The Performance of Globe Artichoke Plants as Affected by Propagation Methods and Spraying With Gibberellic Acid

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ABSTRACT: Globe artichoke is considered as one of the most important vegetable crops in the countries bordering the Mediterranean basin including Egypt, but due to lateness of its flowering, lowering its yield capacity and exposure to extinction of the Egyptian cv. 'Balady'. Two field experiments were carried out during the two successive seasons of 2016/2017 and 2017/2018. The experiments were executed in a private farm located at Abou El-Matameer city, in Behiera Governorate, Egypt, under open field condition. Three propagation methods (explants) were used, included stumps cuttings (crown pieces), offshoots, and a mixture between the both explants (stumps cuttings + offshoots) of the same aforementioned globe artichoke plants 'Balady' cv. were joined tightly on planting. Each explant was of the same constant weight, more or less, *ca*. 160 g /explant. It was planted at 0.5 m apart and 1.0 m width of ridge. So, the total number of plants/ feddan were approximately 8400 plants (2 plants/m^2). Also, four concentrations of dissolved GA_3 were used in the present study (0, 25, 50 and 75 mg/l) as a foliar spraying. 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). The untreated control plants were sprayed with tap water. The layout experimental was split plots system in a Randomized Complete Blocks Design with three replications. Plant propagation methods (explants) were arranged as the main plots, and the gibberellic acid concentrations were considered as the sub- plots. The effects of both variables and their interactions were investigated on the vegetative growth-related characters, yield and its components, head quality, leaves and heads chemical composition. The obtained results indicated, generally, that the interaction between any propagation method (explants) and GA_3 at its higher level (75 mg/l) recorded the highest average values; nevertheless, the offshoots + stumps cuttings upon interacted with GA_3 at 75 mg/l ; 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 under the environmental conditions of Behiera Governorate and other similar regions.

Keywords: globe artichoke, 'Balady' cv., propagation methods, gibberellic acid, foliar application.

INTRODUCTION

Globe artichoke is considered as one of the most important vegetable crops in the countries bordering the Mediterranean basin including Egypt, whereas the total area grown with artichoke in Egypt was 29726 fed., which produced about 236314 tons with an average yield of 7.95 ton/fed (FAO, 2016). In Egypt, the conventional method for globe artichoke propagation is based on the use of offshoots, ovoli (underground dried shoots with apical and lateral buds) and portion of stump [crown pieces] (Sharaf-Eldin, 2002). Globe artichoke is propagated following two approaches (or methods or modes): a sexual method (using seeds) or an asexual method (vegetative propagation). However, each of these methods has its limitations. On the other extreme, its vegetative propagation not efficient yet; therefore, many investigators in some countries such as Italy (Tesi *et al*., 2004; Cardarelli *et al*., 2005), Turkey (Zeybekoglu and Ugur, 2013; Leskovar and Othman, 2016), and the United States (Rangarajan *et al*., 2000) carried out several trials in order to improve the vegetative propagation materials. The production technique of globe artichoke depends on the mother plant healthiness in the basic concept. Although the micro propagated plants being the most common method in use on a large-scale production (Moncousin, 1979), the vegetative propagation is still results in low multiplication rate (*ca*. shoots per plant per year) as reported by Lauzer and vieth (1990) and Mauromicale *et al.* (2003). Micropropagaton of globe artichoke as vegetatively propagated system became true and applicable method, too (Vetrano *et al*., 2000; Cadinu *et al*., 2004), but still expensive technique.

Therefore, the conventional propagation of globe artichoke still the prominent method under *in vivo* conditions but still limited since long time ago. Searching for additive or new technique improves the production of this important crop is a prerequisite item.

However, gibberellic acid is a vegetarianism hormone which produce by late leaves and growing caps in the roots and stems. It has many applications on vegetable crops, one of them is extend of period of storage by delaying the senescence. Likewise, gibberellic acid (GA_3) is known as growth hormone (endogenously and occurs as natural hormone) for growth and development and added exogenously as plant growth regulator to hasten or accelerate flowering process and subsequently head production in globe artichoke especially during the period from December to February which have a major importance for promoting the local market (with highest market prices) and export. This period is economically interesting for export, because there is no production in most European countries during these months (Abd El-Hameid *et al*., 2008). In order to accelerate the early production of heads and obtain increased benefits from higher prices, hence exogenous gibberellic acid (GA_3) application is proposed. It affects many mechanisms of plant growth including stem elongation, flowering, fruit development and breaking dormancy (Neil and Reece, 2002). Gibberellin, also, induces elongation and osmoregulation in internodes (Azuma et al., 1997), dry matter and biomass production (Gupta et al., 2001), and activities of key enzymes such as carbonic anhydrase (Shah and Ahmad, 2006), nitrate reductase (Afroz *et al*., 2006), and α-amylase (Gilroy and Jones, 1992); subsequently, accelerate the growth of the plant (Salisbury and Ross, 1994). EL-Abagy *et al*. (2010) reported that fresh and dry weights of the 4^{th} leaf of globe artichoke cv. 'Herious' was significantly correlated with the applied concentration of the GA_3 compare to untreated (control) plants. Likewise, GA_3 increased significantly plant height of globe artichoke plants compared to untreated one (El-Gridly, 1994; El-Shal, 1998). Similarly, El-Gazar *et al*. (1995) and El-Bassiouny and Hassan (2003) obtained higher number of leaves and offshoots with application of GA_3 at 100 ppm. Also, similar trend was noticed as for earliness and yield of cv. 'Imperial Star' Goreta *et al.* (2003). On the other extreme, Gibberellic acid (GA_3) is highly resistant and bioactive agent in soil for months (EL-Zohiri, 2015). In terms of heading process of globe artichoke (Cynara scolymus L.), GA_3 application on artichoke plants accelerated earliness, productivity and uniformity and replaced coldness requirement (Miguel *et al*., 2003; Temirkaynak *et al*., 2009). Numerous articles concerning effect of GA_3 on flowering of globe artichoke exhibited inconsistent trend in annual artichokes (Schrader and Keith, 1997). Also, gibberellic acid (GA_3)

influences initiation and stem elongation, as well as the development of lateral heads (Elia *et al*., 1993; Goreta *et al*., 2003). Schrader and Keith (1997) reported that under field conditions between September and January, globe artichoke plants treated with GA_3 were harvested earlier than control plant by about 42 days. Halter *et al.* (2005) ascertained that gibberellic acid has been shown to promote earliness in artichoke and thus, it is interesting for determining timing of harvest. Further, Elia *et al.* (1993) reported that single spray of globe artichoke '044' cv. plants with GA_3 at 80 ppm at 90 or 120 days after sowing or spraying them twice at 90 then 120 days, forced the treated plant to earlier harvest dates and significantly increased yield compared to control plants. 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.

Aside from, 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). Also, GA_3 exerts significant effects on plant chemical compositions; regarding the maximum TSS% (Helaly *et al*., 2016), protein content (Shah, 2004; Premabatidevi, 1998). Nevertheless, Sharaf-Eldin *et al*. (2003) reported that GA_3 application had no direct effect on carbohydrates as well as on protein, but the same authors Sharaf-Eldin *et al.* (2003) indicated that spraying gibberellic acid increased the content of inulin in the buds. But *vice versa* was reported by El-Zohiri (2015). Abd El-Fattah (1978) reported that GA_3 concentrations gave a highly significant increase in dry matter contents of heads over that obtained from the control. Sharaf-Eldin (2002) stated that Egyptian growers plant a local variety coined as 'Baladay' which is very heterozygous and forms buds of poor quality, not suitable for exportation, and it is necessary to replace it with other varieties as the seed cultivar "Imperial star". But this study sakes among their objectives providing a good agriculture practices (GAPs) to conserve and maintain the 'Balady' cv., from extinction.

Therefore, the objectives of this paper are endeavor to test the outcomes of using various explant types, various levels of gibberellic acid, and to evaluate the expected outcomes that may have on its growth, yield and quality of globe artichoke 'Balady' cv. under Egyptian environment to produce early, high yield and best quality of globe artichoke *via* testing three types of propagation explants under various levels of GA_3 applied as foliar applicants.

MATERIALS AND METHODS

Two field experiments were carried out during the two successive seasons of 2016/2017 and 2017/2018. The experiments were executed in a private farm located at Abou El-Matameer city, in Behiera Governorate, Egypt, under open field conditions. 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 Table (1).

Three propagation methods (explants) were used, included stumps cuttings (crown pieces), offshoots, and a mixture between the both explants (stumps cuttings + offshoots) of the same aforementioned globe artichoke plants were joined tightly on planting. Each explant was of the same constant weight, more or less, *ca*. 160 g/explant. It was planted at 0.5 m apart and 1.0 m width of ridge. So, the total number of plants/ feddan were approximately 8400 plants (2 plants/m^2). Four concentrations of dissolved GA_3 were used in the present study (0, 25, 50 and 75 mg/l). They were applied as a foliar spraying until run-off using a hand sprayer. The spraying was applied twice; the first one was carried out after 65 days from planting (when the plants had approximately 12-15 leaves). The second application was 20 days after the first one (plants had approximately 20 leaves). The untreated control plants were sprayed with tap water. The layout experimental was split plots system in a Randomized Complete Blocks Design with three replications.

Table (1). Some physical and chemical properties of the experimental site during both seasons of experimentation (2016/2017 and 2017/2018)

Soil properties	Season	
	2016/2017	**2017/2018**
Mechanical Analysis:		
Clay (%)	07.28	07.35
Silt (%)	20.00	20.50
Sand (%)	72.72	72.15
Textural class	Sandy loam	Sandy loam
Chemical Analysis:		
pH (1:2 water suspension)	8.00	8.10
EC at 25° C (1:2 soil: water extract) (dS/m)	1.63	1.60
Soluble cations in (1:5) soil: water extract (meq/l)		
Ca^{++}	1.80	1.75
Mg^{++}	2.04	2.05
K^{+}	1.63	1.65
Na^{+}	6.96	6.55
Soluble anions in (1:5) soil: water extract (meq/l)		
CO_3^{--}	00.00	0.00
HCO_3^{-}	03.60	03.10
Cl^{-}	07.20	07.25
SO_4^{--}	01.62	01.65
Available N (mg/kg soil)	90.00	95.00
Available P (mg/kg soil)	11.00	15.00
Available K (mg/kg soil)	360.0	380.0

The analyses were carried out at Soil and Agricultural Chemistry Departement, The Faculty of Agricultur (Saba Basha), Alexanderia University, Egypt.

Plant propagation methods (explants) were arranged as the main plots, and the gibberellic acid concentrations were considered as the sub- plots. Each sub- plot consisted of two ridges; each ridge was 7.00 m length and 1 m width. The recommended agricultural practices for commercial globe artichoke production were followed.

Five plants from each experimental unit were randomly chosen and tagged for growth measurements as follows:

Growth attributes' records, after one hundred and fifteen days from planting, plant height (cm), length of the fifth leaf (cm), number of leaves per plant, survival rate (%), and number of offshoots per plant characters were determined. The latter characters 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 2^{nd} till February 28^{th}) and total yield was calculated for all pickings during both seasons. The following criteria were determined for early and total yield: number of heads per plant, number of heads per feddan × 10^3, yield per plant (kg), yield per feddan (ton), average head fresh weight (g), and heads dry matter content (%).

Heads chemical quality characters

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).

Heads chemical composition, Head nitrogen, phosphorus and potassium concentrations (%, D.W.) were determined by using 100 g of fresh samples which were taken from each treatment. The samples were dried at 75˚C to constant weight. The obtained dry matter was ground into fine powder and 0.5 g of the ground dried material was digested with H_2O_2 according to Evenhuis and Dewaard (1980). Total nitrogen in digested samples was determined colorimetrically according to Chapman and Pratt (1961). Total P in digested samples was determined colorimetrically as described by (Singh *et al*., 2005). Total K in digested samples was measured using flame photometer as described by (Singh *et al*., 2005). In addition, NO_2-N and NO_3-N (mg/kg, F.W.) were determined using head fresh samples according to the method described by Singh (1988).

Statistical Analysis

All obtained data of the present study were, statistically, analyzed according to the design used by the MSTAT-C computer software program (Bricker, 1991). The revised least significant difference 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 (1965) and Gomez and Gomez (1984).

RESULTS AND DISCUSSION

The results, generally, revealed that explants types, and gibberellic acid and their interactions affected, significantly ($p \leq 0.05$), the traits under the study as an overall during both seasons of the study.

Vegetative growth characters:

Results presented in Table (2) show that both variables under the study and their interaction exert significant ($p \leq 0.05$) effect on the vegetative growth-related characters of globe artichoke plants cv. 'Balady'. In terms of the main effect of propagation methods (explants) the postulated results exhibited clearly that the combined methods of propagation (explants) of offshoots +stump cuttings showed significantly ($p \leq 0.05$) the highest average values during both seasons compare to the other two tested propagation methods (explants). Whereas, plant height (cm), length of the fifth leaf (cm), number of leaves per plant, survival rate (%), number of offshoots per plant, and leaves dry matter content (%).

Table (2). Average values of some vegetative growth-related characters of globe artichoke plants cv. 'Balady' as affected by propagation methods (explants), foliar application with gibberellic acid (GA_3) and their interaction during the winter seasons of 2016/2017 and 2017/2018

Treatments		Plant height (cm)		The fifth leaf length (cm)		No. leaves/plant		Survival rate (%)		No. offshoots/plant		Leaves dry matter (%)	
		2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018
Propagation methods (explants) [main effect]													
Offshoots		82.13 b	83.21 b	72.37 b	73.58 b	16.49 b	16.62 b	47.50 b	48.74 b	4.79 ab	4.84 b	15.74 b	16.10 b
Stump cuttings		81.92 b	81.96 c	72.50 b	73.66 b	16.01 b	16.18 c	45.50 c	46.84 c	4.58 b	4.64 c	15.60 b	15.94 c
Offshoots+Stump cuttings		90.93 a	90.82 a	74.70 a	75.92 a	17.33 a	17.50 a	52.50 a	53.95 a	5.24 a	5.30 a	15.93 a	16.29 a
Gibberellic acid (GA_3) [main effect]													
Control		63.03 d	61.42 d	65.18 d	66.18 d	11.35 d	11.48 d	33.33 d	34.11 d	4.07 c	4.13 d	14.86 d	15.19 d
25 mg/l		79.08 c	81.85 c	70.82 c	72.05 c	15.95 c	16.11 c	41.00 c	42.11 c	4.39 bc	4.43 c	15.51 c	15.87 c
50 mg/l		91.40 b	89.51 b	77.20 b	78.48 b	17.67 b	17.78 b	51.67 b	53.36 b	4.96 b	5.03 b	16.05 b	16.41 b
75 mg/l		106.47 a	108.54 a	79.57 a	80.83 a	21.47 a	21.69 a	68.00 a	69.78 a	6.06 a	6.12 a	16.60 a	16.97 a
Interaction effects													
Propagation methods	GA_3 (mg/l)												
Offshoots	Control	61.68 k	59.40 k	64.70 g	65.72 j	11.64 fg	11.72 i	32.00 fg	32.65 i	4.23 cd	4.28 g	14.86 fg	15.20 j
	25	74.90 i	77.56 i	68.42 e	69.59 h	15.58 e	15.63 g	40.00 e	41.22 g	4.29 cd	4.33 f	15.47 e	15.83 h
	50	89.68 e	89.37 e	77.43 bc	78.65 d	17.57 cd	17.61 e	50.00 cd	51.64 e	5.04 bc	5.13 c	16.04 d	16.40 e
	75	102.27 c	106.49 b	78.94 b	80.35 b	21.16 ab	21.51 b	68.00 ab	69.44 b	5.60 b	5.64 b	16.60 ab	16.97 b
Stump cuttings	Control	57.90 l	56.63 l	64.25 g	65.25 j	10.17 g	10.35 j	30.00 g	31.27 j	3.71 d	3.77 h	14.67 g	14.96 k
	25	77.30 h	81.43 h	71.43 d	72.87 g	16.09 de	16.36 f	38.00 ef	39.00 h	4.30 cd	4.33 f	15.47 e	15.83 h
	50	87.07 f	87.95 f	76.20 c	77.43 e	17.17 c-e	17.35 e	50.00 cd	51.37 e	4.78 b-d	4.85 d	15.84 d	16.20 f
	75	105.41 b	101.83 c	78.12 b	79.11 c	20.60 b	20.66 c	64.00 b	65.71 c	5.54 b	5.60 b	16.40 bc	16.78 c
Offshoots+Stump cuttings	Control	69.50 j	68.23 j	66.58 f	67.57 i	12.24 f	12.37 h	38.00 ef	38.41 h	4.27 cd	4.33 f	15.06 f	15.41 i
	25	85.05 g	86.55 g	72.61 d	73.69 f	16.17 de	16.35 f	45.00 de	46.12 f	4.59 b-d	4.63 e	15.59 e	15.95 g
	50	97.45 d	91.20 d	77.98 b	79.37 cd	18.28 c	18.38 d	55.00 c	57.07 d	5.07 bc	5.11 c	16.26 c	16.64 d
	75	111.72 a	117.29 a	81.63 a	83.04 a	22.66 a	22.90 a	72.00 a	74.20 a	7.04 a	7.12 a	16.79 a	17.17 a

- Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using the revised L.S.D. test at 0.05 level of probability.

Irrespective of the lower percentage of survival rate (%) due to propagation methods (explants), this finding could be taken place due the injuries caused by chopping and excluding the explants off the mother stock plants, then refining them leaving behind deliberately roots and leafy stems. Likewise, with reference to stump propagation method (explants) which demonstrated the least survival rates this result might be ascribed to the methods of taking–off, but since these types of propagation methods (explant) have no roots or very weak roots (fibrous not fleshy).

The obtained results are in agreement with those of Sharaf-Eldin (2002). As for propagation method (explant) through combination of offshoot + stump cuttings, they exhibited such higher survival rate compare with the other two propagation methods (explants). This finding might be attributed to including them on some dormant buds (as stump) and both shoot and root systems (offshoots) which could express dual merits (advantages) of both combined explants; brought about a higher survival rate (Cardarelli *et al.*, 2005). However, the lowest percentage values of survival rate were recorded from stump cuttings.

This result is in agreement with that of Ismail (2016) who indicated that the lowest values of survival % were taken place with both non-vernalized crown pieces and offshoots of 'Heryous' cv., during both tested seasons. However, these results are in contradictory with those of Besher and Mostafa (1981). Generally, the reduction of survival rate of the methods of propagation (explants) could attract the attention for further additive effect of environmental stimulus or intrinsic stimuli or others. With reference to the main effect of gibberellic acid (GA_3), 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 GA_3 and the given traits. In other words, as GA_3 level increases; the given traits' average values increase and *vice versa*; whereas, the highest level of GA_3 (75.0 mg/l) brought about the highest average values for survival rate, 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. Similar results were obtained by El–Gridly (1994). The positive effect of GA_3 on the characteristics under the study could be attributed to additive effect on survival rate, and on plant height could be taken place due to its mode of action as a growth promoter or regulator on cell division and cell extensibility (elongation); resulting in a taller plant. Such explanation could be match with length of the fifth leaf (Georg *et al*., 2008). The stimulation effect of GA_3 on the number of offshoots per plant may be attributed to the promotive effect of GA_3 on globe artichoke plants to produce more lateral branches on its main stem (Goreta *et al.*, 2003).

The combination between both variables practiced significant effect ($p \leq 0.05$) on the traits under the study. Notably, the interaction between any propagation method (explants) and GA_3 at its higher level (75 mg/l) recorded the highest average values for survival rate, 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 explants with GA_3. However, under various explants treated with the intermediate levels of GA_3; recorded significantly ($p \leq 0.05$) intermediate average values.

Head yield and its components

Early yield

Pertaining the main effect of propagation methods (Table 3), the combined explants (comprised offshoot + stump cutting) differed significantly ($p \leq 0.05$) from the other two methods of propagation, in general even if the difference is not significant to such limit, and recorded the highest average values for number of heads/plant, number of heads/feddan, early yield /plant(kg), early yield/feddan (ton), and average head weight, consecutively compare to the other two propagation methods.

Table (3). Average values of early yield characters of globe artichoke plants cv. 'Balady' as affected by propagation methods (explants), foliar application with gibberellic acid (GA_3) and their interaction during the winter seasons of 2016/2017 and 2017/2018

Treatments		No. of heads/plant		No. of heads/feddan × 10^3		Early yield/plant (kg)		Early yield/feddan (ton)		Average head weight (g)	
		2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018
Propagation methods (explants) [main effect]											
Offshoots		6.45 ab	6.66 b	54.18 ab	55.94 b	1.16 b	1.21 b	9.73 b	10.17 b	179.62 b	181.87 b
Stump cuttings		5.93 b	6.20 c	49.81 b	52.08 c	1.06 b	1.12 c	8.86 b	9.38 c	177.95 c	180.12 c
Offshoots+ Stump cuttings		7.07 a	7.23 a	59.39 a	60.73 a	1.30 a	1.35 a	10.94 a	11.32 a	184.13 a	186.33 a
Gibberellic acid (GA_3) [main effect]											
Control		4.60 d	4.85 d	38.64 d	40.74 d	0.75 d	0.80 d	6.28 d	6.71 d	162.59 d	164.77 d
25 mg/l		5.86 c	6.05 c	49.22 c	50.82 c	1.02 c	1.07 c	8.60 c	8.99 c	174.76 c	176.82 c
50 mg/l		6.73 b	6.89 b	56.53 b	57.88 b	1.26 b	1.30 b	10.57 b	10.95 b	187.04 b	189.22 b
75 mg/l		8.75 a	9.00 a	73.50 a	75.60 a	1.73 a	1.80 a	14.54 a	15.14 a	197.88 a	200.28 a
Interaction effects											
Propagation methods	GA_3 (mg/l)										
Offshoots	Control	4.92 h	5.05k	41.33 h	42.42 k	0.80 h	0.83 k	6.72 h	7.01 k	162.52 jk	165.23 k
	25	5.58f-h	5.77 i	46.87 gh	48.47 i	0.95 f-h	1.00 i	8.00 f-h	8.36 i	170.67 hi	172.46 i
	50	6.70 de	6.92 e	56.28 de	58.13 e	1.25 cd	1.31 e	10.52 cd	10.99 e	186.98 de	189.13 e
	75	8.62 b	8.92 b	72.41 b	74.93 b	1.71 b	1.79 b	14.36 b	15.04 b	198.32 ab	200.67 b
Stump cuttings	Control	3.59 i	4.05 l	30.16 i	34.02 l	0.57 i	0.65 l	4.79 i	5.47l	158.84 k	160.72 l
	25	5.82 fg	6.03 h	48.89 fg	50.65 h	1.02 e-g	1.07 h	8.54 e-g	8.96 h	174.67 gh	176.90 h
	50	6.41d-f	6.60 f	53.84 d-f	55.44 f	1.17 c-e	1.22 f	9.85 c-e	10.26 f	182.96 ef	185.13 f
	75	7.90 bc	8.10 c	66.36 bc	68.04 c	1.54 b	1.60 c	12.96 b	13.45 c	195.32 bc	197.72 c
Offshoots+ Stump cuttings	Control	5.29 gh	5.46 j	44.44 gh	45.86 j	0.88 gh	0.92 j	7.39 gh	7.72 j	166.39 ij	168.35 j
	25	6.17 ef	6.36 g	51.83 ef	53.42 g	1.10 d-f	1.15 g	9.27 d-f	9.68 g	178.95 fg	181.11 g
	50	7.08 cd	7.14 d	59.47 cd	59.98 d	1.35 c	1.38 d	11.37 c	11.60 d	191.19 cd	193.41 d
	75	9.72 a	9.96 a	81.65 a	83.66 a	1.94 a	2.02 a	16.33 a	16.94 a	199.99 a	202.45 a

- Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using the revised L.S.D. test at 0.05 level of probability.

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 (explants), temperature, photoperiod, hormones, and set of floral–promoting genes (Lee and Lee, 2010; Srikanth and Schmid, 2011).

Concerning the main effect of GA_3 concentrations, GA_3 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 GA_3 was sprayed at 75 mg/l; brought about the highest average for number of heads/plant, number of heads/feddan, early yield/plant (kg), early yield/feddan (ton), average head weight (g), respectively compare to control (untreated) plants, despite of the other two concentration of GA_3 (25 and 50 mg/l), were different statistically ($p \leq 0.05$) from the control plants, too. This finding is in agreement with Kocer and Eser (1999) and Miguel *et al*. (2003). It is known that number of heads per plant is a crucial factor, whereas this trait is directly in correlation with the number of heads per feddan, number of early yield per plant (kg) and per feddan (ton); hence, gibberellic acid plays an important role in this respect, as reported earlier. The earliness of globe artichoke plant yield may be taken place owing to GA_3 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). The interaction among various combinations exerted significant ($p \leq 0.05$) effects on the tested characteristics, especially when the explants treated with the highest concentration of GA_3 (i.e. 75 mg/l) compare with the other concentrations and control plants. The combination gave rise to the highest average values for number of heads/plant, number of heads/feddan, early yield /plant (kg), early yield/feddan, and average head weight (g) compare with the other combinations, during both seasons. These results are in line with Kocer and Eser (1999). This finding could be assigned to that combined explant (offshoots +stump cutting) which resembles an integrated and organized growth contributes together towards the creation or maintenance of a defined structure. It occurs as when plant organs such as the growing points of shoots or roots are transferred to soil to grow with their preserved structure.

Total yield

Results outlined in Table (4) exhibited that both propagation methods (explants) and foliar application of GA_3 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 propagation methods (explants), 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 combined explants (offshoots + stump cuttings) exhibited significantly ($p \leq 0.05$) the highest average values compare to the other two methods for number of heads/plant, number of heads/feddan, total yield/plant (kg), total yield/feddan (ton), average head weight (g) and head dry matter (%), compare with using offshoots as propagation method (explants) which differed significantly ($p \leq 0.05$) from using combined explants, but expressed intermediate average values, and average values of using stump explants which expressed the lowest average values. The gained results are in compatible with those published by Riahi *et al.* (2017). Respecting the main effect of GA_3, foliar application showed significant ($p \leq 0.05$) effect on the given traits of the variable. Further, there is a direct proportionate relationship between GA_3 concentration and the traits under the study especially upon using GA_3 at 75 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 for the counterpart plants.

Table (4). Average values of total yield characters of globe artichoke plants cv. 'Balady' as affected by propagation methods (explants), foliar application with gibberellic acid (GA_3) and their interaction during the winter seasons of 2016/2017 and 2017/2018.

Treatments		No. of heads/plant		No. of heads/feddan × 10^3		Total yield/plant (kg)		Total yield/feddan (ton)		Average head weight (g)		Head dry matter (%)	
		2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018
Propagation methods (explants) [main effect]													
Offshoots		9.22 b	9.51 b	77.45 b	79.88 b	1.48 b	1.56 b	12.47 b	13.06 b	161.06 b	163.53 b	25.35 a	25.94 b
Stump cuttings		8.64 c	8.97 c	72.58 c	75.35 c	1.38 c	1.45 c	11.59 c	12.21 c	159.71 b	162.10 c	25.18 a	25.76 c
Offshoots+ Stump cuttings		10.11 a	10.35 a	84.92 a	86.94 a	1.67 a	1.74 a	14.05 a	14.59 a	165.44 a	167.86 a	25.62 a	26.16 a
Gibberellic acid (GA_3) [main effect]													
Control		6.73 d	7.03 d	56.53 d	59.05 d	0.99 d	1.05 d	8.34 d	8.84 d	147.48 d	149.66 d	24.09 c	24.63 d
25 mg/l		8.32 c	8.59 c	69.89 c	72.16 c	1.31 c	1.37 c	10.98 c	11.51 c	157.11 c	159.55 c	25.34 b	25.90 c
50 mg/l		9.59 b	9.84 b	80.56 b	82.66 b	1.60 b	1.67 b	13.46 b	14.01 b	167.06 b	169.47 b	25.60 b	26.19 b
75 mg/l		12.66 a	13.00 a	106.34 a	109.20 a	2.24 a	2.33 a	18.78 a	19.58 a	176.63 a	179.31 a	26.49 a	27.10 a
Interaction effects													
Propagation methods	GA_3 (mg/l)												
Offshoots	Control	7.05 h	7.23 k	59.22 h	60.73 k	1.04 j	1.08 k	8.73 j	9.09 k	147.43 k	149.69 k	24.07 gh	24.63 j
	25	7.98 fg	8.28 i	67.03 g	69.55 i	1.23 hi	1.30 i	10.31 hi	10.88 i	153.86 i	156.46 i	24.88 e-g	25.45 h
	50	9.46 d	9.74 e	79.46 d	81.82 e	1.58 e	1.65 e	13.27 e	13.86 e	167.00 e	169.43 e	25.61 b-e	26.22 e
	75	12.39 b	12.78 b	104.08 b	107.35 b	2.18 b	2.28 b	18.31 b	19.17 b	175.94 b	178.53 b	26.82 a	27.45 a
Stump cuttings	Control	5.66 i	6.13 l	47.54 i	51.49 l	0.82 k	0.90 l	6.87 k	7.55 l	144.49 l	146.60 l	23.72 h	24.26 k
	25	8.26 ef	8.53 h	69.38 ef	71.65 h	1.30 gh	1.36 h	10.90 gh	11.42 h	157.05 h	159.38 h	25.36 c-f	25.94 f
	50	8.99 de	9.29 f	75.52 de	78.04 f	1.47 ef	1.54 f	12.37 ef	12.97 f	163.85 f	166.19 f	25.22 d-f	25.82 g
	75	11.65 b	11.94 c	97.86 b	100.30 c	2.02 c	2.10 c	16.97 c	17.68 c	173.46 c	176.25 c	26.40 ab	27.02 b
Offshoots+ Stump cuttings	Control	7.49 fg	7.71 j	62.92 gh	64.76 j	1.13 ij	1.18 j	9.47 ij	9.89 j	150.52 j	152.70 j	24.48 f-h	25.00 i
	25	8.71 d-f	8.95 g	73.16 def	75.18 g	1.40 fg	1.46 g	11.74 fg	12.24 g	160.42 g	162.79 g	25.77 b-e	26.30 e
	50	10.31 c	10.47 c	86.60 c	87.95 d	1.76 d	1.81 d	14.75 d	15.20 d	170.34 d	172.78 d	25.98 a-d	26.52 d
	75	13.94 a	14.28 a	117.10 a	119.95 a	2.52 a	2.62 a	21.13 a	21.97 a	180.49 a	183.16 a	26.24 a-c	26.84 c

- Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using the revised L.S.D. test at 0.05 level of probability.

The obtained results are in parallel with those reported by Garcia *et al*. (1999). Irrespective of type of tested explant, foliar application of GA_3 up to 75 mg/l, recorded the highest average values of the tested traits. However, treating the combined propagation method (offshoot+ stump cuttings) with 75 mg/l GA_3 exhibited the highest average values compared to the control plants during both seasons of the study. This finding may be ascribed for the mode of action GA_3 and/ or could be due to spraying the appropriate or optimal level of GA_3 (i.e.75 mg/l) where explant tissues responded actively and induced the desirable and noticeable result.

Head chemical quality characteristics

Results depicted in Table (5) express the average values of head (*capitulum*) chemical quality characters of globe artichoke plants cv. 'Balady' as affected by propagation methods (explants), Gibberellic acid concentrations and their combinations. The effects were significant ($p \leq 0.05$) for various characters except for total phenols of the tested propagation methods (explants). With reference to the main effect of propagation methods (explants), the combined or mixed propagation methods (explants) [offshoots + stump cuttings] recorded the highest average values of crude protein, TSS (%), inulin (%) and total sugars (%) compared to the other treatments, during both seasons. This finding suggests that globe artichoke heads of cv. 'Balady' derived from the combined explants is an important source for crude protein. Its crude protein assures the best nutritional value of the globe artichokes heads. Then the differences among tested propagation methods (explants) could provide useful information about the best explant to be used for cultivation and marketing. Concerning the total phenol content (%, F.W.), despite the absence of the significant ($p > 0.05$) differences among propagation methods (explants) justifies the richness of globe artichoke's heads, generally, in polyphenolic acids and flavonoids (Pandino *et al*., 2012), and the therapeutic properties observed and addresses the extension of the artichoke plantation as a novel source of natural nutraceutical for human nutrition (Lattanzio *et al*., 2009; pandino *et al.*, 2012).

Table (5). Averages values of head chemical quality characters of globe artichoke plants cv. 'Balady' as affected by propagation methods (explants), foliar application with gibberellic acid (GA_3) and their interaction during the winter seasons of 2016/2017 and 2017/2018

Treatments		Head chemical quality contents									
		C-Protein (%)		Total phenols (%)		TSS (%)		Inuline (%)		Total sugars (%)	
		2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018
Propagation methods (explants) [main effect]											
Offshoots		11.74 b	12.19 b	0.209 a	0.211 a	7.00 d	7.11 b	13.16 b	13.40 b	16.18 b	16.61 b
Stump cuttings		11.46 b	11.96 c	0.208 a	0.211 a	6.93 c	7.06 c	12.99 c	13.28 c	15.99 c	16.32 c
Offshoot+ Stump cuttings		12.34 a	12.77 a	0.209 a	0.211 a	7.16 a	7.27 a	13.54 a	13.81 a	16.67 a	16.99 a
Gibberellic acid (GA_3) [main effect]											
Control		9.28 d	9.60 d	0.196 d	0.198 d	6.48 d	6.59 d	11.81 d	12.00 d	14.75 d	15.10 d
25 mg/l		11.09 c	11.57 c	0.206 c	0.209 c	6.85 c	6.96 c	12.73 c	13.04 c	15.57 c	15.93 c
50 mg/l		12.63 b	12.95 b	0.213 b	0.216 b	7.20 b	7.32 b	13.71 b	14.01 b	16.78 b	17.11 b
75 mg/l		14.40 a	15.12 a	0.220 a	0.223 a	7.59 a	7.71 a	14.66 a	14.94 a	18.03 a	18.41 a
Interaction effects											
Propagation methods	GA_3 (mg/l)										
Offshoots	Control	9.35 j	9.69 h	0.200 ef	0.201 j	6.47 k	6.57 j	11.82 k	11.91 k	14.71 j	15.31 h
	25	10.48 i	10.83 g	0.204 d-f	0.206 i	6.75 i	6.87 h	12.44 i	12.73 i	15.22 j	15.54 h
	50	12.63 e	12.92 d	0.213 a-c	0.216 e	7.18 e	7.29 e	13.75 e	14.01 e	16.78 e	17.17 d
	75	14.50 b	15.33 a	0.220 ab	0.222 b	7.59 b	7.71 b	14.65 b	14.95 b	18.02 b	18.42 b
Stump cuttings	Control	8.81 k	9.15 i	0.198 fg	0.201 j	6.35 l	6.45 k	11.54l	11.82 k	14.44 k	14.58 i
	25	11.17 h	11.83 f	0.206 c-f	0.209 h	6.83 h	6.95 g	12.72 h	13.04 h	15.53 i	15.91 g
	50	12.08 f	12.35 e	0.211 b-d	0.214 f	7.09 f	7.23 e	13.34 f	13.64 f	16.37 f	16.71 e
	75	13.79 c	14.52 b	0.218 ab	0.221 c	7.46 c	7.58 c	14.34 c	14.61 c	17.63 c	18.07 c
Offshoot +Stump cuttings	Control	9.66 j	9.96 h	0.190 g	0.192 k	6.63 j	6.73 i	12.08 j	12.27 j	15.10 i	15.43 h
	25	11.63 g	12.04 f	0.208 c-e	0.210 g	6.96 g	7.06 f	13.04 g	13.34 g	15.97 g	16.33 f
	50	13.19 d	13.58 c	0.216 a-c	0.218 d	7.32 d	7.42 d	14.05 d	14.38 d	17.18 d	17.47 d
	75	14.90 a	15.50 a	0.222 a	0.225 a	7.71 a	7.85 a	14.98 a	15.27 a	18.44 a	18.74 a

-Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using the revised L.S.D. test at 0.05 level of probability.

This finding indicate that the artichoke heads derived from various propagation methods (explants) could represent an important source of polyphenols in comparison with the other vegetables owing to their capacity to provide a high level of these important biomolecules and possibility to be used in therapeutic and nutraceutical activity (Dabbou *et al.*, 2017). Pertaining the main effect of GA_3 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 GA_3 affected significantly ($p \leq 0.05$) traits under study. Also, it is obvious that there is a direct proportionate relationship between GA_3 level and the given traits. Foliar application of GA_3 at 75 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. But in contradictory to the results of the present study, EL-Zohiri *et al*. (2015) reported that GA_3 application significantly ($p \leq 0.05$) decreased inulin content. This variation could be due to the genotype under the study and/or due to the complex metabolic processes taken place during growth and development of plants and its flowering processes (Abd EL-Hamid *et al*., 2008). Also, Sharaf-Eldin *et al.* (2003) suggested that application of GA_3 had no significant effect on inulin contend in edible part of globe artichoke. On the other extreme, EL-Abagy *et al.* (2010) reported that inulin content was affected significantly by GA_3 foliar application at 100 and 200 mg/l. It should be realized that the recorded results of foliar application of GA_3 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 (Abd EL Hameid, 2008) 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 interaction effect of both propagation methods (explants) and GA_3 concentrations, results of Table (5) revealed such significant ($p \leq 0.05$) differences among the various tested combinations. As reported earlier the interaction between any propagation methods (explants) and foliar application of GA_3 at 75 mg/l, brought about the highest average values of the tested traits individually; nevertheless, the combination between combined propagation method (offshoot + stump cutting) and foliar application of GA_3 (75 mg/l) on the plants derived from this explant, recorded the highest average values compare to the other levels of GA_3, and differed significantly ($p \leq 0.05$) from the other combinations between offshoot explants and stump explants at the same concentration of GA_3 (75 mg/l). Regardless, the GA_3 concentration (i.e., 75 mg/l), the comparison of head chemical quality contents of the heads derived from the combined explant (offshoot + stump cuttings), offshoot, then stump cutting; declared that the former cutting recorded increment percentages were 54.94 % for crude protein, 17.02 % for total phenols, 16.47 % for TSS, 24.23 % for inulin , and 21.78% for total sugars compare to untreated plants and as average of both seasons. Irrespective arc-sine transformation of the percentages of head chemical quality of the given traits, total phenol content of the combined propagation method (offshoots + stump) exhibited higher percentages compare to the other two methods of propagation.

This finding indicate that the free phenolic extracted from heads or bracts of *cynara scolymus* L. might be of interest within the developing market of nutritional ingredients and is capable of yielding nutritional supplements with antimicrobial activities (Gaafar and Salama, 2013), in addition to the role of polyphenol in plant defense. These findings add a new scientific knowledge, whereas it is known that external factors such as fertilization, ambient temperature, insect predation, light and water, also affect the concentration of polyphenol content either negatively or positively (Yao *et al*., 2007). Polyphenolic contents of globe artichoke plants depend on a number of intrinsic (genetic) and extrinsic (environmental, handling and storage) factors (Fratianni *et al*., 2007).

Chemical constituents of heads

Results postulated in Table (6) demonstrate that the average values of head nutrient contents of globe artichoke plants cv. 'Balady' were affected and differed significantly ($p \leq 0.05$) between and among both variables and their interactions. Concerning the main effect of propagation methods (explants), generally, the given variable affected the trait under study significantly ($p \leq 0.05$), whereas the flower derived from stump cutting have the highest average values of NO_2-N (mg/kg, F.W.), followed by those heads derived from offshoot cuttings, then followed by the outcome of the mixed explants. Pertaining NO_3-N (mg/kg, F.W.), despite the significant differences, the NO_3-N did not express clear trend, where the highest average value was recorded for heads produced during the first season from the combined explants, while the highest average value for NO_3-N was recorded from heads originated from stump cutting during the second season. In terms of head elemental composition of NPK, results declared not defined trend, except for K whereas that the heads derived from the combined explants; declared the highest average values of NPK contents compare to the other two propagation methods. With regard to the main effect of GA_3 the tabulated averages disclosed that there is an inverse relationship between GA_3 concentrations and NO_2-N and NO_3-N, whereas control (untreated) plants recorded the highest average values during both seasons, respectively. On the other side, there is a direct proportionate relationship between N P K content of the heads and GA_3 concentrations especially at 75 mg/l GA_3. This finding reflects the profound effect of GA_3 especially at 75 mg/l on reduction both serious components for the sake of human health upon using edible part of globe artichoke.

Interestingly, increasing N P K contents progressively which enhances the nutritional status of the edible part of the *capita* (flowers' head). It is noteworthy that nitrite (NO_2-N) in globe artichoke heads of the control (untreated) plants was higher and significantly different, and in descending order of the other GA_3 levels.

Table (6). Average values of head nutrient contents of globe artichoke heads cv. 'Balady' as affected by propagation methods (explants), foliar application with gibberellic acid (GA_3) and their interaction during the winter seasons of 2016/2017 and 2017/2018

Treatments		Nutrient contents of heads									
		NO_2-N (mg/kg, FW)		NO_3-N (mg/kg, FW)		N (%, DW)		P (%, DW)		K (%, DW)	
		2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018
Propagation methods (explants) [main effect]											
Offshoots		1.10 b	1.14 b	6.30 b	6.42 b	1.88 b	1.95 b	0.329 b	0.336 a	1.70 b	1.74 b
Stump cuttings		1.21 a	1.27 a	6.42 c	6.57 a	1.84 b	1.91 c	0.325 c	0.332 a	1.65 c	1.69 c
Offshoot+ Stump cuttings		0.99 c	1.04 c	6.05 a	6.20 c	1.98 a	2.04 a	0.340 a	0.337 a	1.82 a	1.86 a
Gibberellic acid (GA_3) [main effects]											
Control		1.51 a	1.56 a	7.19 a	7.33 a	1.49 d	1.54 d	0.291 d	0.296 c	1.28 d	1.31 d
25 mg/l		1.29 b	1.35 b	6.58 b	6.73 b	1.78 c	1.85 c	0.317 c	0.324 b	1.59 c	1.62 c
50 mg/l		0.97 c	1.01 c	5.94 c	6.10 c	2.02 b	2.07 b	0.344 b	0.339 b	1.87 b	1.92 b
75 mg/l		0.63 d	0.67 a	5.30 d	5.41 a	2.30 a	2.42 a	0.372 a	0.379 a	2.15 a	2.20 a
Interaction effects											
Propagation methods	GA_3 (mg/l)										
Offshoots	Control	1.50 b	1.55 b	7.18 b	7.28 b	1.50 h	1.55 h	0.292 j	0.296 gh	1.28 l	1.32 k
	25	1.30 d	1.35 d	6.80 d	6.93 d	1.68 g	1.73 g	0.307 g	0.314 e-h	1.50 i	1.54 i
	50	0.98 g	1.01 g	5.93 h	6.02 h	2.02 d	2.07 d	0.347 c	0.353 b-d	1.87 e	1.91 e
	75	0.62 j	0.63 j	5.29 k	5.44 k	2.32 a	2.45 a	0.369 b	0.380 ab	2.14 b	2.19 b
Stump cuttings	Control	1.60 a	1.67 a	7.41 a	7.57 a	1.41 i	1.46 i	0.282 j	0.287 h	1.18 l	1.22 i
	25	1.40 c	1.45 c	6.59 e	6.75 e	1.80 f	1.89 f	0.318 f	0.326 d-g	1.59 h	1.63 h
	50	1.09 f	1.15 f	6.18 g	6.33 g	1.93 e	1.98 e	0.335 d	0.341 c-e	1.77 f	1.81 f
	75	0.75 i	0.80 i	5.50 j	5.62 j	2.21 b	2.32 b	0.364 b	0.372 a-c	2.06 c	2.11 c
Offshoot +Stump cuttings	Control	1.42 c	1.47 c	6.99 c	7.15 c	1.55 h	1.59 h	0.300 h	0.304 f-h	1.36 j	1.39 j
	25	1.18 e	1.24 e	6.36 f	6.52 f	1.86 f	1.93 f	0.327 e	0.333 d-f	1.68 g	1.72 g
	50	0.85 h	0.88 h	5.73 i	5.95 i	2.11 c	2.17 c	0.351 c	0.323 d-g	1.98 d	2.03 d
	75	0.53 k	0.57 k	5.10 l	5.17 l	2.38 a	2.48 a	0.382 a	0.387 a	2.24 a	2.29 a

-Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using the revised L.S.D. test at 0.05 level of probability.

The findings of NO_2-N and NO_3-N could be attributed to the fact that nitrite is easily oxidized to nitrate (WHO, 1978) and nitrate ion is stable and is chemically unreactive under most environmental conditions (IARC, 2010; WHO, 2011). Also, GA_3 at any concentration, especially at 75 mg/l, may be integrated in the processes of oxidizing NO_2-N into NO_3-N, and production more proteins in flower heads (Kilgore, 1993), hence it plays a crucial role in lowering the health hazards associated with NO_2-N in the edible part of the globe artichoke (heads), and subsequently it is possible to draw that GA_3 may represent a dual benefit agent as plant growth regulator and safe factor against health risks in this respect. Also, lowering nitrate (NO_3-N) concentration with increasing GA_3 concentration, reflects the fact that there is an excessive nitrate accumulation occurs in control plants compare to those of plants treated with GA_3 levels, where the uptake of nitrate exceeds the production of plant proteins (Kilgore, 1993). This could explain increasing crude protein with increasing GA_3 level as reported earlier. In case of NPK content of the heads, the GA_3 concentration is in a direct proportionate relationship with this trait. This finding refers to the beneficial mode of action of GA_3 at the given concentration (75 mg/l) on the nutritional status of the 'Balady' cv., globe artichoke heads for human being's health improvement as a dietary (healthy or called a functional food) as reported by Ceccarelli *et al.* (2010). These results are in agreement with those of EL-Abagy *et al*. (2010). Likewise, increasing K under GA_3 foliar application may be due to the effect of GA on the ability of cells to absorb more assimilates, and the latter is translocate in the presence of K (EL-Abagy *et al.*, 2010). With respect to the interaction between both variables and their interactions, the given interactions affected significantly ($p \leq 0.05$) both NO_2-N and NO_3-N contents. Notably, the control treatment showed the highest average values of the heads per plants that derived from stump cuttings, followed by those derived from offshoots, then those originated from combined cuttings (offshoot + stump cutting). The foliar application of the various plants derived from the last explants with 75 mg/l, in general, led to the lowest average values of both nitrogen forms in the heads. Pertaining the NPK content of heads of globe artichoke cv. 'Balady', it was affected significantly ($p \leq 0.05$) by both studied variables and their interaction. Generally, propagation methods (explants) derived plants' heads that foliar application with GA_3 at 75 mg/l; followed such descending order, whereas the combined explants produced *capita* (buds or flower heads) enriched with NPK contents. Similar performance, more or less, was closely as for the NPK of head content of plants derived from offshoot cuttings compare to control treatment, within both seasons.

This study recommends, generally, that the interaction between any propagation method (explants) and GA_3 at its higher level (75 mg/l) recorded the highest average values; nevertheless, the offshoots + stumps cuttings upon interacted with GA_3 at 75 mg/l ; 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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الملخص العربي

سلوك نباتات الخرشوف تأثراً بطرق الإكثار والرش الورقي بحمض الجبريليك

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يعتبر الخرشوف من أهم المحاصيل النباتية في الدول المطلة على حوض البحر الأبيض المتوسط بما في ذلك مصر. ولكن بسبب تأخره في الإزهار وانخفاض القدرة الإنتاجية وتعرض صنف الخرشوف 'البلدي' للاندثار لذلك، تم إجراء تجربتان حقليتان خلال موسمي ٢٠١٦/٢٠١٧ و٢٠١٧/٢٠١٨. وتم تنفيذ التجارب في مزرعة خاصة تقع في مدينة أبو المطامير، محافظة البحيرة، مصر، تحت ظروف الحقل المفتوح. تم استخدام ثلاث طرق لإكثار نباتات الخرشوف صنف 'البلدي' وهي تجزئة الأمهات، الفسائل، وخليط بين كل من تجزئة الأمهات +الفسائل، وكان كل قطعة إكثار لها وزن ثابت ١٦٠ جم تقريباً. تمت الزراعة على مصاطب عرضها ١,٠٠ متر والمسافة بين القطع النباتية ٠,٥ متر. لذا، بلغ إجمالي عدد النباتات / الفدان ٨٤٠٠ نبات (نباتان / م ٢). أيضاً، تم استخدام أربع تركيزات من حمض الجبريليك GA_3 وهي (٠ ، ٢٥ ، ٥٠ و ٧٥ ملليجرام / لتر) رشاً ورقياً. وتم الرش مرتين؛ الأولى بعد ٦٥ يوماً من الزراعة (في المرحلة التي كانت فيها النباتات تحتوي على ما يقرب من ١٢–١٥ ورقة) والثانية بعد ٢٠ يومًا من الرشة الأولى (أو عندما كانت النباتات تحتوي على ٢٠ ورقة تقريبًا). تم رش نباتات المشاهدة بماء الصنبور. التصميم الإحصائي كان عبارة عن نظام القطع المنشقة في تصميم القطاعات العشوائية الكاملة في ثلاث قطاعات. تم وضع طرق الإكثار في القطع الرئيسية، وتركيزات حمض الجبريليلك في القطع تحت الرئيسية. تم دراسة تأثير كل من المتغيرين والتداخل بينهما على صفات النمو الخضري والمحصول ومكوناته وجودة الرأس والتركيب الكيميائي لها. وأوضحت النتائج التي تم الحصول عليها ، بشكل عام ، إلى أن التفاعل بين أي طريقة من طرق التكاثر المستخدمة والرش الورقي بحمض الجبريليك GA_3 عند التركيز الأعلى (٧٥ ملليجرام / لتر) سجل أعلى متوسطات القيم ؛ ومع ذلك ، فإن طريقة التكاثر الخليط بين تجزئة الأمهات + الفسائل مع الرش الورقي بحمض الجبريليك GA_3 بتركيز ٧٥ ملليجرام / لتر أنتجت أعلى متوسطات القيم للصفات المدروسة ويمكن اعتبارها المعاملة الأمثل لإنتاج محصول مرتفع وذو جودة من نباتات الخرشوف في ظل الظروف البيئية لمحافظة البحيرة والمناطق الأخرى المماثلة لها.