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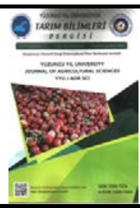

Araştırma Makalesi (Research Article)

$CaCl_2$ Solution Sprayed on Leaves Changes the Nutrition and Qualitative Properties of Pomegranate (*Punica granatum* L. cv. Hicaznar)

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Anahtar kelimeler
Calcium chloride,
Foliar fertilization,
Quality,
Nutrition.
Pomegranate (*Punica granatum* L. cv. Hicaznar),
Yield.

Abstract: The purpose of this experiment was to define the influence of different doses of calcium chloride ($CaCl_2$) applications on fruit yield, some quality properties, and nutrition of plant in Hicaznar pomegranate cultivar during 2016 and 2017 in Aydın (Turkey) ecological condition. In the study, 0.2, 0.4, 0.6, 0.8, and 1.0% solutions of calcium chloride ($CaCl_2$) were applied by spraying except the control dose to the trees. The solution doses were twice applied during the fruit growing season in June and August. According to the results, fruit yield, peel thickness, fruit length, diameter, and weights were increased compared to control dose with $CaCl_2$ applications. Foliar $CaCl_2$ applications increased foliar Ca content by 60%. Concentrations of other plant nutrients other than N and Ca were decreased in parallel with increasing $CaCl_2$ doses. Foliar P content was not affected in this case. As a result, the amount of $CaCl_2$ solution to be applied to leaves in Hicaznar pomegranate was determined as 0.6%.

Yapraklara Püskürtülen $CaCl_2$ Çözeltisi Nar (*Punica granatum* L. cv. Hicaznar)'ın Beslenme ve Niteliksel Özelliklerini Değiştirir

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Nar (*Punica granatum* L. cv. Hicaznar),
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Öz: Bu çalışmanın amacı, Aydın (Türkiye) ekolojik koşullarında 2016 ve 2017 yıllarında Hicaznar çeşidinde farklı dozlarda kalsiyum klorür ($CaCl_2$) uygulamalarının meyve verimi, bazı kalite özellikleri ve bitkinin beslenmesine etkisini belirlemektir. Çalışmada ağaçlara kontrol dozu dışında % 0.2, 0.4, 0.6, 0.8 ve 1.0 kalsiyum klorür ($CaCl_2$) çözeltileri püskürtülerek uygulanmıştır. Çözelti dozları, 15 Haziran ve 15 Ağustos'ta meyve yetiştirme mevsimi boyunca iki kez uygulanmıştır. Elde edilen sonuçlara göre, $CaCl_2$ uygulamaları ile meyve verimi, kabuk kalınlığı, meyve uzunluğu, çapı ve ağırlıkları kontrol dozuna göre artmıştır. Yaprak $CaCl_2$ uygulamaları, yaprak Ca içeriğini % 60 arttırmıştır. Artan $CaCl_2$ dozlarına paralel olarak N ve Ca dışındaki diğer bitki besin maddelerinin konsantrasyonları azalmıştır. Yaprak P içeriği bu durumda etkilenmemiştir. Sonuç olarak Hicaznar çeşidinde yapraklara uygulanacak $CaCl_2$ uygulama dozu % 0.6 olarak belirlenmiştir.

1. Introduction

Pomegranate's homeland Turkey, Middle East, south-southeast of Iran, the Caucasus and including also northern India is known to be a large region. The fruit of the pomegranate, which is one of the subtropical climate fruit species, can be evaluated in various ways in the food industry as well as for fresh consumption (Çelik et al., 2019). Today, pomegranate cultivation is carried out in a wide area from Australia to South Africa, USA and China (Ünal, 2011). Hicaznar pomegranate is one of the main varieties in pomegranate cultivation in Turkey. Turkey's total pomegranate production was realized as 600 021 tonnes in 2020 (TUIK, 2020).

Calcium is an obligatory and a very important mineral for plants. It performs structural functions in the cell walls and membranes of the plant. It is also required as a balancing agent against inorganic and organic anions. Middle lamellae of cells that expand in calcium deficiency weaken and crack. (White, 2001; Asgharzade et al., 2012).

During the development of the fruit, its nutrition is the most important factor determining fruit quality and post-harvest performance (Schuman et al., 1973). The calcium intake and distribution in the plants are affected by the movement of water in the organs that become apparent and the use of calcium in the transport route (Saure, 2005). Although there is enough calcium in the garden soil, the occurrence of calcium deficiency creates great economic losses and becomes a problem for many fruit types (Montanaro et al., 2006).

Proper fruit ripening is related to calcium. The low calcium content in the fruit causes susceptibility to many physiological and pathological diseases and a short shelf life (Conway et al., 1992; Fallahi et al., 1997). It has been determined that calcium application before harvest prevents physiological disorders as well as delaying maturity and increasing fruit quality in many fruit species (Hernandez Munoz et al., 2006). Foliar application of calcium significantly increases the calcium content in fresh fruit and the effectiveness of ripening and aging-related changes (Pooviah, 1979).

This study was carried out based on the method of spraying pomegranate leaves at different levels and in two periods of $CaCl_2$, a powerful source of calcium, and the results of the effects on some quality characteristics and nutrition of pomegranate are discussed in this article.

2. Materials and Methods

The experiment was conducted during 2016 and 2017 in a 25 years old Hicaznar pomegranate cultivar commercial orchard located in Aydın (Turkey) ecological condition. In the vegetation duration (between March and November), the total rainfall is 660.9 mm in 2016 and 729.1 mm in 2017. In addition, the average temperature was 20.1 °C in 2016 and 21.2 °C in 2017. The average temperature in the research duration is coherent with the long-term average temperature (20.5 °C) and the total rainfall is compatible with the long-term total rainfall (647.0 mm).

In April, soil samples were taken from the research orchard, air-dried, and sieved through a 2 mm sieve. The soil characteristics and analysis methods of the orchard were presented in Table 1. When the orchard soil analysis results are evaluated; pomegranate orchard is lower calcareous and medium organic matter content, slightly acidic, clay loamy, and lower salinity (EC: Electirical conductivity). However, it was determined that soil samples were sufficient by macro and micronutrients (Kacar, 1994).

Leaf samples were collected on four sides of the trees from that year's shoots to determine leaf nutrient concentrations. The samples were before washed with mains water and after with distilled water. Then dried at 65 ± 5 ° C for 2 days. Samples removed from the oven were made ready for analysis. Total N, Kjeldahl method, foliar P concentration spectrophotometrically (Shimadzu UV-1208, 430 nm), K, Ca, Mg, Fe, Cu, Zn, and Mn contents were analyzed using atomic absorption spectrophotometer (Kacar and İnal, 2008).

The research was planned according to the randomized parcel design. The applications are stated below.

1- Control (0% $CaCl_2$ tree^{-1}), 2- 0.20% $CaCl_2$ tree^{-1}, 3- 0.40% $CaCl_2$ tree^{-1}, 4- 0.60% $CaCl_2$ tree^{-1}, 5- 0.80% $CaCl_2$ tree^{-1}, 6- 1.00% $CaCl_2$ tree^{-1}

Table 1. Some soil physicochemical characteristics of the research orchard (0-30 cm)

Soil characteristics (0-20 cm depth)		Methods	Soil characteristics (0-20 cm depth)		Methods
Soil texture	Clay loamy	Bouycous	Potassium (mg kg^{-1})	280.2	NH_4OAc
EC (dS m^{-1})	0.17	Saturation sludge	Calcium (mg kg^{-1})	220	NH_4OAc
pH; 1:1 (w/v)	5.58	Saturation sludge	Magnesium (mg kg^{-1})	162	NH_4OAc
$CaCO_3$ (%)	0.71	Scheibler	Iron (mg kg^{-1})	6.25	DTPA
Organic matter (%)	2.74	Walkley-Black	Zinc (mg kg^{-1})	1.24	DTPA
Total nitrogen (%)	0.124	Kjendahl	Manganese (mg kg^{-1})	4.14	DTPA
Phosphorus (mg kg^{-1})	11.57	Olsen	Cupper (mg kg^{-1})	2.51	DTPA

NH_4OAc: Amonium Acetate, DTPA: Diethylenetriaminepentaacetic acid.

Regular fertilization was carried out in the experimental orchard. Every year, 2.5 kg of 20:20:20 compound fertilizer, 0.5 kg of potassium nitrate, and 1.0 kg of Urea were applied per tree. The experiment consisted of 3 replications, 3 trees in each replica and 6 applications; It was carried out on 54 trees (6 x 6 planting order). The $CaCl_2$ solutions were applied twice (June 15 and August 15) by sprayed to leaves. The water requirement of the plants was met with the drip irrigation system in the orchard. Irrigation was measured with an evaporation pot and water was applied according to the moisture in the soil. Cultural weed cleaning is done regularly in the pomegranate orchard.

Leaf samples of Hicaznar pomegranate varieties were taken 10 September in the middle of the annual shoots of fruitless (Özkan et al., 1999). As a result of applications were determined to yield per tree (kg $tree^{-1}$), fruit length (cm), diameter (cm), peel thickness (mm), foliar macro and micronutrients in 2016 and 2017 years.

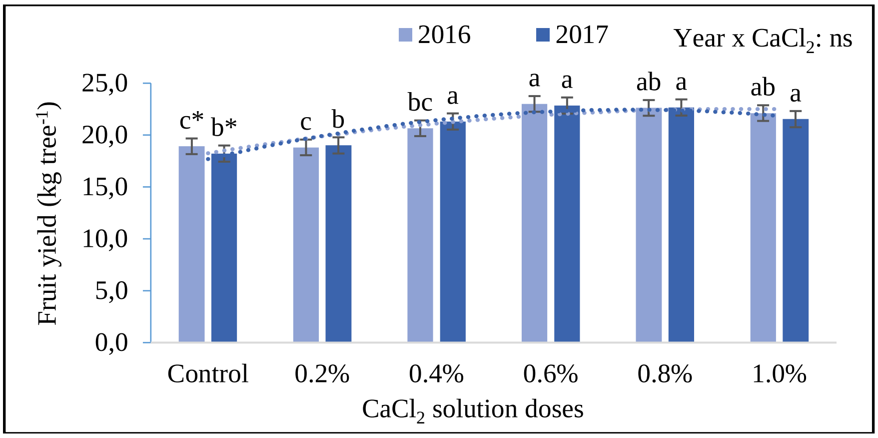
Analysis of variance (ANOVA) and Duncan's tests were conducted with a $P \leq 0.05$ significance level using SPSS Version 22 (IBM Corp., 2013) statistical software.

3. Results and Discussion

3.1. Fruit yield

Applied $CaCl_2$ doses, statistically increased fruit yield per tree. According to statistical results, significant relationships were found between application doses and fruit yield (Figure 1). The highest fruit yield was determined as 23.0 kg $tree^{-1}$ in the 2016 year and 22.8 kg $tree^{-1}$ in the 2017 year at 0.6% $CaCl_2$ dose, 22.6 kg $tree^{-1}$ in the first year and 22.7 kg $tree^{-1}$ in the second year at 0.8% $CaCl_2$ dose.

They reported that calcium applied by spraying to pomegranate plant was effective on yield and fruit quality in tangerine (Eroğul et al., 2011), cherry (Simon, 2006), apple (Raese, 2000 and Wojcik et al., 2002).



Letters overhead the columns indicate the effects of the Duncan test (*: $P \leq 0.05$) for the yields of the pomegranate fruit (CV_{2016}: 9.52; CV_{2017}: 9.46).
2016: $y = -0.1941x^2 + 2.2091x + 16.234$. $R^2 = 0.822$. LSD*: 2.10 (2016)
2017: $y = -0.3487x^2 + 3.2721x + 14.765$. $R^2 = 0.912$. LSD*: 1.77 (2017).

Figure 1. Effect of foliar $CaCl_2$ applications on fruit yield of pomegranate.

Fruit yield increased 23% at 0.6% $CaCl_2$ dose compared to the control dose. Besides, the average tree yield was realized to be around 22 kg in 0.8% and 1.0% $CaCl_2$ applications. Results were determined that foliar Ca applications increased fruit yield in parallel with the studies conducted by Güneri et al. (2014); Korkmaz and Aşkın (2015); Bakeer (2016).

3.2. The some quality properties of pomegranate

According to the results, statistically significant relationships were determined between the applied $CaCl_2$ doses and all the qualitative parameters indicated in Table 2. Only fruit diameter was not affected by $CaCl_2$ doses in 2016. However, statistical differences were obtained according to application doses in 2017. The highest fruit diameter was found to be 16.3 cm at a dose of 0.8% $CaCl_2$ in the same year. The size of the fruit is highly influenced by environmental and cultural care conditions as determined by the genetic characteristics of the variety (Al-Maiman and Ahmad, 2002).

Table 2. Effect of foliar $CaCl_2$ applications on some qualitative properties of pomegranate fruit

Solution doses	Fruit weight (g)		Fruit diameter (cm)		Fruit length (cm)		Peel thickness (mm)	
	2016	2017	2016	2017	2016	2017	2016	2017
Control	579 ^{b}	585 ^{b}	15.5	15.3 ^{c}	13.2 ^{b}	13.3 ^{b}	4.71 ^{b}	4.82 ^{c}
0.2% $CaCl_2$	604 ^{ab}	598 ^{ab}	15.4	15.6 ^{bc}	13.7 ^{ab}	13.6 ^{b}	4.82 ^{b}	4.88 ^{bc}
0.4% $CaCl_2$	605 ^{ab}	610 ^{ab}	15.3	15.2 ^{c}	13.8 ^{ab}	13.9 ^{ab}	4.93 ^{a}	4.92 ^{abc}
0.6% $CaCl_2$	626 ^{a}	624 ^{a}	15.7	16.0 ^{ab}	14.2 ^{a}	14.4 ^{a}	4.96 ^{a}	4.97 ^{ab}
0.8% $CaCl_2$	619 ^{ab}	622 ^{a}	15.8	16.3 ^{a}	14.1 ^{ab}	14.5 ^{a}	4.97 ^{a}	5.03 ^{a}
1.0% $CaCl_2$	617 ^{ab}	611 ^{ab}	15.4	15.3 ^{c}	14.0 ^{ab}	13.9 ^{ab}	5.02 ^{a}	4.95 ^{ab}
LSD *	6.98	11.33	ns	0.26	0.17	0.57	0.18	0.03
Year x $CaCl_2$	ns		ns		ns		ns	
CV (%)	3.95	3.45	2.27	3.04	3.95	3.88	5.47	4.75

ns: not significant, * : ($P \leq 0.05$).

The highest fruit weights were recorded as 626 g in the 2016 year and 624 g in the 2017 year at a dose of 0.6% $CaCl_2$. However, the highest fruit length was determined as 14.2 and 14.4 cm at 0.6% $CaCl_2$ dose in both application years, respectively. Finally, in parallel with increasing application doses, fruit peel thickness increased. The highest fruit peel thickness value was 5.02 mm at 1.0% $CaCl_2$ application in the first year and 5.03 mm at 0.8% $CaCl_2$ application in the second year. In some pomegranate varieties, it has been determined that there is a relationship between some morphological and physiological characteristics, leaf characteristics, and nutritional level, and a high correlation between leaf N and K / Ca ratio and pell thickness (Hepaksoy et al., 1998). In many studies, it was determined that foliar calcium applications increased pomegranate fruit quality properties (Bakeer, 2016; Korkmaz et al., 2016).

3.3. The macro and micro nutrients status of pomegranate leaves

The effect of $CaCl_2$ solution doses on the change of macronutrients in pomegranate leaves is presented in Table 3. The findings obtained in this study clearly demonstrate the effect of $CaCl_2$ solution doses on the intake of macronutrients and the interaction between them.

Although the doses of $CaCl_2$ applied did not change statistically the N level of the plant in the 2016 year, major differences were obtained in the 2017 year. The highest N level was determined at 0.6% $CaCl_2$dose (2.0% N). However, there was no statistically significant change in P level of the plant. On the other hand, reductions in foliar P concentrations were recorded in the final doses compared to the control.

Foliar K concentrations were tended to decrease rapidly after the first dose (0.2% $CaCl_2$). The highest K concentration was detected in 0.2% $CaCl_2$ dose (2016: 1.67%, 2017: 1.65%), and the lowest at 1.0% $CaCl_2$ dose (2016: 1.52%, 2017: 1.55%). As expected in the study, as $CaCl_2$ doses increased, foliar Ca concentrations increased at the same rate. This increase is 15% on average. However, foliar Mg concentrations gave a negative response to the administered $CaCl_2$ doses and the lowest value was recorded at the last application dose. As a result, increasing doses of $CaCl_2$ solution doses increased the only N and Ca concentrations in plants, but decreased P, K and Mg concentrations. Results of leaf analyses indicated that Ca application runs to a significant increase in the foliar Ca content when matched with the control dose. Increases in Ca contents after foliar Ca applications have been previously reported by Korkmaz et al. (2016).

Table 3. Effect of foliar $CaCl_2$ applications on macronutrient of pomegranate leaves

Solution doses	N (%)		P (%)		K (%)		Ca (%)		Mg (%)	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Control	1.87	1.86 ^{b}	0.17	0.19	1.64 ^{ab}	1.64 ^{a}	1.82 ^{e}	1.85 ^{c}	0.62 ^{a}	0.63 ^{a}
0.2% $CaCl_2$	1.90	1.87 ^{b}	0.19	0.18	1.67 ^{a}	1.65 ^{a}	1.94 ^{d}	1.93 ^{b}	0.63 ^{a}	0.62 ^{a}
0.4% $CaCl_2$	1.92	1.93 ^{ab}	0.18	0.18	1.64 ^{ab}	1.61 ^{ab}	1.98 ^{c}	1.94 ^{b}	0.60 ^{ab}	0.60 ^{ab}
0.6% $CaCl_2$	1.98	2.00 ^{a}	0.17	0.18	1.59 ^{b}	1.59 ^{bc}	2.04 ^{b}	2.05 ^{a}	0.59 ^{b}	0.60 ^{ab}
0.8% $CaCl_2$	1.93	1.96 ^{ab}	0.17	0.17	1.58 ^{bc}	1.57 ^{cd}	2.06 b	2.05 ^{a}	0.57 ^{bc}	0.57 ^{bc}
1.0% $CaCl_2$	1.94	1.93 ^{ab}	0.17	0.16	1.52 ^{c}	1.55 ^{d}	2.10 a	2.09 ^{a}	0.56 ^{c}	0.56 ^{c}
LSD *	ns	0.02	ns	ns	0.03	0.03	0.04	0.12	0.03	0.02
Year x $CaCl_2$	ns		ns		ns		ns		ns	
CV (%)	3.47	3.44	8.53	8.29	3.72	2.69	4.86	4.74	4.58	4.71

ns: not significant * : ($P \leq 0.05$).

Interaction between nutrients in cultivated plants are closely related to plant nutrition and quality characteristics. In this context, calcium is an element that is subject to much work. Calcium, especially phosphorus, potassium, magnesium, and microelements have been confirmed by many studies (Altuntaş, 2016; Güneri et al., 2014; Eroğul 2011; Kacar and Katkat, 1998; Hepaksoy et al.,1998).

The high amount of Ca accumulation in the leaves is in contention with K, Mg and other micronutrients, especially P. Besides, Ca / N balance in the plant must be in balance for plant growth. The amount of Ca in the plant stabilizes the N state in the leaf up to a certain level and at increasing levels, Ca decreases the N accumulation in the leaves (Barker and Pillbeam, 2007; Kacar and Katkat, 2011).

In a study, due to the increased low calcium concentrations in the nutrient solution, the phosphorus content of the leaves in the rice plant was not affected, but when the calcium concentrations were further increased, the decrease in phosphorus coverage was more severe (Fageria, 2001). However, the results obtained are coherent with the research of Guneri et al. (2014).The macronutrient contents of the leaves have remained within the specified limit values for pomegranate (Sheik, 2006).The effect of $CaCl_2$ solution doses on the change of micronutrients in pomegranate leaves is shown in Table 4. The findings carry out in this research plainly demonstrate the effect of $CaCl_2$ solution doses on the level of micronutrients.

Table 4. Effect of foliar $CaCl_2$ applications on micronutrient of pomegranate leaves

Solution doses	Fe (mg kg^{-1})		Zn (mg kg^{-1})		Mn (mg kg^{-1})		Cu (mg kg^{-1})	
	2016	2017	2016	2017	2016	2017	2016	2017
Control	221 ^{a}	218 ^{a}	50.1 ^{a}	52.1 ^{a}	53.4 ^{a}	53.0 ^{a}	44.9 ^{a}	45.3 ^{a}
0.2% $CaCl_2$	211 ^{ab}	212 ^{ab}	49.4 ^{a}	48.3 ^{b}	51.5 ^{ab}	51.4 ^{ab}	42.1 b	41.9 ^{b}
0.4% $CaCl_2$	202 ^{bc}	203 ^{bc}	48.1 ^{ab}	47.5 ^{b}	50.3 ^{b}	50.5 ^{b}	42.0 ^{b}	41.2 ^{b}
0.6% $CaCl_2$	196 ^{cd}	195 ^{c}	45.8 ^{bc}	45.3 ^{bc}	49.8 ^{b}	50.3 ^{b}	39.7 ^{bc}	39.9 ^{bc}
0.8% $CaCl_2$	192 ^{cd}	193 ^{cd}	43.6 ^{c}	42.5 ^{cd}	47.2 ^{c}	46.5 ^{c}	39.4 ^{bc}	39.8 ^{bc}
1.0% $CaCl_2$	186 ^{d}	184 ^{d}	39.8 ^{d}	40.8 ^{d}	45.3 ^{c}	46.1 ^{c}	38.4 ^{c}	38.5 ^{c}
LSD *	8.33	4.69	1.30	2.17	1.63	1.10	2.63	2.10
Year x $CaCl_2$	ns		ns		ns		ns	
CV (%)	6.68	6.42	8.54	8.85	5.76	5.50	6.13	5.88

ns: not significant * : ($P \leq 0.05$).

In study, doses of $CaCl_2$ solution sprayed to leaves caused statistically significant differences in foliar micronutrient contents. Although the micronutrient contents of the leaves decreased with the doses applied, it remained within the specified limit values for pomegranate (Sheik, 2006). According to the findings, the highest Fe, Zn, Mn and Cu contents in 2016 and 2017 years were 221, 218, 50.1, 52.1, 53.4, 53.0, 44.9, and 45.3 mg kg^{-1}, respectively.

In addition, the increase in the calcium concentration of the nutrient solution micro-elements gave a more pronounced response, this response was generally in the direction of decline (Fageria, 2001). Similarly, increasing doses of Ca applied to leaves decreased micronutrient contents in leaves parallel to the study of Güneri et al. (2014). In this case, it shows us once again that there is a negative interaction between Ca and micronutrients.

4. Conclusions

$CaCl_2$ solutions applied increased pomegranate fruit yield and some quality properties compared to the control dose. Increases in fruit yield, fruit weight, diameter, height, and peel thickness were determined as average 21%, 7.5%, 9%, 8%, and 13%, respectively. The applied $CaCl_2$ solutions were increased the N and Ca concentrations compared to the control dose and no significant change was determined in the foliar P content. However, foliar K, Mg, Fe, Zn, Mn, and Cu concentrations were decreased. However, these decrease did not exceed 15% rate compared to control doses in the pomegranate leaves. The level of all plant nutrients in the leaves remained within the specified standard level ranges. Supplemental studies would be essential to anymore update the content and timing of the Ca fertilizations, with the purpose to reduce the proportion of some physiological irregularity and optimized nutrient in products such as pomegranate, which limits fruit qualitative and quantitative properties every year.

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