Effect of Potassium Fertilization on Growth, Flowering, Corms Production and Chemical Contents of *Gladiolus hybrida*, L. Cv. "Rose Supreme"

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ABSTRACT

A pot experiment was conducted on *Gladiolus hybrida* cv."Rose Supreme" throughout the two successive growing seasons 2014 and 2015 in Antoniades Botanical Gardens, Horticulture Research Institute, Alex., Egypt to study the effect of potassium sulphate (48%K_2O) foliar spray, applied at (1% and 2%) alone or combined with three percentages of the recommended (2g pot) soil amended potassium (50%, 75% and 100%), on growth, flowering quality and chemical constituents of gladiolus. Whereas, the control treatment was only, applying the complete percentage of the recommended soil amendment of potassium (100%). The results revealed that applying K foliar treatments significantly affected all the studied parameters compared to the control. The results indicated that applying 2% K foliar combined with 100% potassium soil dressing gave the highest significant values of plant height, number of leaves per plant, fresh and dry weight of leaves, number of florets per spike, floret diameter, spike length, fresh and dry weights of florets, new corm diameter, fresh weight and cormlets number per plant as well as leaf chlorophyll a and b contents and petals anthocyanins content. The results revealed that fertilizing the plants with 2% K foliar combined with 75% K as soil dressing advanced flowering dates by 4.47 days and 5.66 days than the control, for the first and second seasons, respectively. Also, it was also observed that applying 2% K foliar combined with 75% K as soil dressing had significant similar effects on floret diameter trait. The data also showed that, fertilizing the plants with 2% K foliar combined either with 100% or 75% K as soil dressing had similar effects on new corm diameter and fresh weight. Applying 2% K foliar combined with 75% K as soil dressing gave significantly superior anthocyanins content values than those obtained with fertilizing the plants with 100% K as soil dressing alone (the control). Regarding the effect of K foliar treatments on leaf nutrient contents, the results indicated that applying 2% K foliar combined with 100% potassium soil dressing gave the highest significant values of leaf N, proteins and P contents. Also, the results revealed that no significant differences were recorded due to applying 2% K foliar combined with 75% K as soil dressing and the control treatment for both of N and proteins contents. Whereas, the highest significant leaf K content values were recorded as a result of applying 100% K as soil dressing. The data revealed that the highest significant values of leaf Fe, Mn and Cu contents (ppm) were recorded as a result of applying 2% K foliar combined with 100% K as soil dressing for both seasons. Also, fertilizing the plants with 2% K foliar combined with either with 75% or 100% K as soil dressing gave similar effects on leaf Fe and Mn contents.

It can be concluded that when applying potassium sulphate as a foliar spray combined with potassium soil dressing, it has a potential effect on growth parameters. Also, potassium foliar spray can be used as a partial substitution of the recommended soil amended potassium for increasing nutrients uptake and thus stimulating growth and flowering characteristics of *gladiolus hybrida* cv."Rose Supreme".

Key words: *Gladiolus hybrida* - foliar application-potassium sulphate – Flowering Bulbs.

INTRODUCTION

Gladiolus is in great demand in the international cut-flower trade and is cultivated all over the world. It is rated as the most popular flower in the world from a commercial point of view. (Cohat ,1993). Gladiolus is one of the four famous cut flowers in the world (Bai *et al.*, 2009). Gladiolus is derived from the native plants of south and central Africa as well as the Mediterranean region. Gladiolus belongs to the family *Iridaceae*. Gladiolus is a valuable and economic flowering bulb used as a landscape plant in gardens, as specimen for exhibition and used in decoration as a rich colored cut flower spike with long-lasting vase life. Due to its excellent vase life and captivating colors, it has great economic value in global trade in landscaping (Bose *et al.*, 2003). Gladiolus is represented by 180 species and 10000 cultivars including almost all colors (Hogan, 1990). The production demand of cut flowers has also been accelerated manifolds in the past decade and it is expected to spring up further around the globe. It has a pivotal position among commercial flower which has high demand in international arena and in domestic markets (Halder *et al.*, 2007).

Intensive cut flower production requires high level of fertilization. Imbalance fertilization may reduce gladiolus flower production and may also result in soil and environmental pollution (Mohsen *et al.*, 2015).

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Received November 27, 2016, Accepted December 26, 2016

Gladiolus productivity hinges upon the amounts, forms and frequency of application of plant nutrients (Zafar, 2007).

Potassium is one of the most important macronutrients that affect growth of gladiolus. It is involved in numerous biochemical and physiological processes vital to plant growth, yield, and quality (Marschner, 1995). Potassium (K) is an essential element for plant nutrition and its ability to influence meristem growth, water status, photosynthesis , long distance transport of assimilates, enhance many enzyme actions, helps translocate sugars and starches, increase protein content as well as control ionic balance (Mengel and Kirkby 2001). Potassium plays roles in regulating the opening and closing of stomata and water retention. It promotes the growth of meristematic tissue, activates some enzymatic reactions, aids in nitrogen metabolism, and the synthesis of proteins, catalyzes activities of some mineral elements, and aids in carbohydrate metabolism and translocation (Bhandal and Malik, 1988 and Zörb *et al*., 2014). Potassium is more mobile in the soil than phosphorus but less than nitrates, which can be readily leached from light sandy soils.

A lack of potassium causes reduced bud count, shortening of the flower stem, and delay in flowering of gladiolus, general yellowing of older leaves, and interveinal yellowing of younger leaves (Wilfret, 1980). Potassium deficiency also causes weak stalks and roots become more easily infected with root-rotting organisms. These two factors cause the plants to be rather easily bent to the ground (lodged) by wind and rain (Salisbury and Ross, 1992). A potassium deficiency may affect respiration, photosynthesis, chlorophyll development, and water content of leaves. Potassium increases the photosynthetic rates of crop leaves and carbon dioxide (CO2) assimilation, and facilitates carbon movement (Sangakkara *et al*., 2000).

Foliar feeding of nutrients has become an excellent procedure for increasing yield and improve the quality of plants .This procedure improves nutrient utilization and lower environmental pollution through reducing the amount of fertilizers added to soil (Kannan, 2010). Foliar application overcomes soil fertilization limitations like leaching, insoluble fertilizer precipitation, antagonism between nutrients and fixation reactions like in the case of phosphorus and potassium. Foliar fertilization is more economical than root fertilization due to the efficiency and lower cost. Foliar application is also less likely to result in ground water pollution (Tomimori *et al*., 1995). Foliar application of nutrients may actually promote root absorption of the same nutrient or other nutrients through improving root growth and increasing nutrients uptake (Romemheld and El-Fouly,1999). Foliar fertilization is theoretically more immediate and target- oriented than soil fertilization since nutrients can be directly delivered to plant tissues during critical stages of plant growth (Fernández and Brown, 2013). Moreover, foliar fertilization method may also be a good substitute to the predictable soil application to avoid the loss of fertilizers by leaching and thereby minimizing the ground water pollution (Tomimori *et al*., 1995). Several researchers investigated the foliar nutrients utilization on growth and flowering of ornamental plants. i.e. Roy *et al*., (1995) on gladiolus, Naik and Barman (2006) on *Cymbidium hybrid*, El-Naggar, (2009) on *Dianthus caryophyllus*, L., Arvinder *et al*., (2015) on carnation, Tegegnework et al., (2015) on *Helianthus Annuus*, L.

Several researchers investigated the effect of different sources and levels of potassium on growth, flower yield and quality of ornamental flowering plants, i.e., Singh *et al*., (1997) on gladiolus, Chanda *et al*., (2000) on gladiolus, Bhattacharjee (2001) on gladiolus, Hend (2002) on *Zinnia elegans*, Militiu *et al*., (2002) on gladiolus, Khan and Ahmed (2004) on *Gladiolus hortulanus*, L. cv. "Wind Song", Barman *et al*., (2005) on gladiolus, Najjar and Rehalia (2005) on rose, Butt (2005) on gladiolus, , El-Bassiony (2006) on gladiolus, Pal and Ghosh, (2010) on african marigold (*Tagetes erecta*, L.) cv. Siracole, Singh *et al*., (2010) on gladiolus , Chouhan *et al*., (2014) on gladiolus cv. "White Prosperity" and Mohsen *et al*., (2015) on *Gladiolus grandiflora*, L.

Therefore, the main objective of the present study was to investigate the effect of potassium foliar spray applied with different doses alone or combined with percentage of the recommended potassium soil amendment, on the growth, flower yield and quality and chemical constituents of *gladiolus hybrida*, L. plants cv. "Rose Supreme". Also, try to substitute part of the potassium ground applications supplemental with foliar spray. Furthermore, to reduce environmental pollution through reducing the amount of potassium fertilizer added to the soil.

MATERIALS AND METHODS

An outdoor experimental study was conducted at Antoniades Botanical Gardens, Horticultural Research Institute, Alex., Egypt. *Gladiolus hybrida* cv. "Rose Supreme" was grown throughout the two successive seasons of 2014 and 2015.

The Growing Medium:

PVC pots (30 cm in diameter) were packed with medium. Each pot contained 3.0 kg medium. Analyses of some chemical and physical properties of the used medium were carried out according to Page *et al.* (1982) and are presented in Tables (1).

Regarding the physical properties of the growing media it was consisted of Coarse Sand (5.3%), fine sand (30.6 %), silt (38.7 %) and clay (25.4 %).

Planting gladiolus corms:

The corms of gladiolus cv."Rose supreme" with size of (8-10 cm in circumference) were planted in PVC pots (30 cm in diameter) on 20th September and 25th September of the growth seasons 2014 and 2015, respectively.

The experimental Treatments:

Gladiolus plants were foliar sprayed with potassium sulphate (48%K_2O)on top of the leaves until run-off occurred at two doses of application (1% and 2%). The foliar spray was started three weeks after planting the corms in both seasons. The foliar spray was applied three times at three -week intervals throughout the growing seasons. The foliar sprayed potassium sulphate was applied alone or combined with three percentages of the recommended soil amended potassium (50%, 75% and 100%). Whereas the control treatment was (applying the complete percentage of the recommended soil amendment of potassium (100%) alone. The potassium was applied monthly throughout the growing season as soil dressing (2 g/pot) as recommended by Abbasi *et al*., (2005) . All gladiolus plants received NP fertilization doses as recommended by Pandey *et al*., (2000).

The treatments were arranged in three replicates with eight corms in each experimental unit in a complete randomized block design. Data were statistically analyzed according to the methods described by Snedecor and Cochran, (1990). Differences among means of treatments were tested with least significant difference (L.S.D.) at 5% level of significance. Regular agricultural practices such as weeding and watering as basic dressing were carried out for all treatments whenever necessary as recommended.

Morphological and chemical constituent measurements:

The following morphological and chemical constituent measurements were carried out on the gladiolus plants:

1- Vegetative growth characteristics: Plant height (cm), number of leaves per plant, fresh and dry weights of leaves (g) and leaf area (cm^2).
2- Flowering characteristics: number of days to flowering (day), number of florets per spike, floret diameter (cm), spike length (cm), florets fresh and dry weights per spike (g).
3- Corm and cormels characteristics: new corm diameter (cm), new corm fresh weight (g) and number of cormlets per plant.
4- Photosynthetic pigments of leaves: Leaf chlorophyll a & b (mg/g leaf fresh weight).
5- Total anthocyanins content of petals (mg/100g petal fresh weight).
6- Chemical constituents of leaves: N, proteins, P,K, Ca and Na (%) and Fe, Mn, Zn and Cu (ppm).

Plant Analyses:

Leaf total chlorophyll content (mg/g L.F.W.) was determined- at the flower bud initiation stage of each growing season- according to the method described by Moran and Porath (1980).

As for determination of the total anthocyanins content in the petals (mg/100 g petal F.W.), The third floret from the bottom of each spike was excised after harvest and the petals (200 mg) were diced, the pieces were immersed in 5 ml of 1% HCl in methanol at 4 C in the dark for overnight. Supernatants were then decanted and washed twice with 2.5 ml of acidified methanol. All supernatants were combined to 10 ml and the absorbance of the combined solution was measured colorimetrically by spectrophotometer at 530 nm (Starck and Wray, 1989).

In addition, chemical analyses of oven-dry leaves (dried at 60 ^oC for 72 hr) were carried out to measure the percentages of N, P and K in gladiolus leaves, the nitrogen was estimated by Kjeldal apparatus; phosphorus was determined in wet digested samples by ammonium molybdate method as described by Chapman and Pratt, (1978) and K, Ca and Na was measured by flame photometer according to the methods outlined by Westerman (1990).

Table 1. The main chemical properties of the growing medium

Growing medium	EC ds/ cm	pH	Anions (meq/l)			Cations (meq/l)			Available macro nutrients(ppm)		
			$HCO3^{--}$	Cl^-	$So4^-$	Ca^+	Mg^+	Na^+	N	P	K
Clay, peatmoss, and sand (2:1:1 v/v/v)	2.5	7.3	3.0	19.0	3.6	10	3.0	12	18.5	12.0	37

Micronutrients (Fe, Mn, Mg and Zn concentrations in ppm) were determined by using Perkin-Elmer Atomic Absorption spectrophotometer.

RESULTS AND DISCUSSION

1- Vegetative growth characteristics:

Evidently data in Table (2) show that all K foliar treatments significantly affected the studied vegetative growth parameters compared to the control.

1-1 Plant height (cm):

Plant height was significantly affected by potassium foliar application treatments as shown in Table (2). Applying 2% K foliar combined with 100% potassium soil dressing gave the tallest plant height for both seasons. Insignificant differences were recorded between plants foliar sprayed with 2% K combined either with 75% or 100% K as soil dressing, in both seasons.

Also, it was observed that fertilizing the plants either with 1% or 2% K foliar combined with the full strength K (100%) as soil dressing had similar effects on plant height. Furthermore, insignificant differences were recorded due to applying the full strength K as soil dressing and treated the plants with 2% K foliar combined with 75% K soil amendment.

1-2 Number of leaves / plant (g):

Data presented in Table (2) showed that the highest significant values of leaf number per plant was detected with plants fertilized with 2% K foliar combined with the full strength K (100%) as soil dressing for both seasons. Also, it was noticed that applying 1% or 2% K foliar combined with either 75% or 100% of the recommended K as soil dressing, had similar effects on this trait.

1-3 Fresh weight of leaves / plant (g):

Data illustrated in Table (2) cleared that, fertilizing the plants with 2% K foliar combined with 100% K as soil dressing, resulted in the heaviest fresh weight of leaves for both seasons. Also, it can be noticed that, no significant differences were detected due to applying 100 % K as soil dressing with treatment of fertilizing the plants with 2% K foliar either with 50% or 75% of the recommended K as soil dressing. Moreover, the results indicated that, application of 100 % K as soil dressing had significant similar effects with applying 1% K foliar combined with 75% K soil amendment.

1-4 Dry weight of leaves / plant (g):

Data presented in Table (2) showed that the highest significant values of dry weight of leaves per plant was detected with plants fertilized with 2% K foliar combined with 100% K as soil dressing for both seasons. Also, it can be observed that, no significant differences were detected due to applying 100 % K as soil dressing with treatment of fertilizing the plants with 2% K foliar combined with 75% of the recommended K as soil dressing.

1-5 Leaf area (cm^2):

The results presented in Table (2) reveal that the plants fertilized with 100 % K as soil dressing had highest significant values of leaf area for both seasons. Also, it can be noticed that, the previously mentioned treatment gave similar effects with applying 1% or 2% K foliar combined with 100% K as soil dressing.

The observed significant increase in vegetative growth parameters as affected by applying potassium foliar was detected with several researchers and confirm our work i.e. Ali and Mowafy (2003) studied the effect of different levels of potassium foliar application on peanut in sandy soil and the results revealed that potassium fertilizer significantly increased leaf area and number of branches per plant. Also, Thalooth *et al.*, (2006) studied the effect of foliar application of zinc, potassium and magnesium on growth of mungbean plants. They reported that K was superior in the growth parameters of leaf area, number of leaves per plant and dry weight of leaves. Mazher *et al.*, (2007) investigate the influence of foliar spray with potassium (25 and 50 ppm) on growth of *Bauhinia variegata* seedlings and found that all growth characters (stem length, stem diameter, leaf number per plant, leaf area and dry weight of stem and leaves) increase by increasing the concentration of potassium up to 50 ppm as compared to the control.

The stimulating effects of fertilizing gladiolus plants with foliar K on the studied vegetative growth parameters could be attributed to the greatly improved biometric characteristics such as photosynthetic activity and N metabolism besides, the increase in leaves number per plant, which in turn supplied more photosynthates. Thalooth *et al*., (2006) study the effect of foliar application of potassium on growth of mungbean plants. They stated that the enhancement effect of spraying on growth parameters was very clear, hence treated plants resulted in taller, greater number and weight of leaves and branches. Such enhancement effect might be attributed to the influence of K on metabolism and biological activity besides its stimulating effect on photosynthetic pigments and enzyme activity which in turn encourage vegetative growth of plants (Michail *et al* ., 2004).

Table 2. Effect of potassium application applied alone or combined with potassium soil dressing on vegetative growth parameters of *gladiolus hybrida* cv. "Rose Supreme" during the two growing seasons of 2014 and 2015

Treatments	Plant height (cm)		Number of leaves/plant		Leaves fresh weight (g)		Leaves dry weight (g)		Leaf area (cm^2)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
1% K foliar + 50% K soil dressing	82.60	85.40	7.26	7.38	34.82	36.6	7.19	7.50	5.52	87.60
1% K foliar + 75% K soil dressing	100.7	104.43	8.26	8.43	42.22	44.26	8.52	8.64	97.76	100.72
1% K foliar+ 100% K soil dressing	113.3	118.56	8.43	8.48	44.63	46.73	9.54	9.73	116.15	118.72
2% K foliar + 50% K soil dressing	106.7	109.26	8.13	8.25	45.81	47.38	8.51	8.64	104.99	108.18
2% K foliar + 75% K soil dressing	115.43	118.56	8.40	8.52	46.46	48.71	9.46	9.61	108.29	110.98
2% K foliar +100% K soil dressing	120.23	123.93	8.54	8.62	48.43	50.34	9.79	9.87	118.22	120.92
1% K foliar	98.80	103.16	6.89	6.98	35.36	36.39	7.90	8.02	86.17	87.79
2% K foliar	100.1	107.63	8.30	8.51	43.36	44.81	8.07	8.19	97.47	99.24
Control (100% K soil dressing)	114.06	116.66	8.58	8.62	45.6	48.74	8.98	9.10	118.55	120.47
L.S.D.$_{(0.05)}$	6.63	6.28	0.54	0.37	4.91	4.88	0.66	0.71	8.05	8.56

L.S.D. $_{(0.05)}$ = Least significant difference at 0.05 level of probability.

2 -Flowering characteristics:

It is obvious from data illustrated in Table (3) that all K foliar treatments significantly affected the studied flowering parameters compared to the control.

2-1 – Number of days to flowering:

Data presented in Table (3) showed that fertilizing the plants with 2% K foliar combined with 75% K as soil dressing advanced flowering dates by 4.47 days and 5.66 days than flowering date of the plants fertilized with 100% K as soil dressing, for the first and second seasons, respectively. Whereas, applying 1% K foliar combined with 50% K as soil dressing cause retardation in flowering dates by 6.16 days and 4.98 days, for the first and second seasons, respectively as compared to the control plants (Plants received 100% K as soil dressing alone).

2-2 Number of florets /spike:

Data in Table (3) demonstrate that the highest significant effect on number of florets per spike was due to applying 2% K foliar combined with 100% K as soil dressing for both seasons. No significant differences were detected between the above mentioned treatment and fertilizing the plants with 2% K foliar combined with 75% K as soil dressing. Moreover, the last mentioned treatment gave similar effects with fertilizing the plants with100% K as soil dressing.

2-3Floret diameter (cm):

The results presented in Table (3) indicated that applying 2% K foliar combined with 100% K as soil dressing gave the highest significant values of floret diameter in both seasons. Also, it was also observed that applying 2% K foliar combined with either 75% or 100% K as soil dressing had significant similar effects on this trait.

2-4 Spike length (cm):

It can be observed from the data illustrated in Table (3), the highest recorded values of spike length was recorded as a result of applying 2% K foliar combined with 100% K as soil dressing for both seasons. This treatment caused an increase in spike length of 7.1 cm and 8.4 cm in the first and second seasons, respectively as compared to fertilizing the plants with100% K as soil dressing (the control treatment).

Also, the results indicated that there were no significant differences detected due to applying the previously mentioned treatment and fertilizing the plants with 1% K foliar combined with 100% K as soil dressing which caused an increase of 5.1 cm and 5,7 cm for both seasons, respectively as compared to the control treatment (100% K as soil dressing).

2-5 Fresh weight of florets / spike (g):

It is obvious from data in Table (4) that the highest significant values of fresh weight of florets per spike was due to applying 2% K foliar combined with 100% K as soil dressing for both seasons. Also, the data indicated that, fertilizing the plants with1% K foliar combined with 100% K as soil dressing had similar effects on this trait.

2-6 Dry weight of florets / spike (g):

It is clear from data in Table (4) that the highest recorded values of dry weight of florets per spike was observed due to applying 2% K foliar combined with 100% K as soil dressing for both seasons. Applying this treatment had similar effects with applying 1% K foliar combined with 100% K as soil dressing. Moreover, the resulted proved that applying 100% K as soil dressing gave same effects with applying 2% K foliar combined with 75% K as soil dressing for both seasons.

The findings are in agreement with those obtained by Mukesh *et al*. (2001) they reported that application of K resulted in higher floret diameter, corm weight, number of corms per plant in *Gladiolus grandiflorus*. Also, Butt, (2005) mentioned that K significantly influenced number of days to spike emergence and first floret opening in gladiolus (Butt, 2005). Younis *et al*. (2006) found that N along with P and K has synergetic effect on flowering characters in dahlias. Mohsin *et al*., (2015) on *Gladiolus grandiflorus*, L. cv. "Essential" reported that the maximum floret diameter was recorded under combined application of P and K. while, the maximum number of florets per spike were observed when K was applied alone.

The improvement in the studied flowering parameters as a result of foliar potassium application could be attributed to positive role of K in floret development (Zubair, 2011). The role of K in the greatly improved biometric characteristics such as photosynthetic activity, N metabolism and protein synthesis besides, the increase in leaf area and leaves number per plant, which in turn supplied more photosynthates. (Baldotto and Baldotto, 2013). The stimulatory effects of foliar application of K might have resulted in better accumulation of assimilates thereby resulting in taller, stronger and sturdier stems of cut flowers (Arvinder *et al*., 2015).

Table 3. Effect of potassium application applied alone or combined with potassium soil dressing on number of days to flowering, number of florets/spike, floret diameter and spike length of *gladiolus hybrida* cv. "Rose Supreme" during the two growing seasons of 2014 and 2015

Treatments	Number of days to flowering (day)		Number of florets/spike		Floret diameter (cm)		Spike length (cm)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
1% K foliar + 50% K soil dressing	86.56	85.80	10.9	11.10	9.17	9.32	61.16	59.63
1% K foliar + 75% K soil dressing	81.03	79.76	12.16	12.33	10.52	10.73	71.06	69.86
1% K foliar+ 100% K soil dressing	79.56	78.40	12.70	12.91	11.39	11.44	80.46	82.50
2% K foliar + 50% K soil dressing	82.76	80.56	11.66	11.81	10.38	10.55	69.43	69.58
2% K foliar + 75% K soil dressing	75.93	75.16	13.30	13.46	11.25	11.44	72.3	73.86
2% K foliar +100% K soil dressing	79.23	80.26	13.80	13.92	11.57	11.73	82.46	85.20
1% K foliar	86.17	85.46	11.30	11.43	9.29	9.40	60.80	62.40
2% K foliar	83.46	82.63	12.27	12.09	10.34	10.46	68.30	69.46
Control (100% K soil dressing)	80.40	80.82	12.63	12.88	11.18	11.40	75.36	76.80
L.S.D.$_{(0.05)}$	2.51	2.54	0.69	0.56	0.55	0.51	4.08	4.25

L.S.D. $_{(0.05)}$ = Least significant difference at 0.05 level of probability.

3 -Corm and cormels characteristics:

The data illustrated in Table (4) indicated that the studied parameters of corm and cormels seemed to be significantly affected as a result of applying K foliar application treatments compared to the control.

3-1 New corm diameter (cm):

It is obvious from data in Table (4) that the highest significant values of new corm diameter was observed due to applying 2% K foliar combined with 100% K as soil dressing for both seasons. Also, the data showed that, fertilizing the plants with 2% K foliar combined with 75% K as soil dressing had similar effects on this trait. Moreover, fertilizing the plants with 100% K as soil dressing (the control treatment) gave similar effects with applying 1% K foliar combined with 75% K as soil dressing and/or applying 2% K foliar combined with 50% K as soil dressing, for both seasons.

3-2 New corm fresh weight (g):

The highest significant values of new corm fresh weight were observed as a result of fertilizing the plants with 2% K foliar combined with 100% K as soil dressing for both seasons (Table 4). The results indicated that applying this treatment had similar effects with applying 2% K foliar combined with 75% K as soil dressing.

3-3 Cormels number/plant*:*

The highest significant values of cormels number per plant were observed as a result of fertilizing the plants with 2% K foliar combined with 100% K as soil dressing (Table 4). Also, it can be noticed that, no significant differences were detected due to applying 100 % K as soil dressing with treatment of fertilizing the plants with 2% K foliar combined with 75% of the recommended K as soil dressing.

The significant enhancement detected in corms and cormels studied parameters as a result of applying K foliar agree with those obtained by Barman *et al.*(1998) who reported that effect of K were much more pronounced on size and weight of corms and cormels. Also, Mukesh *et al.* (2001) reported that application of adequate amount of K resulted in higher corm weight and number of corms per plant in *Gladiolus grandiflorus*.

Table 4. Effect of potassium application applied alone or combined with potassium soil dressing on florets fresh and dry weights/spike, new corm diameter and new corm fresh weight and cormels number/plant of *gladiolus hybrida* cv. "Rose Supreme" during the two growing seasons of 2014 and 2015

Treatments	Florets fresh weight /spike (g)		Florets dry weight/spike (g)		New corm diameter (cm)		New corm fresh weight (g)		Cormels number/plant	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
1% K foliar + 50% K soil dressing	19.55	20.87	2.71	2.79	3.6	4.09	27.23	27.49	8.13	8.01
1% K foliar + 75% K soil dressing	25.5	27.95	4.63	4.71	4.44	4.56	31.87	32.10	9.27	9.37
1% K foliar+ 100% K soil dressing	28.49	30.76	5.04	5.12	5.14	5.27	38.37	38.51	13.52	13.64
2% K foliar + 50% K soil dressing	21.41	23.39	3.44	3.66	4.58	4.67	35.62	35.49	12.22	12.36
2% K foliar + 75% K soil dressing	27.02	29.27	4.92	4.98	5.12	5.27	43.46	43.74	13.87	13.96
2% K foliar +100% K soil dressing	28.99	31.22	5.40	5.53	5.42	5.57	45.21	45.44	16.29	16.50
1% K foliar	22.44	22.70	4.24	4.35	3.41	3.52	26.89	27.06	6.45	6.57
2% K foliar	24.06	25.58	4.44	4.51	4.28	4.41	32.33	32.41	9.26	9.39
Control (100% K soil dressing)	26.71	27.38	4.94	5.02	4.74	4.63	39.11	39.25	14.08	14.20
L.S.D.$_{(0.05)}$	1.92	1.72	0.42	0.51	0.32	0.41	2.03	1.76	0.72	0.61

L.S.D. $_{(0.05)}$ = Least significant difference at 0.05 level of probability.

Stimulating effects of potassium sulphate on gladiolus corm and cormels yield as a result of potassium fertilization may be due to the reason that potassium has a prevalent action in plants and is involved in maintenance of ionic balance in cell and bounds ionically to the enzyme pyruvate kinase which is essential in respiration and carbohydrate metabolism (Aisha *et al*., 2007). Cormlets development and formation is based on foliage and when the foliage is good enough, with proper plant height and number of leaves, the plant produce sufficient photosynthates. That support stolon formation (Misra, 1994). Furthermore, plant height has a positive direct effect on bulb yield, diameter and weight (Haydar *et al*., 2007). Besides, the stimulating effect of dry mass production through enhancement of cell division and chlorophyll accumulation (Amin *et al*., 2007). Moreover, the positive effect of KNO_3 might be due to the availability of potassium and nitrogen that resulted in more plant height which contributing towards corm diameter, corm weight (Ramzan *et al* ., 2010).

4- Photosynthetic pigments in leaves and total anthocyanins contents in petals:

As shown in Table (5) the data proved that leaf chlorophylls content (a and b) as well as the total anthocyanins content of petals seemed to be significantly affected as a result of applying K foliar application treatments compared to the control.

4-1 Chlorophylls content of Leaves (mg/g L.F.W):

The highest significant values of chlorophyll (a) were recorded as a result of fertilizing the plants with 2% K foliar combined with 100% K as soil dressing (Table 5). Also, it can be noticed that, applying 2% K foliar combined with 75% K as soil dressing gave significant higher chlorophyll (a) values than those obtained after fertilizing the plants with 100% K as soil dressing (control treatment). Furthermore, the previously mentioned treatment gave similar effects on this trait with the treatment of 1% K foliar combined with 75% K as soil dressing.

Regarding the effects of foliar K treatments on chlorophyll (b), the data in Table (4) indicated that the highest significant values of chlorophyll (b) were recorded as a result of fertilizing the plants with 2% K foliar combined with 100% K as soil dressing. Moreover, Applying 2% K foliar combined with 75% K as soil dressing gave significantly superior values than those obtained with fertilizing the plants with 100% K as soil dressing alone (control treatment).

The data are in agreement with those obtained by Chouhan *et al*., (2014) who reported that the maximum leaf chlorophyll contents in *Gladiolus hybrida* cv. "White Prosperity" were recorded as a result of fertilizing the plant with K dose of (1.8 g/plant). Similar trend of results were reported by Mohsen *et al*., (2016) they observed that the leaf total chlorophyll contents of gladiolus plants were increased consistently when K was applied in sufficient quantity.

The significant increase in photosynthetic pigment contents as a result of applying K foliar application could be due to: increasing the availability of nitrogen, which could led to increase chlorophyll formation due to the importance of nitrogen in chlorophyll composition and synthesis, consequently increasing its absorption by the plant, acceleration of N uptake, enhancing N metabolism, stimulation of assimilation and production of protein that ultimately increase chlorophyll contents (Haghighi *et al*., 2012).

4-2 Total anthocyanins content of petals (mg/100 g petal.F.W):

The highest significant values of total anthocyanins content of petals were recorded as a result of fertilizing the plants with 2% K foliar combined with 100% K as soil dressing (Table 5). Also, the data indicated that applying 2% K foliar combined with 75% K as soil dressing gave significantly superior values than those obtained with fertilizing the plants with 100% K as soil dressing alone (control treatment).

The results are in line with those obtained by of Pal and Ghosh (2010) on African marigold reported that anthocyanins content in petal tissues increased with increasing levels of potassium application. Singh *et al*., (2010) and Sewedan *et al*., (2012) on gladiolus, Chavan *et al*., (2010) on china aster. Also, Chouhan *et al*., (2014) on gladiolus plants who reported that the maximum anthocyanins content in petals were recorded with K rate of application of (2.25g/plant).

5- Nutrients contents of gladiolus leaves:

The data illustrated in tables (6 and 7) demonstrate that K foliar application treatments significantly affected leaf nutrient contents studied parameters compared to the control.

5-1 Nitrogen, proteins, phosphorus and potassium leaf contents (%):

Results of the plant leaves analyses for their N, proteins, P and K contents (%) are listed in Table (6). The results revealed that the highest significant values of leaf N, proteins and P contents were recorded as a result of applying 2% K foliar combined with 100% K as soil dressing.

Table 5. Effect of potassium application applied alone or combined with potassium soil dressing on leaf chlorophyll contents (a&b) (mg/g leaves fresh weight) and total anthocyanins content (mg/100 g petal fresh weight) of *gladiolus hybrida* cv. "Rose Supreme" during the two growing seasons of 2014 and 2015

Treatments	Chlorophyll (a) (mg/g leaves fresh weight)		Chlorophyll (b) (mg/g leaves fresh weight)		Total anthocyanins content (mg/100 g petal fresh weight)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
1% K foliar + 50% K soil dressing	3.65	3.57	1.55	1.59	19.70	19.87
1% K foliar + 75% K soil dressing	5.36	5.27	1.74	1.80	23.44	23.56
1% K foliar+ 100% K soil dressing	5.97	5.83	2.24	2.32	34.99	34.87
2% K foliar + 50% K soil dressing	4.35	4.26	1.70	1.80	23.47	23.73
2% K foliar + 75% K soil dressing	6.17	6.05	2.31	2.38	35.23	35.43
2% K foliar +100% K soil dressing	6.48	6.40	2.46	2.55	37.55	37.35
1% K foliar	3.03	2.96	1.39	1.48	20.22	20.31
2% K foliar	3.48	3.38	1.60	1.67	23.04	23.38
Control (100% K soil dressing)	5.45	5.36	2.17	2.26	31.02	29.39
L.S.D.$_{(0.05)}$	0.188	0.215	o.o76	0.086	1.28	1.54

L.S.D. $_{(0.05)}$ = Least significant difference at 0.05 level of probability.

Also, it can be noticed that, no significant differences were recorded due to applying 2% K foliar combined with 75% K as soil dressing and the treatment of fertilizing the plants with 100% K as soil dressing (control treatment) for both of N and proteins contents. Furthermore, it was noticed that fertilizing the plants with 2% K foliar combined with 100% K as soil dressing gave superior significant nitrogen values than those obtained after fertilizing the plants with 100% K as soil dressing alone.

The data revealed that, fertilizing the plants with 2% K foliar combined with 75% K as soil dressing gave similar effects on leaf protein values with those obtained after fertilizing the plants with 100% K as soil dressing alone.

Regarding the effect of K foliar application on leaf K content, data shown in (Table 6) cleared that, the highest significant leaf K content values were recorded as a result of applying 100% K as soil dressing.

5-2 Calcium and sodium leaf contents (%):

The data presented in Table (6&7) revealed that applying 2% K foliar alone gave the highest significant recorded values of these traits. Also, the data revealed that fertilizing the plants either with 1% K foliar combined with 75% K as soil dressing or 2% K foliar combined with 50% K as soil dressing gave superior significant values of Ca and Na leaf contents than those recorded as a result of applying 100% K as soil dressing alone.

5-3 Fe, Mn, Zn and Cu leaf contents (ppm):

The data illustrated in table (7) demonstrate that K foliar application treatments significantly affected leaf Fe, Mn, Zn, and Cu contents, parameters compared to the control.

The data revealed that the highest significant values of leaf Fe, Mn and Cu contents (ppm) were recorded as a result of applying 2% K foliar combined with 100% K as soil dressing for both seasons. Whereas, the highest significant values of leaf Zn content were recorded due to fertilizing the plants with 1% K foliar combined with 100% K as soil dressing for both seasons. Also, the previously mentioned treatment gave similar effects on leaf Zn content with the treatment of 2% K foliar combined with 100% K as soil dressing for both seasons. Also, it can be noticed that fertilizing the plants with 2% K foliar combined with 100% K as soil dressing gave similar effects, on leaf Fe and Mn contents, with the treatment of applying 2% K foliar combined with 75% K as soil dressing.

Moreover, the data revealed that fertilizing the plants either with 1% K foliar combined with either

50% or 75% K as soil dressing gave superior significant values of Fe leaf content than those recorded as a result of applying 100% K as soil dressing alone.

Also, it can be noticed that applying 2% K foliar combined with 75% K as soil dressing gave superior significant values of Mn and Zn leaf contents than those recorded as a result of applying 100% K as soil dressing alone.

Furthermore, the data revealed that, fertilizing the plants with 1% K foliar combined with 75% K as soil dressing or 2% K foliar combined either with 50% or 75% K as soil dressing gave superior significant value of Cu leaf content than those recorded as a result of applying 100% K as soil dressing alone.

Our findings are in agreement with those obtained by Erner *et al*., (1993) reported that foliar sprays of potassium nitrate were more effective in rapidly increasing the potassium content of citrus leaves than ground applied fertilizers. Also, Zhang *et al*., (2002) found that foliar potassium application affected development, nutrients uptake and photosynthesis of melon. Also, Lin and Danfeng (2003) observed an increase in vegetative growth parameters, net photosynthetic rate; NPK contents and chlorophyll content associated with enhancement of K levels. Mostafa and Saleh (2006) mentioned that spraying Balady mandarin with potassium from several forms i.e. KH_2 PO_4 or KNO_3 had a positive effect on leaf mineral of mandarin since they raised N, P and K levels in the leaves. El-Tohamy *et al*., (2011) reported that N, P and K concentrations in carrot leaves were significantly increased by potassium foliar application as compared with the control. Sarrwy *et al*., (2010) studied the effect of foliar spray with potassium nitrate on leaf mineral contents of Picual olive trees grown under sandy soil. They found that foliar application of K, improved the chlorophyll and NK content. Sarrwy *et al*., (2012) investigate foliar spraying with different potassium forms i.e,potassium nitrate (KNO_3), mono potassium phosphate (MKP) and potassium thiosulfate (KTS) at different concentrations on mandarin trees either pre or post bloom. The results showed that all potassium forms induced a remarked promotion in leaf mineral status. Pande *et al*., (2012) reported increased accumulation of N, P, K, and micronutrients (Fe, Cu, Zn & Mn) in soybean tissues when foliar K fertilizer was applied. Mohsen (2013) who mentioned that applying foliar potassium nitrate on cucumber either alone or combination with humic acid significantly affected leaf NK and chlorophyll contents. Manju *et al*., (2014) evaluate the effectiveness of soil and foliar application of potassium on leaf mineral concentration levels of soybean.

Table 6. Effect of potassium application applied alone or combined with potassium soil dressing on leaf NPK, proteins and calcium contents (%) of *gladiolus hybrida* cv. "Rose Supreme" during the two growing seasons of 2014 and 2015

Treatments	N (%)		Proteins (%)		P (%)		K (%)		Ca (%)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
1% K foliar + 50% K soil dressing	1.09	1.06	6.71	6.59	0.172	0.169	4.10	4.03	2.50	2.40
1% K foliar + 75% K soil dressing	1.09	1.07	6.71	6.63	0.182	0.180	4.40	4.26	2.50	2.40
1% K foliar+ 100% K soil dressing	1.14	1.12	7.10	7.03	0.192	0.186	4.60	4.50	2.30	2.23
2% K foliar + 50% K soil dressing	1.10	1.08	6.77	6.54	0.182	0.179	4.40	4.53	2.50	2.46
2% K foliar + 75% K soil dressing	1.14	1.12	7.10	7.03	0.194	0.191	4.60	4.46	2.50	2.46
2% K foliar +100% K soil dressing	1.21	1.19	7.46	7.30	0.226	0.223	4.80	4.66	2.40	2.36
1% K foliar	0.86	0.84	5.27	5.16	0.158	0.155	3.90	3.76	2.60	2.50
2% K foliar	1.07	1.04	6.58	6.46	0.166	0.163	4.00	3.93	2.60	2.53
Control (100% K soil dressing)	1.14	1.11	7.10	7.03	0.212	0.208	4.80	4.66	2.30	2.26
$L.S.D._{(0.05)}$	0.034	0.021	0.102	0.09	0.003	0.002	0.17	0.09	0.17	0.09

Table 7. Effect of potassium application applied alone or combined with potassium soil dressing on leaf Na, Fe, Mn, Zn and Cu contents of *gladiolus hybrida* cv. "Rose Supreme" during the two growing seasons of 2014 and 2015

Treatments	Na (%)		Fe (ppm)		Mn (ppm)		Zn (ppm)		Cu (ppm)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
1% K foliar + 50% K soil dressing	0.28	0.27	42	41	25	24	28	26	7	6
1% K foliar + 75% K soil dressing	0.25	0.24	49	47	26	25	27	26	9	8
1% K foliar+ 100% K soil dressing	0.24	0.23	50	49	30	29	32	31	9	8
2% K foliar + 50% K soil dressing	0.26	0.25	49	48	25	24	27	26	8	7
2% K foliar + 75% K soil dressing	0.24	0.23	62	60	29	29	31	30	10	9
2% K foliar +100% K soil dressing	0.24	0.23	62	61	32	31	32	31	11	11
1% K foliar	0.29	0.28	36	35	22	21	23	23	6	5
2% K foliar	0.28	0.27	40	40	23	22	25	24	8	7
Control (100% K soil dressing)	0.21	0.20	30	29	26	25	25	25	6	6
L.S.D.$_{(0.05)}$	0.03	0.03	3.43	2.96	3.43	3.17	3.43	1.30	1.71	0.85

L.S.D. $_{(0.05)}$ = Least significant difference at 0.05 level of probability.

The results revealed that potassium content in leaves was high in all treatments, and the highest percentage of K was observed at the higher rate of foliar application compared to control. Nitrogen content was also high in K foliar applications rate of 1.75%. Whereas, Fe increased with the lower content K foliar treated plants. Concentration of Na significantly increased in leaves of both foliar treatments.

The simulative effects of potassium foliar spray on gladiolus leaf mineral contents could be due to that potassium is necessary for the uptake and translocation of various nutrients. Blevins *et al.* (1978) mentioned that K has an important role as a counter ion for the uptake and translocation of nitrate ($NO3^-$) within the plant. Foliar K sprays can be an effective method to shorten the time required for uptake compared to soil application (Embleton *et al* ., 1969) . Potassium has favorable effects on metabolism of nucleic acids, proteins, vitamins and growth substances (Bisson *et al.*, 1994). These are manifested in metabolites formed in plant tissues and directly influence the growth and development processes. Furthermore, K has an important role in the translocation of photosynthates from sources to sinks (Cakmak *et al.*, 1994).

From our findings, it can be concluded that when applying potassium sulphate as a foliar spray combined with potassium soil dressing, it has a potential effect on growth parameters. Also, potassium foliar spray can be used as a partial substitution of the recommended soil amended potassium for increasing nutrients uptake and thus stimulating growth and flowering characteristics of gladiolus plants cv."Rose Supreme".

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الملخص العربي

تأثير التسميد بالبوتاسيوم على نمو وازهار وانتاج الكورمات والمحتوى الكيماوى لنباتات الجلاديولس صنف روز سوبريم

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أجريت تجربة أصص على نباتات الجلاديولس صنف "روز سوبريم" خلال الموسمين ٢٠١٤ و٢٠١٥ فى فرع بحوث نباتات الزينة بحدائق انطونيادس التابعة لمعهد بحوث البساتين- الاسكندرية. وذلك لدراسة تأثير التسميد بسلفات البوتاسيوم (٤٨%بو٢أ) رش منفرداً مستخدماً أيا من التركيزين(١% أو٢%) أومجتمعاً مع ثلاثة نسب مئوية من الموصى به من الاضافة الارضية (٢جم/الاصيص) من البوتاسيوم (٥٠% و٧٥% و١٠٠%) وذلك على صفات النمو الخضرى ومحصول وجودة الازهار والمحتوى الكيماوى(المحتوى المعدنى وصبغات التخليق الضوئى) للأوراق بالاضافة الى محتوى البتلات من صبغة الانثوسيانين. فى حين كانت معاملة الكنترول هى النسبة المئوية الكاملة(١٠٠%) من الاضافة الارضية من السماد البوتاسى الموصى به. وذلك لخفض كمية البوتاسيوم المضاف أرضياً واستبدال جزء من الاضافة الارضية ليحل محلها بوتاسيوم مضاف بالرش الورقى. وأوضحت النتائج أن معاملات استخدام الرش الورقى بالبوتاسيوم أثرت معنوياً على كل الصفات المدروسة مقارنة بالمعاملة الكنترول. وأشارت النتائج ان استخدام الرش الورقى للبوتاسيوم بتركيز ٢% مجتمعاً مع ١٠٠% من الموصى به من الاضافة الارضية أعطى أعلى قيم معنوية لصفات: ارتفاع النبات وعدد الاوراق/ نبات والوزن الطازج والجاف للاوراق/نبات وعدد الزهيرات/حامل نورى وقطر الزهيرات وطول الشمراخ الزهرى والوزن الطازج والجاف للزهيرات وقطر الكورمات وعدد الكريمات/ نبات والوزن الطازج للكريمات بالاضافة الى محتوى الاوراق من صبغات الكلوروفيل ومحتوى البتلات من صبغة الانثوسيانين. وأظهرت النتائج أن تسميد النباتات باستخدام الرش الورقى للبوتاسيوم بتركيز ٢% مجتمعاً مع ٧٥% من الموصى به من الاضافة الارضية من البوتاسيوم أحدث تبكير فى التزهير ب ٤,٤٧ يوم و٥,٦٦ يوم مقارنة بالكنترول بالنسبة للموسم الاول والثانى على الترتيب. ولوحظ أيضاً أن المعاملة المشار اليها سلفاً كان لها تأثير معنوى على قطر الزهيرات مقارنة بالكنترول. وأوضحت النتائج أنه لم يكن هناك فروق معنوية كنتيجة لتسميد نباتات الجلاديولس باستخدام الرش الورقى للبوتاسيوم بتركيز ٢%

مجتمعاً مع ٧٥% أو١٠٠% من الموصى به من الاضافة الارضية من البوتاسيوم وذلك على صفات قطر الكورمات ووزنها الطازج. وأشارت النتائج الى أن معاملة النباتات باستخدام الرش الورقى للبوتاسيوم بتركيز ٢% مجتمعاً مع ٧٥% من الاضافة الارضية الموصى من البوتاسيوم أعطى أعلى محتوى معنوى من صبغة الانثوسيانين بالبتلات مقارنة بالتسميد بمعدل١٠٠% من الاضافة الارضية الموصى بها فقط (الكنترول). وفيما يتعلق بتأثير معاملات الرش الورقى بالبوتاسيوم على محتوى الاوراق من العناصر، أشارت النتائج الى أن تسميد النباتات باستخدام الرش الورقى للبوتاسيوم بتركيز ٢% مجتمعاً مع ١٠٠% من الموصى به من الاضافة الارضية من البوتاسيوم أعطى أعلى قيم معنوية لمحتوى الاوراق من النتروجين والبروتين والفوسفور. ولم تلاحظ فروق معنوية لمحتوى الاوراق من النتروجين كنتيجة للرش الورقى للبوتاسيوم بتركيز ٢% مجتمعاً مع ٧٥% من الموصى به من الاضافة الارضية من البوتاسيوم والمعاملة الكنترول. فى حين لوحظ أن التسميد بمعدل ١٠٠% من الموصى به من الاضافة الارضية من البوتاسيوم منفردة أعطت أعلى قيم معنوية لمحتوى الاوراق من البوتاسيوم. أما أعلى القيم المعنوية لمحتوى الاوراق من عناصر الحديد والمنجنيز والنحاس فسجلت كنتيجة للمعاملة بتركيز ٢% رش ورقى للبوتاسيوم مجتمعاً مع ١٠٠% من الموصى به من الاضافة الارضية من البوتاسيوم.

ويمكن القول اجمالاً أنه باستخدام الرش الورقى بسلفات البوتاسيوم (٤٨%بو٢أ) لنباتات الجلاديولس مجتمعاً مع الاضافة الارضية كان لها تأثير واضح على غالبية الصفات المدروسة. وانه يمكن استخدام الرش الورقى للبوتاسيوم ليحل جزئياً محل نسبة من الاضافة الارضية الموصى بها وذلك لزيادة امتصاص العناصر وبالتالى تنشيط نمو وازهار وانتاج الكورمات لنباتات الجلاديولس صنف " روز سوبريم".