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# Foliar Application of Potassium Nitrate and Silicate Can Improve the Fruit Quality of Pomegranate cv. 'Malase Yazdi'

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## ABSTRACT

***Introduction:*** Pomegranate is an ancient fruit plant, that nowadays there is an increasing worldwide demand for this fruit owing to its superior pharmacological and therapeutic properties. Foliar nutrient applications could potentially be used in commercial pomegranate production, to improve fruit quality. Therefore, the current study was conducted to investigate the physicochemical properties of pomegranate fruits under foliar spraying of potassium nitrate and silicate.

***Materials and Methods:*** The twenty years old uniform pomegranate trees cv. 'Malase Yazdi' that have grown on a commercial orchard in Ardakan, Iran were selected during the 2017–2018 growing seasons. Five levels of potassium spraying treatments were used. The foliar spray treatments included: 250 and 500 mg/l potassium nitrate; 250 and 500 mg/l potassium silicate and distilled water (control). The foliar spray was carried out two times. The first stage was after the conversion of most of the flowers to the fruit and when fruits reached about walnut size, from June to July, and the second stage of the foliar application was at the end of the fruit growth, in mid-September. At the time of the harvest, healthy fruits were taken from the middle of the crown of each tree in different directions, and qualitative and quantitative characteristics of the harvested fruits were analyzed. Physicochemical properties such as fruit and total aril weight, seed dry weight, peel fresh weight, fruit volume and juice, soluble solids concentration (SSC), maturity index, color, total phenol content, and vitamin C were investigated.

***Results and Discussion:*** Results showed that all of foliar treatments increased fruit volume and weight, total aril weight, fruit juice, and color and decreased seed dry weight, compared to control treatment (without nutrient treatment). $KNO_3$ (250 mg/l) increased SSC and maturity index and 500 mg/l $KNO_3$ increased both valuable characteristics: total phenol and vitamin C content. Also potassium silicate improved vitamin C content compared to the control treatment.

***Conclusion:*** The nitrogen in potassium nitrate increases the amount of the carbohydrate reserves that affects the fruit growth and development, thus reducing water stress and competition between fruits, which leads to the increased growth and development of fruits. The use of foliar application of potassium silicate has many advantages in enhancing the leaf area and improving the efficiency of photosynthesis and increasing the plant's ability to increase growth and yield and to increase strength, and reduce temperature stress. Therefore, according to these results, and due to the increasing global desire to use pomegranate fruit because of its high nutritional value, foliar application of potassium nitrate and silicate is recommended in pomegranate orchards.

## Introduction

Pomegranate is one of the oldest known edible fruits with a high nutritional value, that is native to central Asia such as Iran and widely cultivated in Mediterranean basin, Asia, Australia, South America, and Africa (Holland et al., 2009; Levin, 2006). The edible portion of pomegranate fruit has approximately comprised of 80% juice and 20% seeds. Fruit and arils' color, sweetness, acidity, astringency, seed hardness, and juice content are some of the factors that determine the consumer preference. Pomegranate fruit is a rich source of bioactive compounds such as flavonoids, phenolic acids, and vitamin C, which are found mainly in the skin, sponge tissue and the juice. Pomegranate is commonly used as fresh fruit or fruit juice. Also, the fruit is used in the food industry for the production of jelly, concentrates, flavors, and coloring materials (Faria and Calhau, 2010; Mphahlele et al., 2014; Pande and Akoh, 2016). Pomegranate is compatible with cold and warm summers. But the plant can adapt to a wide range of weather conditions. The plants can be heavily damaged by temperatures below -11°C (Kahramanoglu and Usanmaz, 2016). There is no precise information on the level and production of pomegranates in the world due to the rapid increase in its production and development (Chandra et al., 2010). Currently, 90 percent of the pomegranate production is occurring in the northern hemisphere, but there is an expanding export opportunity for southern hemisphere countries to provide fruit to the market during the opposition season. South Africa is one of the pomegranate producers in the southern hemisphere (Erkan and Dogan, 2018). Nutrition of pomegranate is one of the important factors in improving the quality and quantity of the fruit. According to the researches, there is a significant positive correlation between nutrient elements and fruit quality characteristics, which shows the importance of leaf spraying in improving the fruit characteristics (Dialamy et al., 2012; Hamouda et al., 2016; Sedaghatkish et al., 2012). Understanding the nutritional needs of pomegranate trees and the role of each of these elements in the plant metabolism cycle, plays an important role in managing and maintaining pomegranate gardens. In recent years, foliar application has become more common in fruit trees, a highly efficient method that results in the uniform distribution of nutrients and the rapid response of the tree to the use of them (Thirupathi and Ghosh, 2015).

Nitrogen is a component of the macro-elements and the most abundant element in the atmosphere, it is also among the most used elements that stimulates the growth of the tree. Nitrogen plays an important role in the growth of the tree, and if this attribute was properly managed in the cultivated trees, they could improve the ability to maximize flower and yield production (Rao and Subramanyam, 2009). Bakeer (2016) found that ammonium nitrate fertilizer and/or calcium chloride alone or in combination, was effective in increasing the fruit quality traits of pomegranate cv. 'Manfalouty' (Bakeer, 2016).

Potassium is also a component of the macro-elements that plays an important role in improving the plant growth. Its main effect is increasing the plant's nutritional value and increasing the plant resistance to pests and diseases; additionally, it improves the fruit color, appearance, form and taste, and plays an important role in photosynthesis. Potassium could maintain the tissue water and, increase the relative content of the leaf water under salinity conditions (Marschner et al., 1996). In addition, latent potassium deficiency is easily managed through spray application. Potassium uptake through leaf spraying is more efficient than potassium adsorption through the soil. Potassium-balanced levels in the plant increase the loading rate of the phloem, nutrient transfers, and sucrose drainage (Lester et al., 2005).

Silicon is an element that is abundant in most soils in the world, and is the second most abundant element in the soil after oxygen. Silicon in plants increases growth, photosynthesis, leaf firmness, chlorophyll content in leaf, and product quality, and decreases evaporation and transpiration

(Richmond and Sussman, 2003). The foliar spraying application is recommended due to the lack of cost, quick fixes of deficiency symptoms, lack of movement of some nutrients in the tree, especially in the phloem to transfer to the sinks (flowers and fruits) such as boron, calcium and zinc, low consumption, high performance under unfavorable conditions (calcareous soils), increasing fruit yield and quality and increasing drought resistance. The chemical content of the pomegranate fruit depends on the cultivar, the conditions of fruit growth, the climate of the region, the fruit's maturity, and agricultural practices. Nutrients are very effective in improving the plant growth and decreasing the deficiency in pomegranate fruit. In pomegranate, potassium, manganese and magnesium, are essential nutrients that are important. In addition, the chemical properties of fruits such as SSC, sugar, vitamin C and the content of anthocyanins play an important role in the quality of post-harvest fruits (Hamouda et al., 2015). In one research, the results showed that the highest soluble solids concentration (SSC) and vitamin C were related to 250 mg/l potassium nitrate treatment, on top of that, potassium nitrate has a significant effect on increasing the quality of the fruits in the early stages of growth (Khayyat et al., 2012). An experiment was conducted to investigate the effects of different potassium concentrations on the pomegranate fruit quality parameters. Results showed that trees that received the highest potassium content had higher titratable acidity and higher SSC than the rest (Tehranifar and Mahmoodi-Tabar, 2009). Considering the fact that nutrition of pomegranate is one of the important factors in improving the quality and quantity of fruit parameters, and given that in recent years, foliar application of nutrients has become more common, this study intended toinvestigat the effects of potassium nitrate and silicate foliar application on the quantitative and qualitative properties of pomegranate fruit cv. ‘Malase Yazdi’.

## Materials and Methods

### Experiment treatments

The current study was carried out on a commercial pomegranate orchard in Ardakan, Iran (32°20′N, 53°46′E), during 2017 and 2018 growing seasons. The physicochemical properties of the soil are illustrated in Table 1. Twenty years old ‘Malase Yazdi’ pomegranate trees were grown in 2 x 3 m spacing. This experiment was designed as a randomized complete block design with five levels of treatment. For each level, four one-tree replications were considered. The effect of two fertilizers (potassium nitrate and potassium silicate) with two concentrations (250 and 500 mg/l) in pomegranate cv. ‘Malase Yazdi’ was investigated. The foliar spraying treatments were applied including five levels [250 mg/l potassium nitrate; 500 mg/l potassium nitrate; 250 mg/l potassium silicate; 500 mg/l potassium silicate; distilled water (control)]. Tween-20 at 0.1% concentration was added to all the treatments.

The foliar spraying treatment was carried out two times. The first stage of foliar application was after the conversion of most of the flowers to the fruit and the fruits reached about a walnut size, which depending on the weather conditions, was carried out from June to July; the second stage of the foliar application, at the end of the fruit growth, for the purpose of increasing the quality of fruit, was carried out in mid-September. At the time of harvest, the healthy fruits from each tree were taken from the middle of the crown of the tree in different directions. The qualitative and quantitative characteristics of harvested fruits were then investigated through the following determinations:

### Physical parameters

Fruit fresh weight (g), peel fresh weight (g), total aril weight (g), seed dry weight (g) and fruit juice volume (ml) were analyzed. The fruit volume ($cm^3$) was measured by the direct placement of water (Westwood, 1993).

**Table 1.** Physico-chemical properties of soil (0-30 cm)

| Texture | EC (ms/cm) | Organic carbon (%) | N (%) | P (ppm) | K (ppm) | Ca (meq/l) | Mg (meq/l) | Na (meq/l) | Cu (ppm) | Zn (ppm) | Fe (ppm) | Mn (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sand | 2.52 | 1.22 | 0.10 | 23.3 | 254.4 | 6.8 | 4.2 | 15.2 | 0.18 | 0.18 | 0.6 | 2.2 |

## Chemical parameters

Soluble solids concentration (SSC) was measured by using a manual refractometer (N1, Atago). Maturity index was obtained by dividing the soluble solids to titratable acidity. For measuring the total phenol, 300 µl of centrifuged pomegranate juice was removed, and 1500 µl of the diluted solution of Folin-Ciocalteau detector was added. After 5 minutes, it was added to 1200 µl of 7% sodium carbonate. Subsequently, after 90 minutes of shaking at room temperature, the absorbance of each sample was measured by a spectrophotometer at 765 nm wavelengths, and then the data reading device was applied for drawing the gallic acid calibration curve (Singleton et al., 1999). Vitamin C was analyzed by using 2,6-dichlorophenol indophenol method (Ting and Rouseff, 1986). The fruit juice color was measured by grading (Ayala-Zavala et al., 2007).

Data analysis variance was performed using SAS v.9.1 software, and the mean comparison of data was done based on the Duncan test at 5% probability level.

## Results and Discussion

According to the analysis of the variance results, the nutrition treatments had significant effects on the physico-chemical fruit properties (Table 2 and 3).

### Fruit Physical Properties

Table 4 illustrates that the fresh weight of pomegranate fruits was affected by the nutrient treatments and increased from 232.13 g in untreated fruits to 296.85 g in fruits treated with 500 mg/l potassium silicate treatment; other levels of the nutritional treatments also significantly increased the weight of the fruit compared to the control treatment. According to the results of Table 4, it was found that the least fruit volume was observed in the control treatment with an average of 234.35 $cm^3$ and all the levels of nutrition treatments significantly increased the fruit volume compared to the control. All treatments, significantly increased the total weight of arils. The lowest amount of this attribute was observed in the untreated fruits (control) with an average of 142.08 g (Table 4). The highest amount of juice was produced in 500 mg/l potassium nitrate treatment (122. 5 ml), which did not significantly differ from the other three levels of nutrition, which was significantly different from the control treatment with an average of 97 ml. The presented results in Table 4 showed that 250 mg/l potassium nitrate and 500 mg/l potassium silicate produced the highest amount of the fresh weight of the peel compared to the control (55.05 g).

**Table 2.** Analysis of variance for fruit physical properties

| Source of variance | df | MS: Fruit weight | Fruit volume | Total aril weight | Fruit juice volume | Seed dry weight | Peel fresh weight |
|---|---|---|---|---|---|---|---|
| Treatment | 4 | 3028.79* | 3494.31* | 791.66* | 402.7* | 46.33* | 571.23** |
| Replication | 3 | 138.43 | 394.6 | 225.35 | 163.91 | 1.21 | 393.01 |
| Error | 12 | 577.14 | 673.13 | 322.4 | 96.43 | 10.23 | 55.93 |
| C.V. (%) | | 5.88 | 11.9 | 9.06 | 8.65 | 4.8 | 10.94 |

* and **: Significant at the 5 and 1% levels of probability, respectively.

**Table 3.** Analysis of variance for fruit chemical properties

| Source of variance | df | MS: SSC | Maturity index | Total phenol content | Vitamin C | Color index |
|---|---|---|---|---|---|---|
| Treatment | 4 | 2.41** | 42.66* | 555.6* | 73.04* | 0.52** |
| Replication | 3 | 0.212 | 5.4 | 146.03 | 34.12 | 0.015 |
| Error | 12 | 0.27 | 14.05 | 1253.1 | 93.19 | 0.0037 |
| C.V. (%) | | 6.3 | 21.41 | 5.17 | 22.009 | 32.1 |

* and **: Significant at the 5 and 1% levels of probability, respectively.

**Table 4.** Effect of potassium nitrate and silicate on some physical properties of pomegranate fruit

| Treatment | Fruit weight (g) | Fruit volume ($cm^3$) | Total aril weight (g) | Fruit juice volume (ml) | Seed dry weight (g) | Peel fresh weight (g) |
|---|---|---|---|---|---|---|
| Control | 13.232[b] | 234.35[b] | 142.08[b] | 97.00[b] | 27.38[a] | 55.05[c] |
| $KNO_3$ (250 mg/l) | 85.294[b] | 299.95[a] | 166.05[a] | 120.12[a] | 21.22[b] | 84.55[a] |
| $KNO_3$ (500 mg/l) | 295.50[a] | 305.08[a] | 168.40[a] | 122.5[a] | 20.90[b] | 65.55[bc] |
| $K_2O_3Si$ (250 mg/l) | 296.85[a] | 302.81[a] | 179.10[a] | 115.50[a] | 18.40[b] | 60.32[c] |
| $K_2O_3Si$ (500 mg/l) | 280.48[a] | 282.23[a] | 173.52[a] | 112.25[a] | 20.05[b] | 76.07[ab] |

Means followed by different letters in each column indicate significant difference at p<0.05 (Duncan test).

Table 4 illustrates that the dry weight of the seeds in all the nutrition treatments was significantly lower than the control (27.38 g). It seems that with the foliar application, the nutrition elements and carbohydrates moved to the pomegranate edible part, but more research is needed to confirm this.

The improvement of the fruit yield and quality characteristics in potassium silicate foliar application can be attributed to the enhancement of photosynthesis. The transfer of the assimilates and photosynthetic materials to fruits increases the yield and the fruit weight and the number of fruits per tree. Also, potassium silicate stimulates cell division and increases the size of the fruit and the tolerance of plants to drought and salinity stress (Rahmani et al., 2017). Nitrogen in potassium nitrate increases the amount of the carbohydrate reserves that affects the fruit growth and development, thus reducing the water stress and competition between fruits, which leads to the increased growth and development of fruits (Sergent et al., 1999). Also, Potassium nitrate spray increased nitrogen and potassium in pomegranate leaves, significantly (Chater and Garner, 2018). The use of the foliar application of potassium silicate has many advantages in enhancing the leaf area and improving the efficiency of photosynthesis and increasing the plant's ability to increase growth and yield and increase strength, and reduce the temperature stress (Smith, 1950). Potassium silicate spray application improves the physiological and biochemical growth characteristics. Silicon increases the crop resistance by improving the water balance, increasing the strength of the epidermis cells, improving the plant's resistance to drought stress (Chen et al., 2011).

The aforementioned results are in agreement with the findings of the following researches. In one research, potassium and manganese foliar application had the highest effect on increasing the fruit weight, length, and diameter of pomegranates (Hamouda et al., 2015). In studying the impact of nutrition on the quality of the pomegranate fruit, researchers found that 500 mg/l potassium nitrate increased the fruit weight (Khayyat et al., 2012). Aref (2011) reported that in the pomegranate cultivar 'Manfalouty', the highest yield was obtained from the potassium and manganese spraying treatments, and the pomegranate fruit weight of this cultivar increased by increasing the level of the potassium treatment (Aref, 2011). However, the effect of all the treatments on the fruit weight was similar in this research. In the study of the effect of the mineral nutrient fertilization on the fruit quality of pomegranate such as the fruit weight, the total weight of aril and the weight of 100 arils did not significantly increase.

In one study, the highest volume of juice was obtained in 5% potassium nitrate treatment (Khayyat et al., 2012). Aref (2011) reported that in pomegranate fruit of ‘Manfalouty’ cultivar, the highest amount of juice was observed in 1000 ppm potassium foliar treatments and 1600 ppm manganese (Aref, 2011). The application of $KNO_3$ improved the flower and fruit characteristics of mango (Sudha et al., 2012).

### Fruit Chemical Properties

Table 5 indicated that the SSC increased under the influence of different nutrient treatments compared to the control, and the highest amount of the soluble solids concentration was observed in 250 and 500 mg/l potassium nitrate treatments, this is while the potassium silicate treatments did not have any significant effects on the fruit SSC compared to the control treatment. The maturity index value was significantly affected by the potassium nitrate treatment (250 mg/l) compared to the control (Table 5).

**Table 5.** Effect of potassium nitrate and silicate on some chemical properties of pomegranate fruit

| Treatment | SSC (° Brix) | Maturity index | Total Phenol Content (TPC) (mg GAE/ml) | Vitamin C (mg/100ml) | Color |
|---|---|---|---|---|---|
| Control | 13.25[c] | 15.68[b] | 268.3[b] | 16.10[b] | 2.5[b] |
| $KNO_3$ (250 mg/l) | 14.62[ab] | 22.12[a] | 277.3[ab] | 19.55[ab] | 4.5[a] |
| $KNO_3$ (500 mg/l) | 15.27[a] | 19.72[ab] | 298.7[a] | 23.00[a] | 4.5[a] |
| $K_2O_3Si$ (250 mg/l) | 14.00[bc] | 14.46[b] | 275.7[ab] | 24.15[a] | 4.25[a] |
| $K_2O_3Si$ (500 mg/l) | 13.25[c] | 15.52[b] | 272.8[ab] | 21.85[a] | 4.5[a] |

Means followed by different letters in each column indicate significant difference at $p<0.05$ (Duncan test).

The amount of the total phenol content of juice, was found in the 500 mg/l potassium nitrate treatment, which increased TPC significantly compared to the control (Table 4). Vitamin C in fruit juice increased under different nutrient treatments, and the highest amount of it was observed in the treatment of 500 mg/l potassium nitrate and 250 and 500 mg/l potassium silicate (Table 5). According to the results of table 4, all levels of the foliar spraying treatments caused a significant increase in the color of juice compared to control treatment. Foliar application of potassium improved the juice color.

The amount of SSC is dependent on the harvest time, the weather conditions, the fruit cultivar, and is even different between the fruits of a tree (Schwartz et al., 2009). In contrary to our results, in the study of the effect of the foliar application of nutrients on Wonderful cultivar, there was no significant difference in SSC value under the effects of different treatments of $MgSO_4$ and $KNO_3$ (Chater and Garner, 2018). In all concentrations of urea (0.5%, 1% and 2%), the SSC of the pomegranate cultivar 'Malase Yazdi' increased (Ramezanian et al., 2009). However, Wassel et al. (2015) reported that the foliar application of potassium silicate significantly increased the content of SSC in Wonderful cultivar, and that change in the amount of SSC may be due to the silicon in potassium silicate, which affects many aspects of the plant growth (Wassel et al., 2015). The highest amount of SSC was obtained in the potassium and manganese spraying treatments (Hamouda et al., 2015). In one research, the results illustrated that SSC in fruits of all the treatments were higher than those of the control at harvest (Fallahi et al., 2006).

Results showed that using potassium with manganese treatment and potassium treatment alone in pomegranate (cv. Manfalouty), produced the highest amount of vitamin C compared to the control (Hamouda et al., 2015). The use offour levels of potassium nitrate (2%) increased the vitamin C in mangoes (Baiea et al., 2015).

In agreement with this research, it was found that the potassium foliar application in pomegranate fruits of the 'Manfalouty' reduced the white-arils by increasing the color and anthocyanins (Aref, 2011; Hamouda et al., 2015). Also, in one research it was understood that ammonium nitrate fertilizer and/or calcium chloride alone or in combination, enhanced the fruit quality traits (Bakeer, 2016). In another study, the total phenol content increased significantly only by using 2% potassium nitrate, and $KNO_3$ at 1 and 3% concentrations did not have any significant effects (Chater and Garner, 2019). Also, the lichi plants treated with K as foliar feeding, significantly improved the fruit colour and quality attributes over the control (Pandey, 2016). Sprays of potassium nitrate at 4 % after pit hardening gave the best values of the fruit quality and the flesh oil content of olive fruit (Hegazi et al., 2011).

## Conclusion

According to the results of the present study, almost all of the applied nutritional treatments improved the physical characteristics of pomegranate fruit compared with the control, but with regard to the chemical fruit properties, potassium nitrate at concentration of 500 mg/l, significantly increased the total phenol and vitamin C content of the pomegranate fruit. Therefore, due to the increasing global desire to use pomegranate fruit due to its high nutritional value, it is recommended that the foliar application be used in pomegranate orchards, but more research is necessary in order to determine the best fertilizer type and level.

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