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CALCIUM AND POTASSIUM FERTILIZATION ON ANTIOXIDANT CAPACITY AND THE FRUIT QUALITY OF 'HICAZ' POMEGRANATES (*PUNICA GRANATUM* L.)

M. GUNERI[1], M. YILDIZTEKIN[2], A. L. TUNA[3] and I. YOKAS[4]
[1] *Mugla Sitki Kocman University, Horticulture Programme, Ortaca Vocational School, Mugla 48600, Turkey*
[2] *Mugla Sitki Kocman University, Medicinal and Aromatic Plants Programme, Koycegiz Vocational School, Mugla 48800, Turkey*
[3] *Mugla Sitki Kocman University, Biology Department, Mugla 48000, Turkey*
[4] *Mugla Sitki Kocman University, Greenhouse Programme, Ortaca Vocational School, Mugla 48600, Turkey*

Abstract

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This study was carried out in two different pomegranate (*Punica granatum* L.) orchards in the Mugla City of Turkey. The aim of the study was to evaluate the effects of calcium and potassium fertilizers on the fruit properties and total antioxidant capacity of pomegranate plants. 1.5% and 3% KNO_3, 1.5% and 3% $Ca(NO_3)_2$, 0.75% KNO_3 + 0.75% $Ca(NO_3)_2$ and 1.5%KNO_3 + 1.5% $Ca(NO_3)_2$ were sprayed on the leaves. The Ferric Ion Reducing Antioxidant Power (FRAP), lipid peroxidation (Malondialdehyde – MDA) and Super Oxide Dismutase (SOD) parameters and fruit pomological properties evaluated after the treatments. Ca fertilization significantly affected to the FRAP. Potassium treatments generally reduced the sugar content of the plants leaves. Considering fruit quality and pomological properties, the Ca treatments significantly increased fruit weight, peel percent, juice yield and acidity. The K treatments higher affected fruit width and length, as well as the fruit peel percent; and Ca + K treatments increased acidity.

Key words: FRAP, fruit characteristics, MDA, Pomegranate, SOD

List of abbreviations: TUIK – Turkey Statistical Institute; $Ca(NO_3)_2$ – Calcium nitrate; KH_2PO_4 – Potassium phosphate; KNO_3 – Potassium nitrate; FRAP*:* Ferric Ion Reducing Antioxidant Power; MDA – Malondialdehyde (Lipid Peroxidation); SOD – Super Oxide Dismutase; SAS*:* Statistical Analysis Software; TSS – Total Soluble Solids; TA – Titrable Acidity; ns – non-significant

Introduction

The pomegranate (*Punica granatum* L.) is a plant of economic value widely used by humans for its nutritional and medicinal properties. It is well-adapted to the Turkey's Mediterranean climate and can resist up to –10°C of cold weather in the winter. Turkey is the third largest pomegranate producer in the world, where pomegranate production in the Mugla province of Turkey was 47.067 tons in 2012 (TUIK, 2014).

Researchers have found that there is a close relationship between calcium and product quality in all fruits and vegetables. More specifically, calcium application on leaves can increase, especially the criterion of quality in fruits and vegetables and can enhance their marketing value. Previous researches have also shown that pre-harvest and post-harvest calcium treatments enabled the production of healthier plants (Hickey et al., 1995; Brown et al., 1996; Wojcik, 2001). One of the most important properties of calcium in

**E-mail:* gmurat@mu.edu.tr (corresponding author), mahmutyildiztekin@gmail.com, tuna@mu.edu.tr, iyokas@mu.edu.tr

terms of increasing the quality criterion is the ratio of calcium pectate, found in the plant cell walls as a stabilizing agent. Some researchers have shown that pre-harvest and post-harvest calcium treatments increased the amount of this compound in apple fruit (Conway et al., 1995; Sidiqui and Bangerth, 1995).

Potassium has many effects on plants. The most important effects are that it increases the nutritional value of plants and positively affects fruit quality by an increased protein composition. Furthermore, it enhances plant resistance to diseases and pests and gives the vegetables and plants more vivid colours. Potassium increases the quality of some citrus fruits by positively affecting colour, appearance, form and taste of fruits. Potassium treatment on citrus fruits have a positive impact on quality by increasing fruit size, colour, acid/sugar percent and soluble solid matter and vitamin C in juice (Kacar, 2005).

There is a large body of research stating that calcium and potassium fertilizers improve the quality properties of fruit trees. For example, Raese and Drake (2000) reported that calcium containing compounds sprayed on pear (*Pyrus communis* L.) trees prevented physiologic defects in fruits; it also increased fruit size and improved fruit colour and juice properties. Similar results were reported for apples (*Malus communis* L.) (Mohammad et al., 1999).

Physical and chemical properties of pomegranate fruit depends on very factors (Fawole and Opara, 2013; Mirdehghan and Rahemi, 2007; Poyrazoglu et al., 2002; Tehranifar and Tabar, 2009). One of these factors is fertilization. For example $Ca(NO_3)_2$ spray was increased total soluble solids while KH_2PO_4 highest reducing sugars were recorded (Heshi et al., 2001).

The 'Hicaz' pomegranate is one of the main cultivars in Turkey's pomegranate production. This cultivar has a medium-large fruit size; oblate fruit form; maroon peel colour; thick peel; moderate aril yield; low-moderate juice yield; small aril size; moderate ease of aril removing; sweet-sour flavour; hard seeds; late season maturity; moderate yield; self-fertile; moderate degree of fruit cracking; and medium-dense thorns (Yilmaz, 2007).

Pomegranate fruit is very rich in nutritious compounds. It contains minerals such as potassium, phosphorus, iron, sodium and magnesium; and vitamins such as ascorbic acid, thiamine, riboflavin and niacin (Yilmaz, 2007).The pomegranate is also important in terms of its antioxidant activity. A study on antioxidant activities of some fruits (e.g., apple, quince, grapes, pear and pomegranate) and some vegetables (e.g., potato, onion, green onion, radish and red cabbage) found that the pomegranate had the highest antioxidant activity (62.7%), followed by the quince (60.4%), grapes (26.6%), apple (25.7%) and pear (13.7%) (Karadeniz et al., 2005). Antioxidant activity in pomegranate leaves are directly associated with phenolic compounds. However, antioxidant activity is not limited to phenols (Amjad and Shafighi, 2012). Different types of extraction method have a big influence on the antioxidant property of obtained pomegranate leaf extracts (Kaneria et al., 2012).

In terms of human food and economic importance the pomegranate plant having a high antioxidant capacity and in addition to this calcium and potassium fertilization are known to improve these properties potentially. The present study was planned in this regard aimed to application of calcium and potassium fertilizers alone and together to determine the effects of total antioxidant capacity and overall fruit quality.

Materials and Methods

This study was carried out in two different 'Hicaz' pomegranate orchards in the Ortaca city of Turkey's Mugla province in 2010 and 2011. One of the orchards (Orchard 1) had 8 year-old trees, while the other (Orchard 2) had 4 year-old trees.

The soil in the study areas had moderate lime and low organic matter content. The soils were of a fine loamy structure, non-saline, had low sodium and manganese, moderate iron, adequate calcium and copper and excessive magnesium content. Soil in Orchard 1 was slightly alkaline, with a moderate phosphorus and very low zinc content. Soil in Orchard 2 was also slightly alkaline, but low in phosphorus and had an adequate zinc content.

The experiment used a 'Completely Randomized Design' with three replications. The three replications included 3 trees at each replication plot and 7 fertilizer treatments, applied on a total of 126 trees. When the fruitlets reached the size of a walnut, one of the twins fruits were thinned (in June); after this, the fertilizer applications as sprays started. Fertilizer applications continued at 10-day intervals during the first half of the fruit growth period and at 15-day intervals during the second half of the period and continued until the fruits were harvested. The treatments were conducted in 2010 and 2011 in two replication years.

The 7 fertilizer treatments were: 1.) Control, 2.) 1.5% KNO_3, 3.) 3% KNO_3, 4.) 1.5% $Ca(NO_3)_2$, 5.) 3% $Ca(NO_3)_2$, 6.) 0.75% KNO_3+0.75% $Ca(NO_3)_2$, 7.) 1.5% KNO_3+1.5% $Ca(NO_3)_2$

Leaf samples were collected from seven month old spring shoots which had no disease, no deficiency of nutrients and seemed healthy at arm level from the tree. Consequently, fifty leaves were collected from each of the test trees. Fruit evaluations were made on 10 fruits collected from different directions of each tree at harvest period.

Ferric Ion Reducing Antioxidant Power (FRAP)

The procedure described by Benzie and Strain (1996) was followed. The principle of this method is based on the reduction of a ferric-tripyridyl-triazine complex to its ferrous, colored form in the presence of antioxidants. Briefly, the FRAP reagent contained 2.5 mL of a 10 mmol/L TPTZ (2,4,6- tripyridyl-s-triazine, Sigma) solution in 40 mmol/L HCl plus 2.5 mL of 20 mmol/L $FeCl_3$ $6H_2O$ and 25 mL of 0.3 mol/L acetate buffer, pH 3.6 and was prepared freshly and warmed at 37°C. Aliquots of 40 µL sample filtrate were mixed with 0.2 mL distilled water and 1.8 mL FRAP reagent and the absorbance of reaction mixture at 593 nm was measured spectrophotometrically after incubation at 37°C for 10 min. Gallic acid, ascorbic acid, BHA and trolox were used as the standard. The final result was expressed as the concentration of antioxidants having a ferric reducing ability equivalent to that of mg of standard used per gram stevia leaves and callus on dry weight basis.

Lipid Peroxidation (Malondialdehyde, MDA)

The content of MDA was determined using the thiobarbituric acid reaction, following the method of Madhava Rao and Sresty (2000), and calculated from the absorbance at 532 nm. The measurements were corrected for non-specific turbidity by subtracting the absorbance at 600 nm, and the results expressed as µmol g^{-1} protein.

Super Oxide Dismutase (SOD)

SOD activity was assayed by measuring its ability to inhibit the photochemical reduction of nitro blue tetrazolium (NBT) (Madhava Rao and Sresty, 2000). One unit of the enzyme activity was defined as the amount of enzyme required to result in a 50% inhibition of the rate of nitro blue tetrazolium reduction at 560 nm.

Reducing sugar content of leaf (g/100 g)

Reducing sugars were measured according to the dinitrophenol method (Yesiloglu, 1988).

Fruit physical and chemical characteristics

Fresh fruit weight (g)

Average fruit weight was determined by measuring 10 random fruits at each repetition on a sensitive electronic balance.

Fruit width and length (mm)

At each replication, the width and length of 10 randomly selected fruits were measured with a digital compass with a sensitivity of 0.1 mm.

Fruit peel percent (%)

The fruits were weighted as fresh. After separating the arils, only the peel percent was scaled. By proportioning the obtained values, the fruit peel percent was determined.

Juice percent (%)

The arils of the fruit were squeezed and the juice was removed. The remaining seed weight was measured. The fruit juice percent was calculated as follows:

Juice percent = Aril weight (g) – Seed weight (g) / Whole fruit weight (g)

Total soluble solids (TSS) (%)

This value was determined with a handheld refractometer.

Titrable acidity (TA) (%)

Titrable acidity was determined from 10 mL of juice diluted to 100 ml with distilled water, titrated with 0.1 N NaOH to pH 8.2, and expressed as the percent citric acid (mass/mass) on a fresh weight basis.

Statistical analysis

The SAS statistical package program was used to evaluate the data (SAS Inst. 1989). The LSD test was used to compare the averages.

Results

Total antioxidant capacity

Effects of the treatments on the total antioxidant capacity are presented in Tables 1 and 2. Results revealed that, in terms of FRAP activity, the lowest value was found in the 0.75% KNO_3 +0.75% $Ca(NO_3)_2$ group (2.60 µmol/g) in the second year treatments in Orchard 2, while the highest value was found in the 1.5% KNO_3 +1.5% $Ca(NO_3)_2$ group (7.50 µmol/g) in the first year treatment in Orchard 1.

When compared to the control group, the increase in FRAP activity was found to be from 17% (Orchard 2, 2nd year) to 104% (Orchard 1, 1st year). This indicates that Ca only or Ca+K treatments significantly increase FRAP levels.

Analysis of the MDA content showed that the lowest value was found 1.03 nmol/g in the 1.5% KNO_3 +1.5% $Ca(NO_3)_2$ group (Orchard 2, 2nd year). The highest value was found in the 3% KNO_3 group (1.85 nmol/g) in Orchard 1 in the second year.

When compared to the control group, the MDA content increased by 25% in Orchard and in Orchard 2 in the second year. The increases observed in the MDA content were affected by the K treatments; however, the effect was not statistically significant ($p > 0.05$).

Table 1
The effects of KNO_3 and $Ca(NO_3)_2$ on FRAP, MDA and SOD (Orchard 1)

Treatments	1st year			2nd year		
	FRAP (µmol Asc. acid equivalent/g)	MDA (nmol/g)	SOD/mg PR/g FW	FRAP (µmol Asc. acid equivalent/g)	MDA (nmol/g)	SOD/mg PR/g FW
1.) Control	3.67cd	1.83	52.27a	4.09bc	1.48abc	31.46abc
2.) 1.5% KNO_3	2.74d	1.83	35.69b	3.10c	1.50abc	27.83c
3.) 3% KNO_3	3.74cd	1.56	26.47b	4.24bc	1.85a	30.17bc
4.) 1.5% $Ca(NO_3)_2$	4.02c	1.82	32.80b	4.31abc	1.58abc	34.45abc
5.) 3% $Ca(NO_3)_2$	6.29b	1.79	30.31b	5.58a	1.42bc	37.60a
6.) 0.75% KNO_3 + 0.75% $Ca(NO_3)_2$	4.59c	1.35	37.30b	5.30ab	1.35c	35.45ab
7.) 1.5% KNO_3 + 1.5% $Ca(NO_3)_2$	7.50a	1.63	32.38b	3.88c	1.80ab	31.90abc
t-test	***	ns	**	*	ns	ns
Lsd=	1.1422	0.79	11 493	1.2809	0.4249	7.4026

The values followed by different letters in the same column are significantly different according to the t-test
ns: non-significant, *P < 0.05, **P < 0.01, ***P < 0.001

Table 2
The effects of KNO_3 and $Ca(NO_3)_2$ on FRAP, MDA and SOD (Orchard 2)

	1st year			2nd year		
Treatments	FRAP (µmol Asc. acid equivalent/g)	MDA (nmol/g)	SOD/mg PR/g FW	FRAP (µmol Asc. acid equivalent/g)	MDA (nmol/g)	SOD/mg PR/g FW
1.) Control	3.74	1.78	40.62a	4.87a	1.24	36.11ab
2.) 1.5% KNO_3	4.38	1.33	34.44ab	4.94a	1.55	32.32b
3.) 3% KNO_3	3.95	1.56	34.49ab	5.44a	1.50	30.60b
4.) 1.5% $Ca(NO_3)_2$	4.59	1.50	42.91a	5.72a	1.31	35.59ab
5.) 3% $Ca(NO_3)_2$	3.81	1.70	37.73ab	3.81b	1.33	40.55a
6.) 0.75% KNO_3 + 0.75% $Ca(NO_3)_2$	4.02	1.55	29.23bc	2.60c	1.21	31.78b
7.) 1.5% KNO_3 + 1.5% $Ca(NO_3)_2$	4.59	1.56	24.35c	5.58a	1.03	31.44b
t-test	ns	ns	**	***	ns	ns
Lsd=	0.886	0.7034	9.2407	0.8603	0.5497	6.9497

The values followed by different letters in the same column are significantly different according to the t- test
ns: non-significant, **P < 0.01, ***P < 0.001

The analysis of the SOD enzyme activity showed that the lowest value was found in the 1.5% KNO_3 +1.5% $Ca(NO_3)_2$ group (24.35 Unit/mg) in Orchard 2 in the first year, while the highest value was found in the control group (52.27 Unit/mg) in Orchard 1 in the first year.

It was found that the K treatment decreased the SOD amount; however, this decrease was not significant. On the other hand, K + Ca treatments were similarly found to cause a decrease in the SOD activity.

Reducing sugar content

In terms of reducing sugar content in Orchard 1, the lowest values were obtained from 3.49 g/100 g (1.5% $Ca(NO_3)_2$) and 3.79 g/100 g (3% $Ca(NO_3)_2$); while the highest values were obtained from 4.89 g/100 g (1.5% KNO_3) and 4.36 g/100 g (3% KNO_3), in the first and second year, respectively. In the Orchard 2, the lowest values were obtained from 3.67 g/100 g (1.5% $Ca(NO_3)_2$) and 4.62 g/100 g (3% KNO_3); while the highest values were obtained from 4.60 g/100 g (3% KNO_3) and 5.40 g/100 g (control), in the first and second year, respectively (Figure 1).

When compared to the control, the increase in the reducing sugar amount was 15.4% in Orchard 2 in the first year. This indicates that a treatment in the 0.75% KNO_3 +0.75% $Ca(NO_3)_2$ group significantly increased the reducing sugar amount. In general, K increased the reducing sugar.

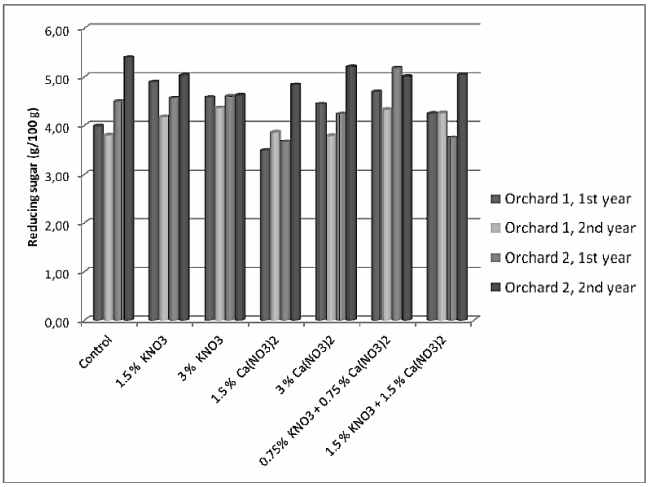

Fig. 1. The effects of treatments on the reducing sugar content of leaf

Fruit quality and pomological properties

Effects of the treatments on the fruit quality and pomological properties are presented in Tables 3, 4, 5 and 6. The lowest fruit weight was 395.0 g (0.75% KNO_3 + 0.75% $Ca(NO_3)_2$ group); the highest fruit weight was 574.7 g (3% $Ca(NO_3)_2$) in the Orchard 1 in the first year treatments.

When compared to the control, it was found that the fruit weight increased 25% in Orchard 1in the first year; 21% in Orchard 1in the second year; 27% in Orchard 2 in first year and 13% in Orchard 2 in the second year. This indicates that 3% $Ca(NO_3)_2$ treatments significantly increase fruit weight.

The fruit width values were found to be 94.1 mm (0.75% KNO_3 + 0.75% $Ca(NO_3)_2$ group) – 1003.6 mm (3% KNO_3 group). The fruit length values were found to be 83.0 mm – 92.2 mm (0.75% KNO_3 + 0.75% $Ca(NO_3)_2$ group).

The increase in fruit width and length was found to be 5.6% and 5.4%, respectively in Orchard 1 in the second year

Table 3

The effects of calcium and potassium fertilization on fruit physical and chemical characteristics (Orchard 1, 1st year)

Treatments	Weight (g)	Diameter (mm)	Length (mm)	Peel percent (%)	Juice percent (%)	TSS (%)	TA (%)
1.) Control	461.0b	98.3ab	85.7	48.1ab	37.3a	13.9b	1.20c
2.) 1.5% KNO_3	415.7c	96.3ab	84.0	49.6a	37.3a	14.4ab	1.39b
3.) 3% KNO3	459.7b	97.3ab	85.7	45.7b	34.9ab	14.1b	1.37b
4.) 1.5% $Ca(NO_3)_2$	552.0a	99.3ab	86.3	47.5ab	33.9 b	14.1b	1.21c
5.) 3% $Ca(NO_3)_2$	574.7a	101.3a	88.3	45.7b	36.1ab	14.8a	1.52a
6.) 0.75% KNO_3 + 0.75% $Ca(NO_3)_2$	395.0c	95.0b	83.0	49.6a	35.7ab	14.3ab	1.22c
7.) 1.5% KNO_3 + 1.5% $Ca(NO_3)_2$	459.0b	96.3ab	84.7	47.3ab	35.0ab	14.1b	1.28bc
t-test	***	ns	ns	ns	ns	ns	***
Lsd=	28 019	5.8457	5.5641	3.0423	2.9061	0.6372	0.1229

The values followed by different letters in the same column are significantly different according to the t-test
ns: non-significant, *P < 0.05, **P < 0.01, ***P < 0.001
TSS: Total Soluble Solids , TA: Titrable Acidity

Table 4

The effects of calcium and potassium fertilization on fruit physical and chemical characteristics (Orchard 1, 2nd year)

Treatments	Weight (g)	Diameter (mm)	Length (mm)	Peel percent (%)	Juice percent (%)	TSS (%)	TA (%)
1.) Control	453.7d	98.1c	86.7c	41.6abc	41.0a	16.0ab	1.28bc
2.) 1.5% KNO_3	486.7c	99.6bc	88.9b	40.6c	41.0a	16.1a	1.30bc
3.) 3% KNO_3	545.0a	103.6a	91.4a	43.8a	38.4ab	15.3b	1.35ab
4.) 1.5% $Ca(NO_3)_2$	477.3cd	98.6c	86.5c	43.3ab	37.0b	15.8ab	1.22c
5.) 3% $Ca(NO_3)_2$	505.7bc	101.4ab	89.9ab	41.2bc	39.7ab	15.9ab	1.46a
6.) 0.75% KNO_3 + 0.75% $Ca(NO_3)_2$	550.7a	101.5ab	90.8ab	43.6a	39.2ab	15.5ab	1.26bc
7.) 1.5% KNO_3 +1.5% $Ca(NO_3)_2$	521.3ab	102.4a	91.0a	43.6ab	38.5ab	15.8ab	1.31bc
t-test	***	**	***	*	ns	ns	*
Lsd=	32 547	2.4662	1.9137	2.4398	3.2586	0.743	0.1265

The values followed by different letters in the same column are significantly different according to the t- test
ns: non-significant, *P < 0.05, **P < 0.01, ***P < 0.001
TSS: Total Soluble Solids , TA: Titrable Acidity

Table 5
The effects of calcium and potassium fertilization on fruit physical and chemical characteristics (Orchard 2, 1st year)

Treatments	Weight (g)	Diameter (mm)	Length (mm)	Peel percent (%)	Juice percent (%)	TSS (%)	TA (%)
1.) Control	397.0c	94.2b	84.7	48.0	30.7b	13.9ab	1.37ab
2.) 1.5% KNO_3	428.0bc	96.7ab	83.8	47.2	34.0a	13.3b	1.08c
3.) 3% KNO_3	497.0a	99.4a	84.2	46.3	32.7ab	14.2ab	1.11bc
4.) 1.5% $Ca(NO_3)_2$	426.0cb	96.5ab	84.4	42.4	34.8a	13.8ab	1.39ab
5.) 3% $Ca(NO_3)_2$	502.6a	100.2a	86.5	48.4	34.5a	13.6ab	1.18bc
6.) 0.75% KNO_3 + 0.75% $Ca(NO_3)_2$	451.0b	94.1b	84.4	48.1	33.5a	13.9ab	1.49a
7.) 1.5% KNO_3 + 1.5% $Ca(NO_3)_2$	460.0b	95.6ab	83.4	45.5	34.7a	14.5a	1.31abc
t-test	***	ns	ns	**	ns	ns	*
Lsd=	36 444	4.8557	3.8197	2.9311	2.6731	0.9675	0.2781

The values followed by different letters in the same column are significantly different according to the t- test
ns: non-significant, *P < 0.05, **P < 0.01, ***P < 0.001
TSS: Total Soluble Solids , TA: Titrable Acidity

Table 6
The effects of calcium and potassium fertilization on fruit physical and chemical characteristics (Orchard 2, 2nd year)

Treatments	Weight (g)	Diameter (mm)	Length (mm)	Peel percent (%)	Juice percent (%)	TSS (%)	TA (%)
1.) Control	482.0b	99.1	88.1	44.7	33.0c	14.6b	1.18bc
2.) 1.5% KNO_3	533.3ab	101.1	91.5	44.0	37.4b	14.9ab	1.11bc
3.) 3% KNO_3	492.7ab	98.7	91.5	44.5	35.9bc	15.0ab	1.09c
4.) 1.5% $Ca(NO_3)_2$	502.0ab	98.3	88.3	45.0	40.9a	14.6b	1.30ab
5.) 3% $Ca(NO_3)_2$	520.0ab	99.7	88.4	45.1	36.2b	14.7b	1.10c
6.) 0.75% KNO_3 + 0.75% $Ca(NO_3)_2$	546.3a	101.6	92.2	46.3	36.9b	15.0ab	1.39a
7.) 1.5% KNO_3 +1.5% $Ca(NO_3)_2$	540.7a	101.1	88.5	44.5	38.1ab	15.3a	1.23abc
t-test	ns	ns	ns	ns	**	ns	*
Lsd=	57 162	3.2938	4.2508	2.8276	3 101	0.5511	0.1916

The values followed by different letters in the same column are significantly different according to the t- test
ns: non-significant, *P < 0.05, **P < 0.01
TSS: Total Soluble Solids , TA: Titrable Acidity

treatments. This indicates that the K treatments significantly increased the fruit width and length.

The analysis of the effects of treatments on the fruit peel percent the lowest value was 40.6% with 1.5% KNO_3, while the highest value was found to be 49.6 % (1.5% KNO_3 and 0.75% KNO_3 + 0.75% $Ca(NO_3)_2$ group) in Orchard 1 in the first year treatments.

The increase in the fruit peel percent was found to be 5.3% in Orchard 1 in the second year and 0.8% in Orchard 2 in the first year. We found that K + Ca sufficiently increased the fruit peel percent.

The fruit juice percent showed that the lowest value was 30.7% (control group) in Orchard 2 in the first year, on the other hand, the highest value was found to be 41.0 % (1.5% KNO_3 and control)) in Orchard 1 in the second year.

The increase in fruit juice yield was 23.9% in Orchard 2 in the second year. It was found that Ca significantly increased the juice yield.

The 1.5% KNO_3 treatments showed that the lowest TSS was 13.3% in the Orchard 2 in the first year, while the highest value was 16.1 % in the Orchard 1 in the second year treatments. The treatments in the first year showed that the lowest values for the TA was 1.08% (1.5% KNO_3) in the Orchard 2, on the other hand, the highest value was 1.52% (3% $Ca(NO_3)_2$ group) in the Orchard 1.

The increased acidity percent was found to be 26.7% in Orchard 1in the first year treatments; 14.1% in Orchard 1in the second year; 8.8% in Orchard 2 in the first year and 17.8% in Orchard 2 in the second year. It was found that the total soluble solid and acidity significantly increased by Ca in Orchard 1and by K + Ca in Orchard 2.

Discussion

In a previous study on antioxidant levels, 1.5 $g.L^{-1}$ and 3 K $g.L^{-1}$ application on the leaves of pomegran-

ate significantly increased antioxidant activity 14.7% and 7.3% respectively (Tehranifar and Tabar, 2009). In a study, the FRAP value in three different cultivars fruit juice was found to be 0.28–0.32 mM TE/ml PJ (Fawole et al., 2012). In another study, the antioxidant capacity (vit. C equivalent gL^{-1}) was found to be 1.25–3.16 (Neori et al., 2009). In a study which analyzed the effects of K, Ca and Mg treatments on total antioxidant capacity of tomato fruit, it was reported that the FRAP value varied between 2.48–5.86 Mm $Fe^{2+}kg^{-1}$of FW; the highest value was obtained from K, Ca and Mg in descending order (Fanasca and et al., 2006). In another study, the FRAP value was found to be 225.17–705.50 mmol/100 g in the peel and 157.33–419.33 mmol/100 g in the fruit juice (Akbarpour et al., 2009). The total antioxidant capacity in pomegranate leaf extracts was found to be equivalent to 1.06 mg/ml ascorbic acid (Chaitra et al., 2012).

In the present study, it was found that only Ca or Ca + K treatments significantly increased the FRAP level. Similar study of Fanasca et al. (2006) on tomato plants, Ca played a more active role than K.

In a previous study on the amounts of MDA in the peel of pomegranate were determined 1.43 nM/g FW at harvest time (Ramezanian and Rahemi, 2011). In the present study, this value in the leaves of pomegranate is similar.

Dogru et al. (2012), in a study on the effect of potassium humate on the growth of maize, found that 400 and 600 ppm potassium humate treatments significantly decreased the SOD activity.

We believe that in our study, the K treatment improved the nutritional level of the plant, and thus, eliminated or decreased the stress conditions; consequently, there was a decrease in the SOD activity.

Akbarpour et al. (2009) performed a physical and chemical analyses on 20 pomegranate cultivars collected from different cultivation regions in Iran during a harvesting period. Their analyses showed that the reducing sugar amount was 13.89-29.83 g/100 ml. Tehranifar and Tabar (2009), the 1.5 $g.L^{-1}$ K treatment on the leaves significantly increased the total sugar percent (1.6%); while the 3 $g.L^{-1}$ K treatment significantly increased the total sugar percent (3.8%). Golukcu et al. (2011) conducted a study on the effect of harvesting time on the sugar and organic acid composition of hicaz pomegranate cultivars and showed that fructose, glucose and maltose amounts were 7.69–8.34%, 5.44–5.7% and 0.59–0.68%, respectively.

In the present study, the reducing sugar content in the leaves was found to be 3.49–5.40 g/100 g. The fact that potassium increased the reducing sugar content is considered a positive effect on fruit quality.

In a previous study, reported that fruit weight was 103.4–505.0 g (Akbarpour et al., 2009). In the present study fruit weight was found to be 395.0 g – 574.7 g.

In a previous study indicated that because fruit volume, fruit weight, and total aril weight are closely correlated, any of these characteristics can be used as an indicator of fruit size (Wetzstein et al., 2011).

In the present study K treatments significantly increased the fruit width and length.

In a previous study reported that folir application of K increased fruit peel (Tehranifar and Tabar, 2009). This result is similar the present study.

Tehranifar and Tabar (2009) found that a 1.5 $g.L^{-1}$ K treatment on the leaves significantly increased the total soluble solid (4.4 and 5.0% respectively) and acidity percent (7.5 and 24.7% respectively). In a study which evaluated the effect of harvesting time on the sugar and organic acid composition of the hicaz pomegranate cultivar, the TSS amount was found to be 15.85–17.10% and the citric acid amount was found to be 6.70–10.19 g/L (Golukcu et al., 2011). Akbarpour et al. (2009) study reported that TSS was 15.17–22.03% and titrable acid was 0.35%–3.36%.

When compared to previous studies, it was observed that the TA percent was rather low, while the TSS percent was similar. It is believed that the delayed harvesting increased the TSS percent, while it decreased the TA percent. Hence, a high acid percent is believed to be closely related to the harvesting time.

Conclusion

The overall evaluation of the results of this study, potassium increased the reducing sugar content. Considering fruit quality and pomological properties, it was found that Ca treatments significantly increased fruit weight, fruit peel percent, fruit juice yield and acidity; K treatments affected the fruit width, length and fruit peel percent. Ca + K treatments increased acidity. We also found that potassium and calcium fertilization positively affected the total antioxidant capacity, reducing sugar, fruit quality and pomological properties and that the mentioned fertilizers can be recommended to increase the quality of the fruits.

This study was conducted to observe the effects of potassium and calcium fertilizers on the leaves in a period on yield and quality and to encourage calcium and potassium fertilization among farmers in the Mediterranean region, which consists of many pomegranate cultivation areas. We believe that the results of the test will serve as an example and enable local producers to make significant gains about appropriate fertilization. Thus, we believe

that a significant gain will also be achieved. Research on pomegranates, a fruit with a high economic value, has gained in impetus in recent years. Considering that there is a limited body of research on this subject, it is important to carry out studies on pomegranates.

In recent years, pomegranate production has reached a significant potential in Turkey. This fruit is widely consumed as an edible food and in industry. Balanced fertilizing is the basic condition applied to obtain productive and quality fruit in increasing production areas. Potassium and calcium are the leading minerals in this field. The fact that producers continue to grow crops using old-fashioned only nitrogen fertilizers and fail to use calcium and potassium at adequate levels causes economic losses. The application of calcium and potassium fertilizers on the top of the leaves of plants, especially at the beginning of the generative period, can increase quality and yield parameters.

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