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Effects of K/Ca ratios of Nutrient Solution on Some Physiological Traits and Cut Flower Vase Life of Rose Cultivars (Capitol and Magic Red)

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Abstract
An experiment was conducted to investigate the effects of K/Ca ratios of nutrient solution on physiological traits, cut flower vase life and postharvest changes of rose. The main experiment was factorial based on completely randomized design with two cvs. of rose (Magic Red and Capitol), five K/Ca ratios in the nutrient solution (4:4, 6:4, 6:3, 8:3, 10:2) and three replications. Increasing the K/Ca ratio in the solution led to accumulation of K in the leaves but decreased the Ca concentration of the leaves. Furthermore, K/Ca ratio of the leaves was affected by K/Ca ratio of the nutrient solution and highest ratio of K/Ca was recorded for the leaves of plants fed with nutrient solution of 10:2 K/Ca ratio and the lowest K/Ca ratio of leaves was observed for plants which supplied with the nutrient solutions of 4:4 and 6:4 K/Ca ratios. The highest chlorophyll index was recorded for Capitol cv. and K/Ca ratios of nutrient solution had significant different effects on chlorophyll fluorescence. It was noted that rising K/Ca ratio caused lower longevity of cut flowers in both cvs. The highest necrosis of petals was occurred at 10:2 ratio of K/Ca and Magic Red cv. was more sensitive with the highest percentage of necrosis. The appropriate K/Ca ratio was obtained in the 6:4 ratio in terms of nutritional balance, reduced antagonistic effects of K and Ca, postharvest quality and more longevity of cut flowers.

Keywords: Necrosis; Postharvest; Rose; Vase life

Introduction

Cut flowers are those ornamental crops that their flowers are being harvested along with stems and delivered to the floristic markets. Rose is the first ranking flower in the world (Anonymous 2006) and is so called the queen of flowers. Management of quality and quantity of production is an important goal in greenhouse crops and one of the essential issues in soilless culture is optimizing the formulation of nutrient components in the applied solutions of crop production. According to International Association for Plant Physiology, calcium and potassium are the macronutrients which required more than 0.5 $mMoll^{-1}$ for normal growth of the plants (Bhojwani and Razdan 1983). Potassium, present within plants as the cation K^+, plays an important role in the regulation of the osmotic potential of plant cells. It also activates many enzymes involved in respiration and photosynthesis (Taiz and Zeiger 2002). Calcium ions are used in the synthesis of new cell walls, particularly the middle lamellae that separate newly divided cells. Calcium is also used in the mitotic spindle during cell division. It is required for the normal functioning of plant membranes and has been implicated as a second messenger for various plant responses to both environmental and hormonal signals. In its function as a second messenger, calcium may bind to calmodulin, a protein found in the cytosol of plant cells. The calmodulin–calcium complex regulates many metabolic processes (Taiz and Zeiger 2002).

Potassium and Calcium play important roles in plant growth and in many physiological activities of flowers (Chang *et al*. 2012). A good fertilizer that accelerates Ca uptake enhances the quality of cut flowers (Choi *et al.* 2005). Applying calcium in the vase solution increased the water flow in the xylem of the plant through corporation in the cell walls along with pectin (Van Ieperen and Gelder 2006). Kalateh *et al*. (2008) studies indicated that 0.5% calcium chloride or calcium nitrate in the vase solution resulted in more longevity of cut flowers through delaying senescence related processes by increasing solution absorption, water content of petals and leaves, preserving soluble proteins and carbohydrates of petals and leaves. Torre *et al*. (2001) found that higher ratios of K/Ca in the nutrient solution had a negative impact on the postharvest longevity of rose cut flowers. Placing the harvested cut flowers within the solutions containing higher K/Ca ratios affected their ornamental qualities very rapidly and left undesirable appearance with spotty petals, yellowish and faded leaves. Calcium caused the delay of flower opening during the postharvest time and hence increased the size of the flower. Also, this element enhanced the fresh weight of the flowers and delayed the decline of fresh weight (Halevy *et al*. 2001). Application of calcium sulphate on the rose plants at the preharvest stage by Luiz *et al*. (2005) revealed that the best time for enhancing vase life and control of gray mold disease was 24 hours before harvest with 10 and 20 mM of this compound.

Information on the effects of a K/Ca ratio on physiological characteristics and vase life of rose is relatively scarce. Therefore, the present investigation was conducted to evaluate the effects of K/Ca ratios on the physiological responses and vase life of two rose cultivars.

Materials and Methods

This experiment was carried out at the research hydroponic greenhouse of Faculty of Aagriculture, University of Tabriz, at Karkadj (situated in a cold region at 38º, 30' N, 46º, 17' E and 1567 m mean sea level). The rose plants were purchased at 21st April from a local (37º 51' N, 46º 50' E 1720 m mean sea level) floristic greenhouse and were taken to the experimental site. The plants had been propagated by cuttings and were one-year old with almost same size having one stem of 0.5 cm diameter with 3-4 leaves. The polyhouse cover was a single layer polyethylene and equipped with heating and cooling systems. Each individual plant was transferred to the 10-liters capacity pots containing 4:1 volumetric ratio of perlite and cocopeat and basic maintenance cares (including irrigating with full strength Hoagland solution and plain water) were taken for one month until subjecting experimental treatments. The top of all plants were cut back to about 20 cm above the crown before implementing the treatments.

The experiment was factorial based on completely randomized design with two cvs. of rose (Magic Red and Capitol), five K/Ca ratios in the nutrient solution (4:4, 6:4, 6:3, 8:3, 10:2) and three replications. Treatments components, their

EC and pH ranges were presented in Tables 1 and 2. The solution pH was adjusted using sulphuric acid. The temperature ranged from 20 to 35ºC, humidity and light intensity were about 60% and 500 µ $mol^{-2}S^{-1}$, respectively. The pots were irrigated automatically with nutrient solution and by installed drippers at the bases of the plants with a flow rate of 4 l/h. The solution amount at the beginning of the experiment was 0.5 l/day per plant and increased to 2.5 l/day per plant by growth and development of the plants. The type of hydroponic system used was open and in order to prevent EC and pH increase of the beds, leaching drainage and washing the bed with plain water was done once a week. The experimental treatments were applied for 3 months till 22nd August.

Samples were taken from two randomly selected plants in each treatment per replicate and the potassium content of samples was determined using flamephotometry410 at 766.5 nm wave length and calcium related wavelength of samples was read by atomic absorption instrument (NOVAA 400, Germany) at 422 nm. Chlorophyll index and photosynthesis efficiency were determined by a chlorophyll meter (SPAD-502-Minolta-Japan) and chlorophyll florescence meter (Hansatech Plant Efficiency Analyser), respectively.

Vase life of harvested cut flowers from treated plants was assessed based on daily observation and increasing the percentage of necrotized petals by the time (number of the days after harvest) was used as an indicator of senescence during the postharvest period until almost 70 percent of petals faded or wilted (Pompodakis *et al*. 2004). The necrotized petals percentage was calculated in such a way that a flower was taken randomly and it's total petals counted at the beginning of the vase life evaluation. The proportion of necrotic to intact petals was calculated based on affected and counted total petals of the selected flowers during the vase life monitoring. Analysis of variance was conducted for the measured characteristicsusing SPSS v.16. The means were compared by the Duncan Multiple Range Test.

Table 1. The concentration of nutrients in the nutrient solutions (mg L^{-1})

Treatments K/Ca ratio mM/mM	Nutrient elements											
	Ca	K	N	Mg	P	S	Fe	B	Mn	Zn	Cu	Mo
4:4	160	156	224	60	31	80	3	0.3	0.1	0.1	0.3	0.3
6:4	160	234	224	60	31	144	3	0.3	0.1	0.1	0.3	0.3
6:3	120	234	224	60	31	80	3	0.3	0.1	0.1	0.3	0.3
8:3	120	312	224	60	31	144	3	0.3	0.1	0.1	0.3	0.3
10:2	80	390	224	60	31	144	3	0.3	0.1	0.1	0.3	0.3

Table 2. pH and EC range of applied treatments

K/Ca ratio mM/mM	10:2	8:3	6:3	6:4	4:4
pH	6.5	6.5	6.4	6.6	6.7
EC (dS/m)	2.6	2.6	2.5	2.6	2.5

Results and Discussion

The potassium concentration of leaves was significantly influenced by K/Ca ratio of nutrient solutions and cultivar, but interaction of cultivar × K/Ca ratio of solutions was not significant (Table 3). As indicated in Figure 1, by increasing K/Ca ratio of the nutrient solution, the potassium concentration of leaves was raised. The highest and lowest concentration of K in the leaves was recorded for the plants which used the nutrition solution of containing 10:2 and 4:4 ratios of K/Ca, respectively. According to Figure 2 the highest concentration of K in the leaves of both cultivars (Magic Red and Capitol) was observed using the nutrient solution consisting of 10:2 ratio of K/Ca. Applying the nutrient solution containing higher levels of K caused the lower absorption of Ca and abnormality of the plants (Bartal and Persen 1996). The antagonistic effects of K on Ca was evidenced in rose nutrition studies (Bass *et al*. 1998).

Table 3. Analysis of variance for the effects of K/Ca ratios of nutrient solutions on measured physiological traits of two rose cultivars

Sources of variation	Degrees of freedom	K concentration of leaves	Ca concentration of leaves	K/Ca ratio	Chlorophyll index	Chlorophyll florescence	Vase life
Treatment	4	1314.728**	10.266**	23.219**	20.001 ^{ns}	0.0004*	5.211**
Cultivar	1	1646.591**	22.712**	16.277 ^{ns}	192.027**	0.0 ^{ns}	6.165**
Treatment × cultivar	4	212.432 ^{ns}	3.696*	1.02 ^{ns}	8.746 ^{ns}	0.0 ^{ns}	1.704*
Error	20	134.66	1.237	1.936	9.529	0.0001	0.622

*, ** and ns, significant at the 5% and 1% probability levels and non-significant, respectively

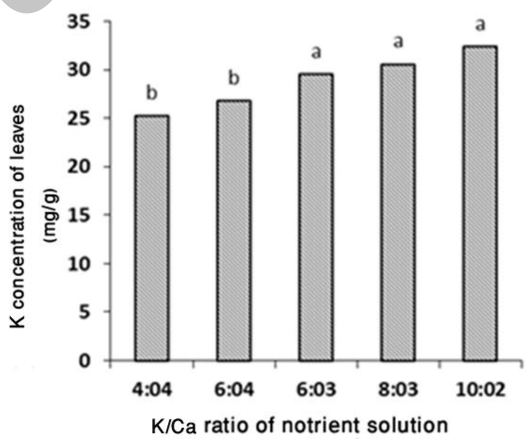

Figure 1. Effect of K/Ca concentration of nutrient solution on accumulation of K in the leaves of rose cultivars. Means with the same letter are not significantly different at p≤0.01 (Duncan's multiple range test)

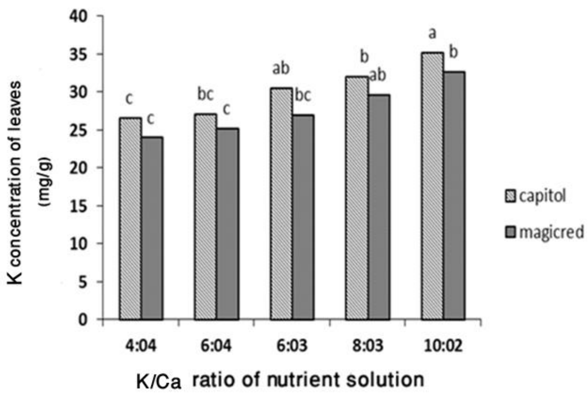

Figure 2. Interaction effect of K/Ca concentration of nutrient solution with cultivar on accumulation of K in the leaves of rose cultivars. Means with the same letter are not significantly different at p≤0.01 (Duncan's multiple range test).

Calcium content of leaves in the rose cultivars grown by applying a nutrient solution formulated with different ratios of K/Ca, was influenced by the cultivar and the interaction of cultivar × K/Ca ratios of solutions (Table 3). As indicated in Figure 3, increasing the ratio of K/Ca in the nutrient solution was led to the reduction of Ca concentration of leaves. The highest concentration of Ca in leaves was recorded in the Magic Red cultivar using 4:4 and 6:4 ratios of K/Ca while for the Capitol cultivar it was observed with the 4:4 ratio of K/Ca.

Opposite effects of potassium on calcium uptake is because of competition of these two cations for the adsorption sites due to their physiological properties (Marshner 1995) which has been proved in different studies (Bar-Tal and Persen 1996). Therefore, by using high concentrations of potassium in the nutrient solution, most of the adsorption sites on the surface of the roots is covered by this element and as a consequence, lower capacity and transport left for Ca. Preventive effects of higher Ca concentration of nutrient solution on K adsorption might be as a result of decreased cell wall permeability (Episten and Bloum 2005). Torreh *et al*. (2001) stated that increasing the K/Ca ratio of nutrient solution lead to Ca reduction of plants. Besides, Ca concentration in rose flowers was significantly higher than that of leaves. Based on Stromme *et al*. (1994) studies on poinsettia (*Euphorbia pulcherrima*), K had a negative impact on the Ca adsorption and consequently severe deficiency of this element was observed as the lesions and necrotized spots on the leaves of this plant.

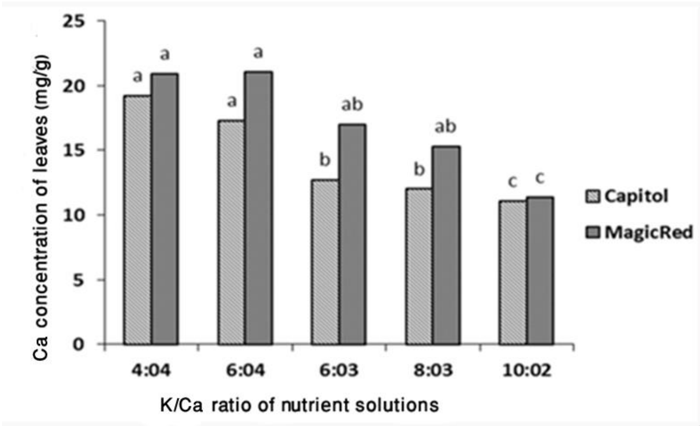

Figure 3. Effect of K/Ca ratio of nutrient solutions on Ca concentration of leaves of rose cultivars. Means with the same letter are not significantly different at p≤0.01 (Duncan's multiple range test).

As the analysis of variance table indicates, K/Ca ratio of leaves was affected by treatments and cultivars, however, their interaction was not significant. Comparing treatment means revealed that increasing the K/Ca ratio of the nutrient solutions raised the K/Ca ratio in the leaves and highest ratio of K/Ca was recorded for the leaves of plants fed with the nutrient solution of 10:2 K/Ca ratio and the lowest K/Ca ratio of leaves was determined for plants which supplied with the nutrient solutions of 4:4 and 6:4 K/Ca ratios (Figure 4).

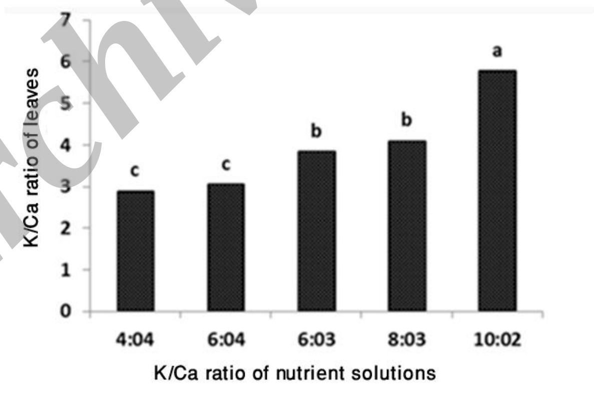

Figure 4. Effect of K/Ca ratio of nutrient solution on K/Ca ratio of leaves of rose cultivars. Means with the same letter are not significantly different at p<0.01 (Duncan's multiple range test).

Chlorophyll index of rose leaves was significantly influenced by cv. but K/Ca ratio of the nutrient solution and interaction of K/Ca ratios × cultivar were not significant for this trait (Table 3). However, chlorophyll fluorescence of rose leaves was significantly influenced by K/Ca ratio of the nutrition solution at 0.05 probability level. Cultivar and interaction of cultivar with K/Ca ratios of the nutrient solution did not have significant effect on the recorded chlorophyll florescence (Table 3). Means of measured chlorophyll florescence differed significantly (Figure 5).

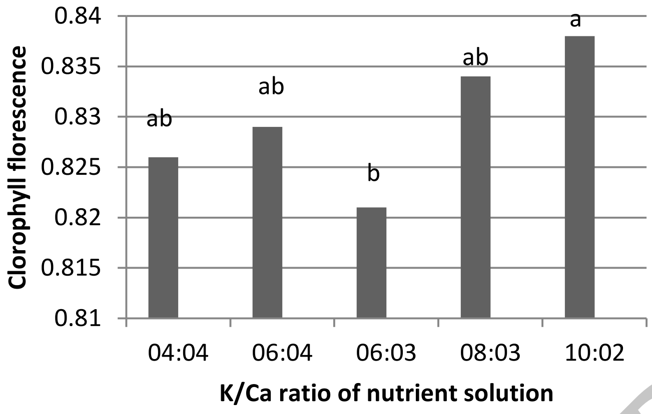

Figure 5. Effect of K/Ca ratio of nutrient solution on chlorophyll florescence of rose leaves. Means with the same letter are not significantly different at p≤0.01 (Duncan's multiple range test).

The analysis of variance results indicated that different ratios of K/Ca, cultivar and interaction of cultivar × K/Ca ratio was significant for the vase life of cut flowers (Table 3) and the highest vase life of cut flowers was recorded for the 6:4 ratio of K/Ca for both Magic Red and Capitol cultivars (Figure 6). Kalateh Jary *et al*. (2008) found that calcium chloride or calcium nitrate (concentration of 0.5 percent) delayed the senescence process by increasing nutrient solution absorption of rose cut flower, enhancing of leaves and petals' water content, preserving water soluble proteins in petals and carbohydrates of leaves and petals and improved the vase life of cut flowers. Van Ieperen and Van Gelder (2006) attributed the water flow rate in the stem of cut flowers to the calcium used in the preservative solution. Mortensen *et al.* (2001) reported that the reduction of K/Ca ratio delayed the flowering of the rose five days and increased the storage life of cut flowers of this crop.

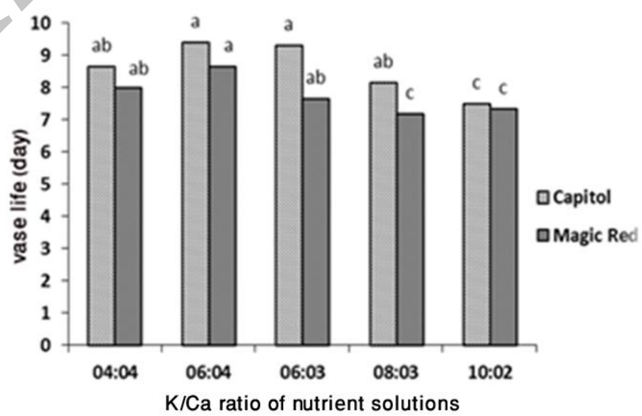

Figure 6. Effect of K/Ca ratios of nutrient solution on vase life of two rose cultivars. Means with the same letter are not significantly different at p≤0.01 (Duncan's multiple range test).

Further analysis of cut flower vase life revealed that K/Ca ratios of nutrient solution, cultivar, time and the interactions of cultivar × time ($p \leq 0.01$) and K/Ca ratios × cultivar ($p \leq 0.05$) had significant effects on the percentage and rate of petal necrosis (Table 4). The highest percentage of petal necrosis was occurred for the 10:2 ratio of K/Ca (Figure 7) and Magic Red cv. was more sensitive than Capitol cv. Also, over the time higher portion of the petals turned to necrosis (Figure 8). Necrosis is the result of local Ca deficiency which is happening by the very low Ca concentration of the nutrient solution or higher K/Ca ratios. Therefore, in order to produce high quality cut flowers it is required that proper level of Ca and K in the leaves and flowers of rose to be maintained (Torre *et al*. 2007).

Table 4. Analysis of variance for K/Ca ratios effects of nutrient solutions on petals necrosis of two rose cultivars at different times

Sources of variation	Degrees of freedom	SS	MS
Treatment	4	306.879	76.72**
Cultivar	1	443.822	443.822**
Time (days)	2	4721.33	2360.665**
Ttreatment × Cultivar	4	76.509	19.127*
Treatment × Time	8	30.419	3.802 ns
Time × Cultivar	2	92.108	46.054**
Time × Cultivar × Treatment	8	12.018	1.502 ns
Error	60	255.99	4.265

*, ** and ns, significant at the 5% and 1% probability levels and non-significant, respectively

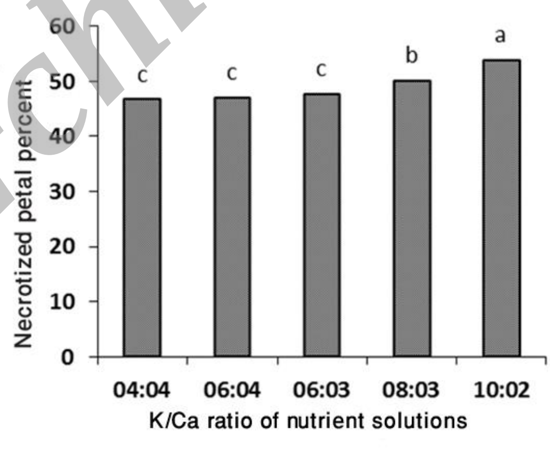

Figure 7. Effect of K/Ca ratios of nutrient solution on necrotizing of petals of rose cultivars. Means with the same letter are not significantly different at p≤0.01 (Duncan's multiple range test).

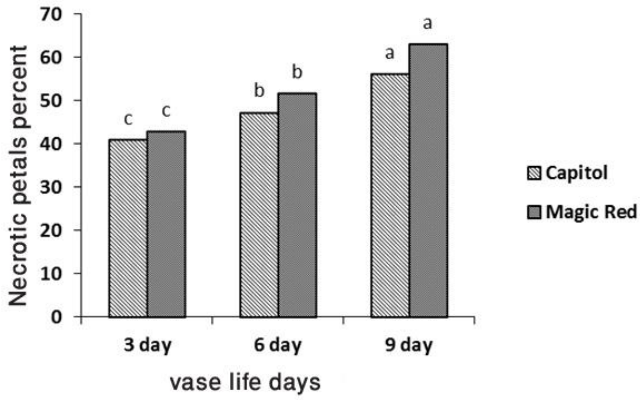

Figure 8. Interactive effect of cultivar and time on necrotizing of rose petals.
Means with the same letter are not significantly different at $p \leq 0.01$ (Duncan's multiple range test).

The results show that reducing the Ca concentration in the nutrient solution leads to an increase of ion leaching. The lower amount of this element due to weakening basic role of Ca in the plant tissues (Lamikanra and Watson 2004) accelerates the senescence and finally tissue necrosis (Poovaiah and Leopold 1973). Calcium can delay the senescence and ripening process of the fruits and vegetables, sustaining the cell wall and membrane through closing the signal path of wounds and prevents wounds and lesion development.

Conclusion

Based on the findings of this research, applying appropriate levels of K and Ca (6 and 4 mM, respectively) in the nutrient solution is recommended for improving the postharvest characteristics and vase life of cut flower of rose cultivars (Magic Red and Capitol).

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