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Improvement Yield and Quality of Dahlia Flowers by Exogenous Application of Gibberellic Acid and Salicylic Acid under *Sandy soil* Conditions

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ABSTRACT

Dahlia is one of the popular cut flowers in the world which characterized by the rich variety and attractive flower colors. Hence, in a field study 100, 200, 300mgL^{-1} gibberellic acid (GA_3) and salicylic acid (SA) were used during two successive seasons 2015 and 2016 to determine the possible role of each growth regulator in improving marketable quality, increasing yield and vase life of dahlia. Results indicated that the tallest plants (118.43cm) were those sprayed with GA_3 at 200mgL^{-1}. Additionally, it showed that foliar application of GA_3 or SA at 200mgL^{-1} significantly increased the number of branches plant^{-1}, fresh and dry weight plant^{-1}, leaf numbers, leaf area plant^{-1}, flower numbers, flower quality and vase life as well as tuber length, and numbers plant^{-1}. The most rapid flowering (39.57 days after planting) occurred when plants were sprayed with GA_3 at 200mgL^{1}. Concomitant to the enhancement in the vegetable and flowering attributes, an increscent in the anthocyanin content and total soluble solids was observed in the petals by increasing GA_3 and SA concentrations up to 200mgL^{-1}. Additionally, a significant increment in the total chlorophyll content was recorded with GA_3 and SA treatments. In conclusion, the vegetative and flowering characters of dahlia could be improved by application of either GA_3 or SA.

Keywords: Dahlia, yield, quality, anthocyanin, stomata density, vase life.

INTRODUCTION

A high demand for cut flowers because of increased social activities started the necessity for industrial flower production. Dahlia (*Dahlia variabilis L.*) is a tuberous rooted perennial half-hardy herbaceous and appreciated flowering bulbs belonging to the family Asteraceae and having 42 species with over one thousand distinct cultivars all over the world (Kamenetsky and Hiroshi, 2012). It has become one of the most imperative and widespread cut flowers gaining importance day by day due to its multitude and attractive colors (Ohno *et al*., 2011), great variation in sizes and flower types availability, the profusion of flowering and easy cultivation (Singh *et al*., 2018). Yield and quality improvement are essential aims of florists production. Low quality of flowers is a serious problem in Egypt compared to other countries. To meet the demand of high-value cut flower crop of dahlia, it is necessary to enhance the production both in quantitative and qualitative aspects.

The color of the flower is an attractive trait, but the underlying mechanism of its appearance is unclear. In addition, it is a central trait of ornamental plants and is determined by plant pigments (Tanaka *et al*., 2008 and Wu *et al*., 2017). Strong colored petals are valuable in the floricultural market compared to pale colored because they often attract consumer attention. The formation of the flower color is complex progress that regulated by lots of genes. Anthocyanins are frequently accumulated in the vacuole and its storage is critical to give the feature colors of the flowers (Ohlsson and Berglund, 2001). Additionally, as reported in previous studies, the flower color intensity of dahlia cultivars (pink, purple, orange, and red) is explained to be attributed to a high accumulation of total anthocyanin (Ohno *et al*., 2013 and Deguchi *et al*., 2016).

On the other hand, the shelf life of cut flowers has critical importance in determining the value of the flowering plant (Mansouri, 2012). Many consumers consider dahlia to have a short vase life (5–7 days), this may be a major reason for curtailed the expansion of demand. The short vase life of cut flowers is related to physio-chemical processes that affect senescence (Ataii *et al*., 2015). It was reported that anthocyanin levels had a significantly greater antioxidant potential (Neill *et al*., 2002). Thus, anthocyanins increment is correlated with flower vase life through the protection of cell membrane from the effects of oxidative damage and delay plant tissue's senescence (Taheri-Shiva *et al*., 2014). It is clear from the mentioned above that increasing of the anthocyanin content may have several benefits for the flowering crops.

Positive impact on the biosynthesis of anthocyanin has been established for plant hormones, such as gibberellins (Goraj *et al*., 2014). Gibberellins (GA_3) have been found to enhance a number of desirable factors including anthocyanin contents; Ohlsson and Berglund (2001) reported that application of GA_3 increased anthocyanin content in *Catharanthus roseus*. On the other hand, salicylic acid (SA) is a natural phenolic compound presented in many plants and has been found to generate a wide range of metabolic and physiological responses in plants thereby affecting their growth and development (Hayat *et al*., 2010). The role of SA in plant growth has been little studied compared with other plant hormones (Vicente and Plasencia 2011).

However, the work done on dahlia is meager. Although the cultivation of dahlia can be an important choice for the ornamental plant marketing in Egypt, it is one of the most poorly understood and studied flowers. Therefore, considering the commercial importance of this high-value plant and problem associated with this plant, to determine the optimum concentration of GA_3 and SA for improving yield, quality, flower color, vase life, getting maximum vegetative and flowering growth, the present experiment was carried out.

MATERIALS AND METHODS

A field experiment was carried out at the Experimental Farm of Faculty of Agriculture, Ismailia Governorate, Egypt, during two successive seasons 2015/2016 and 2016/2017 on a sandy soil (Table 1) to study the effect of foliar application of three concentrations of GA_3 and SA as 100, 200 and 300 mgL^{-1} on some vegetative characters, chlorophyll, vase life, flower quality and some biochemical constituents of dahlia plants.

In both seasons, a foliar spray (pH 5.8) was applied thrice, after 30 days from planting and repeated two times with 2 weeks intervals at early morning. Solutions were sprayed until runoff. The untreated control plants were sprayed with water, 0.01% Tween-20 was also added to all treatments as a surfactant.

Dahlia tubers were cultivated in the field on the 21st October in both seasons on ridges with P × P and R × R spacing of 20 and 60 cm respectively. All the cultural practices were same for all treatments.

The experimental design was a completely randomized block design with three replications and 7 treatments, each replicate comprised of 20 plants. Five plants were selected randomly from each treatment for recording observations.

Table 1. Particle size distribution and chemical analysis of the experimental soil

Parameters	Unit	Values	Parameters	Unit	Values
A. Particle size distribution			**B. Chemical analysis**		
Coarse sand	%	81.0	Organic matter	%	0.39
Fine sand	%	15.3	Total nitrogen	%	0.25
Silt	%	0.9	Total phosphorus	%	.008
Clay	%	2.8	Total potassium	%	0.03
Texture class		Sandy			

Data recorded:

Vegetative attributes:

The plant growth characters that were measured were: plant height, stem diameter, number of branches/plant, internode length, plant spread, plant fresh and dry weight, number of leaves plant^{-1} and average of leaf area.

Flowering attributes:

The number of days to flower emergence was recorded from the time of planting to the emergence of floral buds on the plants. Flower diameter was measured when the flowers were fully opened, length of inflorescence stalk, stalk diameter, flower fresh weight, number of flowers plant^{-1} were recorded.

Vase life: the flowers were harvested when the outer wreath of petals has separated from the rest of the flower (Figure 1); flowers were placed in glass vases having 200 ml of distilled water. After every two days, vase water was replaced with fresh distilled water, and lower 1.5 cm of the stems were removed with a sharp shear to get rid of physiological plugging of the stems. Ten randomly selected flowers per treatment were used for vase life evaluation (in a day). Flowers were considered dead when more than 50% of petals started wilting and became discolored. The laboratory room was illuminated at 950 Lux at flower level by white fluorescent lamps.

Fig. 1. The stage at which buds were harvested.

Flower quality was determined on a rating scale from 1 to 9. Scale 9 was used for highest quality, and uniform flowers, while, for medium average of quality of flowers scale 5 was used, and scale 1 were used for weak and poor quality flowers.

Leaf stomata density (mm^2)

Leaf samples were gathered from plants when they reached the 4–5 true-leaf stage. Briefly, according to Xu and Zhou (2008), the lower epidermis of the leaf was cleaned using a cotton ball, and then carefully smeared with nail varnish. After it dried, the nail polish impression was peeled off from the leaf surface using a strip of scotch tape. The tape was then mounted on a microscope slide and observed under light microscope. (Nikon Eclipse 50i; Nikon Corp.). Twenty stomata had been measured for each leaf. To determine the stomata density, stomata in 10 microscopic fields had been counted for each plant. Stomata sizes and density/ (mm^2) were recorded at 100× magnification.

Membrane stability index (MSI):

MSI was calculated on the basis of the electrolyte leakage of petals. Electrolyte leakage was measured in three randomly selected flowers from each. The electrolyte was measured according to Huan *et al.* (2017). The membrane stability index was expressed as percent value according to the formula given below.

$$\text{Membrane stability index (\%)} = \left(\frac{EC1}{EC2} x\ 100\right)$$

Tubers attribute: The number of tubers for each plant and tuber length was recorded.

Chemical attributes:

Determination of total anthocyanin content (mg.100 g^{-1} of petals)**:**

Anthocyanin content in the fresh petals was determined colorimetrically according to Ranganna (1997). Fresh samples of petals (0.5 gm) were blended with 10 ml of ethanol-hydrochloric acid in a blender. The mixture stored overnight at 4°c and then filtered through a filter paper (Whatman No.1). The combined extract was completed to 10 ml; a small quantity of this extract was taken for the colorimetric determination using UV/Vis 2100 Spectrophotometer at the wavelength of 535 nm. Ethyl (95% v/v) acidic with hydrochloric acid (1%) was used as a blank.

Total absorbance per 100 g of petals was calculated as follows:

$$\frac{\text{Absorbance at 535nm} \times \text{volume made for color measurment} \times \text{Total voulme} \times 100}{\text{ml of the extract used} \times \text{Wt of sample taken}}$$

Total anthocyanin content in mg 100g^{-1} petals=

$$\frac{\text{Total absorbance of the sample}}{98.2}$$

Total chlorophyll was determined in leaves by a portable SPAD-502 meter (Minolta, Osaka, Japan).

Total soluble solids (TSS): A small piece of the petal in each treatment was squeezed then a drop of the obtained extract was used to measure refractive index by a hand refractometer (Atago N1, Japan) according to AOAC (1996) and expressed as %. This trait was measured on 3rd days of postharvest life.

Statistical Analysis:

The collected data for both growing seasons were analyzed according to Fisher's analysis of variance (ANOVA) technique and treatments means were compared using Duncan's new multiple range test at $p \leq 0.05$.

RESULTS

Vegetative attributes

Data presented in Tables 2 and 3 show that foliar application of GA_3 or SA at 100, 200 and 300mgL^{-1} substantially promoted all vegetative growth.

In all cases, during both seasons the increments in growth parameters were often highly significant in comparison with control plants. The most effective treatments on vegetative growth parameters were the foliar application of GA_3 or SA at 200mgL^{-1} followed by GA_3 at 100mgL^{-1} and 300mgL^{-1}. The maximum plant height (118.43cm) was achieved when plants treated with GA_3 at 200 mgL^{-1}, followed by (97.42 cm) when plants treated with GA_3 at 100 mgL^{-1}, while minimum height (63.86 cm) was observed in control plants. Significant differences were observed among those treated with GA_3, SA and untreated plant. Increasing GA_3 and SA doses from 100mgL^{-1} to 200mgL^{-1} increased the plant height; in contrast, increasing doses from 200 to 300 mgL^{-1} decreased plant height.

As shown in Table (2) data indicated that GA_3 or SA had pronounced effect on the number of branches in dahlia. Maximum number of the branches plant^{-1} (18.14) was found with 200mgL^{-1} GA_3, followed by those plants that were treated with GA_3 at 100mgL^{-1} (15.57), while the minimum number of branches plant^{-1} (8.14) was found in the control plants. All doses of GA_3 and SA were succeeded in increasing number of branches plant^{-1} in the two seasons of this study.

The maximum stem diameter (15.90 mm) was observed in 200mgL−1 of SA followed by 200mgL^{-1} of GA_3 (14.11 mm) and 100mgL^{-1} of GA_3 (13.97 mm), while minimum stem diameter (9.65 mm) was observed in control plants.

Table 2. Plant height (cm), stem diameter (mm) and number of branches plant^{-1} of dahlia as influenced by application of GA_3 or SA during 2015-2016 /2016-2017 seasons.

Treatment	Plant height (cm)		Stem diameter (mm)		Number of branches plant^{-1}	
	Seasons		Seasons		Seasons	
	15/16	16/17	15/16	16/17	15/16	16/17
Control	63.86e	65.33e	9.65d	9.76d	8.14 d	7.33e
GA_3 100	97.42b	93.66b	13.97bc	14.03abc	15.57b	13.67bc
GA_3 200	118.43a	121.00a	14.11ab	15.08ab	18.14a	17.67a
GA_3 300	95.86b	94.00b	13.21bc	13.17abc	14.71b	15.33b
SA100	76.07d	79.33d	12.26bc	12.56bcd	11.43c	12.00c
SA200	85.29c	84.66c	15.90a	15.65a	12.43c	11.67cd
SA300	52.28f	55.33f	12.17c	11.80cd	10.43c	9.67d

Mean values within columns followed by different letters are significantly different according to Duncan's new multiple range test ($p \leq 0.05$)

As illustrated in Fig. 2 average length of internode of dahlia had a significant effect ($p \leq 0.05$) due to different concentrations of GA_3 and SA. The most promising results of internode length (12.86 cm), obtained with GA_3 at 200mgL^{-1}, followed by 100mgL^{-1} (11.71 cm), while the minimum length was recorded (6.64 cm) in control plants.

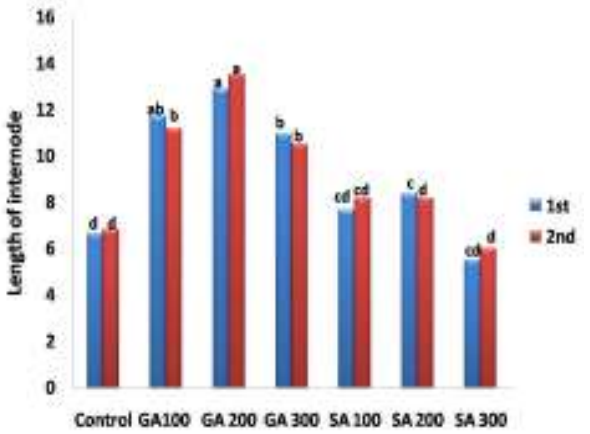

Fig. 2. Effect of gibberellic acid and salicylic acid concentrations on the average length of internode of dahlia

Plant spread: Maximum plant spread (45.14cm) was observed in plants treated with SA at 200mgL^{-1} followed by treating with GA_3 at 200mgL^{-1} (41.71cm), while the minimum plant spread (29.71cm) was observed in untreated plants.

Plant fresh weight: Plant fresh weight exhibited significant differences among the different treatments by GA_3 and SA (Table 3). The heaviest fresh and dry weight of herbs plant^{-1} was in plants treated with GA_3 at 200mgL^{-1}, followed by the treatment of SA at 200mgL^{-1} in the two seasons. Meanwhile, the treatment of GA_3 at 100mgL^{-1} ranked the third order in this respect.

Plant dry weight: The total dry weight accumulation plant^{-1} significantly differed among various treatments during both seasons (Table 3). Maximum dry weight (35.04g plant^{-1}) was recorded by spraying of GA_3 at 200mgL^{-1} which was on par with SA at 200mgL^{-1} (18.24 g plant^{-1}), while the minimum total dry weight plant^{-1} was recorded by control plots (9.42g plant^{-1}).

Number of leaves plant^{-1}: There was a substantial difference in the number of leaves in dahlia as affected by various concentrations of GA_3 and SA. Higher number of leaves (109.43) was recorded in plants treated with GA_3 at 200mgL^{-1}, while it was less (56.85) in untreated plants. Profound difference was recorded among control, GA_3 and SA. Plants treated with GA_3 at 100 mgL^{-1} and 200mgL^{-1} showed no significant difference with each other (Table 3).

Leaf area (cm^2): As shown in Table (3) a considerable difference among the different treatments of GA_3 and SA. Broader area (15.05cm^2) was recorded when plants were treated with SA at 200mgL^{-1}, while it was smaller (10.08 cm^2) in untreated plants.

Table. 3. Plant spread, plant fresh weight, plant dry weight, number of leaves and leaf area of dahlia as influenced by application of GA_3 and SA during 2015-2016 /2016-2017 seasons.

Treatment	Plant spread (cm) Seasons		Plant fresh weight (g) Seasons		Plant dry weight (g) Seasons		Number of leaves Seasons		Leaf area (cm^2) Seasons	
	15/16	16/17	15/16	16/17	15/16	16/17	15/16	16/17	15/16	16/17
Control	29.71c	30.00d	61.20g	58.20f	9.42e	9.67e	56.85e	58.33f	9.93e	10.08e
GA_3 100	40.43ab	46.33a	93.64c	92.53bc	13.91cd	12.77cd	102.29a	105.33b	11.93c	12.22c
GA_3 200	41.71ab	40.33ab	163.09a	165.00a	35.04a	33.23a	109.43a	114.67a	12.17bc	13.06b
GA_3 300	39.28b	40.00b	80.22e	79.80de	12.66d	11.85de	80.57c	79.33d	11.74c	11.44d
SA100	40.57ab	37.60bc	86.33d	87.03cd	14.59c	14.66c	73.43cd	75.67de	12.59b	11.68cd
SA200	45.14a	41.67ab	102.31b	100.56b	18.24b	17.94b	89.71b	92.00c	15.05a	15.01a
SA300	30.00c	32.00cd	72.46f	73.66e	13.34cd	13.70cd	70.26d	72.66e	10.52d	11.00d

Mean values within columns followed by different letters are significantly different according to Duncan's new multiple range test ($p \leq 0.05$)

Thereby, it could be concluded that all these treatments were succeeded in increasing all the studied vegetative growth parameters in the two seasons of this study. However, 200mgL^{-1} GA_3 treated plants showed to be the most effective treatment for inducing the tallest plants, the highest significant increase of the number of branches plant^{-1}, and the heaviest fresh and dry weights of herbs plant^{-1}, followed by the treatment of GA_3 at 100mgL^{-1} in the two seasons. Meanwhile, the treatment of SA at 200mgL^{-1} ranked the third order in this respect.

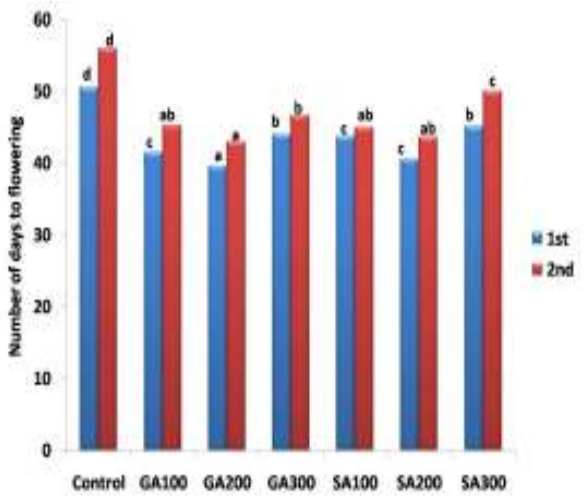

Fig. 3. Effect of GA_3 and SA concentrations on number of days to flowering of dahlia

Flowering attributes:

Data presented in Tables 4 and 5 shows that all tested concentration of GA_3 and SA improved all the studied parameters in both seasons.

Number of days to flowering:

Results in fig. 3 indicate that pre-harvest foliar application of GA_3 or SA significantly ($p \leq 0.05$) decreased days to the emergence of flowers in all treatments. Plants treated with GA_3 at 200mgL^{-1} were emerged in substantially less number of days and earlier the flower by 7.57 and 11 days in the first and second seasons, respectively, as compared to the control.

Flower diameter:

The flower diameter was remarkably affected by the different concentrations of GA_3 and SA (Table 5). The bigger size (13.01cm) was recorded with the foliar application of SA at 200mgL^{-1} followed by (11.11 cm) which obtained by treatment with GA_3 at 200mgL^{-1}. The smaller size was recorded in the untreated plants (7.91 cm).

Table. 4. Flower diameter (cm), stalk length (cm), stalk diameter (mm) and flower fresh weight (g) of dahlia as influenced by application of GA_3 and SA during 2015-2016 /2016-2017 seasons.

Treatment	Flower diameter (cm) Seasons		Stalk length (cm) Seasons		Stalk diameter (mm) Seasons		Flower fresh weight (g) Seasons	
	15/16	16/17	15/16	16/17	15/16	16/17	15/16	16/17
Control	7.91e	8.03e	8.57e	8.20d	2.25d	2.20c	7.07c	7.36c
GA_3 100	9.04d	9.57cd	17.71a	18.00a	3.55b	3.67a	9.38b	9.56b
GA_3 200	11.11b	11.6b	19.00a	19.00a	4.08a	3.95a	12.16a	13.00a
GA_3 300	9.24cd	9.23d	13.00c	13.33b	3.53b	3.62a	8.94b	9.23b
SA100	10.14bc	10.10c	11.67cd	11.9bc	3.37b	3.48ab	9.53b	9.23b
SA200	13.01a	13.30a	15.43b	14.00b	3.94a	4.06a	13.27a	13.66a
SA300	9.64cd	9.16d	10.64d	10.00cd	3.04c	2.82bc	9.41b	9.20b

Mean values within columns followed by different letters are significantly different according to Duncan's new multiple range test ($p \leq 0.05$)

Stalk length:

Flower stalk height is one of the most important qualitative factors, which was influenced by GA_3 and SA. Stalk length of flowers has been increased by applying all concentrations of GA_3 and SA treatments compared to control. The least and highest flower stem length were obtained by using GA_3 at 200mgL^{-1} (19.00cm) and 100 mgL^{-1} (17.71cm), respectively. The stalk length was (8.57 cm) in control plants (Table 4).

Flower fresh weight:

Fresh weight of flowers has been increased by applying all concentrations of GA_3 and SA treatments compared to control (Table 4). A significant increase in the flower fresh weight is mainly happening due to promoting the effect of GA_3 and SA on vegetative growth. The higher fresh weight (13.27g) was recorded when plants sprayed with SA at 200mgL^{-1}, while it was less (7.07g) in control plants.

Number of flowers plant^{-1}:

The data in Fig. 4 indicate that GA_3 and SA have significant effect on the number of cut flowers plant^{-1} ($p \leq 0.05$). The highest flower number was obtained at 200mgL^{-1} of GA_3 concentrations with 17.86 cut flowers plant^{-1} followed by (14.57) 100mgL^{-1} of GA_3 as compared to control which produced fewer flowers. Also, treatments with different doses of SA produced more flowers compared to the control plants.

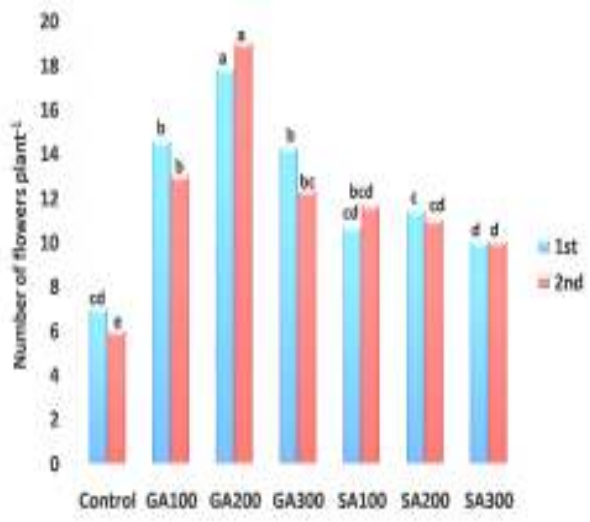

Fig. 4. Effect of GA_3 and SA concentrations on number of flowers plant^{-1} of dahlia

Vase life:

According to the results shown in fig. 5, foliar application of GA_3 or SA resulted in a greater extension of vase life compare to control. The most effective treatment for enhancing flower vase life is SA at 200mgL^{-1} followed by GA_3 at 200mgL^{-1} compare to the other treatments.

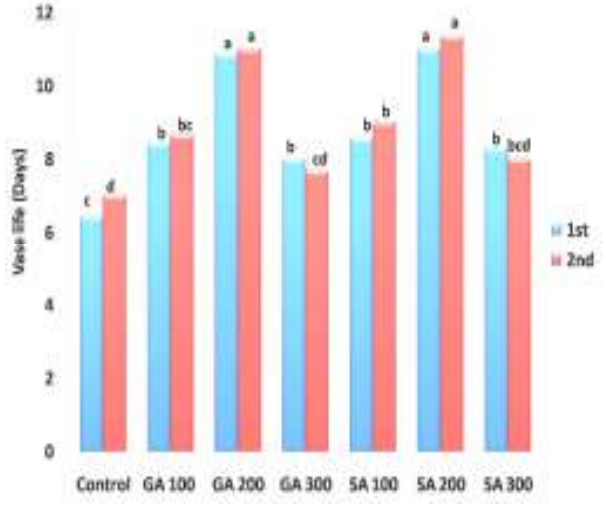

Fig. 5. Effect of GA_3 and SA concentrations on vase life of dahlia

Data presented in Table (5) show that foliar spray of GA_3 or SA significantly increased the flower quality more than control plants. These treatments were at par with each other. The maximum flower quality rank (7.57) was observed when the plants were sprayed with SA at 200mgL^{-1}.

Leaf stomata density:

one way ANOVA revealed that stomata density strongly affected by growth regulators application. The application of GA_3 or SA at concentrations of 100, 200 and 300 mgL^{-1} altered the stomata length, width and density of the leaf. Although, stomata numbers were significantly fewer than in the control treatment (Fig. 6), but the stomata length and width were significantly bigger than in the control treatment (Fig. 7, data not presented).

Membrane stability index for all treated plants significantly increased compared to control plants. Treatments of plants with GA_3 at 200mgL^{-1} followed by SA at 200mgL^{-1} have significantly increased the membrane stability index rate compared to the control (Table 5).

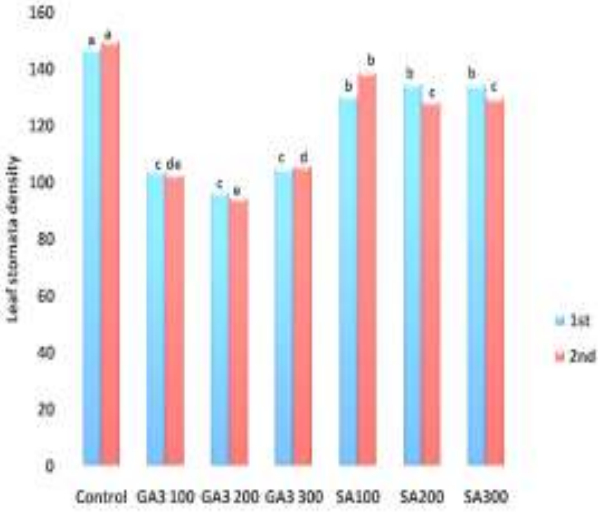

Fig. 6. Effect of GA_3 and SA concentrations on leaf stomata density (stomata mm^{-2}) of dahlia

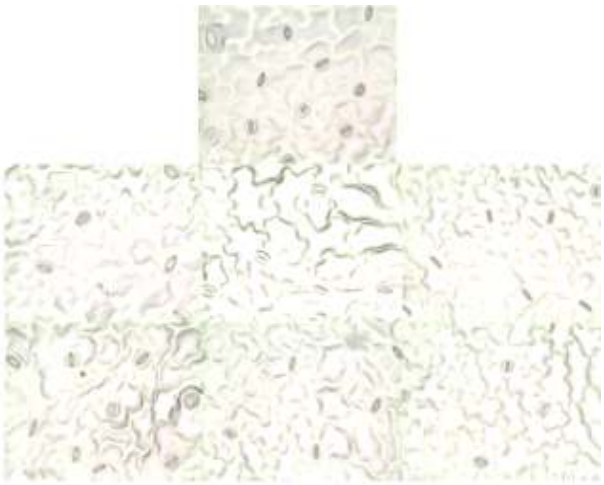

Fig. 7. Stomata density in lower epidermis in leaves of dahlia: A. Control plants, B. Plants treated with GA_3 at 100 mgL^{-1}, C. Plants treated with GA_3 at 200 mgL^{-1}, D. Plants treated with GA_3 at 300 mgL^{-1}, E. Plants treated with SA at 100 mgL^{-1}, F. Plants treated with SA at 200 mgL^{-1} and G. Plants treated with SA at 300 mgL^{-1}. (400x).

It is evident from the data presented in Table (5) that foliar spray of different concentrations of GA_3, and SA had significantly affected the tubers characteristics of dahlia plants. The results show that the highest tuber length (18 cm) was obtained using GA_3 at 200mgL^{-1}, followed by SA at 200mgL^{-1}, while the differences between them were not significant.

Number of tubers:

The effect of GA_3 and SA concentrations on number of tubers was significant ($P \leq 0.05$). The results show that the highest number of tubers (10.14) was obtained using GA_3 at 200mgL^{-1}, followed by SA at 200mgL^{-1}.

Table 5. Flower quality, electron leakage, tuber length and number of tubers plant^{-1} of dahlia as influenced by application of GA_3 and SA during 2015-2016 /2016-2017 seasons.

Treatment	Flower quality Seasons		Membrane stability index Seasons		Tuber length Seasons		Number of tubers plant^{-1} Seasons	
	15/16	16/17	15/16	16/17	15/16	16/17	15/16	16/17
Control	4.28c	4.50c	74.27d	73.30c	10.85d	9.33d	3.71e	4.00d
GA_3 100	5.64b	5.83b	78.31bc	79.33ab	15.29bc	13.66bc	7.00c	6.66c
GA_3 200	6.93a	7.16a	82.11a	83.73a	18.00a	17.66a	10.14a	11.00a
GA_3 300	5.57b	5.66b	77.47c	76.66bc	14.57bc	14.66abc	6.14cd	6.66c
SA100	5.86b	5.50b	79.7abc	80.00ab	14.28c	13.33c	6 .00cd	6.33c
SA200	7.57a	7.66a	80.88ab	82.16a	16.57ab	17.33ab	8.28b	8.66b
SA300	5.78b	6.00b	76.74cd	76.16bc	13.86c	14.00abc	5.71d	6.33c

Mean values within columns followed by different letters are significantly different according to Duncan's new multiple range test ($p \leq 0.05$)

Chemical attributes:

Data presented in Table (6) show that chlorophyll content in the leaves of dahlia plants. Generally, foliar application of either GA_3 or SA at any concentration significantly increased the chlorophyll content more than controls. Foliar spray of dahlia plants at all GA_3 and SA concentrations (100,200 and 300mgL^{-1}) tested significantly increased photosynthetic pigments compared to untreated plants. The most effective concentration was 200mgL^{-1} of either GA_3 or SA, whereas, the lowest chlorophyll content was found in control plants.

Results in table (6) show that the anthocyanin content of petals increased in all treatments. Treatment with GA_3 at 200mgL^{-1} followed SA at 200mgL^{-1} showed maximum increases in the anthocyanin content compared to control plants.

Table 6. Total chlorophyll, anthocyanin content (mg 100g^{-1}) and TSS of dahlia as influenced by application of GA_3 and SA during 2015-2016 /2016-2017 seasons.

Treatment	Total chlorophyll (SPAD) Seasons		Anthocyanin mg 100g^{-1} Seasons		TSS Seasons	
	15/16	16/17	15/16	16/17	15/16	16/17
Control	38.71e	40.00e	59.86d	62.30e	2.33e	2.50e
$GA_3$100	45.54d	46.33cd	74.83c	69.45de	3.41d	3.36d
$GA_3$200	53.23a	52.36a	94.58a	97.27a	5.20a	5.16a
$GA_3$300	45.28d	44.80d	77.88bc	79.83bcd	3.84c	4.00c
SA100	49.79b	50.03b	84.85ab	89.73abc	3.91c	4.03c
SA200	51.67a	52.46a	86.56ab	91.49ab	4.40b	4.53b
SA300	47.67c	48.4bc	74.18c	76.51cde	3.80c	3.66cd

Mean values within columns followed by different letters are significantly different according to Duncan's new multiple range test ($p \leq 0.05$)

Soluble solid content in all treated plants increased and this incensement was shown in all treatment at rates significantly more than the control during both seasons (Table 6). Spraying of GA_3 at 200mgL^{-1} recorded the highest total soluble solids (5.20) which was significantly superior to other treatments whereas; a minimum of 2.33 total soluble solids was recorded by untreated control plants.

Regardless the control plants, the lowest means values of all abovementioned parameters by dahlia were registered by spray the plant with GA_3 and SA at 300mgL^{-1} in the first and the second season in most parameters.

DISCUSSION

With the aim of Improving yield and quality of dahlia flowers, we investigated the pre and postharvest characteristics of the plant and flower and the effectiveness of GA_3 and SA treatments. The results show that GA_3 and SA greatly promoted the vegetative growth and flowering production of dahlia by enhancing cell division and chlorophyll accumulation (Jahanbazi, 2014 and Mohamed, 2017). Foliar application of GA_3 might have encouraged the stem elongation by stimulating cell division and elongation led to enhance the vegetative growth (Paroussi *et al.,* 2002 and Al-Khassawaneh *et al*., 2006). Moreover, the number of branches per plant was also higher with the application of GA_3 which helped to initiate more leaves which resulted in more photosynthesis to initiate early flowering and complete life cycle of the plant. Increase in of GA_3 concentration from 100mgL^{-1} to 200mgL^{-1} improved plant height as evident from the data recorded presented in Table (2). These results correspond with findings of Sajid *et al*. (2016) who observed an increase in plant height with the increase in GA_3 concentrations in *Chrysanthemum morifolium*. Schmidt *et al*., (2003) found 16.78% increase in plant height when applied GA_3 at 300 mgL^{-1} on chrysanthemum. The same trend was recorded by Kumar *et al*. (2012) in carnation and by Padaganur *et al.* (2005) in tuberose.

On the other hand, the effect of exogenous application of SA on plant growth relies upon the plant species and SA concentrations. It has been reported that the growth-promoting effects of SA could be attributed to changes in the hormonal status (Abreu and Munne´-Bosch, 2009) or by improvement of photosynthesis and the rate of gas exchange (Stevens *et al*., 2006 and Koppad *et al*., 2017). As presented above increasing SA concentration to 300mgL^{-1} negatively affected the plant height. These results support earlier findings of Kova *et al*. (2009) and Ibrahim *et al*. (2017); they reported that a lower concentration of SA improves the growth of leaf and roots of chamomile plants, however higher concentrations have the opposite effect.

The data on dry matter accumulation of the plant at maturity clearly showed that maximum values were recorded at 200mgL^{-1} of GA and SA. Untreated plants were not able to accumulate more dry matter into plants when compared to the treatments with GA_3 and SA as observed by the results on flower numbers plant^{-1}. This showed that the greater improvement in the photosynthetic ability and its partitioning into flowers coupled with

enhancement of plant height and leaf area became the motives for better productivity in case of treatments with GA and SA. As provided above, there has been an increase in the flower numbers plant^{-1} by the foliar application of GA_3 and SA when compared to control. There was no addition within the flower numbers of dahlia by increasing the concentration of GA_3 beyond 200 mgL^{-1}. Dorajeerao *et al.* (2012) attributed the increase in flower number plant^{-1} to the application of GA_3 to the increase in plant height and number of branches plant^{-1} compared to untreated plants. These findings are also in agreement with the ones of Sajid (2016) in chrysanthemum, Dabas *et al*. (2001) in marigold and Krishnamoorthy and Madalagery (2000) who recorded increasing in the branch numbers of in Ajovan.

Increasing the number of flowers by GA_3 and SA application might be due to increase in the number of leaves as well as leaf area as compared to control, which might have enhanced the production and accumulation of increased photosynthesis that became diverted to the sink and produced more flowers (Sharifuzzaman *et al*., 2011). Kumar *et al*. (2012) recorded a substantial increase in the number of flowers when carnation plants were treated with GA_3 at 150 mgL^{-1}.

The number of days required for flowering is a crucial parameter for flowering plants; application with GA_3 accelerated flower bud development of *Ajania pacifica* (Zalewska and Antkowiak, 2013). Two suggested opinions for the early flowering of plants treated by GA_3 and SA, first, might be due to decreasing the concentration of ABA in shoots (Phengphachanh *et al*., 2012). Second, the vital role of the stated growth regulators in the production and regulation of floral stimulus. Many authors agreed with our findings that GA caused early flowering such as Jaleel *et al*. (2007) on *Catharanthus roseus* and Gomathinayagam *et al*. (2009) on *Andrographis paniculata*.

GA_3 and SA treatment of dahlia plants led to an increase in the flower size. The increase in the flower size is probably attributed to the increase in the number of leaves and leaf area that produced more photosynthesis which in turn might have increased the flower size. Furthermore, it might results from the production of additional petals (data not presented) as reported by Kumar *et al*. (2012); they stated that increasing flower size might be attributed to the formation of secondary growth center. On the other hand, application of different concentrations of GA_3 and SA increased the flower fresh weight of dahlia. The increase in fresh flower weight might be due to an increase in leaf area and the number of leaves that resulted in the production of greater photosynthesis which diverted to flowers to increase fresh weight. On the other hand, regarding flower stalk, Al-Khassawaneh *et al*. (2006) reported that GA_3 treatment was led to increasing flower stalk length in Iris. Additionally, it was reported to increase flower diameter in Zantedeschia (Janowska, 2013). In the current study, the impact of GA_3 and SA on flower stalk length was dependent on its concentration. Interestingly, our results show that decreases the number of stomata in the leaf of the studied plant produced the best quality of cut flowers. A similar tendency was shown by Schroeder and Stimart, 2005 in *Antirrhinum majus*.

Various studies have demonstrated that membrane stability index, which is a measure of comparative electrolyte leakage through the tissue, varies little with the first stage of postharvest cut flowers, but thereafter decreases rapidly with the cut flower age, reducing its lowest value when the flower senesces (Ezhilmanthi *et al*., 2007; Singh *et al*., 2008). Foliar spray of different concentrations of GA_3 and SA improved membrane stability index that led to increasing flower vase life. Comparable consequences on the membrane stability index have been reported in *Gerbera jamesonii* (Danaee *et al*., 2011), gladiolus with GA_3 (Singh *et al*., 2008) and in gladiolus with salicylic acid (Ezhilmanthi *et al*., 2007).

Chlorophyll content of dahlia leaves was substantially enhanced through the application of GA_3 or SA, which would possibly delay chlorophyll destruction or increase their biosynthesis or stabilize the thylakoid membrane. Growth regulators may also retard flower senescence by improving the stability of membranes via protecting chloroplasts from senescing and therefore slow down chlorophyll loss (Amin *et al*., 2011).

Flower coloration is an important quality determinant that not only impacts the ornamental benefit of a plant but also directly affects its commercial value (Zhao and Tao 2015). Preceding studies have proven that the improvement of flower color is associated with petal tissue structure, pigment distribution, and its types; it may be regulated via genetic engineering and environmental factors. The color of flowers is related to the internal or surface tissue structure of a petal and the type and amount of pigments in the petal cells, but pigment plays a prime function. He *et al.,* (2011) analyzed the pigments of red, yellow, purple, orange, and white *Lycorislongituba* and found that only one of the four identified anthocyanins was present in all purple and red colors. Anthocyanins are colored flavonoid compounds which are accumulative inside the vacuoles of epidermal cells on the petal. These compounds ranging from red to purple in flowers of various plant species result in the appearance of splendid coloration patterns (Zhao and Tao, 2015). Our results show that dahlia plants treated with different concentrations of GA_3 and SA have anthocyanin content in petals more than of the control plants. Raifa *et al.* (2005) also showed that spraying *Hibiscus sabdariffa* plants with GA_3 at 200mgL^{-1} enhances Anthocyanin content of flowers due to increase in phenylalanine ammonia-lyase activity.

The results show that GA_3 and SA can increase the vase life of dahlia flowers. The expression of the flower senescence-enhanced genes is encouraged by oxidative stress, and SA plays an essential role in regulating of such genes expression during senescence (Kazemi *et al*., 2017). Based on our results, GA_3 and SA might extend vase life through improving MSI and anthocyanin content. MSI and anthocyanin content was higher (p<0.05) in petals of plants that were sprayed with different concentrations of GA_3 or SA compared to those untreated plants. Also, it might be extended because of the low number of stomata as reported by Schroeder and Stimart, 2005. As presented above, after the application of GA_3 and SA, stomata in the lower leaf epidermis were bigger than in the control treatment, while their number declined (Pogroszewska, 2002).

CONCLUSION

The present study was an attempt to investigate the potential roles of GA_3 and SA in improving yield and quality of dahlia flowers. Foliar application of GA_3 or SA at 200mgL^{-1} was able to increase all vegetative, flowering and tuber characteristics and this could be a good and economical way for enhancing flower's visual, marketable quality and improving vase life. Additionally, for getting compact plants bearing bigger leaves and high-quality flowers to be sued as pot plants, it is recommended to spray dahlia plants with SA at 200 mgL^{-1}. Meanwhile, to produce plants with taller shoots useful for getting more flowers with high quality, GA_3 at 200 mgL^{-1} is recommended. Economically, SA which is a natural, plant-derived and inexpensive compound has the potential to enhance vegetative, flowering and vase life of dahlia flowers, and because of the higher cost of GA_3 compared to SA. Therefore, foliar application of SA at 200 mgL^{-1} followed by GA_3 at 200 mgL^{-1} is recommended.

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تحسين إنتاجية وجودة أزهار الداليا عن طريق الرش بحمض الجبريليك وحمض الساليسيليك تحت ظروف الأراضي الرملية

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الداليا هي واحدة من أشهر أزهار القطف في العالم والتي تتميز بمجموعة متنوعة وألوان جذابة من الأزهار. في دراسة ميدانية ، تم استخدام تركيزات ١٠٠ و ٢٠٠ و ٣٠٠ مل جم/لتر من حمضي الجبريلين (GA_3) و الساليسيليك (SA) لدراسة تأثيركل منهم على زيادة الإنتاجية وجودة وعمر الأزهار بعد القطف في نباتات الداليا خلال موسمين متتاليين ٢٠١٥/٢٠١٦. وأشارت النتائج إلى أن أطول النباتات (١١٨.٤٣ سم) تم الحصول عليها عند الرش بالجبريلين 200 مل جم/لتر. وأظهرت النتائج أن الرش الورقي بالجبريلين أو الساليسيليك عند تركيز ٢٠٠ مل جم/لتر أعطي زيادة ملحوظة في ارتفاع النبات وعدد الأفرع لكل نبات والوزن الطازج والجاف للنبات وعدد الأوراق والمساحة الورقية للنبات وكذلك عدد الزهرة وجودة الزهرة وعمر الأزهار بعد القطف و أيضاً طول وعدد الدرنات لكل نبات. تكوين الأزهار كان أسرع (٣٩.٥٧ يوم بعد الزراعة) عند رش النباتات بالجبريلين 200 مل جم/لتر. وبالإضافة للزيادة في النمو الخضري والزهري ، لوحظ أيضاً زيادة في محتوى الأنثوسيانين والمواد الصلبة الذائبة في بتلات الأزهار بزيادة تركيز الجبريلين و الساليسيليك حتى ٢٠٠ مل جم/لتر. بالإضافة إلى ذلك، تم تسجيل زيادة في محتوى الكلوروفيل الكلي في الجبريلين و الساليسيليك. ونستخلص مما سبق انه يمكن تحسين الصفات الخضرية والزهرية من الداليا من خلال الرش ب الجبريلين أو الساليسيليك.