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Effect of Pre-harvest Foliar Application of Polyamines and Calcium Sulfate on Vegetative Characteristics and Mineral Nutrient Uptake in *Rosa hybrida*

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Abstract

In order to improve the quality of cut rose 'Dolce Vita', an investigation was performed with 20 treatments, 3 replications, and 2 plants in each replicate in a greenhouse with the open soilless culture system. The treatments included control (distilled water), putrescine (Put) at the rates of 1, 2 or 3 mM, spermidine (Spd) at the rates of 0.5, 1 or 1.5 mM, spermine (Spm) at the rates of 1, 2 or 4 mM, calcium sulfate (CS) at the rates of 2.5 or 5 mM, and the combined treatments of Put + CS and Spd + CS. The traits such as stem height, flower length and diameter, stem fresh weight, vase life, and leaf mineral uptake including N, P, K, Ca, Fe and Zn were measured. According to the results, the combined application of polyamines (PAs) with CS had a significant influence on increasing the parameters such as stem height, flower length and diameter, stem fresh weight, and vase life. The rose flowers treated with Put 2 mM + CS 2.5 mM, Spd 0.5 or 1 mM + CS 5 mM showed the highest vase life (16.2, 16 and 16 days, respectively) compared to other treatments. The combined application of PAs and CS enhanced the uptake of minerals when compared to their individual application. The plants sprayed with Spd and CS exhibited the highest Ca uptake. Generally, the results showed that PAs and CS increased quantitative and qualitative characteristics of rose flower 'Dolce Vita' in soilless culture system due to the increased uptake of minerals. It can be inferred that the foliar application of PAs and CS sulfate can be effective in improving the quantitative and qualitative traits of this cultivar.

Keywords: Putrescine, Spermidine, Spermine, Stem height, Vase life.

INTRODUCTION

Rose (*Rosa hybrida* L.) from Rosaceae family is one of the most commercial and popular cut flowers in the world so that nowadays it has the leading position in planting area, production rate, employment, and exports. It is of paramount importance to enhance the quantitative and qualitative characteristics of cut rose flowers because of the high demand for this plant species in the market. From this perspective, the application of minerals and PAs can be an effective way to improve the quantitative and qualitative traits of this valuable species (Hosseini Farahi *et al.*, 2013). PAs are a major plant growth regulator playing role in a wide range of biological, physiological and bio-cycles processes such as cell division, vessel differentiation, chromatin performance, protein synthesis, structure integration of nucleic acids, cell membrane dynamic, root initiation, shoot formation, flower induction and evocation, fruit ripening, senescence, and embryo formation in tissue culture (Handa and Mattoo, 2010; Wallace, 2009; Abdel Aziz Nahed *et al.*, 2009; Kusano *et al.*, 2008; Martin-Tanguy, 2001; Thomas and Thomas, 2001).

Plant growth rate is directly dependent on cell PAs so that when the biosynthesis of these compounds is stopped, plant growth is slowed down or stopped. PAs are necessary to complete cell division in some animal and plant cells. Putrescine (di-amine), spermidine (three-amine) and spermine (tetra-amine) are the most important PAs in the plants (Valero *et al.*, 2002). It has been documented that PAs play an important role in enhancing vase life. It has been reported that the application of spermine 5 mM increased the vase life of *Gladiolus* flowers by 3 days as compared to control treatment (Sivaprakasam *et al.*, 2009). The application of sucrose 2% + calcium 200 mg + penicillin 100 mg + calcium nitrate 0.15% + spermidine 0.1 mM on rose flowers significantly delayed senescence process and prolonged the vase life (Xiao Ling *et al.*, 2007). In a study on carnation cut flowers 'Riko' and gerbera 'Lissa', spermidine 10 mM in the preserving solution extended vase life and delayed senescence of carnation flowers. The best result in gerbera flower was obtained from the foliar application of spermidine 0.1 mM and spermidine 10 mM in the preserving solution (Bagni and Tassoni, 2006).

Calcium is one of the most important elements to increase and preserve cut flower quality. Calcium accumulation in plant tissues induces polymer connections between middle lamella of pecto-cellulose membrane in which it contributes to stabilizing cell wall network and increasing the mechanical resistance of tissues (Hepler, 2005). In addition, calcium is effective in keeping membrane permeability, thereby stabilizing it and delaying cell senescence (White and Broadly, 2003). Sufficient calcium supply to achieve desirable postharvest properties in the ornamental plants such as rose flower has been reported by some researchers (Halevy *et al.*, 2001; Mortensen *et al.*, 2001; Torre *et al.*, 2001). The effect of calcium on rose flower permanency is due to its role in senescence delaying and the reduction of ethylene production. Calcium delays senescence of plant tissues in general and of rose petals in particular. This element acts as a moderator agent of senescence process to extend the vase life of flowers (Torre *et al.*, 1999). Extended vase life and reduced bending disorders in gerbera flower as influenced by the application of $CaCl_2$ 1% have been reported by Gerasopoulos and Chebli (1999). Treating tuberose cut flowers with different concentrations of calcium chloride salt delayed flower dehiscence, which was attributed to the delaying of dejection and senescence of flowers. This salt also reduced flower respiration and increased water absorption by inflorescence (Handa and Mattoo, 2010). Exotic application of salicylic acid and calcium chloride increased the growth and uptake of macro and microelements such as N, P, K, Ca and Mg and enhanced chlorophyll, relation moisture of leaf, flower quality, and vase life of rose 'Dolce Vita' (Abdolmaleki *et al.*, 2015). The aim of the present study was to evaluate the effect of PAs and CS on increasing quantitative and qualitative parameters and uptake of minerals in the leaves of rose 'Dolce Vita' in an open soilless culture system.

MATERIALS AND METHODS

In order to assess the effect of PAs and CS on quantitative and qualitative characteristics

and the uptake of mineral elements by the leaves of roses 'Dolce Vita', an investigation was carried out in a completely randomized block design with 20 treatments, three replications, and two plants in each replicate in a commercial hydroponic greenhouse of rose growing in Yasooj County, Iran. For this purpose, the rooted two-month-old cuttings of rose 'Dolce Vita' were purchased from Negin Falat Aria Company. Then, they were planted in the hydroponic system in a perlite (1) + cocopeat (1) substrate. The experiment lasted from February until July of 2011. The nutrient solution was prepared with tap drinking water whose features are presented in Table 1. The applied nutrient formulation is mentioned in Table 2.

Table 1. The properties of drinking water used for irrigation of the plants.

EC (µmho s/m)	pH	Carbonate	Bicarbonate	Chloride	Sulfate	Calcium	Magnesium
		Meq/l					
380	7.3	0	4	0.5	1	3.3	2.7

Table 2. The elements used for nutrition of the plants based on greenhouse conditions.

Element	Quantity (g in 1000 liter)	Element	Quantity (g in 1000 liter)
Calcium nitrate	230	Magnesium sulfate	40
Ammonium nitrate	80	Manganese (chelate)	0.9
Potassium nitrate	400	Zinc sulfate (chelate)	0.9
Iron chelate (6%)	23	Borax	1.5
Mono-potassium phosphate	140	Cupper	0.18
Sodium molybdate	0.5		

Nutrient solutions were fed to the plants from the bed by pumping and open drip irrigation system. Protection operations were performed according to commercial greenhouse conditions during the growth period such as pruning, pest and disease control, and stem bending. Average day/night temperature of the greenhouse was set at 24±4/15±2°C and its RH was set at 40-60%. The applied treatments are described in Table 3.

Table 3. The applied treatments in the experiment.

Treatment no.	Treatment	Treatment no.	Treatment
T_1	Control	T_{11}	Put 1 mM + CS 2.5 mM
T_2	Put 1 mM	T_{12}	Put 1 mM + CS 5 mM
T_3	Put 2 mM	T_{13}	Put 2 mM + CS 2.5 mM
T_4	Put 3 mM	T_{14}	Put 2 mM + CS 5 mM
T_5	Spd 0.5 mM	T_{15}	Spd 0.5 mM + CS 2.5 mM
T_6	Spd 1 mM	T_{16}	Spd 0.5 mM + CS 5 mM
T_7	Spd 1.5 mM	T_{17}	Spd 1 mM + CS 2.5 mM
T_8	Spm 1 mM	T_{18}	Spd 1 mM + CS 5 mM
T_9	Spm 2 mM	T_{19}	CS 2.5 mM
T_{10}	Spm 4 mM	T_{20}	CS 5 mM

Put: Putrescine, Spm: Spermine, Spd: Spermidine, CS: Calcium sulfate.

Measured parameters

To measure fresh weight, the cut flower was cut from above of the first 5-leaflets by sharp scissors at harvest time and it was weighted in the laboratory using a digital scale in grams. Flower size (height and diameter) and stem height were measured by a digital caliper and a ruler in centimeters, respectively.

Vase life

To evaluate vase life, six flower stems were harvested from each treatment and they were immediately transferred to a laboratory and were placed in 20-cm glass pots containing 250 ml water. Postharvest vase life of flowers was assessed as per the emergence of such symptoms as crookneck, bent neck, petal senescence, complete rolling of petals, color change, and their abscission, which impair the attractiveness and marketing of flower (Jowkar *et al.*, 2012).

Leaf minerals

For this purpose, the leaf samples of the treated plants were collected and transferred to the laboratory. At first, the leaf samples were washed by HCl solution 0.1 N and then, they were washed with distilled water and dried at 80°C for 48 hrs. Finally, they were powdered. Nitrogen was measured by the Kjeldahl method, phosphorous and boron by spectrophotometry method and other elements by atomic absorption device model Atom-Absorption-Spectrometer FMD4 made in Germany (Hosseini Farahi *et al.*, 2017).

Statistical analysis

Data analysis was performed using MSTAT-C software, and the means were compared using LSD test.

RESULTS AND DISCUSSION

Effect of PAs and CS on vegetative characteristics of rose flower

The results indicated that the application of PAs with CS had a significant influence on such parameters as stem height, flower diameter, flower height, stem fresh weight, and vase life (Table 4).

Table 4. Analysis of variance for rose flower vegetative traits as influenced by PAs and CS treatments.

SoV	df	MS				
		Stem height	Flower diameter	Flower height	Stem fresh weight	Vase life
Replication	2	13.7	8.5	112.4	215.9	4.063
Treatment	19	246.8**	25.9**	53.7**	878.0**	3.470**
Error	38	38.8	10.9	16.0	183.0	0.094
CV (%)		7.6	9.6	8.9	21.0	6.4

*, ** show significance at the P < 0.05 and P < 0.01, respectively.

The results of mean comparison presented in Table 5 showed that the highest stem height was obtained from the flowers sprayed with Put 2 mM, Spd 1.5 mM, Spm 2 mM, or Spd 0.5 mM (96.5, 100.7, 92.2 and 92.0 cm, respectively). The lowest stem height was observed in the application of Put 3 mM, Put 2 mM + CS 2.5 mM, Spm 1 mM + CS 2.5 mM, Put 1 mM + CS 5 mM, and Put 2 mM + CS mM (71, 73, 69, 72, 73 and 72 cm, respectively) (Table 5).

The application of different levels of PAs and CS led to an increase in flower diameter. The

greatest flower diameter was observed in the treatments with Put 2 mM, Spd 1 mM, Spm 2 mM, Put 1 mM + CS 2.5 mM, Spm 0.5 mM + CS 2.5 mM and CS 2.5 mM (35.4, 40, 35, 33, 35 and 40.5 mm, respectively). On the other hand, the lowest flower diameter was observed in control, Put 1 mM, Spd 0.5 mM, Spm 1 mM + CS 5 mM treatments (30.0, 30.5, 31.5 and 29.5 mm, respectively) (Table 5).

Various treatments had different effects on flower length so that the highest flower length was observed in the flowers sprayed with Spm 2 mM, Put 1 mM + CS 5 mM, Spm 0.5 mM + CS 2.5 mM, or CS 2.5 mM (50.5, 50.5, 49.0 and 49.0 mm, respectively). In addition, the lowest flower length was observed in control, Spd 0.5 mM and CS 5 mM (36.2, 36.6 and 38.0 mm, respectively) (Table 5).

Table 5. Effect of PAs and CS on quantitative parameters of roses in hydroponic culture.

Treatments	Stem height (cm)	Flower diameter (mm)	Flower length (mm)	Stem fresh weight (g)	Vase life (day)
Control	71.0^{f}	30.3^{ef}	36.2^{e}	61cd	15.2^{c-f}
Put 1 mM	82.5^{c-e}	30.6^{d-f}	43.9^{b-d}	64.7^{c-e}	14.2^{c-f}
Put 2 mM	96.5^{ab}	35.4^{a-e}	49.8^{a-c}	67.5^{cd}	15^{a-d}
Put 3 mM	73.0^{ef}	33.8^{c-f}	44.0^{a-d}	30.2^{f}	15.3^{b-d}
Spd 0.5 mM	92.0^{a-c}	31.5^{d-f}	36.6^{e}	56.8^{c-e}	15.8^{ab}
Spd 1 mM	84.3^{cd}	40.1^{ab}	44^{a-d}	92.1^{b}	13^{ef}
Spd 1.5 mM	100.7^{a}	34.8^{b-f}	48.8^{a-c}	58.2^{c-e}	15.3^{a-d}
Spm 1 mM	86.2^{cd}	33.7^{c-f}	47.2^{a-c}	61.1^{c-e}	16^{ab}
Spm 2 mM	92.2^{a-c}	35.5^{a-e}	50.6^{a}	75.7^{bc}	14.5^{b-e}
Spm 4 mM	83.5^{cd}	33.5^{c-f}	43.7^{cd}	119.4^{a}	15.3^{a-d}
Put 1 mM + CS 2.5 mM	76.5^{def}	33.5^{c-f}	45^{abc}	78.9^{bc}	15.5^{a-d}
Put 1 mM + CS 5 mM	73.2^{ef}	36.0 $^{a-d}$	50.5^{ab}	68.1^{cd}	14.8a-d
Put 2 mM + CS 2.5 mM	69.0^{f}	32.7^{d-f}	43.6^{cd}	44.9^{e}	16.2^{a}
Put 2 mM + CS 5 mM	72.3^{ef}	34.2^{c-f}	43.9^{b-d}	63.6^{c-e}	15.7^{a-c}
Spd 0.5 mM + CS 2.5 mM	78.7^{d-f}	38.4^{a-c}	48.9^{a-c}	61.9^{c-e}	15^{a-d}
Spd 0.5 mM + CS 5 mM	82.6^{c-e}	35.0^{b-e}	44.8^{a-c}	47.5^{de}	16^{ab}
Spd 1 mM + CS 2.5 mM	72.0^{f}	35.4^{a-e}	45.8^{a-c}	62^{c-e}	15.3^{a-d}
Spd 1 mM + CS 5 mM	78.7^{def}	29.6^{f}	44.7^{a-c}	58.3^{c-e}	12.6^{f}
CS 2.5 mM	76.7^{d-f}	40.5^{a}	48.8^{a-c}	67.1^{c-e}	13.0^{ef}
CS 5 mM	96.5^{bc}	32.1^{d-f}	38de	50.8^{de}	14 $^{d-f}$

Means with similar letter(s) in each column were not significantly different at the P < 0.01 level according to the LSD test.

The highest and lowest stem fresh weight was observed in the flowers sprayed with Spm 4 mM and Put 3 mM, respectively (119.4 and 30.0 g, respectively). Among the applied PAs, the effect of Spm and Spd was more appreciable than that of Put. PAs are a new group of plant hormones that play role in many biochemical and physiological processes in plants. Increasing growth and stem height of roses can be attributed to the effect of PAs on enhancing cell division, cell elongation, and inter-node length enhancement. The effect of PAs on enhancing stem height and fresh weight of plants has been reported by other researchers too (Abdel Aziz Nahed *et al.*, 2009; Abd El-Wahed and Gamal El-Din, 2004; Hosseini Farahi *et al.*, 2014; Leea *et al.*, 1997; Youssef, 2007). Similar findings have been reported for chrysanthemum (El-Sayed, 2009). Researchers have attributed these results to the naturalization of PAs in a wide range of biological processes such as

growth and development, response to environmental stresses, and cell division and differentiation. Mahros *et al.* (2011) reported that foliar application of Put on chrysanthemum flowers at the rate of 100, 200, or 300 mg/L improved flowering period, yield, stem length, and inflorescence length, fresh and dry weight. In addition, foliar application of 250 mg/L Put on wallflowers significantly increased plant height, leaf number, and leaf fresh and dry weight in the vegetative stage (Youssef, 2007). Spd and stigmasterol increased growth parameters such as plant height, shoot number, and fresh and dry weight of *Chamomilla recutita* L. 'Rausch', but Spd was much more effective than stigmasterol (AbdEl-Wahed and Gamal El-Din, 2004).

Vase life

The results (Table 4) demonstrated that the application of PAs at various rates accompanied with CS had a significant effect on vase life. The results presented in Table 5 indicated that the foliar application of Put 2 mM + CS 2.5 mM, Spm 1 mM and Spd 0.5 mM + CS 5 mM extended the vase life of the plants by 16.2, 16.0 and 16.0 days, respectively compared to other treatments. In addition to their nutritional role, they delayed senescence via inhibition of ACC synthase (Leea *et al.*, 1997). PAs have delayed senescence of gladiolus cut flowers by stabilizing membrane (Dantuluri *et al.*, 2008). PAs delay senescence via prevention of ethylene synthesis. PAs prevent peroxidation of lipids and it may be one of the anti-senescence mechanisms of PAs (Borrell *et al.*, 1997).

PAs can increase leaf starch, protein and RNA in rose flowers and can delay the activity of cellular and peroxidase enzymes in the plants (Sood and Nagar, 2003). Putrescine significantly enhanced vase life of chrysanthemums from 11-13 days in the non-treated plants to 26-27 days in the treated plants due to the increase in the amount of protein in the petals and ovaries in which it can prevent the synthesis of internal ethylene (Mahros *et al.*, 2011). External application of spermidine in the vase solution of carnation cut flowers significantly delayed senescence as it disrupted ethylene mechanism (Tassoni *et al.*, 2006). Sood and Nagar (2003) also reported the prevention of senescence by PAs due to the inhibition of ACC synthase activity.

In a study, the application of calcium chloride improved water relations and vase life and delayed the senescence of rose flowers (Kalatehjari *et al.*, 2008). Investigations have shown that treating with calcium significantly prolongs vase life (Capdeville *et al.*, 2005; Pearson-Mims and Lohr, 1990). Calcium is one of the most important elements in quality enhancement and maintenance of cut flowers. Calcium maintains membrane permeability, thereby contributing to cell wall stability, which delays the aging of cells. Calcium accumulation in plant tissues encourages polymeric connections between middle lamella of pecto-cellulose membrane, and this helps the stability of the cell wall network resulting in the enhancement of tissue mechanical resistance (Hepler, 2005).

Macro element content

The results (Table 6) showed that the application of PAs in various concentrations accompanied with CS had a significant influence on the concentrations of N, P, K and Ca elements in the leaves of roses ($P < 0.01$). Figs. 1 to 4 illustrate that the combined application of Put + CS had better effects on increasing mineral concentrations in the leaves of roses compared with their individual application. The plants sprayed with Put 1 mM + CS 2.5 mM, Put 1 mM + CS 5.0 mM or Put 2 mM + CS 2.5 mM exhibited the highest concentrations of N, P, K and Ca.

Table 6. Analysis of variance of the effect of polyamine on the concentrations of some macro and micro elements in the leaves of roses 'Dolce Vita' in soilless culture system.

SoV	df	MS					
		N	P	K	Ca	Fe	Zn
Replication	2	0.191*	1496.5	3791.4	32.6	3.6	528.3
Treatment	19	1.252**	40783.3**	65952.4**	11737.0**	6500.2**	7519.3**
Error	38	0.049	849.0	3362.6	288.9	126.3	143.5
CV (%)		11.3	7.9	7.4	10.5	13.4	12.7

*, ** show significance at the P < 0.05 and P < 0.01, respectively.

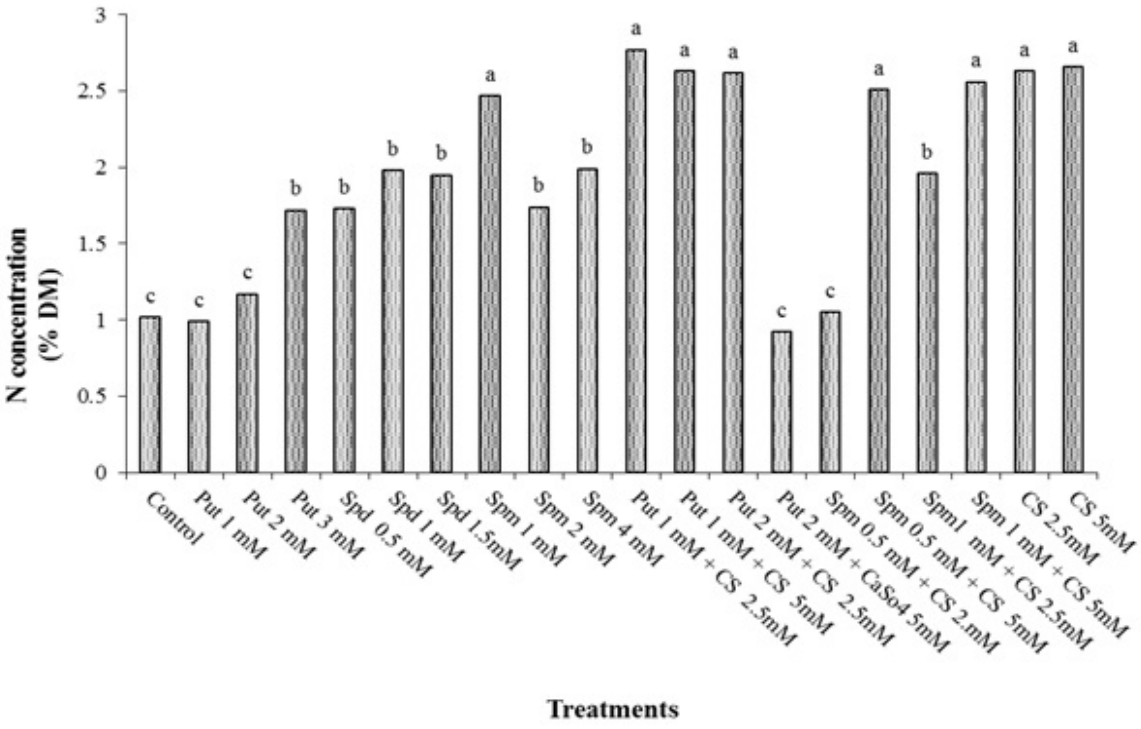

Fig. 1. Effect of PAs and CS on rose leaf nitrogen content. Means with similar letter (s) in each column were not significantly different at the P < 0.01 level according to the LSD test.

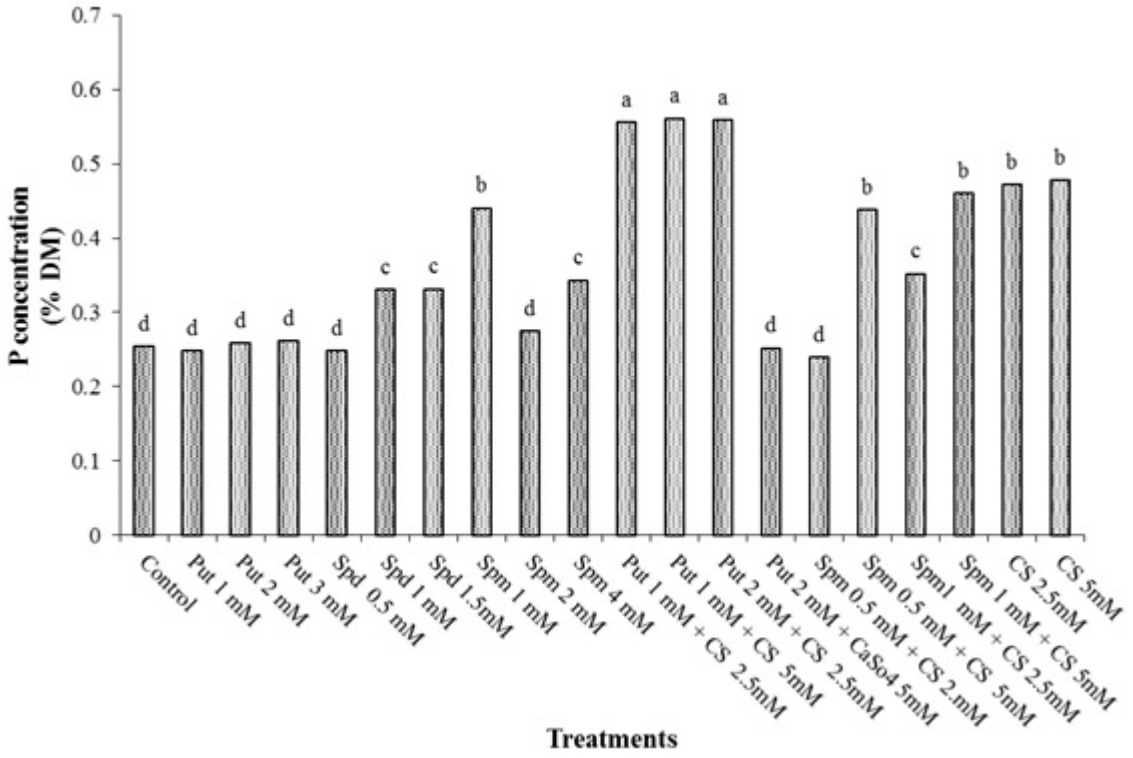

Fig. 2. Effect of PAs and CS on rose leaf phosphorous (P) content. Means with similar letter (s) in each column were not significantly different at the P < 0.01 level according to the LSD test.

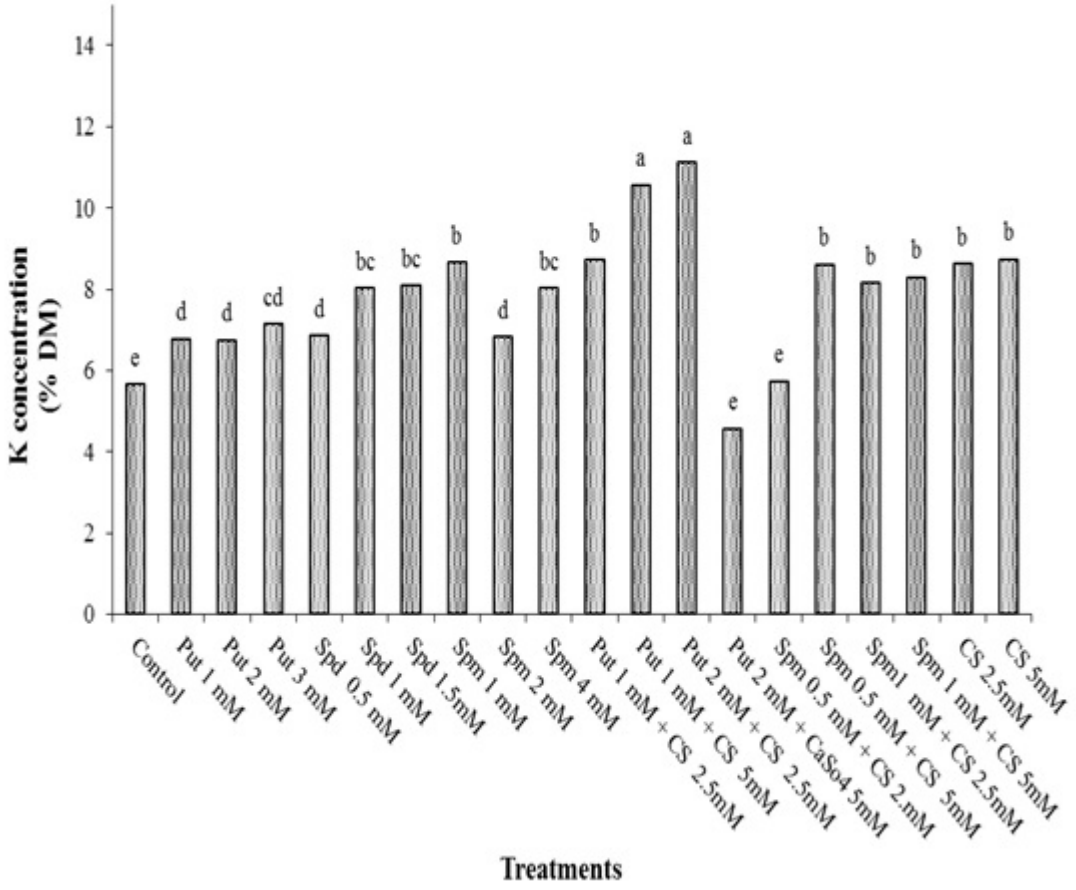

Fig. 3. Effect of PAs and CS on rose leaf potassium (K) content. Means with letter (s) in each column were not significantly different at the P < 0.01 level according to the LSD test.

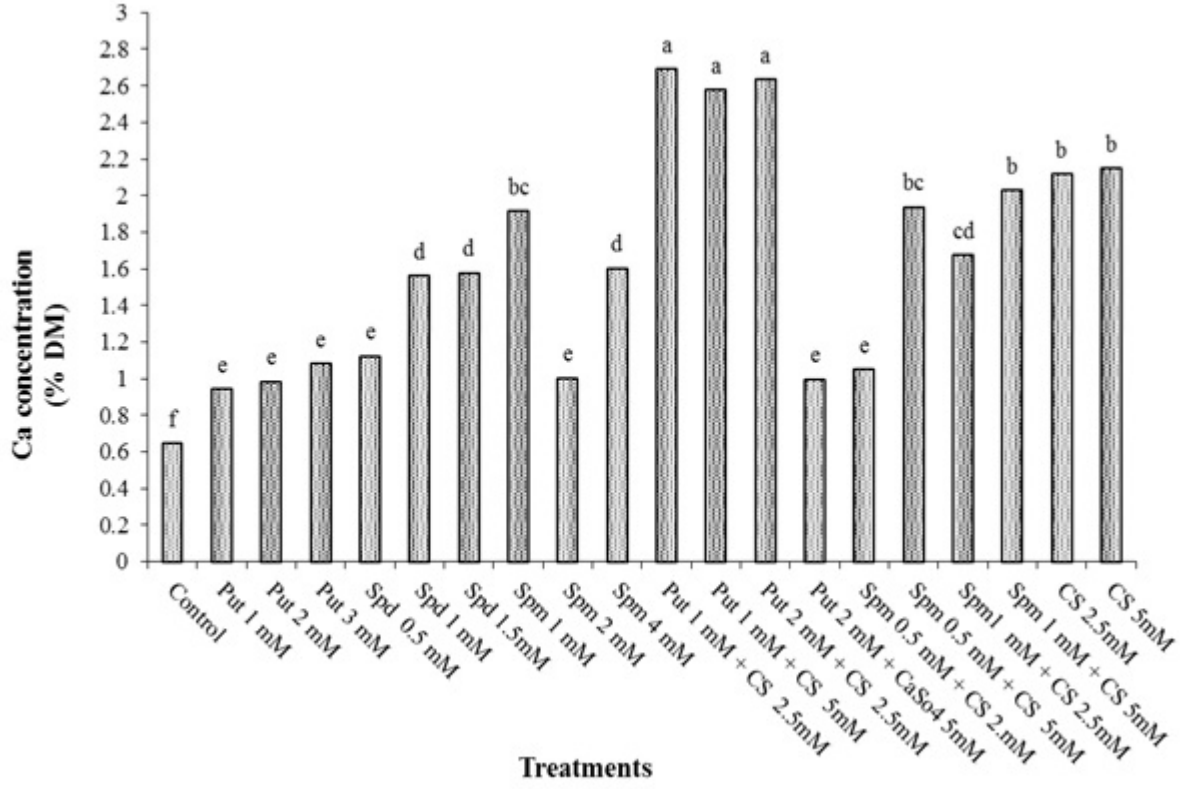

Fig. 4. Effect of PAs and CS on rose leaf calcium (Ca) content. Means with similar letter (s) in each column were not significantly different at the P < 0.01 level according to the LSD test.

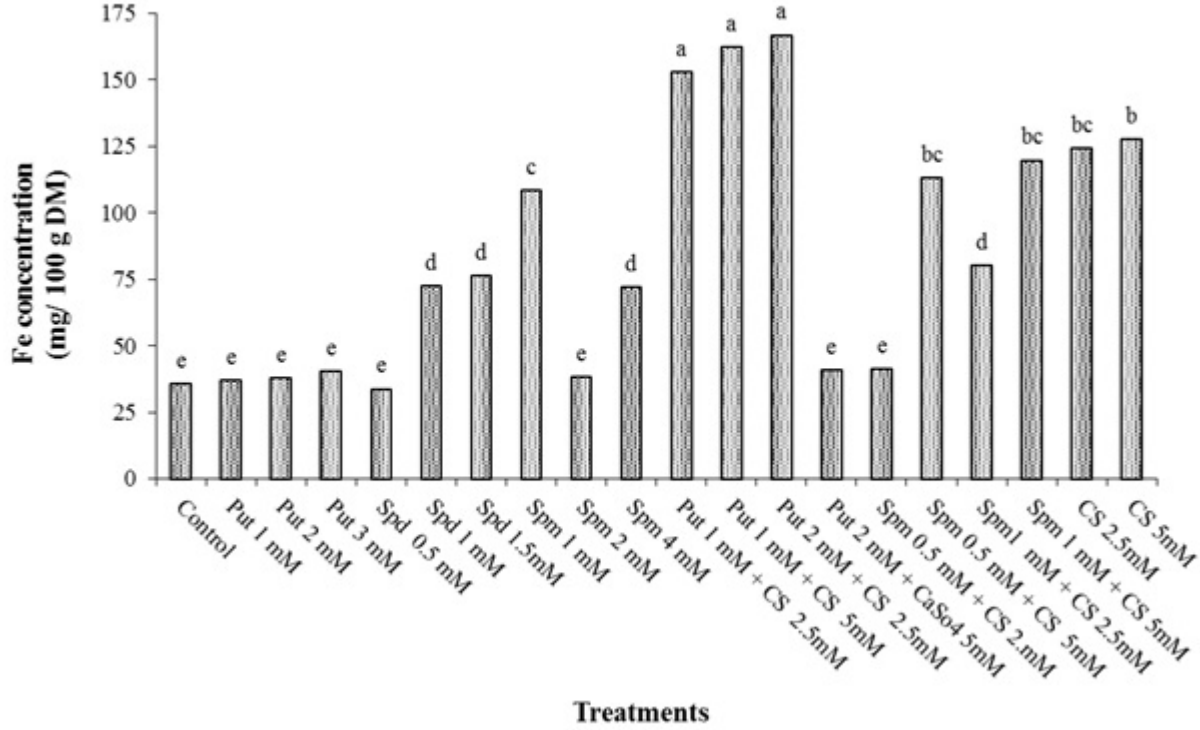

Fig. 5. Effect of PAs and CS on rose leaf Fe content. Means with similar letter (s) in each column were not significantly different at the P < 0.01 level according to the LSD test.

Micro element content

The results of ANOVA (Table 6) showed that the application of PAs in various concentrations accompanied with CS had a significant influence on the concentrations of Fe and Zn elements in the leaves of roses ($P < 0.01$). According to Figs. 5 and 6, the combined application of Put + CS outperformed their individual application in its effect on increasing Fe and Zn concentrations in the leaves of roses. The plants sprayed with Put 1 mM + CS 2.5 mM, Put 1 mM + CS 5 mM or Put 2 mM + CS 2.5 mM had the highest Fe and Zn contents among all treatments.

It seems that PAs can regulate mycorrhiza development or stimulate mycorrhiza formation and growth of fungi mycelium. Exogenous application of Put and Spm significantly increased *Arbuscular* number and application of Spd specially enhanced the number of vesicle sacs. Exogenous application of Put and Spd has significantly increased root and shoot dry weight. PAs regulate plant root development and the interaction of microbes and plant roots, but this function has not been well understood yet (Hummel *et al.*, 2002; Walters, 2000). Anjum *et al.* (2001) reported that the addition of Spd (0.1 or 0.5 mM) to the nutrient solution containing salt and weekly foliar application of Spd on tuberose ornamental flower under salinity stress increased nitrogen uptake by the plants as well as leaf number, chlorophyll, yield, and net photosynthesis. Wu *et al.* (2010) reported that the application of Put plus arbuscular mycorrhizal fungi and inhibitor of Put synthesis enhanced phosphorous content of leaves and roots and the activity of rhizosphere phosphates in *Citrus tangerine* Hort. ex Tanaka. In addition, uptake enhancement of N, P and K elements has been reported in the leaves of *Gladiolus* by foliar application of Put (50, 100 and 200 mg/L) (Abdel Aziz Nahed *et al.*, 2009). Similarly, it has been reported that PAs, especially Put, increased the uptake and accumulation of N, thereby protecting the plants against salinity stress via formation of the components such as amino acids in different biological processes.

PAs increase photosynthesis intensity and root discharge and these enhancements help to better uptake elements by plant roots (Hanafy-Ahmed *et al.*, 2002). In an evaluation of PAs application on uptake of minerals in *Nymphoides peltatum* under Zn deficiency stress, Xue (2008) reported that plants exposed to 100 µM/L Zn deficiency exhibited lower rate of P, K and Na uptake but higher rate of Cu, Mn, Mg and Ca uptake, but exogenous application of Spm and Spd alleviated Zn deficiency.

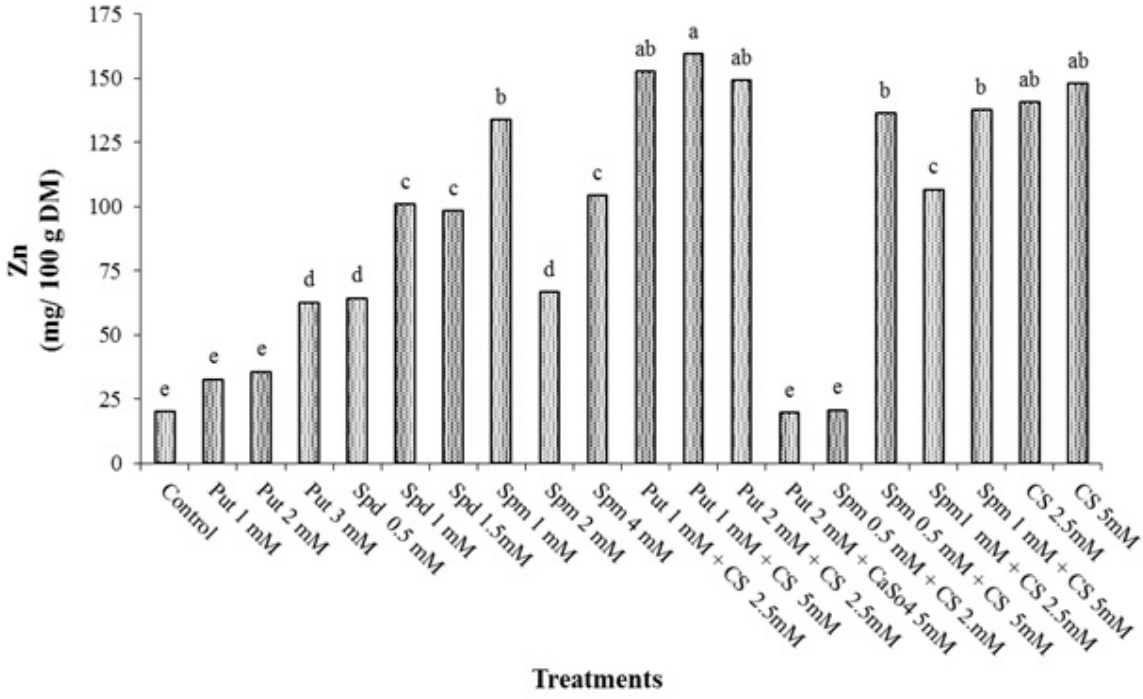

Fig. 6. Effect of PAs and CS on rose leaf zinc (Zn) content. Means with similar letter (s) in each column were not significantly different at the $P < 0.01$ level according to the LSD test.

The results indicated that the addition of Spd (0.1 or 0.5 mM) to the nutrient solution containing salt on Troyer citrange under salinity stress improved leaf nitrogen amount. Mg^{2+}/Ca^{2+} ratio severely improved only when Spd 0.5 mM was added to the salt-containing nutrient solution. Spd application at the rates of 0.1 and 0.5 mM reduced the accumulation of Cl and Cu in the leaves (Youssef, 2007). It has been reported that the foliar application of PAs increased the uptake of some elements, especially K whose vital role in photosynthesis has been manifested by its direct impact on increasing the growth and photosynthesis pigments and uptake of CO_2 (Salama Karima, 1999). The higher rate of uptake of minerals like N, P and K by PAs treatments and promotion of growth and efficiency may be due to the effects of PAs on many biochemical and physiological processes (Shawky Neveen, 2003). PAs increase the activity of metabolic processes in the plants and as such, the physiological function of the plants is improved because of the improvement of root efficiency in absorbing macro elements from soil (Youssef *et al.*, 2004).

CONCLUSION

Generally, our results show that PAs and CS increased quantitative and qualitative characteristics of roses 'Dolce Vita' in soilless culture system due to the increase in the uptake of minerals, so this treatment can be recommended to cut rose producers to improve their production.

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Literature Cited

Abdel Aziz Nahed, G., Taha Lobna, S. and Ibrahim Soad, M.M. 2009. Some studies on the effect of putrescine, ascorbic acid and thiamine on growth, flowering and some chemical constituents of gladiolus plants at nubaria. Ozean Journal of Applied Sciences, 2 (2): 169–179.

AbdEl-Wahed, M.S.A. and Gamal El Din, K.M. 2004. Stimulation effect of spermidine and stigmasterol on growth, flowering, biochemical constituents and essential oil of chamomile plants (*Chamomilla recutita* L. Rausch). Bulgarian Journal of Plant Physiology, 30 (3-4): 48-60.

Abdolmaleki, M., Khosh-Khui, M., Eshghi, S. and Ramezanian, A. 2015. Improvement in vase life of cut rose cv. 'Dolce Vita' by preharvest foliar application of calcium chloride and salicylic acid. Intenational Journal of Horticultural Science and Technology, 21 (1): 55-66.

Anjum, M.A., Naveed, F., Shakeel, F. and Amin, S. 2001. Effect of some chemicals on keeping quality and vase life of tuberose (*Pollianthes tuberose* L.) cut flowers. Journal of Research Science, 12: 1-7.

Bagni, N. and Tassoni, A. 2006. The role of polyamines in relation to flower senescence. Floriculture, Ornamental and Plant Biotechnology, (pp. 88-9.) Global Science.

Borrell, A., Carbonel, L., Farras, R., Puig Parellads, P. and Tiburcio, A.F. 1997. Polyamines inhibit lipid peroxidation in senescing oat leaves. Physiologia Plantarum, 99: 385-390.

Capdeville, G.D., Maffia, L.A., Fernando, L. and Batista, U.G. 2005. Pre-harvest calcium sulfate applications affect vase life and severity of gray mold in cut roses. Scientia Horticulturae, 103: 329-338.

Dantuluri, V.S.R., Misra, R.L. and Singh, V.P. 2008. Effect of polyamines on postharvest life of gladiolus spikes. Journal of Ornamental Horticultural, 1 (1): 66-68.

El-Sayed, M. 2009. Physiological and biological studies on chrysanthemum plant. MSc. Agricultural, Science, Cario. University. Egypt.

Gerasopoulos, D. and Chebli, B. 1999. Effects of pre and postharvest calcium applications on the vase life of cut gerberas. The Journal of Horticultural Science and Biotechnology, 74: 78-81.

Halevy, A.H., Torre, S., Borochov, A., Porat, R., Philosoph-Hadas, S., Meir, S. and Fridman, H. 2001. Calcium in regulation of postharvest life of flowers. Acta Horticulturae, 543: 345-351.

Hanafy-Ahmed, A.H., Gad, M.A., Hassan, H.M. and Amin, M.A. 2002. Improving growth and chemical composition of *Myrtus communis* grown under soil salinity conditions by polyamines foliar application. *In*: Proceedings of 1th Conference for Agricultural and Environmental Science, 25-28 March., Minia, Egypt. pp. 25-28.

Handa, A.K. and Mattoo, A.K. 2010. Differential and functional interactions emphasize the multiple roles of polyamines in plants. Plant Physiology and Biochemistry, 48: 540–546.

Hepler, P.K. 2005. Calcium: A central regulator of plant growth and development. The Plant Cell, 17: 2142-2155.

Hosseinifarahi, M., Dastyaran, M. and Yousefi, F. 2017. Effect of polyameins (PAs) and humic acid (HA) on growth, yield and concentration of mineral elements in shoot and root of strawberry. Iranian Journal of Horticultural Science and Technology, 18 (2): 209-220.

Hosseini Farahi, M., Eshghi, S., Kavoosi, B., Amirifahliani, R. and Dastyaran, M. 2013. Effects of spermidine and calcium sulfate on quantitative and qualitative traits and vase life of rose (*Rosa hybrida* 'Dolce Vita') grown in hydroponic system. Journal of Science and Technology of Greenhouse Culture, 4 (14): 15-26. (In Persian).

Hosseini Farahi, M., Kholdbarin, B. and Eshghi, S. 2014. Effect of NO_3^-: NH_4^+: Urea ratio in nutrient solution on mineral nutrient concentration and vase life of rose (*Rosa hybrida* L.) cut flower in soilless culture. Journal of Science and Technology of Greenhouse Culture, 5 (19): 133-146. (In Persian).

Hummel, I., Coueé, I., El Amrani, A., Martin-Tanguy, J. and Hennion, F. 2002. Involvement of polyamines in root development at low temperature in the subantarctic cruciferous species *Pringlea antiscorbutica.* Journal of Experimental Botany, 53: 1463-1473.

Jowkar, M.M., Kafi, M., Khalighi, A. and Hasanzadeh, N. 2012. Postharvest physiological and microbial impact of hydroxy quinoline citrate as 'Cherry Brandy' rose vase solution biocide. Annals of Biological Research, 3 (5): 2238-2247.

Kalatehjari, S., Khalighi, A., Moradi, F. and Fatahi Moghadam, M.R. 2008. The effects of calcium chloride and calcium nitrate on the maintain quality and vase life of cut rose flowers cv. 'Red Gant'. Iranian Journal of Horticultural Science and Technology, 9 (3): 163-176. (In Persian).

Kusano, T., Berberich, T.T., Tateda, C. and Takahashi, Y. 2008. Polyamines: Essential factors for growth and survival. Planta, 228: 367–381.

Leea, M.M., Leea, S.H. and Parkb, K.Y. 1997. Effects of spermine on ethylene biosynthesis in cut carnation (*Dianthus caryophyllus* L.) flowers during senescence. Journal of Plant Physiology, 151 (1): 68–73.

Mahros, K.M., El-Saady, M.B., Mahgoub, M.H., Afaf, M.H. and Abd El-Sayed, M.I. 2011. Effect of putrescine and uniconazole treatments on flower characters and photosynthetic pigments of *Chrysanthemum indicum* L. plant. Journal of American Science, 7 (3): 399-408.

Martin-Tanguy, J. 2001. Metabolism and function of polyamines in plants. Recent Development (new approaches). Plant Growth Regulation, 34 (14): 135-148.

Mortensen, L.M., Ottensen, C.O. and Gislerod, H.R. 2001. Effect of air humidity and K/Ca on growth, morphology, flowering and keeping quality of pot roses. Scientia Horticulturae, 90: 131-141.

Pearson-Mims, C. and Lohr, V. 1990. Fluoride injury to cut 'Samantha' roses may be reduced by

pulsing with calcium nitrate. Journal of Horticultural Science, 25: 1270-1271.
Salama Karima, H.A. 1999. Amelioration of salinity effect in wheat plant by polyamines. Ph.D. Thesis, Faculty of Agriculture Ain Shams University, Egypt.
Shawky Neveen, B.T. 2003. Physiological studies on the effect of salinity, ascorbic acid and putrescine on sweet pepper plant. Ph.D. Thesis, Faculty of Agriculture Cairo University, Egypt.
Sivaprakasam, G., Singh., V.P. and Arora, A. 2009. Physiological and molecular analysis of effect of spermine on senescing petals of gladiolus. Indian Journal of Plant Physiology, 14 (4): 384-391.
Sood, S. and Nagar, P.K. 2003. The effect of polyamines on leaf senescence in two diverse rose species. Plant Growth Regulation, 39: 155–160.
Tassoni, A., Accettulli, P. and Bagni, N. 2006. Exogenous spermidine delays senescence of *Dianthus caryophyllus* flowers. Plant Biosystems, 140: 107-114.
Thomas, T. and Thomas, T.J. 2001. Polyamines in cell growth and cell death: Molecular mechanisms and therapeutic applications. Cellular and Molecular Life Sciences, 58 (2): 244-258.
Torre, S., Borochov, A. and Halevy, A.H. 1999. Calcium regulation of senescence in rose petals. Physiologia Plantarum, 107: 214-219.
Torre, S., Fjeld, T. and Gislerod, H.R. 2001. Effect of air humidity and K/Ca ratio in nutrient supply on growth and postharvest characteristics of cut roses. Scientia Horticulturae, 90: 291-304.
Valero, D., Martines-Romero, D. and Serrano, M. 2002. The role of polyamines on the improvement of the shelf life of fruit. Trends in Food Science and Technology, 13 (6-7): 228-234.
Wallace, H.M. 2009. The polyamines: Past, present and future. Essays in Biochemistry, 46: 1-9.
Walters, D.R. 2000. Polyamines in plants-microbe interactions. Physiological and Molecular Plant Pathology, 57: 137-146.
White, P.J. and Broadly, M.R. 2003. Calcium in plants. Annals of Botany, 92: 487-511.
Wu, Q.S., Zou, Y.N., Zhan, T.T. and Liu, C.Y. 2010 a. Exogenous polyamines affect mycorrhizal development of *Glomus mosseae-colonized* citrus (*Citrus tangerine*) seedlings. Science Asia, 36: 254–258.
Xiao Ling, X., Zhongshen, W. and Zifa, D. 2007. Effects of polyamines and penicillin on preservation of cut roses. Journal of Nanjing Forestry University, 31 (6): 53-56.
Xue, W.A.N.G. 2008. Effects of polyamines on nutrient element absorption in the leaves of *Nymphoides peltatum* under Zn stress. Journal of Anhui Agricultural Sciences, 30: 016.
Youssef, E.A.E. 2007. Increasing drought tolerance of gladiolus plants through application of some growth regulators. M.Sc. Thesis. Faculty of Agricultural Zaggazig University, Egypt.
Youssef, A.A., Mahgoub, M.H. and Talaat, I.M. 2004. Physiological and biochemical aspects of *Matthiola incana* L. plants under the effect of putrescine and kinetin treatments. Journal of Applied Science, 19 (9B): 492-510.

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