogibberellico, in fasidiversedell'accrescim entodelle piante, sullaproduzione del carciofo. In: Atti 3° CongrIntCarciofo, Bari, Laterza, Bari, Italy, 565-579

Mauromicale, G. and Ierna, A. (1995) Effects of gibberellic acid and sowing dates on harvest time and yields of seed-grown globe artichoke (*Cynarascolymus* L.). *Agronomie*, **15**, 527–538.

Mauromicale, G. and Ierna, A. (2000) Characteristics of heads of seed-grown globe artichoke (*Cynaracardunculus* L. var. scolymus (L.)Fiori) as affected by harvest period, sowing date and gibberellic acid. *Agronomie*, **20**, 197–204.

Miguel, A., Baixauli, C., Aguilar, J.M., Giner, A., Maroto, J.V., López, S. San Bautisa, A. and Pascual, B. (2004) Gibberellic acid concentration in seed propagated artichoke. *Acta Hort*., **660**, 167–172.

Mondal, M.M.A., Malek, M.A. Puteh1, A.B. Ismail, M.R. Ashrafuzzaman, M. and Naher, L. (2012) Effect of foliar application of chitosan on growth and yield in okra. *A.J.C.S.,* **6** (5), 918-921.

Mondal, M.M.A., Malek, M.A., Puteh, A.B. and Ismail, M.R. (2013) Foliar application of chitosan on growth and yield attributes of mung bean (*Vignaradiata* (L.) Wilczek). *Bangladesh J. Bot.,* **42** (1), 179-183

Page, A.L. (1982) Methods of soilanalysis, part2: chemical and microbiological properties. Amer. Soc. Agron., Madison, Wisconsin, USA.

Paradiso, R., Cuocolo, B., De Pascale, S. (2007) Gibberellic acid and nitrogen rate affect yield and quality of artichoke. *Acta Hort.,* **630**, 211–216

Patkowska, E., Pieta, D. and Pastucha, H. (2006) The effect of biochikol 020 pc on microorganisms communities in the rhizosphere of Faba bean plants. *Polish Chitin Sco Monograph,* **11**, 171-178.

Ryder, E.J., De Vos, N.E. and Bari, M.A. (1983) The globe artichokeke (*Cynarascolymus* L.). *HortScience*, **18** (5), 646-653.

Schrader, W.L. (1992) Growth Regulator Effects on Earliness and Yield in Artichokes Grown as Annuals from Seed. *HortScience*, **27**, 643.

Sharaf-Eldin, M.A.A. (2003) Studies on the effect of some agricultural treatments on growth and productivity of artichoke (*Cynaracardunculus* var. scolymus (L.) Fiori) and their Relation to Earliness and Physical and Chemical Characters of Heads. Ph.D. Student, Chair of Vegetable Science, Technische Universität München, Freising-Weihenstephan, Germany. Soltani.

Shehata, S.A., Fawzy, Z.F. and El-Ramady, H.R. (2012) Response of cucumber plants to foliar application of chitosan and yeast under greenhouse. *Australian J. Basic Appl. Sci.,* **6** (4), 63-71.

Snedecor, G.W. and Cochran, W.G. (1980) *Statistical Methods*, 7th ed. Ames, Iowa state university press. 507 p.

Sugiyama, H., Hisamichi, K., Sakai, K., Usui, T., Ishiyama, J.I., Kudo, H., Ito, H. and Senda, Y. (2001) The conformational study of chitin and chitosan oligomers in solution. *Bioorganic and Medicinal Chemistry,* **9**, 211-216

Yumin, C., Gu, W., Zhang, J., Chu,Y., Ye, X., Hu, Y. and Chen, J. (2013) Effects of chitosan, aqueous extract of ginger, onion and garlic on quality. *Food Chemistry*, **141**, 1655–1660.

(*Received* 11/12/2019;
accepted 22/02/2019)

تاثير الرش بحمض الجبريليك والشيتوزان على النمو والمحصول والجودة للخرشوف

جيهان عبد العزيز الشرقاوي وإبراهيم محمد غنيم
قسم الخضر كلية الزراعة - جامعة الاسكندرية

أقيمت هذه الدراسة بمحطة البحوث الزراعية بأبيس التابعة لكلية الزراعة - جامعة الاسكندرية لدراسة تاثير الرش بحمض الجبريليك ومعرفة إلى أي مدى يمكنه تعويض الاحتياجات الحرارية المنخفضة اللازمة للإزهار في الخرشوف وذلك للحصول على محصول مبكر للتصدير. تكونت هذه الدراسة من اثني عشرة معاملة وهي عبارة عن عدد مرات الرش بحمض الجبريليك مرة او مرتين او ثلاث مرات بمعدل ٢٥ جزء في المليون من حمض الجبريليك بفارق أسبوعين بين كل رشة والأخرى وذلك بالمقارنة بالكنترول وهو الرش بالماء المقطر. أما العامل الآخر تحت الدراسة فهو الرش بالشيتوزان بتركيزات ٠ و ١٥٠ و ٣٠٠ جزء في المليونوذلك على النمو والتبكير والمحصول والجودة لصنف الخرشوف البلدي. و قد أظهرت النتائج أن الرش بحمض الجبريليك مرة أو مرتين أعطى أفضل النتائج لصفات النمو الخضري والمحصول المبكر ومتوسط وزن النورة بعد التقشير بينما الرش ثلاث مرات من حمض الجبريليك أعطى أفضل النتائج لصفات عدد النورات للنبات والمحصول الكلي ومتوسط وزن النورة قبل وبعد التقشير وقطر النورة بعد التقشير. بالإضافة أن الرش بتركيز ٣٠٠ جزء في المليون من الشيتوزان أظهر أفضل النتائج المعنوية لصفات النمو والمحصول. أما بالنسبة لتاثير التداخل بين عدد مرات الرش بحمض الجبريليك وتركيزات الشستوزان فأوضحت النتائج أن الرش بأي عدد من المرات من حمض الجبريليك مع إستخدام التركيز ٣٠٠ جزء في المليون من الشيتوزان أعطى أفضل النتائج المعنوية لكل الصفات المدروسة. وأوضحت النتائج أن التركيب المحصولي زاد في الشهور الاولى في الجمع من ديسمبر إلى فبراير بالنسبة للرش بالجبريليك أو بالشيتوزان مقارنة بالكنترول.