Journal of Ornamental Plants
Available online on: www.jornamental.iaurasht.ac.ir
ISSN (Print): 2251-6433 ISSN (Online): 2251-6441
Research Paper

Evaluation of the Effect of Different Potassium Concentrations in Nutrient Solution on Growth and Postharvest Life of Lily Flowers (Lilium spp.) in Hydroponic Cultivation

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Received: 01 October 2020 Accepted: 25 December 2020

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Abstract

Lilium is scientifically named *Lilium longiflorum* is a cut bulbous flower. In the process of producing lilium flowers, the quality of the flowers has a special importance and one of the most important factors is proper nutrition. Balanced and optimal nutrition is easily possible in hydroponic systems. In contrast, improper management of the nutrient solution significantly reduces plant growth and impairs the quantitative and qualitative production of the product. Nutrients often interact and the diagnosis of deficiency or toxicity of the nutrients is made by experimental studies under controlled conditions. In order to study the effect of different concentrations of potassium on lily growth and postharvest life, a hydroponic experiment based on a randomized complete design with different concentrations of potassium at three levels of 0, 3 and 6 mM in three replicates in planting bed of 40% perlite + 60% sand was performed. The results showed that most of the plant growth indices, especially shoot dry weight, decreased with potassium consumption in nutrient solution, but at a concentration of 6 mM potassium in nutrient solution, postharvest life increased significantly compared to the control.

Keywords: Deficiency, Nutrition, Postharvest.

INTRODUCTION

Among the many types of bulbous plants, lily is one of the unique ornamental plants whose many and colorful flowers are very popular, have a high price and are cultivated as cut flowers or pots in Iran and other countries (Mohammadi Torkashvand and Seyedi, 2016). Lily is the fourth plant in the world after roses, cloves and chrysanthemums (Shiravand and Rostami, 2010). Having a long, strong stem and a green background from the leaves is very important in the marketing of cut flowers such as lilies. In addition to buds, it is necessary to pay full attention to vegetative characteristics when growing flowers. Any decrease in the quality of plant vegetative characteristics will reduce the value of cut flowers (Seyedi *et al*., 2013). Stem length, stem strength and number of flowers per stem are commercially important in flower quality. In terms of quality, stem upright, without curvature or minimal curvature of the stem in the pot or flower basket after harvest is a very important criterion. (Davis *et al*., 2002). In recent years, soilless cultivation has been one of the main cultivation systems among the various techniques used in horticulture and lily flower production. One of the important strategies to achieve maximum yield in the shortest time and with excellent quality is to grow plants in a soilless greenhouse (Alizadeh, 2004).

Supply nutrients for ornamental plants is a rigorous process. In order to use a soilless culture medium with proper drainage and dense production, the grower must provide all the necessary plant elements with the lowest margin of error (Ramezanzadeh *et al*., 2014; Mohammadi Torkashvand *et al*., 2015; Ashourzadeh *et al*., 2016; Majidi *et al*., 2019). Creating a balanced and optimal nutrition in hydroponic systems is easily possible. In contrast, improper management of nutrient solution causes a significant reduction in plant growth and development and impairs the production of quantitative and qualitative products (Khoshgoftar Manesh *et al*., 2007). Due to the difficulties in diagnosing the symptoms of deficiency and toxicity of various nutrients, the diagnosis of symptoms often requires having a history of fertilizer operation, soil type, location and leaf decomposition. Nutrients often interact and the diagnosis of deficiency or toxicity of the nutrient or nutrients is made by experimental studies under controlled conditions. Nutritional experiments on bulbous florets are difficult to perform because the nutrients in bulbs are stored, on the one hand, many soils retain large amounts of nutrients (Seyedi *et al*., 2013). Therefore, to overcome the mentioned nutritional problems, culture experiments in nutrient-free culture media with nutrient solutions are recommended. Proper and optimal nutrition is one of the factors that have an appropriate effect on the quantity and quality of flowers (Naseri and Ebrahimi, 2002).

Potassium is the third major nutrient that is present in many plant processes as a regulator of various physiological reactions and is essential for maximum crop production (Barker and Pilbeam, 2015). In addition to its role in pH stability and osmotic regulation, it is also involved in the production of proteins, transport processes, and the activation of enzymes (Marschner, 1995). The transfer of potassium from the soil to the roots of the plant is one of the most important issues in plant nutrition that most of this transfer is done through mass flow and diffusion (Malakouti *et al*., 2008). Due to the importance of determining the optimal concentration of potassium for lily cultivation, this study was conducted to investigate the effect of different levels of potassium on growth, potassium concentration and longevity of lily cut flowers under hydroponic cultivation.

MATERIALS AND METHODS

The present study in the research greenhouse of IAU, Tehran Science and Research Branch with a temperature range of 15-20 °C and a humidity of about 80% in a factorial experimental based on randomized complete design with different concentrations of potassium in three levels 0 (K_0), 3 (K_1) and 6 (K_2) mM were administered in three replications. In this study, the lily hybrid Asiatic, which produces yellow flowers, was investigated. The pre-ripened bulbs of this flower were planted in a fixed culture medium containing 70% sand and 30% perlite. The Hoagland formula was used to treat the pots with nutrient solution. This formula is a complete nutrient solution that contains micronutrients and macronutrients that are produced in two stages. The first step involves preparing the stock solution from salts containing macronutrients. The salts in Hoagland's formula include potassium phosphate, potassium nitrate, calcium nitrate and magnesium sulfate, which contain six macro elements: Phosphorus, potassium, nitrogen, calcium, sulfur and magnesium and one molar solution of each of them is prepared as the stock solution. By using a certain amount of the stock solution of each salt, a sufficient and required amount of the mentioned nutrients is provided. But to control or change the concentration of application of one or more nutrients, instead of the mentioned salts, potassium sulfate salts (for potassium and sulfur supply), calcium carbonate (for calcium supply), magnesium sulfate (for magnesium and sulfur supply), ammonium nitrate (for nitrogen supply) and phosphoric acid (to supply phosphorus and to some extent to adjust the pH) was used. The main reason for using ammonium nitrate is to supply nitrogen in both nitrate (NO^{3-}) and ammonium (NH^{4+}) forms.

After selecting the type of salt, first, stock solution was prepared and stored separately based on the chemical formula and molecular mass of each salt or acid. Then, to prepare one and a half liters of complete nutrient solution, appropriate and determined amounts of each base solution are taken and mixed together, and then it was brought to a volume of 1.5 liters with distilled water (Table 1).

Table 1. Consumption amounts of macro elements in nutrient solution.

Macronutrients Salts	Potassiumphophate	Nitratepotassium	Calcium nitrate	Magnesium-sulphate	Ammonium nitrate	Calcium carbonate	Potassium sulphate	Phosphoric acid
K_0	1.5*	-	-	3	11.25	-	-	1.5
K_1	1.5	7.5	-	3	3.75	-	-	-
K_2	1.5	15	-	3	-	-	1.5	-
Micronutrient Salts	**Boric acid**	**Manganese chloride**	**Zinc sulphate**		**Molybdic acid**	**Iron chelate**		**Copper sulphate**
	1.5	1.5	1.5		1.5	1.5		1.5

*These amounts are increased to 1.5 liters with distilled water and used to irrigate 6 pots per treatment (250 ml for each pot).

Each treatment had three replications and included six pots. Dissolution was done manually and for each pot of 200 ml. In the first month of planting, the bulbs in the pots went through the production and rooting stages without nutrient solution. Regular solution and in the first month every three days and from the following months, every two days, the solution was prepared and the plant root was dissolved, so that both water and food reach the plant quickly and sufficiently. The following traits were measured at the end of the experiment to evaluate the effect of treatments.

Flowering time: To measure this trait, the number of days from planting bulbs in the pot to the day of harvesting the branches, when at least one of the buds was colored, was counted.

Stem height: The final height of the stem of lily flowers was measured from the surface of the pot to below the peduncle using a meter.

Stem diameter: Stem diameter was measured using a hand caliper in the lower part of the peduncle.

Number of flower buds and number of aborted buds: The number of flower buds is one of the factors of quality and marketability of flowers of lily cut branches. The final number of flower buds in each sample was counted.

Reproductive height: In order to measure this trait, the distance between the lowest petiole to the tip of the tallest flower bud was measured using a millimeter ruler.

Flower diameter: In determining the quality of the lily and its marketability, the diameter of the flowers is of particular importance. Flower diameter was measured using a hand caliper. The measurement of this trait was that the average of the largest and smallest flower diameters in each sample was calculated as the flower diameter.

Number of leaves: The number of leaves from the bottom of the stem to below the peduncle was counted.

Fresh weight of shoots: After cutting the stem from the crown, the branches were transferred to the soil and water laboratory of IAU, Science and Research Branch, and their fresh weight was measured by a digital scale with an accuracy of 0.01.

Dry weight of shoots and flowers: After the end of post-harvest life, the samples were placed at 75 ° C for 48 hours until completely dry and then the dry weight of shoots and flowers was measured by digital scale.

Longevity of cut flowers: The longevity of the pot actually indicates the potential for the duration of the flower in the hands of the consumer. Therefore, when at least one of the buds was stained and bent downwards, the harvest was performed and in order to measure this trait, the cut flowers were placed in distilled water in the horticultural laboratory. The number of days from harvest of cut flowers until 50% of the petals of each specimen had fallen was counted.

Potassium concentration: First, to prepare plant extract, 0.3 g of dried stems and leaves were soaked in an oven with 3 ml of a mixture of sulfuric and salicylic acids for 24 hours, and then the samples were heated to 180 ° C. The temperature was heated and the solution was discolored by the intermittent addition of a little oxygenated water. Then the relevant solution was made up to volume with distilled water and filtered. The prepared extract was used to measure potassium and was measured by flame diffusion (Jenway model flame photometer).

To statistical calculations, SPSS and Excel software were used to analyze the results obtained from the data.

RESULTS AND DISCUSSION

The results showed that the effect of potassium concentration on flower number, number of leaves, stem height, flower dry weight, flower longevity and root length at 5% level, on fresh weight and flower diameter in 1% level was significant. However, stem height, reproductive height, number of buds, number of aborted buds, stem diameter and flowering time were not significant (Table 2).

Tables 3 and 4 show the effect of treatments on plant growth indices. From the point of view of flowering time, the best result was obtained from the application of 3 mM concentration at the rate of 78.6 days, which had a significant decrease compared to the concentrations of 0 and 6 mM potassium in the nutrient solution. One of the signs of potassium deficiency in flocks is delayed flowering (Wilfret, 1980). The effect of different concentrations of potassium in nutrient solution on the stem height of the lily shows that the highest stem height was observed in nutrient solution without K. The average height of the stem at this concentration was 74.6 cm. After this treatment, the highest stem height was from the application of 3 mM potassium concentration and the lowest height was related to the 6 mM potassium concentration, which were not significantly different. A similar result of Rahdari (2011) on the fenugreek medicinal plant has been reported that due to potassium deficiency, the plant stem height increased. Potassium is an important substance in cell expansion and the growth of different parts of plants is the result of potassium concentration in cells and vacuoles (Mohiti *et al*., 2011; Mohammadi Torkashvand *et al*., 2018).

Barker and Pilbeam (2015) believed that rapid plant growth requires adequate potassium, which results in potassium deficiency, cell division, and plant stunting. It seems that the increase in height without potassium is due to the fact that the flower bulbs is a source of nutrients and it is possible that the plant consumes stored elements in the bulbs.

Table 2. The ANOVA analysis of the effect of different concentration of K in nutrient solution on the growth indices of *Lilium*.

S.o.V	df	MS						
		Stem height	**Reproductive height**	**Bud no.**	**Aborted bud no.**	**Flower no.**	**Leaf no.**	**Longevityof cut flower**
K concentration	2	152.2*	36.6 ns	1.35 ns	10.6 ns	28.4*	102.1*	53.4**
Error	10	42.3	34.7	2.10	9.0	9.2	30.1	7.2
CV (%)		14.7	31.6	24.2	45.2	20.2	8.3	13.4
		Stem diameter	**Shoot fresh weight**	**Shoot dry weight**	**Flower dry weight**	**Flower diameter**	**Flowering time**	**Leaf K concentration**
K concentration	2	1.0 ns	546.2**	24.3**	1.02*	10.2**	10.8 ns	354.2**
Error	10	0.7	81.2	5.2	0.27	2.1	8.2	14.8
CV (%)		11.7	12.2	14.3	20.2	32.2	7.6	22.8

*, ** and ns: Significant at P<0.05, P<0.01 and insignificant respectively.

Table 3. Mean comparison of the effect of K concentration in nutrient solution on growth indices of lily.

Treatments	Stem height	Reproductive height	Bud no.	Aborted bud no.	Leaf no.	Stem diameter
K_0	74.6 a*	25.3 a	4.6 a	1.51 a	81.6 b	0.62 a
K_{3mM}	72.3 a	24.1 a	5.2 a	1.61 a	86.2 b	0.61 a
K_{6mM}	68.8 b	22.9 a	4.8 a	1.57 a	89.8 a	0.58 a

*In each column, means with the similar letters are not significantly different (P < 0.05) using the LSD test.

Table 4. Mean comparison of the effect of K concentration in nutrient solution on shoot weight and flower indices of lily.

Treatments	Shoot fresh weight	Shoot dry weight	Flower dry weight	Flower no.	Flower diameter	Flowering time
K_0	92.1 a*	8.2 a	2.1 a	4.2 a	11.2 b	82.6 a
K_{3mM}	89.2 a	7.6 ab	2.0 a	4.0 a	12.9 ab	78.6 a
K_{6mM}	82.3 b	7.5 b	1.8 b	3.7 b	15.1 a	84.8 a

*In each column, means with the similar letters are not significantly different (P < 0.05) using the LSD test.

The highest number of flower per plant using different levels of potassium concentration was related to the concentration of zero mM potassium, which was not significantly different from 3 mM. Mohammadi Torkashvand and Kaviani (2014) in the study of three levels of 0, 50 and 100% of potassium concentration in nutrient solution on the growth of *Camellia* ornamental plant, reported that there was no significant difference between different levels of potassium on the number of flowers. The highest flower number was related to without potassium and the lowest number was related to the application of two treatments of 3 and 6 mM potassium in nutrient solution. Kiani *et al.* (2009) stated that the application of potassium in nutrient solution at a rate of 5 mM L^{-1} has led to an increase in rose yield compared to the level of 10 mM l^{-1}. Potassium affects crop production by increasing metabolic processes and plant growth (Bennett, 1993; Barker and Pilbeam, 2015).

The results show that increasing potassium in nutrient solution has no positive effect on growth index such as flower number. Considering the role of potassium in the reproductive growth of the plant, it seems that the reason in this study is the nutritional imbalance created in the nutrient solution. Treder *et al*. (2008) stated that consuming small or large amounts of nutrients leads to disruption of plant cell functions. The highest number of leaves with 89.2 was obtained from treatment with a concentration of 3 mM potassium in nutrient solution. The result of the present study is consistent with the results of Mohammadi Torkashvand and Kaviani (2014) that 50% potassium in nutrient solution had the greatest effect on increasing the number of leaves compared to zero and 100% potassium in solution. Aslam Khan and Iftikhar Ahmad (2004) evaluated the effect of different levels of NPK on the growth and flowering characteristics of gladiolus, concluded that the appropriate amount of potassium and phosphorus increases vegetative growth indices including the number of leaves. Potassium, as an active enzyme in many important metabolic processes in plants, is important for phloem transport, osmotic balance and photosynthesis. Therefore, potassium has a positive effect on the quantity and quality of the product (Mohammadi Torkashvand *et al*., 2018).

According to the results, the highest stem diameter was obtained from a concentration of 6 mM potassium at 0.62 mm that the three levels of potassium in the nutrient solution were not significantly different. Bani Jamali (2004) investigated the effect of nutrition of potassium sources and trace elements on the quantitative and qualitative yield of chrysanthemums and showed that the treatment of 180 kg ha^{-1} of potassium oxide was superior to the control. Potassium is an important substance in cell expansion and the growth of different parts of plants is the result of potassium concentration in cells and vacuoles (Marschner, 1995). Due to the role of potassium in the formation of thicker cell walls in epidermal cells, it will increase the diameter of the stem. The maximum fresh weight of shoots was observed in a solution with a concentration of zero mM potassium at the rate of 92.1 g, there was no significant difference with a concentration of 3 mM. However, the fresh weight of shoots was significantly reduced to 89.2 g by applying a concentration of 3 mM potassium and the minimum weight was obtained from a concentration of 6 mM potassium with 82.3 g, which was obtained by solution. Rahdari (2011) in a study on the fenugreek medicinal plant reported that due to potassium deficiency, fresh weight of roots and shoots increased significantly. The highest shoot dry weight was related to the concentration of zero mM potassium at 8.2 g and the lowest value was related to the concentration of 6 mM potassium at 7.5 g.

In most plant species, potassium plays a major role in changes in turgor pressure within stomatal cells. Increasing the concentration of potassium in the stomatal cells leads to the uptake of water from the cells and with it, increases the turgor pressure of the stomatal cells and thus leads to the opening of the stomatal cells, also in the accumulation and transport of carbon hydrates has a role. It is caused to gain dry weight (Malakouti, 2008; Barker and Pilbeam, 2015). It seems that the reason for the inverse result in this study is either due to nutritional imbalance or it may be that the plants use the potassium in flower bulbs for their growth from. Also, the highest dry weight of flower was related to the solution with a concentration of 3 mM potassium at 2.1 g and the lowest amount was related to the solution with a concentration of 6 mM potassium at 1.8 g. The results of this study showed that the best result in terms of dry weight of flowers was obtained in the use of 3 mM potassium in nutrient solution. The results of Daneshkhah *et al*. (2007) on damask rose of Barzak Kashan cultivar have shown that among the levels of potassium

0, 30 and 60 kg ha^{-1}, 30 kg ha^{-1} of potassium on flower diameter, fresh weight and dry weight of flower was significant. This is probably due to the role of potassium in the production of carbohydrates and proteins, in cell division and growth in the plant (Mohammadi Torkashvand *et al*., 2018).

In the present study, the effect of different levels of potassium concentration in nutrient solution on the diameter of lily flowers shows that the highest amount of flower diameter is related to the concentration of 6 mM potassium with 15.1 cm and the lowest amount is related to the concentration of 0 mM potassium with 11.2 cm. Daneshkhah *et al*. (2007) in a study on damask rose flower reported that different levels of potassium had a significant increase on characteristics such as flower diameter and number of flowers. Potassium is an important substance in cell expansion and causes growth in plants due to its accumulation in cells (Marschner, 1995; Barker and Pilbeam, 2015).

Fig. 1 shows the effect of potassium concentration on the longevity of cut lily flowers. Flowers grown at a concentration of 6 mM potassium in nutrient solution with 13.82 days and in nutrient solution without potassium with 11.65 days had the highest and lowest vase life, respectively. According to the results of this study, increasing the concentration of potassium in the nutrient solution has increased the vase life of flowers in lilies. The result of this research is consistent with the results of Shariati (2011) in tuberose. He reported that the maximum life after harvesting flower from potassium levels of 50 and 100 kg ha^{-1} was 21.3 and 20.3 days, respectively. Also, potassium-based treatments had a lifetime mutation compared to basal potassium-free treatments. Also, Bani Jamali (2004) studied the effect of different levels of potassium and nitrogen on the quantitative and qualitative characteristics of gladiolus and concluded that the best post-harvest life of 200-300 kg ha^{-1} compared to 0 and 100 kg ha^{-1} were obtained. There are many components involved in postharvest life, of which nutritional conditions are one of the most important (Mohammadi Torkashvand and Seyedi, 2016; Ramezanzadeh *et al*., 2014; Majidi *et al*., 2019). The role of endogenous sugars in extending flower life is well known. Sugars improve the water balance in the plant and are effective in regulating the pores, thereby reducing water evaporation. Sugars improve the osmotic potential and increase the amount of carbohydrates needed for growth and respiration. This facilitates the opening of the petals and delays aging. On the other hand, they inhibit the production of ethylene in flocks and reduce their sensitivity to ethylene (Barker and Pilbeam, 2015).

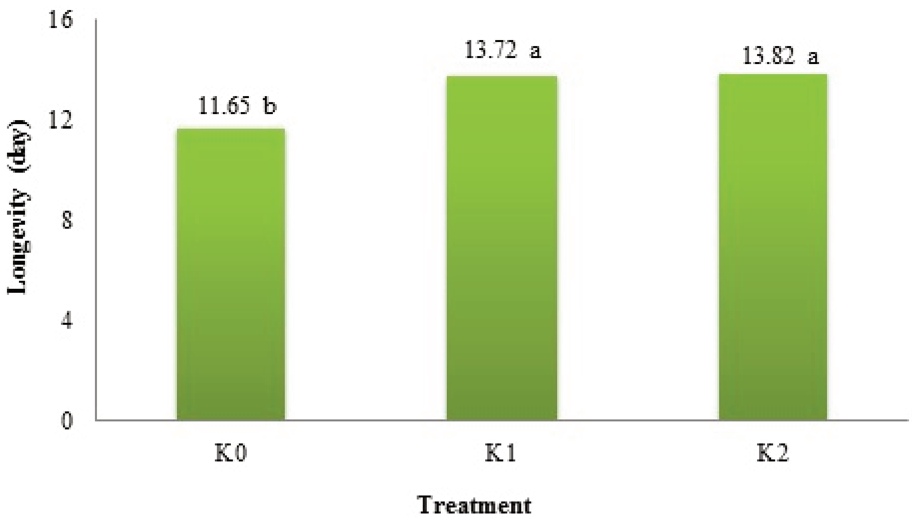

Fig. 1. The effect of potassium concentration on flower longevity.

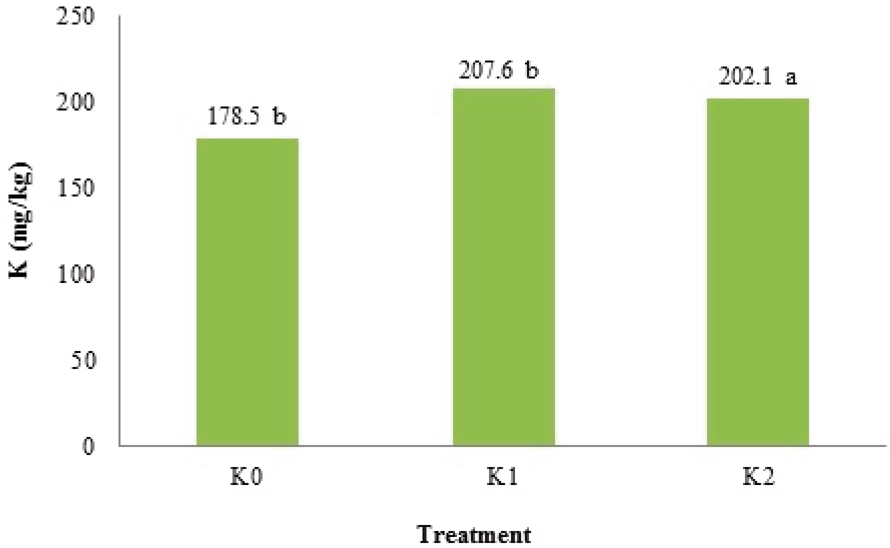

Fig. 2. The effect of potassium concentration on shoot K concentration.

According to Fig. 2, the highest uptake of potassium was observed in a 3 mM potassium solution with 207.6 mg in a pot. The lowest potassium uptake was obtained from solution feeding without potassium which was 178.5 mg in a pot. But no significant difference was observed between 3 and 6 mM concentrations of potassium in the nutrient solution.

In general, increasing the amount of potassium in the nutrient solution led to a significant increase in the concentration of potassium in the stems and leaves of lily flowers at the level of one percent. Increasing the concentration of potassium in different parts of the plant as a result of increasing the amount of potassium in nutrient solution in studies conducted in cut roses by Torre *et al*. (2001) and in potted roses by Mortensen *et al*. (2001) have also been reported. The high mobility of this element in plant tissues and its transmission through phloem vessels (Barker and Pilbeam, 2015; Mohammadi Torkashvand *et al*., 2018) can be a reason for this. Kiani *et al*. (2011) in investigating the effect of different levels of potassium and calcium on the absorption of nutrients in roses reported that with increasing the amount of potassium in the nutrient solution, the concentration of potassium in different parts of the plant increases.

CONCLUSION

According to the results, increasing the concentration of potassium in the nutrient solution did not increase plant growth. It seems that the lack of increased plant growth in nutrient solutions containing 3 and 6 mM is due to the storage of nutrients in lily bulbs. But postharvest life in potassium-containing nutrient solution was significantly increased compared to control (potassium-free nutrient solution). Therefore, in bulbous flowers such as lilies, adding potassium to the plant nutrient may not be effective in increasing growth, but it can increase the longevity of the flower, which is very important for the producer.

ACKNOWLEDGMENT

This research has been carried out in the greenhouse of IAU, Science and Research Branch, Tehran, appreciated due to facilities and equipment's.

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How to cite this article:

Sahari Moghadam, A. and Seyed Nasir, S. 2020. Evaluation of the Effect of Different Potassium Concentrations in Nutrient Solution on Growth and Postharvest Life of Lily Flowers (*Lilium* spp.) in Hydroponic Cultivation. *Journal of Ornamental Plants,* 10(4), 253-262.

URL: http://jornamental.iaurasht.ac.ir/article_678651_2b0e141231aa90095359c163ba30829c.pdf