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# Response of two seed-grown artichoke cultivars to GA<sub>3</sub> and melatonin treatments

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## Abstract

**Background:** Globe artichoke *Cynara scolymus* L. is an important vegetable crop. Poor crop stand due to the low ratio of stumps surviving is the common problem which occurs with using vegetative parts. The current study evaluated two seed-propagated cultivars of artichoke: treated by GA<sub>3</sub> and melatonin applications in newly reclaimed land.

**Results:** Results showed that Imperial Star produced higher values of vegetative growth, yield productivity, and chemical contents, compared with Romanesco cultivar. GA<sub>3</sub> foliar application treatment ranked the first to increase vegetative growth, yield productivity, and chemical contents, followed by melatonin treatment, compared with untreated control.

**Conclusion:** It could be concluded that the use of GA<sub>3</sub> and melatonin were favorable for the production of both artichoke cultivars: Imperial Star and Romanesco. The highest productivity was achieved by foliar application of GA<sub>3</sub> to Imperial Star cultivar.

**Keywords:** Cultivars growth, Head yield, Chemical composition, GA<sub>3</sub>, Melatonin

## Background

Globe artichoke *Cynara scolymus* L. is an important vegetable crop belongs to Composite family and a native Mediterranean crop (Ryder et al. 1983; Lattanzio et al. 2009).

In Egypt, artichoke fields are traditionally established by using the vegetative parts, e.g., offshoots and stump sections from plants that have been cut down from older fields. Globe artichoke is cultivated mainly in El-Behira, Alexandria, and Giza governorates and newly reclaimed lands. Globe artichoke was cultivated on 30,111 feddans during September 2015 (The year book of Agric. Statistics and Economic Agric. Dept., Ministry of Agric., Egypt). Poor crop stand due to the low ratio of stumps surviving is the common problem which occurs with using vegetative parts. Seed-grown globe artichoke seems to be promising technique and can represent a valid alternative to traditional methods all over the world. More attention is given to promote artichoke productivity in Egypt to satisfy the increased demands of the local consumption and exportation. Seed-propagated

artichoke has gained popularity, compared with vegetative propagation for several years (Foti et al. 2005; Garcia et al. 2016; Lombardo et al. 2012). Seed-propagated cultivars permit several advantages: uniformity, high productivity, resistance for diseases, and profitability (Saleh et al. 2007; Baixauli et al. 2012; Lombardo et al. 2012; Saleh et al. 2017). Until now, few studies were conducted on seed-propagated cultivars in Egypt. The lateness is the main disadvantage of seed-propagated cultivars.

The beneficial effect of GA<sub>3</sub> has been widely recognized for artichoke earliness (Mauromicale et al. 2005; Baixauli et al. 2012; El-Zohiri 2015). Also, the application of melatonin can reduce the negative effect of climate change on plant productivity (Arnao and Hernandez-Ruiz 2009; Tan et al. 2012; Wang et al. 2012; Zhang et al. 2014; Abd El-Naby et al. 2019).

The current study evaluated two seed-propagated cultivars: Imperial Star and Romanesco treated by GA<sub>3</sub> and melatonin applications.

## Materials and methods

The field experiments were conducted in the research and production station of National Research Centre, Noharia, El-Behira Governorate (Northern Egypt),

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during the two successive cultivation seasons of 2017/2018 and 2018/2019 to study the effect of cultivar variations: Imperial Star and Romanesco, and application treatments of GA<sub>3</sub> and melatonin, compared with untreated control on the vegetative growth, head yield, and its physical and chemical quality of globe artichoke. The soil characteristics were as follows: sand 57.9%, silt 35.6%, clay 6.5%, pH 7.8, and EC 1.4 ds/m.

The experiment was carried out in a split plot design with three replicates. The experiment contained six treatments as combinations between two artichoke cultivars: Imperial Star and Romanesco (factor A) treated by GA<sub>3</sub> and melatonin applications, compared with untreated control (factor B). GA<sub>3</sub> and melatonin were prepared as aqueous solution of 50 ppm. Artichoke seeds were soaked in aqueous solution of GA<sub>3</sub> and melatonin for 10 min. The wet seeds were sown in cellular trays 7 × 12 filled with peatmoss substrate in the direction greenhouse of the Ministry of Agriculture in Dokki. After germination, good seedlings were transplanted in the open field at the first of September. Additional foliar spraying by GA<sub>3</sub> and melatonin were applied two times 60 and 90 days after transplanting (DAT). Plot area was 20 m<sup>2</sup> which consists of one ridge (5.0 m long and 1.0 m width) containing 20 artichoke plants with 1.0 m apart between each two plants. Five plants were randomly selected to evaluate vegetative growth characters: plant height, leaves number per plant, leaf area, leaf fresh weight, and leaf dry weight as well as total chlorophyll content were measured as using Chlorophyll content Meter 003109 (CCM-200 plus Opti-Sciences). The measurements of vegetative growth characters were recorded at 70 and 110 DAT. The early yield was determined as weight and number of heads per plant from the beginning of harvest until the end of February. The total yield of heads was recorded as weight and number of heads per plant from the beginning of harvest until the end of growing season. The weight, length, and diameter as well as the weight of edible part of main and secondary heads were measured in February and April, respectively. Representative samples from edible parts (receptacles) were taken for chemical analyses. Samples were dried for 3 days in an oven at 70 °C until a constant weight, ground, and digested using an acid mixture consisting of nitric, perchloric, and sulfuric acids in the ratio of 8:1:1 (v/v), respectively according to Chapman and Pratt (1978). Nitrogen estimated by semi-micro Kjeldahl method of Plummer (1978). Phosphorus was determined using a Spectrophotometer at 882-OVV by the method outlined by Jackson [1973]. Potassium, calcium, iron, manganese, and zinc were determined using Atomic Absorption Spectrophotometer "Perkin Elmer 1100 B" (Cottanie et al. 1982). The chemical analyses were done in Agricultural Services Unit and Laboratory Analysis of

Research Project (Micronutrients and Other Plant Nutrition Problems in Egypt) in NRC.

The treatment effects were evaluated by analysis of variances. The mean values were compared according to Duncan's multiple range test at  $P < 5\%$  as reported by Gomez and Gomez (1984).

## Results

### Vegetative growth characters

The effects of foliar application treatments (GA<sub>3</sub> and melatonin treatments) on all vegetative growth characters: plant height, number of leaves per plant, leaf area, leaf fresh weight, and leaf dry weight as well as chlorophyll content compared with untreated control of the two artichoke cultivars (Imperial Star and Romanesco) are presented in Table 1 at 70 days after transplanting (DAT) and Table 2 at 110 DAT during the two successive growing seasons of 2017/2018 and 2018/2019, respectively.

### Evaluation of cultivars

The obtained results revealed that Imperial Star cultivar resulted in the highest values of all plant growth characters: plant height, number of leaves per plant, leaf area, leaf fresh weight, and leaf dry weight as well as chlorophyll content, compared with Romanesco cultivar at 70 DAT (Table 1) and at 110 DAT (Table 2) during the two growing seasons of 2017/2018 and 2018/2019, respectively. The variations between the two cultivars on chlorophyll content during the first season of 2017/2018 and leaf dry weight during the second season of 2018/2019 at 110 DAT (Table 2) were not enough to be statistically significant.

### Effect of GA<sub>3</sub> and melatonin applications

The obtained results showed positive effects for both GA<sub>3</sub> and melatonin treatments on all vegetative growth characters: plant height, number of leaves per plant, leaf area, leaf fresh weight, and leaf dry weight as well as chlorophyll content compared with untreated control at 70 DAT (Table 1) and at 110 DAT (Table 2) during the two growing seasons of 2017/2018 and 2018/2019, respectively. GA<sub>3</sub> treatment ranked the first, followed by melatonin treatment to improve vegetative growth characters of artichoke plants, compared with untreated control. There were no significant differences between GA<sub>3</sub> treatment and untreated control on chlorophyll content at 70 DAT during the second season of 2018/2019 (Table 1). The variations among all foliar application treatments on leaf number per plant during the first season of 2017/2018 and leaf dry weight during the second season of 2018/2019 at 110 DAT (Table 2) were not enough to be statistically significant.

**Table 1** Effect of GA<sub>3</sub> and melatonin on vegetative growth of two artichoke cultivars 70 DAT during the two growing seasons of 2017/2018 and 2018/2019

Treatments	Plant height, cm	Leaf No. /plant	Leaf area, cm <sup>2</sup>	Leaf fresh W, g	Leaf dry W, g	Chlorophyll SPAD	
First season (2017/2018)							
Cultivars							
Imperial Star (IS)	52.1 a	12.3 a	475 a	106.5 a	14.6 a	46.3 a	
Romanesco (R)	48.9 b	11.3 b	457 b	93.8 b	11.9 b	44.3 b	
Foliar application							
Melatonin	50.2 b	12.2 a	468 a	101.3 b	13.6 a	45.8 b	
GA <sub>3</sub>	52.2 a	13.2 a	471 a	102.8 a	13.7 a	47.0 a	
Control	49.2 b	10.2 b	458 b	96.8 c	12.6 b	43.3 c	
Interactions							
IS	Melatonin	52.0 a	12.7 a	478 a	107.1 a	15.1 a	46.7 a
	GA <sub>3</sub>	54.0 a	13.7 a	483 a	109.9 a	15.2 a	48.0 a
	Control	50.3 a	12.7 a	464 b	102.4 b	13.6 b	44.3 a
R	Melatonin	48.3 a	11.7 a	458bc	95.6 c	12.1 c	45.0 a
	GA <sub>3</sub>	50.3 a	12.7 a	460bc	95.7 c	12.1 c	46.0 a
	Control	48.0 a	9.7 a	453 c	90.2 d	11.1 d	42.3 a
Second season (2018/2019)							
Cultivars							
Imperial Star (IS)	47.0 a	11.1 a	465 a	102.0 a	14.8 a	45.0 a	
Romanesco (R)	45.4 b	9.9 b	451 b	93.8 b	12.9 b	43.8 b	
Foliar application							
Melatonin	46.0ab	10.5ab	460 a	101.3 a	14.1 a	43.8 b	
GA <sub>3</sub>	48.3 a	11.2 a	462 a	102.8 a	13.9 a	47.3 a	
Control	44.3 b	9.8 b	453 b	96.8 b	12.5 b	42.0 b	
Interactions							
IS	Melatonin	46.7 b	11.3 a	466 b	102.0 a	15.4 a	44.7 a
	GA <sub>3</sub>	49.3 a	12.0 a	473 a	101.7 a	14.5ab	48.0 a
	Control	45.0 c	10.0 a	457 c	101.2 a	14.3 b	42.3 a
R	Melatonin	45.3 c	9.7 a	453 cd	96.3 b	12.8 c	43.0 a
	GA <sub>3</sub>	47.3 b	10.3 a	451d	97.3 b	13.2 c	46.7 a
	Control	43.7 d	9.7 a	448 d	92.7 c	12.7 c	41.7 a

Means within each column within main effects and interactions followed by the same letter are not significantly different at  $P < 5\%$

### Effect of the interactions

The interaction effects between two artichoke cultivars and foliar application treatments on all vegetative growth characters at 70 DAT and at 110 DAT during the two growing seasons are presented in Tables 1 and 2. Imperial Star cultivar which was sprayed with GA<sub>3</sub> resulted in the highest values of leaf area, leaf fresh weight, and leaf dry weight during the first growing season, and plant height and leaf area during the second growing season at 70 DAT (Table 1), while Imperial Star cultivar which was sprayed with melatonin resulted in the highest values of leaf fresh weight and leaf dry weight during the second growing season at 70 DAT (Table 1). At 110 DAT, Imperial Star cultivar which foliar sprayed by GA<sub>3</sub> resulted in the highest values of leaf

fresh weight and chlorophyll content during the first growing season, and plant height and leaf area during the second growing season (Table 2). On the other hand, Romanesco cultivar without any foliar application resulted in the lowest values of all vegetative growth characters during both growing seasons (Tables 1 and 2). The obtained results revealed that no significant variations were found among all interaction treatments concerning their effects on plant height, leaf number, and chlorophyll content at 70 DAT during the first growing season and leaf number and chlorophyll content during the second growing season (Table 1). At 110 DAT, no significant variations were found among all interaction treatments concerning their effects on plant height, leaf number, leaf area, and leaf dry weight during the first

**Table 2** Effect of GA<sub>3</sub> and melatonin on vegetative growth of two artichoke cultivars 110 DAT during the two growing seasons of 2017/2018 and 2018/2019

Treatments	Plant height, cm	Leaf No./plant	Leaf area, cm <sup>2</sup>	Leaf fresh W, g	Leaf dry W, g	Chlorophyll SPAD	
First season (2017/2018)							
Cultivars							
Imperial Star (IS)	126.4 a	21.7 a	506 a	109.0 a	16.7 a	50.7 a	
Romanesco (R)	113.8 b	21.2 b	485 b	100.3 b	15.6 b	49.1 a	
Foliar application							
Melatonin	119.5 b	21.4 a	495ab	105.5 a	16.1ab	50.3 a	
GA <sub>3</sub>	123.5 a	22.0 a	504 a	107.5 a	16.7 a	50.6 a	
Control	116.8 c	21.1 a	488 b	101.1 b	15.7 b	48.9 b	
Interactions							
IS	Melatonin	126.3 a	21.7 a	504 a	109.7 a	16.4 a	51.1 a
	GA <sub>3</sub>	129.7 a	22.0 a	513 a	112.8 a	17.5 a	51.4 a
	Control	123.3 a	21.3 a	501 a	104.5 b	16.1 a	49.7 b
R	Melatonin	112.7 a	21.0 a	486 a	101.3bc	15.8 a	49.5 b
	GA <sub>3</sub>	117.3 a	21.9 a	495 a	102.1bc	15.9 a	49.8 b
	Control	110.2 a	20.8 a	474 a	97.6 c	15.2 a	48.1 c
Second season (2018/2019)							
Cultivars							
Imperial Star (IS)	120.0 a	21.0 a	519 a	111.7 a	17.9 a	49.2 a	
Romanesco (R)	105.6 b	18.7 b	493 b	103.3 b	17.2 a	46.5 b	
Foliar application							
Melatonin	112.3 b	20.0 a	507ab	108.7 a	17.7 a	48.0 a	
GA <sub>3</sub>	115.8 a	20.6 a	519 a	109.3 a	17.9 a	48.8 a	
Control	110.4 c	19.0 b	493 b	104.6 b	17.0 a	46.8 b	
Interactions							
IS	Melatonin	119.7 a	21.5 a	518ab	113.3 a	18.1 a	49.5 a
	GA <sub>3</sub>	122.5 a	21.4 a	526 a	113.4 a	18.2 a	50.3 a
	Control	117.9 a	20.1 a	512 b	108.5 a	17.3 a	47.8 a
R	Melatonin	104.9bc	18.5 a	495 c	104.0 a	17.3 a	46.5 a
	GA <sub>3</sub>	109.1 b	19.8 a	502bc	105.2 a	17.5 a	47.3 a
	Control	102.8 c	17.9 a	481 d	100.6 a	16.6 a	45.7 a

Means within each column within main effects and interactions followed by the same letter are not significantly different at  $P < 5\%$

growing season, and leaf number, leaf fresh weight, leaf dry weight, and chlorophyll content during the second growing season (Table 2).

## Head yield

### Evaluation of cultivars

The variations in artichoke head yield and its components between the two evaluated cultivars during the two cultivated seasons of 2017/2018 and 2018/2019 are presented in Table 3. The obtained results showed that Imperial Star cultivar ranked the first to increase artichoke productivity, followed by Romanesco cultivar during the growing season of 2017/2018 (Table 3), whereas Imperial Star cultivar produced the highest values of

both early yield and total yield of artichoke heads as number of heads per plant and weight (g) per plant during the two cultivated seasons of 2017/2018 and 2018/2019 (Table 3).

### Effect of GA<sub>3</sub> and melatonin applications

Both foliar application treatments of GA<sub>3</sub> and melatonin enhanced the earliness and improved head yield of artichoke plants, compared with untreated control during the two cultivated seasons of 2017/2018 and 2018/2019 (Table 3), whereas GA<sub>3</sub> treatment increased both early yield and total yield of artichoke heads as number of heads per plant and head weight (g) per plant during the two cultivated seasons of 2017/2018 and 2018/2019

**Table 3** Effect of GA<sub>3</sub> and melatonin on head yield of two artichoke cultivars during the two growing seasons of 2017/2018 and 2018/2019

Treatments		Early yield		Total yield	
		No./plant	g/plant	No./plant	g/plant
First season (2017/2018)					
Cultivars					
	Imperial Star (IS)	5.7 a	1614 a	20.6 a	4130 a
	Romanesco (R)	4.8 b	1245 b	18.7 b	3460 b
Foliar application					
	Melatonin	5.2ab	1424 b	19.6ab	3800 b
	GA <sub>3</sub>	5.7 a	1561 a	20.7 a	3999 a
	Control	5.0 b	1304 c	18.8 b	3587 c
Interactions					
IS	Melatonin	5.7 a	1620 b	20.2 b	4091 b
	GA <sub>3</sub>	6.2 a	1735 a	21.9 a	4385 a
	Control	5.3 a	1486 c	19.8bc	3914 c
R	Melatonin	4.6 a	1228 d	18.9 c	3508 d
	GA <sub>3</sub>	5.2 a	1387 c	19.5bc	3612 d
	Control	4.7 a	1221 d	17.7 d	3260 e
Second season (2018/2019)					
Cultivars					
	Imperial Star (IS)	6.5 a	1729 a	20.0 a	4058 a
	Romanesco (R)	5.0 b	1284 b	18.8 b	3527 b
Foliar application					
	Melatonin	5.8 a	1532 a	19.8 a	3828 a
	GA <sub>3</sub>	6.1 a	1601 a	20.3 a	3970 a
	Control	5.4 b	1387 b	18.2 b	3580 b
Interactions					
IS	Melatonin	6.8 a	1790 a	20.6 a	4033 b
	GA <sub>3</sub>	6.9 a	1800 a	21.1 a	4258 a
	Control	5.9 b	1597 b	18.3 a	3883 b
R	Melatonin	4.8 d	1274 d	18.9 a	3623 c
	GA <sub>3</sub>	5.3 c	1401 c	19.5 a	3682 c
	Control	4.8 d	1177 d	18.1 a	3276 d

Means within each column within main effects and interactions followed by the same letter are not significantly different at  $P < 5\%$

(Table 3). Next to GA<sub>3</sub>, melatonin treatment also led to increase both early yield and total yield of artichoke heads, compared with untreated control (Table 3). Therefore, high productivity could be achieved by using suitable cultivar and cultivation management such as foliar application treatments of GA<sub>3</sub> and melatonin.

#### Effect of the interactions

Imperial Star cultivar that was sprayed by GA<sub>3</sub> resulted in the highest values of earliness and head yield of artichokes both number of heads per plant and head weight

(g) per plant during the two cultivated seasons of 2017/2018 and 2018/2019 (Table 3), while the lowest values of earliness and head yield of artichoke as number of heads per plant and head weight (g) per plant were related to Romanesco cultivar without any foliar application during the two cultivated seasons of 2017/2018 and 2018/2019 (Table 3). However, the variations among all interaction treatments were not enough to be significant concerning their effects on number of early heads per plant during the first cultivated season of 2017/2018 and number of total heads per plant during the second cultivated season of 2018/2019 (Table 3).

#### Head characters

##### Evaluation of cultivars

The obtained results revealed that Imperial Star cultivar produced the highest values of all physical measurements on main heads (Table 4) and secondary heads (Table 5) such as weight, length, and diameter as well as the weight of edible part during the two growing seasons of 2017/2018 and 2018/2019. Conversely, the lowest values of all physical properties of artichoke head weight, length, and diameter as well as the weight of edible part for both main heads (Table 4) and secondary heads (Table 5) were always related to Romanesco cultivar during the two growing seasons of 2017/2018 and 2018/2019.

##### Effect of GA<sub>3</sub> and melatonin applications

All measurements on physical properties of artichoke heads: weight, length, diameter, and the weight of edible part recorded improvements by GA<sub>3</sub> and melatonin treatments comparing with untreated control during the two growing seasons of 2017/2018 and 2018/2019. The superiority in all physical measurements of artichoke heads: main heads (Table 4) and secondary heads (Table 5) was due to GA<sub>3</sub> treatment, whereas the weight, length, diameter, and the weight of edible part of main heads (Table 4) and secondary heads (Table 5) reached maximum values by GA<sub>3</sub> treatment during the two growing seasons of 2017/2018 and 2018/2019. In a descending order next to GA<sub>3</sub>, melatonin also improved all physical measurements of artichoke heads main and secondary during the two growing seasons of 2017/2018 and 2018/2019. On the other hand, the lowest values of all physical measurements of artichoke heads were related to untreated control during the two growing seasons of 2017/2018 and 2018/2019. However, the variations among all foliar application treatments were not enough to be significant concerning their effects on head length and the weight of edible part of main heads during the second cultivated season of 2018/2019 (Table 4).

**Table 4** Effect of GA<sub>3</sub> and melatonin on main head quality of two artichoke cultivars during the two growing seasons of 2017/2018 and 2018/2019

Treatments		Weight (g)	Length (mm)	Diameter (mm)	Edible part (g)
First season (2017/2018)					
Cultivars					
Imperial Star (IS)		301.0 a	102.8 a	99.2 a	59.5 a
Romanesco (R)		264.6 b	95.7 b	86.7 b	50.5 b
Foliar application					
Melatonin		283.6 b	99.3 a	93.3 a	54.9ab
GA <sub>3</sub>		285.4 a	100.2 a	93.9 a	56.4 a
Control		279.4 c	95.5 b	91.8 b	53.8 b
Interactions					
IS	Melatonin	301.4 a	102.7ab	99.8 a	59.3 a
	GA <sub>3</sub>	302.5 a	104.2 a	100.4 a	60.9 a
	Control	299.1 a	101.5 b	97.5 b	58.2 a
R	Melatonin	265.7 b	95.9 c	86.7 c	50.4 a
	GA <sub>3</sub>	268.3 b	96.2 c	87.3 c	51.8 a
	Control	259.7 c	95.1 c	86.0 c	49.3 a
Second season (2018/2019)					
Cultivars					
Imperial Star (IS)		296.7 a	100.8 a	100.0 a	60.0 a
Romanesco (R)		268.2 b	95.6 b	87.0 b	51.9 b
Foliar application					
Melatonin		283.6 a	98.5 a	93.7 a	56.2 a
GA <sub>3</sub>		283.9 a	98.7 a	94.0 a	56.3 a
Control		279.9 b	97.5 a	92.9 b	55.3 a
Interactions					
IS	Melatonin	297.1 a	100.9 a	100.2 a	60.2 a
	GA <sub>3</sub>	297.8 a	101.4 a	100.8 a	60.3 a
	Control	295.3 a	100.1 a	99.1 a	59.5 a
R	Melatonin	270.1 b	96.0 b	87.2 b	52.2 a
	GA <sub>3</sub>	269.9 b	95.9 b	87.1 b	52.2 a
	Control	264.5 c	94.8 b	86.7 b	51.1 a

Means within each column within main effects and interactions followed by the same letter are not significantly different at  $P < 5\%$

#### Effect of the interactions

The interaction effects between two artichoke cultivars and foliar application treatments on physical properties: weight, length, diameter, and the weight of edible part of main and secondary artichoke heads during the two growing seasons are presented in Tables 4 and 5. Imperial Star cultivar sprayed with GA<sub>3</sub> resulted in the highest values of weight, length, diameter, and the weight of edible part of main and secondary artichoke heads during the two growing seasons of 2017/2018 and 2018/2019 (Tables 4 and 5), while the lowest values of all physical measurements of artichoke heads: main heads (Table 4) and secondary heads (Table 5) were related to Romanesco cultivar without any foliar application during the

two cultivated seasons of 2017/2018 and 2018/2019. However, the variations among all foliar application treatments were not enough to be significant concerning their effects on the weight of edible part of main and secondary artichoke heads during the two growing seasons of 2017/2018 and 2018/2019 (Tables 4 and 5).

#### Chemical composition

##### Evaluation of cultivars

The chemical analyses of representative samples from edible parts (receptacles) of secondary artichoke heads during two cultivated seasons of 2017/2018 and 2018/2019 are presented in Table 6. Imperial star cultivar recorded higher contents of N, Ca, and Zn, while, Romanesco recorded

**Table 5** Effect of GA<sub>3</sub> and melatonin on secondary head quality of two artichoke cultivars during the two growing seasons of 2017/2018 and 2018/2019

Treatments		Weight (g)	Length (mm)	Diameter (mm)	Edible part (g)
First season (2017/2018)					
Cultivars					
Imperial Star (IS)		202.4 a	97.3 a	92.9 a	41.6 a
Romanesco (R)		186.0 b	86.7 b	82.5 b	38.4 b
Foliar application					
Melatonin		195.0 a	92.2 a	87.7ab	40.1ab
GA <sub>3</sub>		195.5 a	92.8 a	88.4 a	40.9 a
Control		192.0 b	91.0 b	87.1 b	39.1 b
Interactions					
IS	Melatonin	203.5 a	97.7 a	92.8 a	41.8 a
	GA <sub>3</sub>	203.9 a	98.3 a	93.7 a	42.1 a
	Control	199.7 b	95.9 b	92.3 a	40.9 a
R	Melatonin	186.5 c	86.7 c	82.6 b	38.3 a
	GA <sub>3</sub>	187.1 c	87.3 c	83.1 b	39.7 a
	Control	184.3 c	86.1 d	81.9 b	37.2 a
Second season (2018/2019)					
Cultivars					
Imperial Star (IS)		199.6 a	96.6 a	91.7 a	41.2 a
Romanesco (R)		184.1 b	86.8 b	80.7 b	38.2 b
Foliar application					
Melatonin		192.1 a	91.9ab	86.4 a	40.0 a
GA <sub>3</sub>		193.2 a	92.3 a	86.9 a	40.4 a
Control		190.4 b	90.9 b	85.3 b	38.9 b
Interactions					
IS	Melatonin	199.6 a	96.8ab	91.9 a	41.4 a
	GA <sub>3</sub>	201.2 a	97.5 a	92.4 a	41.9 a
	Control	198.0 a	95.4 b	90.7 a	40.5 a
R	Melatonin	184.5 b	87.0 c	80.8 b	38.5 a
	GA <sub>3</sub>	185.2 b	87.1 c	81.4 b	38.8 a
	Control	182.7 b	86.3 c	79.8 b	37.3 a

Means within each column within main effects and interactions followed by the same letter are not significantly different at  $P < 5\%$

higher contents of K and Fe during first cultivated season of 2017/2018 (Table 6). In the second cultivated season, Imperial star cultivar recorded higher contents of N, while, Romanesco recorded higher contents of Mn during the second cultivated season of 2018/2019 (Table 6). There was no significant variation between Imperial star and Romanesco cultivars concerning their contents of P and Mn during the first cultivated season of 2017/2018 and P, K, Ca, Fe, and Zn during the second cultivated season of 2018/2019 (Table 6).

#### **Effect of GA<sub>3</sub> and melatonin applications**

GA<sub>3</sub> and melatonin treatments increased the contents of both macronutrients: N, K, and Ca and micronutrients:

Fe, Mn, and Zn in representative samples from edible parts (receptacles) of secondary artichoke heads compared with control treatment during the two cultivated seasons (Table 6), whereas melatonin treatment resulted in higher content of K and Ca, while, GA<sub>3</sub>foliar application resulted in higher contents of N and Fe in the first cultivated season of 2017/2018 (Table 6), whereas in the second season of 2018/2019, the higher contents of K, Fe, Mn, and Zn were related to melatonin treatment (Table 6). On the other hand, the lower contents of N, K, Ca, and Fe during the first cultivated season of 2017/2018 and K, Fe, Mn, and Zn were related to untreated control during the second season of 2018/2019 (Table 6). However, the variations among all foliar application

**Table 6** Effect of GA<sub>3</sub> and melatonin on head chemical composition of two artichoke cultivars during the two growing seasons of 2017/2018 and 2018/2019

Treatments	N (%)	P (%)	K (%)	Ca (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)	
First season (2017/2018)								
Cultivars								
Imperial Star (IS)	3.48 a	0.13 a	2.22 b	0.55 a	51 b	20 a	29 a	
Romanesco (R)	2.70 b	0.11 a	2.47 a	0.54 b	54 a	21 a	27 b	
Foliar application								
Melatonin	3.12 a	0.12 a	2.48 a	0.59 a	52ab	21 a	29 a	
GA <sub>3</sub>	3.13 a	0.13 a	2.34ab	0.55ab	55 a	22 a	28 a	
Control	3.02 b	0.12 a	2.22 b	0.51 b	50 b	19 a	27 a	
Interactions								
IS	Melatonin	3.44 a	0.14 a	2.29 a	0.54bc	50 a	22 a	32 a
	GA <sub>3</sub>	3.53 a	0.13 a	2.18 a	0.58 b	52 a	20 a	28 a
	Control	3.46 a	0.11 a	2.19 a	0.54bc	49 a	18 a	26 a
R	Melatonin	2.80 b	0.09 a	2.67 a	0.64 a	54 a	19 a	26 a
	GA <sub>3</sub>	2.73bc	0.12 a	2.49 a	0.51 c	58 a	24 a	28 a
	Control	2.58 c	0.12 a	2.25 a	0.48 c	50 a	21 a	27 a
Second season (2018/2019)								
Cultivars								
Imperial Star (IS)	3.23 a	0.14 a	2.88 a	0.56 a	49 a	16 b	25 a	
Romanesco (R)	2.58 b	0.13 a	2.81 a	0.57 a	44 a	20 a	26 a	
Foliar application								
Melatonin	2.99 a	0.14 a	2.96 a	0.59 a	50 a	21 a	30 a	
GA <sub>3</sub>	2.88 a	0.13 a	2.82ab	0.58 a	48 a	19 a	25 b	
Control	2.83 a	0.13 a	2.75 b	0.53 a	42 b	15 b	23 b	
Interactions								
IS	Melatonin	3.35 a	0.15 a	2.93 a	0.58 a	49 a	19 a	26 a
	GA <sub>3</sub>	3.10 a	0.13 a	2.87 a	0.59 a	53 a	16 a	26 a
	Control	3.23 a	0.13 a	2.83 a	0.52 a	45 a	13 a	22 a
R	Melatonin	2.63b	0.14 a	3.00 a	0.60 a	51 a	22 a	34 a
	GA <sub>3</sub>	2.66b	0.14 a	2.77 a	0.58 a	42 a	22 a	23 a
	Control	2.43b	0.13 a	2.67 a	0.54 a	38 a	17 a	23 a

Means within each column within main effects and interactions followed by the same letter are not significantly different at  $P < 5\%$

treatments on the contents of P, Mn and Zn during the first season of 2017/2018 and the contents of N, P and Ca during the second season of 2018/2019 were not enough to be significant (Table 6).

#### Effect of the interactions

Imperial Star cultivar contained more N when foliar sprayed with GA<sub>3</sub> during the first season of 2017/2018, and foliar sprayed with Melatonin during the second season of 2018/2019 (Table 6), while Romanesco cultivar contained more Ca when foliar sprayed with Melatonin during the first season of 2017/2018 (Table 6). On the other hand, the lowest contents of N and Ca were related to Romanesco cultivar without any foliar

application during the two cultivated seasons of 2017/2018 and 2018/2019 (Table 6). However, the variations among all interaction treatments were not enough to be significant concerning their effects on P, K, Fe, Mn, and Zn during the first cultivated season of 2017/2018 and P, K, Ca, Fe, Mn, and Zn during the second cultivated season of 2018/2019 (Table 6).

#### Discussion

The current study showed more differences between the investigated cultivars: Imperial Star and Romanesco on vegetative growth characters, head yield, physical head quality, and chemical contents of artichoke plants. It could be concluded that seed-grown cultivars (Imperial



Star and Romanesco) are promising cultivars in Egypt. Imperial Star ranked the first, followed by Romanesco concerning their productivity. This is true during the two cultivated seasons of 2017/2018 and 2018/2019. These results could be attributed to the genetic differences between current investigated cultivars: Imperial Star and Romanesco. The actual performance of any cultivar depends on its genetic parameters interacted with all surrounded environmental conditions. This result is in agreement with that observed by Saleh et al. (2007) and Saleh et al. (2017). In this concern, Abd-El-Salam (1996) mentioned that Balady cultivar was less, compared with Imperial Star cultivars. Also, Saleh et al. (2017) recorded high differences among four seed-propagated cultivars: Green Globe, Imperial Star, Violetto, and Balady. Leskovar et al. (2013) mentioned that the marketable yield of Imperial Star cultivar was similar to Green Globe Improved. However, many previous studies revealed more variations among artichoke cultivars (Baixauli et al. 2012; Salata et al. 2012; Garcia et al. 2016; Leskovar and Othman 2016; Macua and Lahoz 2016; Saleh et al. 2017).

Our current investigation reported that both foliar application treatments of GA<sub>3</sub> and melatonin enhanced the vegetative growth and increased the earliness and head yield as well as improved head quality and chemical contents compared with untreated control during the two cultivated seasons of 2017/2018 and 2018/2019. GA<sub>3</sub> foliar application ranked the first to increase growth and productivity, followed by melatonin treatment. Therefore, high productivity could be achieved by using suitable cultivation management. Abd El-Hameid et al. (2008) reported that GA<sub>3</sub> treatment is a common practice to achieve artichoke earliness. It is well known that GA<sub>3</sub> is used as a plant regulator to stimulate both cell division and cell elongation that positively affect the vegetative growth characters. It affects many mechanisms of plant growth including stem elongation by stimulating cell division and elongation, flowering, fruit development, and breaking dormancy (Neil and Reece 2002). The beneficial effect of GA<sub>3</sub> on plant vegetative growth resulted in more accumulation of dry matter which is possibly the main reason for bud yield increases and improvement of bud traits. Various investigators studied GA<sub>3</sub> on Globe artichokes, but their results are variable based on the application time and concentration, etc. (Mauromicale et al. 2005; Baixauli et al. 2012; Salata et al. 2013; El-Zohiri 2015; Garcia et al. 2016; Macua and Lahoz 2016; Saleh et al. 2017). Melatonin is inexpensive and safe for animals and humans. Its application as a bio-stimulator could be a good, feasible, and cost-effective method useful in agriculture. Among many functions that melatonin performs in plants, its role as an antioxidant and a growth

promoter is most supported by experimental evidence. This compound is an independent PGR, and it may mediate the activities of other PGRs. Due to its antioxidant properties, melatonin can stabilize the cell redox status and protect tissues against reactive oxygen, which accumulated under stressful environment. It is believed that melatonin can increase the food quality (the aspect of functional food) and may improve the human health. Melatonin effectively lowered chlorophyll degradation in aging leaves of barley (Arnao and Hernandez-Ruiz 2009) and detached leaves of apple protecting the photosystems from damage (Wang et al. 2012). Zhang et al. 2014 provided new evidence suggesting that melatonin alleviated the inhibitory effects of Na Cl stress on germination mainly by regulating the biosynthesis and catabolism of ABA and GA<sub>4</sub>, and promoted seed germination of cucumber under high salinity. This indole amine also increased photosynthetic efficiency of chlorophyll in plants (Tan et al. 2012). Exogenously applied melatonin affects the developmental processes during both vegetative and reproductive growth. Abd El-Naby et al. (2019) recorded positive effect for foliar application of melatonin to Apricot trees, whereas, melatonin improved vegetative growth, yield, and fruit quality of Apricot. This compound has similar chemical structure as auxin; thus, it seems that melatonin may play a similar role in plants as this hormone.

## Conclusion

It could be concluded that the use of GA<sub>3</sub> and melatonin was favorable for the production of both artichoke cultivars: Imperial Star and Romanesco. The highest productivity was achieved by foliar application of GA<sub>3</sub> to Imperial Star cultivar. Therefore, high productivity could be achieved by using suitable cultivar and cultivation management such as foliar application treatments of GA<sub>3</sub> and melatonin.

## Abbreviations

DAT: Days after transplanting; GA<sub>3</sub>: Gibberellin; IS: Imperial Star; R: Romanesco

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## Authors' contributions

This work is a combined effort of all of the authors. SS conceptualized and designed the experiment. SS and ME performed the experiment and collected the sample; RK contributed to prepare the samples for analysis and supported the lab work; Said Saleh analyzed the data and wrote the paper; SAE-N followed of treatment and germination of seeds in greenhouse and contributed to write chemical analyses methods and revised it. All authors read and approved the final manuscript.

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#### Availability of data and materials

The datasets generated and/or analyzed during the current study are included in this published study.

#### Ethics approval and consent to participate

Not applicable.

#### Consent for publication

Not applicable.

#### Competing interests

The authors declare that they have no competing interests.

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