

## Effects of Silicon Levels and Application Methods on Growth and Quality Characteristics of *Narcissus tazetta* L.

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### ABSTRACT

Two pot experiments were carried out during the two successive Winter seasons of 2015/2016 and 2016/2017. The experiments were executed in a private commercial nursery located at Damanhour City, El-Beheira Governorate, Egypt under greenhouse conditions. The objective of this research was to evaluate the effect of silicon (Potassium silicate; Si) as a spray, or a soil drench at concentrations of 0, 5 and 7.5 mmol in enhancing *Narcissus tazetta* L. growth, flower production, and quality. The experiment was conducted as a split-plot in a randomized complete block design (RCBD). The obtained results of the two seasons, generally, showed that application of silicon as soil drench at 7.5 mmol recorded the highest mean values of the most data recorded and might be considered as optimal treatment for the production of high yield and quality of narcissus plants under the environmental conditions of Beheira Governorate and other similar regions.

**Keywords:** Potassium silicate, silicon, Narcissus.

### INTRODUCTION

Narcissus, is the most important early-season blooming flowering plant, belongs to the Amaryllidaceae family that includes about 63 species classified into 12 divisions (Hanks, 1993; Dole and Wilkins, 2005). *N. tazetta* is native to the Mediterranean region of Europe and has been acclimatized throughout Europe (Hanks, 2002; Santos-Gally *et al.*, 2011). It's a valuable plant for cosmetics, cut flowers, and landscape plants (Benschop *et al.*, 2010; Hanks, 2002; Steininger, 2010; Sochacki and Orlikowska, 2005). *N. tazetta* flowers have a pleasant and very strong scent, so it is highly valued in the fragrance industry (Van Dort *et al.*, 1993; Chen *et al.*, 2013).

The growth and flower quality of narcissus could be improved by adopting proper cultural practices, application of plant nutrients such as silicon (Si), which plays a vital role in the quality of flowers. In this concern, Khenizy and Ibrahim (2015) mentioned that Si is one of the most important nutrients influencing growth and yield in gladiolus by increasing shoot and flower growth parameters. Also, Si is a growth promoter of various higher plant species (Epstein, 1999 and Zhao *et al.*, 2013). It stimulates growth either indirectly by the accumulation of the Si in the epidermal tissue of the plant, which provides defense against insect and fungal attacks and alleviates biotic and abiotic stresses, or directly by originating both morphological changes and physiological processes in plants.

Silicon is not yet classified as an essential nutrient for most plants (Epstein 1994 and 1999). It is considered the second most abundant element in the earth's crust next to oxygen, with soils containing approximately 32% by weight (Lindsay, 1979;

Wedepohl, 1995; Liang *et al.*, 2006). Several studies suggested that silicon has several beneficial effects on different aspects of the plant growth such as stimulation of photosynthesis, reduction of transpiration, crop quality, enhancement of plant resistance to abiotic and biotic stresses and postharvest quality parameters (Epstein, 1994; Hodson and Sangster, 1999; Liang *et al.*, 2001; ; Seebold *et al.*, 2001; Ma and Takahashi, 2002 and Zhou *et al.*, 2002).

Mechanistically, Si is absorbed by plants in silicic acid form where it is transported to the shoot in concentrations ranging from 0.1 to 0.6 mmol in the soil (Epstein, 1994). After the loss of water, it is polymerized as silica gel on stems surface and leaves surface and blade, which keep the leaf erect, thereby improving light-capturing by leaves and stimulating canopy photosynthesis (Ma and Takahashi, 2002).

Also, the concentrations range of silicon in different plants from 0.1% (similar to P and S) to more than 10% of whole plant dry matter (Epstein, 1999, Kamenidou *et al.*, 2009). One of the most important facts is that silicon in the soil helps plants survive in the bad conditions like water shortage and drought by decreasing transpiration in cells with higher silicon concentration (Gao *et al.*, 2006). All of these may influence plant development, for example, shoot growth, flowering quality and longevity and fruit production. (Jana and Jeong, 2014; Wróblewska and Dębicz, 2011). Therefore, the objectives of the current study were to a) evaluate silicon (as Potassium Silicate) as an enhancer of *Narcissus tazetta* crop and flower quality and b) compare the best application method as a spray or drench.

## MATERIALS AND METHODS

Two pot experiments were carried out during the two successive winter growing seasons of 2015/2016 and 2016/2017. The experiments were executed in a private commercial nursery located at Damanhour City, in Beheira Governorate, Egypt under greenhouse conditions. Uniform bulbs of paperwhite *Narcissustazetta* cv. "Ziva" 13-15 cm circumference, were obtained from Orman Botanical Garden, Giza, Egypt. This variety was chosen because of its fame. It usually has three to twenty flowers on a stout stem with perianth segments spreading not reflexed and flowers. Bulbs were grown on 20 October of both seasons in 25 cm black plastic pots filled with sandy soil. Soil samples were collected and physical and chemically analyzed according to the published procedures of Black *et al.* (1965).

**Table 1: Physical and chemical analyses of soil samples of the experiment.**

Physical analysis	Firstseason	Secondseason
Clay (%)	0.77	0.72
Silt (%)	7	8.03
Sand (%)	92.23	91.25
<b>Texture class</b>	<b>sand</b>	<b>sand</b>
<b>Chemical analysis</b>		
EC(dS/m)	0.8	0.87
pH	7.9	7.8
Ca (meq/L)	20.1	20.52
Mg ( meq/L)	6.23	6.98
SO <sub>4</sub> ( meq/L)	8.21	7.98
K ( meq/L)	5.23	5.35

After 60 days of planting, bulbs were treated with silicon (potassium silicate) concentrations as a foliar spray or soil drench at the rates of 0, 5, and 7.5 mmol. Bulbs were divided into two equal groups. the first group was specified for the foliar spray and the second one was specified for soil drench treatments.

Silicon aqueous solutions were applied as foliar spray and soil drench 4 times at the concentrations of 0 (tap water) 5 and 7.5 mmol. The two application methods (spray or soil drench) were firstly applied after 67 days from planting. The second, third and fourth applications were after 74, 81 and 88 days of planting, respectively. For the foliar spray, the pot surface was covered with polyethylene before application to avoid falling of spray drips on the growing medium. All concentrations were applied using a hand sprayer and non-ionic surfactant tween 80 at 0.05% (v/v) was added to all treatments to reduce the surface tension and increase the contact angle of sprayed droplets. Each plant was sprayed individually, so that, all foliage was moistened until the point of run-off. The spraying volume was 15 ml. per plant. Considering the soil drench, no watering was

applied for two days before the application. The drench volume was 450 ml per pot. Two days after chemical application, plants didn't receive any irrigation.

All plants were fertilized with the same rates of N, P and K fertilization. All other cultural practices were adapted whenever they were necessary and as commonly recommended in the commercial production of narcissus. Irrigation was done as needed. A week after last treatment the following characteristics were recorded:

### **Vegetative growth characters**

Three random plants were chosen and the vegetative growth traits namely; number of leaves per plant, leaf length, leaf area (cm<sup>2</sup>) according to Zidan (1962), leaves fresh weight (g), leaves dry weight per plant (g) were measured without the inflorescences and bulbs at the end of the experiment for all plants. Dry weight measurements were done by drying the plant samples in the oven at 70 °C for 72 hours to a constant weight then left to cool inside the oven and weighed in grams. In all cases, the weight measurements were performed using a digital scale with a precision of 0.001 digits.

### **Bulbs characters**

Bulb size (cm<sup>3</sup>) according to a modified method of AOAC Official Method (2000). Exactly, bulbs were poured into a 500 ml beaker with 300 ml of water without immersing the bulbs. The vertical levels of water in the beaker were reported before and after the addition of bulbs. Then the difference was used to calculate the volume of bulbs in cm<sup>3</sup>. The size measurements were repeated 5 times. Also, bulbs fresh weight/plant (g), and bulbs dry weight/plant (g) were measured. Dry weight measurements were done as described in the previous section.

### **Flowering growth characters**

Flowering date (expressed as the mean number of days from planting to first open flower for each plant in each treatment per replicate), number of flowers per inflorescence, flower diameter (cm), flowering duration (day), longevity of flower (number of days from the buds opening to the wilt of flowers), flower fresh weight (g; all fully opened flowers per plant at the beginning of fading stage were used), flower dry weight (g), scape length (cm), scape fresh weight (g) and scape dry weight (g).

### **Chemical analyses**

**Chlorophyll a, b and total carotenoid contents (µg/mL)** were measured spectrophotometrically according to (Lichtenthaler and Buschmann, 2001).

**Silicon content in leaves, bulbs, and flowers (µg/g)** was measured according to a modified extraction procedure described by Novozamsky *et al.* (1984). For silicon analysis a spectrophotometric method for determining gross silicon amounts from either tissue

or aqueous solution. Adapted from (Elliott and Snyder, 1991; Taber *et al.*, 2002).

#### Statistical Analysis

The experiments were conducted as a split plots system in a randomized complete blocks design (RCBD) with three replications (Snedecor and Cochran, 1967). The application methods (spray or soil drench) were arranged as the main plots, and the silicon concentrations were considered as sub-plots. Each treatment consisted of three pots. Data were analyzed by Statistical Analysis Systems (CoStat, 2008) and the means were compared by Tukey multiple comparison *post-hoc* test at 0.05 probability.

## RESULTS AND DISCUSSIONS

### Vegetative growth characters:

The data showing the main effects of the two studied factors (“spray and soil drench” and different levels of silicon) and their interactions on vegetative growth of narcissus plants during the two growing seasons of 2015/2016 and 2016/2017 were presented in Table(2).

Regarding the main effect of application methods “spray and soil drench” on vegetative growth parameters, data in Table (2) indicated that soil drench showed significant difference and higher mean values of leaf length, leaf area and leaves fresh weight in both seasons and numbers of leaves per plant in the second season than that of spray method. However, there was no significant difference between the two application methods in leaves dry weight in both seasons and numbers of leaves per plant in the first season only.

Soil drench application gave better results than foliar spray one in most of the studied cases of vegetative growth of both seasons. This may be attributed to that after the absorption of the silicon element available in the soil solution, this element moves through the flow of water transpiration in the xylem to the aerial part and stabilize on the epidermal tissues as silica (Ma and Yamaji, 2006). The layer of silica that settled on the plant strengthens the plants cell wall, making the leaves more straight. Consequently, there is an increase in light interception, which causes an optimization of the photosynthetic apparatus (Tamai and Ma, 2008 and Isa *et al.*, 2010). Moreover, the beneficial effects of silicon may also be attributed to the amelioration in the water use efficiency and to the cell elongation, which, promoting the plant’s growth and consequently, the increase of biomass (Hossain *et al.*, 2002; Isa *et al.*, 2010).

The aforementioned results are in good accordance with those postulated by Ahmad *et al.* (2013), Gonzalez-Peres *et al.* (2014) and Khenizy and Ibrahim (2015) on gladiolus, Mirabbasi *et al.* (2013) on Asiatic lily plant and Zaky (2014) on calla lily.

Concerning the main effect of different rates of silicon on vegetative growth parameters, data in Table (2) indicated that, as silicon levels increased the given vegetative growth parameters i.e. leaf length, leaf area, leaves fresh weight and leaves dry weight increased significantly during both seasons compared to the control treatments. However, the difference between silicon at 5 mmol and control treatment was not affected in leaves dry weight in the first season only. Results, also, showed that there was no significant difference between the two silicon concentrations (5 and 7.5 mmol) in the numbers of leaves per plant and leaves fresh weight in both seasons. The highest values of leaf length, leaf area and leaves dry weight were obtained from silicon level at 7.5 mmol in both seasons. At 7.5 mmol silicon level, the estimated percentages increase in leaf length, leaf area, leaves fresh weight and leaves dry weight were (36.05 and 40.72 %), (61.24 and 58.42 %), (30.17 and 27.47 %), and (74.85 and 84.54 compared to the control treatment for the first and second season, respectively.

Generally, the superior influence of Si treatments on stimulating the vegetative growth parameters may be due to enhancing the uptake and transport of water and minerals in xylem sap, increasing antioxidant activity, the concentration of IAA hormone and improving the function of the photosynthetic apparatus and photo-assimilate translocation (Lu *et al.*, 2002; Le *et al.*, 2014 and Janmohammadi *et al.*, 2017), thus leading to augmentation of plant growth parameters. The increasing of leaf length and leaf area in treating plants with silicon suggest that in addition to benefits of Si in increasing cell turgor by keeping water, Si could be involved in cell wall metabolism improving the ability of the cell wall to expand and consequently enhancing cell enlargement (Romero-Aranda *et al.*, 2006). The increases in numbers of leaves per plant due to silicon may be attributed to its role in improving morphological, anatomical and physiological characteristics of leaves (Sivanesan and Park, 2014) and, it’s an important role in improving plant water status and adequate supply of nutrients (Romero-Aranda *et al.*, 2006) and its indirect effects such as increased capacity and efficiency of photosynthesis and transpiration (Korndörfer *et al.*, 2004 and Liang, 2003). Increasing the leaf length, leaf area and numbers of leaves per plant leads to increase in leaves fresh and dry weight

Results of leaf length seemed to agree with those reported by Ahmad *et al.* (2013), Gonzalez-Peres *et al.* (2014) and Khenizy and Ibrahim (2015) on gladiolus, Shanan and El Sadek (2017) on tuberose plants and Zaky (2014) on calla lily.

**Table 2: Effects of silicon concentrations (0, 5 and 7.5 mmol) and its application method (S = foliar spray, D = soil drench) on the vegetative characteristics of *N. tazetta* plants during both seasons.**

Treatments	Number of leaves per plant		leaf length (cm)		Leaf area (cm <sup>2</sup> )		LFW (g)		LDW (g)	
	1 <sup>st</sup>	2 <sup>nd</sup>	1 <sup>st</sup>	2 <sup>nd</sup>	1 <sup>st</sup>	2 <sup>nd</sup>	1 <sup>st</sup>	2 <sup>nd</sup>	1 <sup>st</sup>	2 <sup>nd</sup>
S	8.00A	8.67 B	19.56B	20.67B	22.33B	22.56 B	30.78 B	31.89 B	4.55 A	4.51 A
D	10.78A	10.33A	24.11A	23.56A	27.33A	27.33 A	36.22 A	34.78 A	4.48 A	4.32 A
0	7.17 B	7.00 B	18.50 C	18.00 C	18.50 C	18.83 C	28.17 B	28.50 B	3.38 B	3.17 C
5	10.67A	10.83A	21.83 B	23.00 B	26.17 B	26.17 B	35.67 A	35.17 A	4.25 B	4.22 B
7.5	10.33A	10.67A	25.17A	25.33A	29.83A	29.83 A	36.67 A	36.33 A	5.91 A	5.85 A
0	7.00 b	7.33 b	17.33 e	17.67 e	18.00 e	18.67 d	27.00 c	28.67 c	3.03 d	3.17 c
S	9.00b	9.33 ab	19.33 d	20.67 d	22.67 d	23.33 c	32.33bc	32.67 bc	4.10 c	4.11 bc
7.5	8.00 b	9.33 ab	22.00 c	23.67 c	26.33 c	25.67bc	33.00bc	34.33ab	6.51a	6.24 a
0	7.33 b	6.67 b	19.67 d	18.33 e	19.00 e	19.00 d	29.33 c	28.33 c	3.73 cd	3.17c
D	12.33a	12.33 a	24.33 b	25.33 b	29.67 b	29.00 b	39.00ab	37.67ab	4.40 c	4.33 bc
7.5	12.67a	12.00 a	28.33 a	27.00 a	33.33 a	34.00 a	40.33 a	38.33 a	5.31 b	5.46 ab

1<sup>st</sup> and 2<sup>nd</sup>, first season and second season. Means were compared using Tukey's Honest Significant Difference test ( $P \leq 0.05$ );  $n = 3$ ; Means with the same small letter show no significant interaction between different concentrations and application method of Si and means with the same capital letters are no significantly different between application methods.

Results of leaf area are in good accordance with those postulated by Helaly and El-Hoseiny (2017) on Banana and Khenizy and Ibrahim (2015) on gladiolus. Results of the numbers of leaves per plant are in harmony with those reported by Bazaraa (2018) on *Freesia refracta* cv. Red Lion and Shanan and El Sadek (2017) on tuberose. And the results of leaves fresh and dry weight are in good accordance with those postulated by Khenizy and Ibrahim (2015) on gladiolus and Shanan and El Sadek (2017) on tuberose.

The interaction effects between the application methods "spray or soil drench" and silicon levels on vegetative growth characters were significant in both seasons (Table 2). The combined treatment of soil drench and silicon at 7.5 mmol recorded the highest mean values for number of leaves per plant, leaf length, leaf area and leaf fresh weight in both seasons. On the other hand, the highest mean value of leaves dry weight was achieved when sprayed silicon at 7.5 mmol. The present results are in parallel with those reported by Khenizy and Ibrahim (2015) on gladiolus.

#### **Bulbs characters:**

In terms of the main effect of application methods "spray or soil drench" on bulb characters, data in Table (3) exhibited clearly that the application method of soil drench exposed significant difference and gave higher mean values of bulb size, number of bulbs per plant, in the first season and bulbs fresh weight in second season than the foliar spray. On the other hand, there was no significant difference between the two application methods on bulb size, number of bulbs per plant in the second season, bulbs fresh weight in the first

season and bulbs dry weight in both seasons. The present results are in agreement with those obtained by several authors; Ahmad *et al.* (2013), Gonzalez-Peres *et al.* (2014) and Khenizy and Ibrahim (2015) on gladiolus.

Regarding the main effect of different rates of silicon on bulbs parameters, data in Table (3) indicated that the application of silicon significantly enhanced bulb size, number of bulbs per plant, bulbs fresh weight and bulbs dry weight of *N. tazetta* plants compared to the control treatment in both seasons. Irrespective of bulb size at 7.5 mmol Si in the first season, there were no significant differences between the two concentrations 5 and 7.5 mmol of silicon in the other bulb characters in both seasons. The increasing of bulb size and number of bulbs per plant in treating plants with silicon may be attributed to the role of Si on promoting the synthesis of more assimilates stored in the new bulbs and make them relatively greater and heavier and the benefits of Si in increasing cell turgor by keeping water, Si could be involved in cell wall metabolism improving the ability of the cell wall to expand and consequently enhancing cell enlargement (Romero-Aranda *et al.*, 2006). The increasing of bulbs fresh and dry weight per plant may be due to the role of Si on promoting the synthesis of more assimilates stored in the new bulbs and make them relatively greater and heavier. On the same line, those results detected by Gonzalez-Peres *et al.*, (2014) and Khenizy and Ibrahim (2015) on gladiolus and Bazaraa (2018) on *Freesia refracta* cv. Red Lion.

**Table 3: Effects of silicon concentrations (0, 5 and 7.5 mmol) and its application method (S = foliar spray, D = soil drench) on the bulb characteristics of *N. tazetta* plants during both seasons.**

Treatments	Bulb size		Number of bulbs		Bulbs fresh weight		Bulbs dry weight	
	(cm <sup>3</sup> )		per plant		(g)		(g)	
	1 <sup>st</sup>	2 <sup>nd</sup>	1 <sup>st</sup>	2 <sup>nd</sup>	1 <sup>st</sup>	2 <sup>nd</sup>	1 <sup>st</sup>	2 <sup>nd</sup>
S	20.11 B	20.89 A	3.22 B	3.00 A	78.67 A	82.67 B	13.66 A	13.96 A
D	21.78 A	21.56 A	3.78 A	3.56 A	83.89 A	85.67 A	15.04 A	14.96 A
0	16.17 C	17.33 B	2.33 B	2.00 B	62.50 B	70.67 B	11.48 B	12.06 B
5	22.17 B	22.33 A	4.00 A	3.83 A	88.33 A	90.33 A	15.38 A	14.76 A
7.5	24.50 A	24.00 A	4.17 A	4.00 A	93.00 A	91.50 A	16.19 A	16.56 A
S	16.33 d	18.00 c	2.33 b	2.00 a	61.00 b	71.67 c	11.23 c	11.91 b
5	20.67 c	21.00 b	3.67 ab	3.33 a	86.67 a	88.33 b	14.01 b	14.28 ab
7.5	23.33 b	23.67 ab	3.67 ab	3.67 a	88.33 a	88.00 b	15.74 ab	15.70 ab
D	16.00 d	16.67 c	2.33 b	2.00 a	64.00 b	69.67 c	11.73 c	12.21 b
5	23.67 ab	23.67 ab	4.33 ab	4.33 a	90.00 a	92.33 ab	16.75 a	15.24 ab
7.5	25.67 a	24.33 a	4.67 a	4.33 a	97.67 a	95.00 a	16.64 a	17.42 a

1<sup>st</sup> and 2<sup>nd</sup>, first season and second season. Means were compared using Tukey's Honest Significant Difference test ( $P \leq 0.05$ ); n = 3; Means with the same small letter show no significant interaction between different concentrations and application method of Si and means with the same capital letters are no significantly different between application methods.

The effect of interaction between the application methods "spray or soil drench" and silicon levels on bulb characters were significant in both seasons (Table 3). The statistical analysis revealed that the highest mean values of bulb size, number of bulbs per plant, bulbs fresh weight and bulbs dry weight of *N. tazetta* were achieved when plants received 7.5 mmol silicon as soil drench in both seasons. At 7.5 mmol silicon level, the estimated percentages increase in bulb size, number of bulbs per plant, bulbs fresh weight and bulbs dry weight were (51.52 and 38.49%), (78.97 and 100%), (48.8 and 29.48 %), and (41.03 and 37.31) compared to the control treatment for the first and second season, respectively. The present results were in parallel with those reported by Ahmad *et al.* (2013), Gonzalez-Peres *et al.* (2014) and Khenizy and Ibrahim (2015) on gladiolus.

#### Flower characteristics:

Concerning the main effect of application methods "spray or soil drench" on flower parameters, the obtained results presented in Table (4) showed that the two application methods of silicon significantly affected flower characters. Spray application gave the longest flowering period in both seasons. However, the drench method gave the highest mean value of flower longevity, flower fresh weight, flower dry weight, scape length, scape fresh weight in both seasons and scape dry weight in the first season only. In addition, the two application methods increased the flowering duration, flower diameter and flowers number per inflorescens in both seasons compared to control while, scape dry weight was increased in the second season only. There were no significant differences between the application methods on flowering duration, flower diameter, flowers number per inflorescens, and

flower scape. Current findings were in agreement with the results of Bayat and Aminifard (2018) on *Narcissus tazetta* L. cv. 'Shahla'.

Pertaining the main effect of different rates of silicon on flowers parameters, data in Table (4) indicated that application of silicon significantly increased flowering duration, flower diameter, flower longevity, flowers number per inflorescens, flower fresh and dry weight, scape length, scape fresh weight, scape dry weight, while the number of days to flowering was decreased compared to control treatments in both seasons. Results, also, indicated that there were insignificant differences between the two silicon concentrations (5.0 and 7.5 mmol) with the exception of flower duration in both seasons and number of days to flowering and flower diameter in the second season only.

Improving the flower longevity and increasing number of the flowers per inflorescens by using Si could be explained through the role of Si in improving water balance and increasing chlorophyll content and more photosynthesis resulted in increasing carbohydrates content in stem and leaves which consequently increased the vase life (Ma and Takahashi, 2002) and flowers number. Moreover, silicon provides the plants with macro- and micronutrients necessary for best growth and high quality (Epstein, 1994).

The aforementioned results of flower longevity are similar to those of Carvalho *et al.*, (2013) on *Dendrobium nobile* orchid and Babalar *et al.*, (2016) on gerbera. And, the obtained data of number of the flowers per inflorescens were in agreement with those obtained by Khenizy and Ibrahim (2015) on gladiolus, Roohizadeh *et al.* (2015) on *Vicia faba* L., and Bazaraa (2018) on *Freesia refracta* cv. Red Lion.

**Table 4: Effects of silicon concentrations (0, 5 and 7.5 mmol) and its application method (S= foliar spray, D= soil drench) on the flower characteristics of *N. tazetta* plants during both seasons.**

Z	Flowering date	Flowering duration (days)		Flower diameter (cm)	Flower longevity (days)		Flowers number per inflorescence		Flower fresh weight (g)		Flower dry weight (g)		Scalpe length (cm)	Scalpe fresh weight (g)		Scalpe dry weight (g)				
		1 <sup>st</sup>	2 <sup>nd</sup>		1 <sup>st</sup>	2 <sup>nd</sup>	1 <sup>st</sup>	2 <sup>nd</sup>	1 <sup>st</sup>	2 <sup>nd</sup>	1 <sup>st</sup>	2 <sup>nd</sup>		1 <sup>st</sup>	2 <sup>nd</sup>	1 <sup>st</sup>	2 <sup>nd</sup>			
S	58.56 <sup>a</sup>	60.00 <sup>a</sup>	14.78 <sup>a</sup>	15.33 <sup>a</sup>	2.87 <sup>a</sup>	2.91 <sup>a</sup>	5.22 <sup>b</sup>	5.44 <sup>b</sup>	5.33 <sup>a</sup>	5.78 <sup>a</sup>	0.60 <sup>b</sup>	0.68 <sup>b</sup>	0.08 <sup>b</sup>	0.11 <sup>b</sup>	24.89 <sup>b</sup>	24.67 <sup>b</sup>	12.80 <sup>b</sup>	12.99 <sup>b</sup>	2.41 <sup>b</sup>	2.34 <sup>b</sup>
	56.67 <sup>b</sup>	58.78 <sup>b</sup>	16.11 <sup>a</sup>	15.89 <sup>b</sup>	2.91 <sup>a</sup>	3.02 <sup>a</sup>	6.56 <sup>b</sup>	6.00 <sup>b</sup>	6.11 <sup>a</sup>	6.11 <sup>a</sup>	0.89 <sup>a</sup>	0.82 <sup>a</sup>	0.21 <sup>a</sup>	0.20 <sup>a</sup>	27.11 <sup>a</sup>	27.78 <sup>a</sup>	16.40 <sup>a</sup>	16.05 <sup>a</sup>	2.52 <sup>a</sup>	2.46 <sup>a</sup>
D	61.33 <sup>a</sup>	62.83 <sup>a</sup>	12.83 <sup>c</sup>	13.17 <sup>c</sup>	2.33 <sup>b</sup>	2.45 <sup>c</sup>	4.17 <sup>b</sup>	4.17 <sup>b</sup>	4.17 <sup>b</sup>	4.17 <sup>c</sup>	0.57 <sup>b</sup>	0.55 <sup>b</sup>	0.03 <sup>b</sup>	0.08 <sup>b</sup>	23.5 <sup>c</sup>	23 <sup>c</sup>	11.60 <sup>c</sup>	11.52 <sup>c</sup>	1.88 <sup>c</sup>	1.76 <sup>c</sup>
	56.67 <sup>b</sup>	59.00 <sup>b</sup>	15.83 <sup>b</sup>	16.00 <sup>b</sup>	3.05 <sup>a</sup>	3.10 <sup>a</sup>	6.33 <sup>a</sup>	6.00 <sup>a</sup>	6.00 <sup>a</sup>	6.33 <sup>b</sup>	0.82 <sup>a</sup>	0.80 <sup>ab</sup>	0.16 <sup>ab</sup>	0.17 <sup>ab</sup>	26 <sup>b</sup>	26.33 <sup>b</sup>	14.01 <sup>b</sup>	15.04 <sup>b</sup>	2.25 <sup>b</sup>	2.28 <sup>b</sup>
5	54.83 <sup>b</sup>	56.33 <sup>c</sup>	17.67 <sup>a</sup>	17.67 <sup>a</sup>	3.28 <sup>a</sup>	3.35 <sup>a</sup>	7.17 <sup>a</sup>	7.00 <sup>a</sup>	7.00 <sup>a</sup>	7.33 <sup>a</sup>	0.58 <sup>b</sup>	0.23 <sup>a</sup>	0.22 <sup>b</sup>	28.5 <sup>a</sup>	29.33 <sup>a</sup>	17.3 <sup>a</sup>	16.998 <sup>a</sup>	3.26 <sup>a</sup>	3.2 <sup>a</sup>	
	61.33 <sup>a</sup>	63.00 <sup>a</sup>	12.67 <sup>a</sup>	13.33 <sup>cd</sup>	2.43 <sup>bc</sup>	2.47 <sup>b</sup>	4.00 <sup>a</sup>	4.33 <sup>a</sup>	4.00 <sup>b</sup>	4.33 <sup>a</sup>	0.53 <sup>d</sup>	0.57 <sup>c</sup>	0.04 <sup>b</sup>	0.08 <sup>ab</sup>	22.33 <sup>d</sup>	21.67 <sup>d</sup>	10.67 <sup>d</sup>	11.01 <sup>d</sup>	1.68 <sup>d</sup>	1.7 <sup>d</sup>
S	58.00 <sup>b</sup>	59.67 <sup>ab</sup>	15.00 <sup>a</sup>	15.67 <sup>bc</sup>	2.93 <sup>ab</sup>	3.00 <sup>ab</sup>	5.33 <sup>cd</sup>	5.33 <sup>bc</sup>	6.00 <sup>b</sup>	6.00 <sup>b</sup>	0.67 <sup>bcd</sup>	0.67 <sup>bc</sup>	0.09 <sup>b</sup>	0.08 <sup>ab</sup>	25.33 <sup>cd</sup>	25.33 <sup>cd</sup>	12.57 <sup>d</sup>	13 <sup>d</sup>	2.07 <sup>bc</sup>	2.11 <sup>bc</sup>
	56.33 <sup>b</sup>	57.33 <sup>bc</sup>	16.67 <sup>a</sup>	17.00 <sup>ab</sup>	3.23 <sup>a</sup>	3.27 <sup>a</sup>	6.33 <sup>bc</sup>	6.33 <sup>b</sup>	6.67 <sup>a</sup>	7.00 <sup>ab</sup>	0.87 <sup>abc</sup>	0.80 <sup>b</sup>	0.12 <sup>b</sup>	0.17 <sup>ab</sup>	27 <sup>b</sup>	27 <sup>b</sup>	15.17 <sup>e</sup>	14.97 <sup>e</sup>	3.47 <sup>a</sup>	3.20 <sup>a</sup>
D	61.33 <sup>a</sup>	62.67 <sup>a</sup>	13.00 <sup>a</sup>	13.00 <sup>a</sup>	2.23 <sup>c</sup>	2.43 <sup>b</sup>	4.33 <sup>bc</sup>	4.00 <sup>b</sup>	4.33 <sup>b</sup>	4.00 <sup>c</sup>	0.60 <sup>cd</sup>	0.53 <sup>c</sup>	0.06 <sup>b</sup>	0.07 <sup>b</sup>	24.67 <sup>c</sup>	24.33 <sup>c</sup>	12.53 <sup>d</sup>	12.03 <sup>d</sup>	2.07 <sup>bc</sup>	1.83 <sup>d</sup>
	53.33 <sup>bc</sup>	58.33 <sup>bc</sup>	16.67 <sup>b</sup>	16.33 <sup>ab</sup>	3.17 <sup>b</sup>	3.20 <sup>b</sup>	7.33 <sup>ab</sup>	6.33 <sup>b</sup>	6.67 <sup>a</sup>	6.67 <sup>a</sup>	0.97 <sup>ab</sup>	0.93 <sup>a</sup>	0.23 <sup>ab</sup>	0.27 <sup>a</sup>	26.67 <sup>bc</sup>	27.33 <sup>b</sup>	17.25 <sup>e</sup>	17.08 <sup>e</sup>	2.43 <sup>b</sup>	2.44 <sup>b</sup>
7.5	53.33 <sup>c</sup>	55.33 <sup>c</sup>	18.67 <sup>b</sup>	18.33 <sup>a</sup>	3.33 <sup>a</sup>	3.43 <sup>a</sup>	8.00 <sup>a</sup>	7.67 <sup>a</sup>	7.33 <sup>a</sup>	7.67 <sup>a</sup>	1.10 <sup>a</sup>	1.00 <sup>a</sup>	0.33 <sup>a</sup>	0.27 <sup>a</sup>	30 <sup>a</sup>	31.67 <sup>a</sup>	19.43 <sup>a</sup>	19.03 <sup>a</sup>	3.05 <sup>a</sup>	3.19 <sup>a</sup>

1<sup>st</sup> and 2<sup>nd</sup> First season and second season. Means were compared using Tukey's Honest Significant Difference test ( $P < 0.05$ ). n = 3. Means with the same small letter show no significant interaction between different concentrations and application method of S1 and means with the same capital letters are no significantly different between application methods.

The increase of flowering duration as a result of Si treatment might be due to the increase of number of flowers per plant and the increases of vase life of the flower on the plant. Results of the duration of flowering are in harmony with the findings of Carvalho *et al.* (2013) on *Dendrobium nobile* orchid and Roohizadeh *et al.* (2015) on *Vicia faba* L.

The increases of flower diameter and flower fresh and dry weight might be due to the role of silicon in reducing evapotranspiration (Lu and Cao, 2001; McAvoy and Bernard, 1996), which could have contributed to increase turgor pressure within the flower, resulting in cell swelling and thus larger flower diameters, which lead to increasing flower fresh and dry weight. Also, silicon encourages the photosynthetic apparatus by promoting the chlorophyll contents, as well as positively impact on the water balance (Rubinowska *et al.*, 2014), which altogether results in the increase of the photosynthetic activity of leaves which supplies flower structures with organic compounds (primarily carbohydrates) and thus larger flower size which lead to increasing flower fresh and dry weight. As primarily carbohydrates are being used to flower growth and/or production of floral reward.

The obtained results of flower diameter are in good accordance with those postulated by Zaky (2013) on rose cv. 'grand prix' and Aghajani and Jafarpour (2016) on gerbera. The results of flower fresh and dry weight per plant seemed to agree with those reported by Amin *et al.*, (2016) on maize and Bayat and Aminifard (2018) on *Narcissus tazetta* L. cv. 'Shahla'.

The increased scape length might be attributed to the benefits of Si in increasing cell turgor by keeping water. Additionally, Si was reported to be involved in cell wall metabolism through the improvement cell wall ability to expand and consequently enhance cell enlargement (Romero-Aranda *et al.*, 2006). Moreover, the beneficial effects of silicon might be attributed to the amelioration of water use efficiency and cell elongation, which promote the plant's growth and consequently, the increase of biomass (Hossain *et al.*, 2002; Isa *et al.*, 2010). The increase in scape fresh and dry weight might be due to the increased of scape length and the fresh and dry weight of flowers as a result of the silicon application. These results were supported by findings of Khenizy and Ibrahim (2015) and Carvalho-Zanão *et al.* (2017) on gladiolus, Shanan and El Sadek (2017) on tuberose, and Bazaraa (2018) on *Freesia refracta* cv. Red Lion.

The decreases in the number of days to flowering due to silicon might be to the role of silicon in the uptake, translocation, and availability of other nutrients like; nitrogen (N) which is an essential element that is increased in the presence of Si. Nitrogen metabolism is a major factor in stem

and leaf growth and too much can delay or prevent flowering. Pati *et al.*, (2016) found that higher concentrations of soluble Si enhanced the uptake and concentration of N. Others have noted that Si has the potential to raise available N and N-use efficiency in plants (Savant *et al.*, 1996 and Singh, 2005). The findings of the present investigation of number of days to flowering are in close conformity with Whitted-Haag *et al.*, (2014) on *Impatiens walleriana*, Helaly and El-Hoseiny (2017) on Banana (*Musa cavendishii* L.) and Shanan and El Sadek (2017) on tuberose.

The interaction effect between the application methods "spray or soil drench" and silicon levels on flower characteristics of *N. tazetta* plants were significant in both seasons (Table, 4). The combined treatment of soil drench and silicon at 7.5 mmol recorded the highest mean values for flowering duration, flower diameter, flower longevity, flower number per plant, flower fresh weight, flower dry weight, scape length, scape fresh and dry weight compared to the control in both seasons. On the other hand, the longest mean value of number of days to flowering was achieved of the control treatment. The estimated percentages increase in flowering duration, flower diameter, flower longevity, flowers number per plant, flower fresh weight, flower dry weight, scape length, scape fresh and dry weight were (37.72 and 34.17 %), (40.77 and 36.74 %), (71.94 and 67.87 %), (67.87 and 75.78%), (71.93 and 63.64 %), (360 and 175%), (21.28 and 27.52), (49.14 and 47.55%) and (73.40 and 81.82%) compared to the control treatment for the first and second season, respectively. The present results are in parallel with those reported by Ahmad *et al.* (2013), Gonzalez-Peres *et al.* (2014) and Khenizy and Ibrahim (2015) on gladiolus.

#### **Photosynthesis pigments:**

Regarding the main effect of application methods "spray or soil drench" on chlorophyll a, chlorophyll b and carotenoids, data in Table (5) that showed clearly that the differences between the two application methods were not significant.

Regarding the main effect of different rates of silicon on photosynthesis pigments content, data in Table (5) indicated that, as silicon levels increased the given photosynthesis pigments parameters i.e. chlorophyll a, chlorophyll b and carotenoids significantly increased in both seasons, while chlorophyll b and carotenoids in the first season were not affected compared to control treatment. Irrespective of chlorophyll a at 5 mmol Si in the second season, there were no significant differences between the two concentrations 5 and 7.5 mmol of silicon in the other photosynthesis pigments characters in both seasons.

**Table 5: Effects of silicon concentrations and its application method on photosynthesis pigments content in *N. tazetta* plants during both seasons.**

Treatments	Chlorophyll A ( $\mu\text{g/mL}$ )		Chlorophyll B ( $\mu\text{g/mL}$ )		Carotenoids ( $\mu\text{g/mL}$ )	
	1 <sup>st</sup>	2 <sup>nd</sup>	1 <sup>st</sup>	2 <sup>nd</sup>	1 <sup>st</sup>	2 <sup>nd</sup>
S	13.08 A	12.56 A	6.70 A	6.56 A	3.66 A	3.34 A
D	13.88 A	13.41 A	6.70 A	6.83 A	3.53 A	3.10 A
0	12.11 B	11.22 C	6.17 A	5.42 B	3.38 A	2.90 B
5	13.81 A	13.60 B	6.91 A	7.33 A	3.65 A	3.26 A
7.5	14.52 A	14.14 A	7.03 A	7.34 A	3.77 A	3.50 A
S	12.42 bc	11.43 bc	6.02 a	5.74 bc	3.23 a	2.86 a
5	13.11 bc	12.98 abc	7.06 a	7.03 ab	3.70 a	3.39 a
7.5	13.72 abc	13.26 abc	7.03 a	6.92 abc	4.05 a	3.78 a
D	11.79 c	11.01 c	6.32 a	5.09 c	3.53 a	2.95 a
5	14.51 ab	14.22 ab	6.76 a	7.64 ab	3.59 a	3.14 a
7.5	15.32 a	15.01 a	7.02a	7.76 a	3.48 a	3.22 a

1<sup>st</sup> and 2<sup>nd</sup>; first season and second season. Means were compared using Tukey's Honest Significant Difference test ( $P \leq 0.05$ );  $n = 3$ ; Means with the same small letter show no significant interaction between different concentrations and application method of Si and means with the same capital letters are no significantly different between application methods.

The increases of photosynthesis pigments content due to silicon might be to the role of silicon in reducing activities of chlorophyll-degrading enzymes (guaiacol peroxidase and ascorbate peroxidase) which, accompanied by increasing the chlorophyll production in Si treated plants as compared to the control (Gong *et al.*, 2005 and Soundararajan *et al.*, 2014). Also, it might be to the main role of Si in increasing the chlorophyll content arises from its conservation of the chloroplast ultrastructure which in turn improving biosynthetic of chlorophyll enzymes or decreasing of chlorophyll-degrading enzymes (Sharifi-Rad *et al.*, 2016).

These results seemed to agree with those reported by Soundararajan *et al.*, (2014) on *Salvia splendens* 'VistaRed' and 'Sizzler Red'.

The interaction effects between application methods and concentrations of silicon on photosynthesis pigments of *N. tazetta* plants are presented in Tables (5). The combined treatment of soil drench and silicon at 7.5 mmol recorded, generally, the highest mean values of chlorophyll a, chlorophyll b and carotenoids of *N. tazetta* leaves in both seasons.

These results seemed to agree with those reported by Khenizy and Ibrahim (2015) on Gladiolus and Shanan and El Sadek (2017) on tuberose.

#### **Silicon content in leaves, bulbs, and flowers ( $\mu\text{g/g D.W}$ ):**

Regarding the main effect of application methods "spray or soil drench" on silicon contents in leaves, bulbs and flowers, data in Table (6) displayed clearly that the application method of soil drench exposed significant difference and gave the highest mean values of silicon contents of bulbs and flowers, however, silicon content in leaves was not

affected in both seasons compared to spray method. The present results are in agreement with those obtained by several authors; Soundararajan *et al.*, (2014) on *Salvia splendens* 'VistaRed' and 'Sizzler Red', Jayawardana *et al.*, (2014) on Capsicum and Kamenidou *et al.*, (2008) on *Helianthus annuus*.

Relating to the main effect of different levels of silicon on silicon contents in leaves, bulbs and flowers data in Table (6) indicated that, as silicon levels increased the silicon contents in leaves, bulbs and flowers significantly increased in both seasons compared to control treatment. Results, also, showed that silicon level at 7.5 mmol recorded the highest mean values for the above-mentioned silicon characters in both seasons. This might be due to the increase in root growth and enhanced soil silicon availability with silicon application. This finding is in agreement with those reported by Kalyan *et al.* (2006) and Khalifa *et al.* (2016) also, this could be due to increased root activity and enhanced the soil nutrient availability in accordance with those reported by Wani *et al.* (2000). The obtained results seemed to agree with those reported by Jayawardana *et al.*, (2014) on Capsicum, Soundararajan *et al.*, (2014) on *Salvia splendens* and Babalar *et al.*, (2016) on *Gerbera jamesonii*.

The interaction effects between application methods and silicon concentrations in different plant parts are presented in Tables (6). The combined treatment of soil drench and 7.5 mmol recorded the highest mean values of silicon content in leaves, bulbs, and flowers in *N. tazetta* plant in both seasons. the estimated percentages increase in Silicon content in leaves, bulbs, and flowers were (45.51 and 49.64 %), (41.96 and 46.28 %), and (90 and 53.47%) compared to the control treatment and for the first and second season, respectively.

**Table 6: Effects of silicon concentrations (Si) and its application method on Si content in leaves, bulbs, and flowers in *N. tazetta* plants during both seasons.**

Treatments	Si content in leaves ( $\mu\text{g/g}$ )		Si content in bulbs ( $\mu\text{g/g}$ )		Si content in flowers ( $\mu\text{g/g}$ )	
	1 <sup>st</sup>	2 <sup>nd</sup>	1 <sup>st</sup>	2 <sup>nd</sup>	1 <sup>st</sup>	2 <sup>nd</sup>
	S	4939.89 A	4929.04 A	5522.64 B	5487.86 B	3575.21 B
D	4950.20 A	4991.44 A	6014.93 A	6032.01 A	4401.39 A	4363.36 A
0	4059.67 C	4064.50 C	4902.76 C	4875.75 C	2627.22 C	3359.24 C
5	4868.35 B	4734.13 B	5443.72 B	5272.03 B	4346.19 B	4184.64 B
7.5	5907.13 A	6082.09 A	6959.89 A	7132.03 A	4991.5 A	5155.25 A
0	4087.33 d	4090.00 c	4723.74 e	4693.84 e	1743.04 e	3229.56 e
S	4939.44 c	4642.25 b	5157.7 d	4812.33 e	3992.93 c	4003.81 c
7.5	5792.90 b	6054.86 a	6686.49 b	6957.4 b	4989.67 a	5074.8 a
0	4032.00 d	4039.00 c	5081.78 d	5057.66 d	3511.4 d	3488.94 d
D	4797.25 c	4826.02 b	5729.74 c	5731.73 c	4699.45 b	4365.48 b
7.5	6021.35 a	6109.31 a	7233.28 a	7306.65 a	4993.33 a	5235.69 a

1<sup>st</sup> and 2<sup>nd</sup>, first season and second season. Means were compared using Tukey's Honest Significant Difference test ( $P \leq 0.05$ );  $n = 3$ ; Means with the same small letter show no significant interaction between different concentrations and application method of Si and means with the same capital letters are no significantly different between application methods.

## CONCLUSIONS

Results of current study reported that most of shoot, root, bulbs, and flower characteristics were improved. Therefore, this study provided a piece of evidence about the possibility of using silicon, especially at 7.5 mmol) as soil drenche for enhancing growth, yield, and quality of *N. tazetta* plants.

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## الملخص العربي

تأثير استخدام مستويات مختلفة من عنصر السيلكون وطريقة التطبيق على معدلات النمو

وخصائص الجوده لنبات النرجس *Narcissus tazetta* L.

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اجريت الدراسة في اصص خلال موسمي الشتاء لعامي ٢٠١٥/٢٠١٦ و ٢٠١٦/٢٠١٧ داخل إحدى الصوب في مشتل خاص - محافظة البحيرة - جمهورية مصر العربية. وكان الهدف من البحث هو دراسته تأثيرات اضافة عنصر السيلكون (في صورة سيليكات البوتاسيوم) وطريقة التطبيق إما رشاً علي النباتات أو بالإضافة السائله للتربة (بتركيزات ٠، ٥، و ٧,٥ ملّي مول) وذلك لتحسين نمو نباتات النرجس وزياده إنتاجيه وتحسين جودة أزهارها. صممت الدراسة باستخدام تصميم القطاعات المنشقه داخل نظام القطاعات كامله العشوائية. وقد أظهرت النتائج المتحصل عليها خلال الموسمين بشكل عام أن تطبيق السيلكون على هيئه تبليل للتربة بتركيز ٧,٥ ملّي مول قد سجل أعلى قيم لمعظم الصفات تحت الدراسة. ويمكن اعتبار هذه المعامله بأنها المعامله المثلى لإعطاء أعلى إنتاجيه وأفضل جوده لنباتات النرجس وذلك تحت الظروف البيئيه لمحافظة البحيره أو المناطق الأخرى المماثله لها.