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ORIGINAL PAPER

EFFECT OF FOLIAR POTASSIUM AND CALCIUM APPLICATIONS ON THE NUTRIENT STATUS, FRUIT QUALITY AND YIELD OF APPLE TREE VARIETIES*

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Abstract

In this study, foliar potassium and calcium fertilizers were applied singly and combined to two different apple tree varieties in order to evaluate the effects of potassium and calcium fertilizers on yield, quality and nutrient levels and to recommend fertilization. For this purpose, the Red Chief and Golden Delicious varieties were used. Leaf analyses (N, P, K, Ca, Mg, Fe, Cu, Zn, Mn), the SPAD measurement, pomological analyses (fruit weight, width, length, skin color, flesh firmness), and yield were made. Differences in nitrogen and phosphorus between the varieties and applications were found to be insiginificant, while Golden Delicious was found to be significantly richer than Red Chief in the content of K, Ca and Mg. According to the values obtained, all the micronutrients except Fe were taken up in greater amounts by Red Chief than by Golden Delicious. Differences between the cultivars in the width, height and weight of fruits were significant, but the differences in the same parameters due to the tested applications were found to be insignificant. When examined in terms of firmness, the difference between the varieties was insignificant, and the difference between the applications was significant, as Golden Delicious achieved higher values than Red Chief. In terms of the leaf SPAD value, Red Chief scored higher than Golden Delicious. Using an appropriate fertilizer for a given variety is important for increasing yield, quality and nutrient concentration when potassium and calcium fertilizers are applied separately or together in similar climatic and soil conditions. In this study, the yield was increased by applying K and Ca separately or together. Among the quality parameters, it was determined that the K+Ca application was more effective than separate applications of K and Ca in terms of fruit firmness. Although there is sufficient potassium and calcium in the soil, 1% Ca + 1% K application to the apple tree leaves can increase fruit quality and yield. The results will be useful for future studies.

Keywords: apple, calcium, potassium, quality, yield

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INTRODUCTION

Apples are one of the most widely produced fruits in the world, hence occupying an important place in the horticultural trade worldwide. In 2017, 83 139 326 tons of apples were produced in an area of 4 933 841 ha (FAO 2019). For apple cultivation, it is fundamental to ensure balanced fertilization at the right time, together with other cultivation methods, in order to grow high yields and high quality apples. Fertilization is one of the essential applications for fruit growing. The amount of high quality fruit is more important than the overall yield in modern horticulture. Consumers make their choices by considering the inside and outside appearance of the fruit, as well as the quality of taste. For this reason, it has become essential to grow attractive, high quality products instead of generating high yields in the fruit sector, especially in apple horticulture. For this reason, foliar fertilization is very important for increasing the quality and yield of apples. High soil pH, high lime content, low organic matter, lack of water, leaching, imbalances between other nutrients, shallow soil profile, soil compaction, fixation, late application of nutrients to soil, etc., may deteriorate the yield volume and quality. Whenever plant nutrients cannot be taken by roots due to different soil conditions, foliar application can be successfully used to meet the nutrient needs of plants.

Potassium is especially important for fruits. Obtaining high sugar content, full and uniform color, and high quality fruit depends on an adequate potassium intake (Zhang et al. 2018, Kuzin, Solovchenko 2021). In apple trees with potassium deficiency, even if fruit setting is normal, fruit size becomes smaller than normal, and the apples are dull, tasteless and thick--skin due to low acidity. Moreover, trees are more sensitive to winter cold, while flowering and fruiting buds are vulnerable to spring frosts (Bai et al. 2021). According to Stiles (1994), even if the amount of K in arid soils is sufficient, a deficiency of this element is observed in the plant. Neilsen, Neilsen (2003) stated that the apple fruit has a good potassium requirement and that potassium is the element most affected by the apple load on a tree. A decrease in the potassium concentration of leaves in midsummer is related to competition between fruits and leaves to utilize newly absorbed potassium by the roots (Bai et al. 2021). Potassium has a positive effect on the carbohydrate metabolism of apples, improves balanced flowering and the quality and quantity of the product. Potassium in fruit has positive effects on developing the fruit color, increasing the amount of dry matter, improving the sugar/ /acid balance and ensuring early harvest. Potassium fertilization positively affects the longer storage of apples in a warehouse, alleviates negative effects of the storage process and the crushing during transportation. Potassium positively affects the density of fruit flesh, leading to lesser water loss during storage and lower degradation of acids in apples (Kacar, Katkat 1999).

Even if there is calcium in the soil, its transport from root to fruit is limited and the element is more immobile in plants, which makes the problems due calcium deficiency manifest demonstrably. Calcium spraying of the aerial parts of plants has been recommended and has become a routine practice in many fruit producing regions to reduce calcium deficiencies and improve fruit quality (Blanco et al. 2010). Factors such as drought, low temperature, high humidity, insufficient soil aeration, excessive nitrogen application and strong plant growth are all the factors that can induce calcium deficiency in plants. Most of the calcium in plants is found in the cell walls and membranes, and its content is closely related to postharvest life expectancy and fruit ripening (Chardonnet et al. 2003). Siddiqui, Bangerth (1995) have reported that calcium application before harvest does not result in firmer fruit.

The amount of nutrients taken up by plants can vary between plant species and between different varieties of the same plant. These changes affect the plant growth, yield and quality to varying degrees. Therefore, in order to develop a good fertilization plan, the nutrient uptake and carrying capacity of plant varieties and species should be considered (Hatipoğlu 1981, Kacar 1995, Marschner 1996, Erdal 2005). The literature reports on studies in which K and Ca application to apple trees increased their nutrient content and fruit quality (Peterson, Stevens 1994, Dilmaghani et al. 2005, Korkmaz 2005, Mimoun, Marchhand 2013, Mosa et al. 2015, Shen et al. 2016, Solhjo et al. 2017, Kucukyumuk, Erdal 2022), but there are also a few studies that deal with both quality and nutrient relationships. In addition, studies on the nutrient intake by different cultivars have demonstrated differences in this parameter between cultivars (Bolat et al.1995, Ersadi, Talaie 2001, Kucukyumuk, Erdal 2009).

This study was carried out to evaluate the effects of foliar calcium and potassium applications on the yield, quality and nutrition level of apple trees. Another aim was to develop recommendations for application of potassium and calcium fertilizers separately and together to leaves of two apple tree varieties, Golden Delicious and Red Chief, grafted on M9 rootstock.

MATERIAL AND METHODS

Study area and climatic characteristics

The experiment was carried out in an apple orchard belonging to the Isparta University of Applied Sciences in 2020. The altitude of the trial area is 1 050 m, and its location was between 30° 20° and 31° 33° east meridians and 37° 18° and 38° 30° north latitude. The trial site is located in the center of the Lake District in Turkey, which has a transitional climate and plant cover between the Central Anatolian region of the Isparta and the Mediter-

ranean region. This area has a transitional climate between the continental climate and the Mediterranean climate.

Sixteen-year-old apple trees of two different apple varieties, Golden Delicious and Red Chief, grafted on M9 and growing at 1.5x4.5 m distance were used in this study. All the trees grew in the same orchard, in the soil with the same properties. In the experiment, Red Chief, which has dark red, bright and glossy fruits, and Golden Delicious, whose apples' skin color is yellow and green, were used. In the experiment, 4 fertilizer applications on both apple cultivars grafted on M9 rootstock and 2 different fertilizer sources of nutrients (K and Ca) were tested. In the experiment, which was planned according to a randomized plot trial design, 4 replications of each application and 15 trees in each replication were included in each experimental object. The experiment was carried out on 60 trees of cv. Golden Delicious, 60 trees of cv. Red Chief, that is on a total of 120 trees. Approximately 50 leaf samples were collected from each tree. The trees used in the experiment were arranged according to a randomized plot experimental design with 4 replicates. The potassium source KNO_3 and the calcium source $CaNO_3$ were used. The application variants were: 0% (control, 1% Ca ($Ca(NO_3)_2$), 1% K (KNO_3), 1% Ca ($Ca(NO_3)_2$) + 1% K (KNO_3). The first applications were performed 20 days since the date of full blossom. Then, the above fertilizers were applied 4 times with a sprayer at intervals of 15 days, while the basic fertilization through a drip irrigation system provided: nitrogen 16 kg/da, phosphorus 8 kg/da and potassium 6 kg/da throughout the season, in addition to ammonium sulfate (AS) + urea, mono-ammonium phosphate (MAP) and potassium nitrate (KNO_3). Pesticide application and pruning were done properly. The harvesting term was determined at the commercial harvest.

Soil analysis methods

The soil properties were as follows: pH 7.8 (1:2.5 soil: water, Jackson 1967), 1.7% organic matter (Black 1965), 25% $CaCO_3$ (Caglar 1949), 0.5 M $NaHCO_3$ 4.5 kg ha^{-1} P (Olsen 1982), NH_4 OAc-exchangeable K 420 kg ha^{-1} (Thomas 1982). The soil structure represents the silty loam, alkaline and salt-free soil class. The soil is also in the highly calcareous class, while the organic matter and phosphorus content are in the low class. Nitrogen, potassium, magnesium, zinc, manganese and copper contents were found to be sufficient, while calcium was found in the high and iron – in the medium content class.

Sampling leaves and chemical analysis methods

Leaf samples were collected in mid-July, from all sides of a tree and from the middle of the shoots of that year, in accordance with the development season of apple trees (Bergmann 1992). After washing first with tap water, then with acidic and distilled water, the samples were dried at 65±5°C for at least 48 hours and then ground. The ground samples were

incinerated by the microwave wet burning method (CEMMars 5, manufactured by CEM Corp., USA). Plant ion concentrations (Ca, K, Mg, Fe, Cu, Zn, Mn of the leaf tissue) were determined by Atomic Absorbtion Spectrophotometry (AAS), phosphorus concentrations were found by the vanadate-molybdate colorimetric method (Kacar, İnal 2008). The evaluation approach developed by Jones et al. (1991), widely used to evaluate the nutrient concentrations in apple tree leaves, was implemented. The SPAD (spectral plant analysis diagnostic) value was determined in the early hours of a day, with a Minolta SPAD-502 brand chlorophyll measuring device. For this purpose, 20 leaves that had completed their development were selected randomly from each of the four predetermined trees, and measurements were made between the midrib and leaf margins 4 times, taking the average of these values as the measurement value. During the harvest period, the fruits were harvested in accordance with the variety harvest time, and their yield (kg/tree) was determined. The starch test was used to determine the harvest time of fruits. According to the method, apples cut from the equatorial region were kept in 1% potassium iodide for 30 seconds. The period in which the core and its surroundings did not darken (starch is converted into sugar from the outside towards the core) was determined. Samplings were made in this period (Karaçalı 2012).

Pomological analyses

In order to determine the effects of the tested applications on fruit quality, 10 fruits were taken from each tree at the harvest date of the variety. Fruit weight (g), fruit width (mm), fruit length (mm), fruit skin color (L, a, b), and fruit firmness (kg cm^{-2}) composed the pomological analyses. Fruit width and fruit length (mm) were measured with the help of a digital caliper at accuracy of 0.01. Fruit weight (g) was determined by weighing on a balance at accuracy of 0.01. Fruit flesh firmness was measured in each replicate on 10 fruits using a digital texture machine (Lloyd Instruments LF Plus), and by compression at harvest using a 1 kN load cell and a stainless steel, 11.1 mm diameter cylindrical probe, at a constant speed of 100 mm min^{-1}. The results were expressed in Newton units (N). Fruit color (L, a, b) was determined with the help of a Minolta CR-300 Model chromometer color device at 2 different symmetrical points on the equatorial region of the fruit: L – lightness coordinate (L:0 indicates black and L:100 is white), a – is the red/green coordinate (+a determines red, -a determines green), b – the yellow/blue coordinate (+b determines yellow, -b determines blue).

Statistics

The data obtained in the study concerning the analyzed traits were submitted to the analysis of variance in a factorial order. In the study, the cultivar factor has two level: Golden Delicious and Red Chief, and the application factor has four variants: as control, potassium, calcium, potassium +

calcium. The number of observations in the subgroups is four. In the study, the Tukey's test was used to determine the differences between the means of the factors.

RESULTS AND DISCUSSION

Table 1 shows the effects of foliar K and Ca applications on N, P, K, Ca and Mg concentrations in leaves of the two apple cultivars. The effect of the variety*application interaction on leaf N concentrations in the two apple cultivars was found to be significant. According to the results, Golden Delicious leaves had 19.5 g kg^{-1} N, while Red Chief leaves had 24.6% g kg^{-1} N. In terms of the N concentration, control (25.0 g kg^{-1}) and Ca applications (25.2 g kg^{-1}) were found to result in higher N in the Red Chief variety than

Table 1

The effect of foliar K and Ca applications on N, P, K, Ca, Mg concentrations in leaves of different apple cultivars

Nutrient (g kg^{-1})	Variety	Application				Mean
		control	K	Ca	K+Ca	
N	Golden D.	20.2*Ab***	20.2*Ab*	19.3*ABb*	18.6*Bb*	19.5
	Red Chief	25.0*Aa*	23.5*Aa*	25.2*Aa*	24.7*Aa*	24.6
	mean	22.6	21.8	22.2	21.6	
P	Golden D.	4.4^{ns}	4.2	3.4	4.1	4.0
	Red Chief	4.4	4.2	3.6	4.1	4.1
	mean	4.4	4.2	3.5	4.1	
K	Golden D.	13.0	14.8	13.5	14.3	13.9*a**
	Red Chief	11.4	13.1	11.6	13.1	12.3*b*
	mean	12.2*B***	14.0*A*	12.5*B*	13.7*A*	
Ca	Golden D.	12.8*Ba***	14.7*Ba*	15.3*Ba*	23.4*Aa*	16.6
	Red Chief	12.7*Bb*	12.7*Bb*	14.1*ABb*	16.8*Ab*	14.1
	mean	12.7	13.7	14.7	20.1	
Mg	Golden D.	4.3*Ab***	4.6*Aa*	4.0*Ab*	5.0*Aa*	4.5
	Red Chief	4.5*Aa*	4.4*Ab*	4.3*Aa*	4.1*Ab*	4.3
	mean	4.4	4.5	4.1	4.5	

The differences between capital letters indicate applications; lowercase letters indicate the differences between the varieties.

** The difference between the means with different letters in the same column and in the same row is significant (P<0.01).

* The difference between the means shown with different letters in the same column and in the same row is significant (P<0.05).

ns – not significant

the other applications and or in the other variety. Our results are consistent with Mosa et al. (2015), who reported that potassium and calcium applications increased leaf N concentrations in apple (Anna variety). When compared with the other nutrients, potassium has a greater effect on the nitrogen content because an adequate potassium supply increases the synthesis of amino acids and proteins as well as the metabolism of nitrogen (Coskun et al. 2016, Xu et al. 2020). In our study, it can be said that the decrease in N according to the applications is due to the dilution effect. In terms of the phosphorus content, the effects of individual factors and interactions of the cultivars and applications were not found to result in statistically significant differences. According to Guneri et al. (2014), in their study in which they applied potassium and calcium to leaves of pomegranate trees, the effect on the P content was not statistically significant. The effect of the cultivar and application interaction was found to be insignificant in terms of the potassium content, and the effect of the cultivar and leaf applications was found to be statistically significant. While the leaf K content of the Golden Delicious apple cultivar was 13.9 g kg^{-1}, the K content of the Red Chief cultivar was 12.3 g kg^{-1}. The K content in leaves of the apple trees treated with potassium (14. 0 g kg^{-1}) and potassium + calcium (13.7 g kg^{-1}) was higher than in the calcium and the controlvariants: control (12.2 g kg^{-1}) and calcium (12.5 g kg^{-1}) applications were in the same group. In some previous studies, such as by Solhjo et al. (2017) on apple trees, Güner et al. (2014) on pomegranate, and by Yagmur et al. (2005) on grapevine, it was determined that K applications increased the potassium content in leaves compared to the control, and the results show consistency with our study.

When the Ca content of apple leaves was examined, it was determined that the cultivar*application interaction caused statistically significant differences. While the Golden Delicious cultivar leaves had the highest Ca content in K+Ca application (23.4 g kg^{-1}), the lowest Ca content was found in the Red Chief cultivar leaves in the control variant (12.7 g kg^{-1}). According to the average values, the Golden Delicious apple cultivar leaves had 16.6 g kg^{-1} Ca, while Red Chief apple cultivar leaves contained 14.1 g kg^{-1} Ca. Regarding the potassium and calcium contents in the trial applications, the limit values for the potassium content of apple leaves vary between 15-20 g kg^{-1}, and the calcium contents range between 12-16 g kg^{-1}, as determined by Jones et al. (1991). Considering these values, the leaf concentrations of K and Ca determined in our study were sufficient. In similar studies in which Ca was applied to apple trees (Korkmaz 2005, Dilmaghani et al. 2009, Kucukyumuk, Erdal 2022) and to pear trees (Shen et al. 2016), an increase in the leaf Ca content was determined. In addition, Kucukyumuk, Erdal (2022) tested Golden Delicious, Pink Lady, Jonabres and Red Delicious apple varieties to determine the effect of calcium on apple quality and mineral nutrient content in different apple varieties. In terms of varietal differences, the Jonabres and Golden Delicious apple cultivars were more affected than the other cultivars. When the Mg content of apple leaves was evalua-

ted, the variety*application interaction was found to be statistically significant. The K+Ca application to the Golden Delicious apple cultivar leaves resulted in the highest Mg content (5.0 g kg^{-1}), while the Ca application to the Golden Delicious apple cultivar led to the leaves having the lowest Mg content (4.0 g kg^{-1}). While Golden Delicious leaves had 0.45% Mg content, Red Chief leaves had 4.3 g kg^{-1} Mg, hence Golden Delicious leaves contained more Mg than Red Chief leaves.

The effects of foliar K +Ca applications of different apple varieties leaves on some micro element contents were given in Table 2. When the effects

Table 2

The effect of foliar K and Ca applications on Fe, Cu, Mn and Zn concentrations in leaves of different apple cultivars

Nutrient (mg kg^{-1})	Variety	Application				Mean
		control	K	Ca	K+Ca	
Fe	Golden D.	153	163	170	181	167*a***
	Red Chief	119	112	107	115	114*b*
	mean	136	138	139	148	
Cu	Golden D.	10	10	10	9	10*b***
	Red Chief	15	15	15	15	15*a*
	mean	13	13	13	12	
Mn	Golden D.	118*Aa***	120*Ab*	92*Bb*	103*Bb*	109
	Red Chief	113*Ab*	122*Aa*	120*Aa*	120*Aa*	119
	mean	116	121	107	112	
Zn	Golden D.	12*Ab**	12*Ab*	12*Ab*	12*Ab*	12
	Red Chief	18*Ba*	21*Aa*	16*Ca*	19*Ba*	18
	mean	15	17	14	15	

The differences between capital letters indicate applications; lowercase letters indicate the differences between the varieties.

** The difference between the means with different letters in the same column and in the same row is significant ($P<0.01$).

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of applications and cultivars on iron (Fe) uptake were examined, it was seen that the cultivar*application interaction was not statistically significant. While there was no statistical significance between the applications, the difference between the cultivars was found to be statistically significant in terms of Fe content. While the leaf Fe concentration of Golden Delicious variety was 167 mg kg^{-1}, Fe concentration of 114 mg kg^{-1} was determined in Red Chief variety. Kucukyumuk, Erdal (2022) found similar with our results that Fe concentrations changed with different varieties, whereas foliar Ca application were not varied. The Cu concentration of the leaves was also similar to the iron results. While statistical significance was not determined between

cultivar*application interaction and applications, statistical significance was determined between cultivars. Malakouti et al. (1999) reported that micro nutrients were not affected by Ca treatments in Red Delicious apple, our results are consisent with the results.

When the effects of the applications and cultivars on the Mn content were examined, it was determined that the cultivar*application interaction caused statistically significant results. It was determined that the leaf Mn content of the Red Chief cultivar due to the K application had the highest Mn content at 122 mg kg^{-1}. The lowest Mn content was determined to be 92 mg kg^{-1} Mn concentration caused by the Ca application to leaves of the Golden Delicious variety. The leaf Mn concentrations of the Golden Delicious (109 mg kg^{-1}) apple cultivar were found to be lower than the leaf Mn concentration of Red Chief (119 mg kg^{-1}). Red Chief leaves had the highest concentration of zinc (21 mg kg^{-1} Zn), while the Golden Delicious cultivar had the lowest concentrations of this element (12 mg kg^{-1} Zn content) following the K application. A lower Zn concentration was determined in Golden Delicious leaves (12 mg kg^{-1}) than in Red Chief leaves (18 mg kg^{-1}). According to the average values, it was determined that the micronutrients (Cu, Mn and Zn) except Fe were taken up in greater amounts by the Red Chief leaves than by the Golden Delicious leaves. In our study, although there were fluctuations in the Zn content as the potassium dose increased, it can be said that the Zn intake decreased. It has been reported that the iron intake showed antagonism with potassium, and that the uptake of iron is lower with an increase in potassium within the plant (Çakmak 2005). In a study conducted on black locust, the potassium doses applied did not have a statistically significant effect on the Fe content, and as the K dose applied in the same study increased, the copper content decreased (Çömez 2019). In a study conducted on apple trees, a linear inverse relationship was determined between increasing potassium doses and the leaf Mn content.

Table 3 contains the data concerning the effect of foliar K+ Ca applications on yield in the two apple cultivars. When the yields were evaluated, the variety*application interaction was found to be statistically significant.

Table 3

The effect of foliar K and Ca applications on yield of different apple cultivars

	Variety	Application				Mean
		control	K	Ca	K+Ca	
Yield (kg/tree)	Golden D.	17.6*Aa***	18.2*Ab*	18*Ab*	18.8*Ab*	18.1
	Red Chief	15.8*Bb*	26A*a*	20.3*ABa*	19.6*ABa*	20.4
	mean	16.7	22.1	19.2	19.2	

The differences between capital letters indicate applications; lowercase letters indicate the differences between the varieties.

** The difference between the means with different letters in the same column and in the same row is significant ($P<0.01$).

The highest yield was found at 26 kg/tree produced by the Red Chief variety owing to the K application, and the lowest yield was obtained from the Red Chief variety in the control variant (15.8 kg/tree). When the applications were evaluated according to the general averages, yield values were 16.7 kg/tree for control, 22.1 kg/tree for K application, 19.2 kg/tree for Ca application, and 19.2 kg/tree for K+Ca application. As for the cultivars, Red Chief (20.4 kg/tree) produced a higher yield than Golden Delicious (18.1 kg/tree). It is thought that the lower increase in yield in the Red Chief variety induced by the K application compared to the control is due to the dropping of fruit by this variety more than by the other variety at harvest. It was found that the applications had a positive effect on yield compared to the control. In a similar, one-year study, Mimoun and Marchhand (2013) investigated the effect of K on apple, pear, plum, olive, peach and citrus fruits, and determined an increase in the apple, citrus and pear yield owing to the foliar application of this nutrient. Increases in fruit weight and quality were also observed. The results concerning effects of potassium application in the above one-year study are consistent with our study results.

Fruit pomological properties resulting from the K and Ca applications to the two different apple varieties are specified in Table 4. While the effect

Table 4

The effects of foliar K and Ca applications on fruit width, length, weight and firmness of apples from different apple cultivars

Pomological feature	Variety	Application				Mean
		control	K	Ca	K+Ca	
Diameter (mm)	Golden D.	70	70	72	71	71*a**
	Red Chief	64	62	63	60	62*b*
	mean	67	66	68	65	
Length (mm)	Golden D.	63	64	66	64	64*a**
	Red Chief	53	52	53	49	52*b*
	mean	58	58	59	56	
Weight (g)	Golden D.	157	164	168	162	163*a***
	Red Chief	95	95	99	101	97*b*
	mean	126	129	134	132	
Flesh firmness	Golden D.	7.7	8.6	8.3	9.6	8.6
	Red Chief	7.9	8.1	8.5	9.2	8.5
	mean	7.8*B***	8.4*B*	8.4*B*	9.5*A*	

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of the application*variety interaction on the fruit width was not found to be statistically significant, the difference between the cultivars was found to be significant. According to the results, Golden Delicious had a greater fruit width than the Red Chief variety. There was no statistical difference between the applications in terms of the fruit width. As for the fruit size, the outcome was similar to the impact on the fruit width. The effect on the fruit size was found to be statistically significant between the cultivars. In terms of the fruit height, Golden Delicious produced apples with a greater fruit height than the Red Chief variety. The effect of foliar Ca applications, according to Kucukyumuk, Erdal (2022), on the width and length of apples harvested from different apple tree cultivars was found to be insignificant, while the effect of the cultivars was found to be significant, and the results reported by these researchers were similar to the results of our study. When fruit weight values were examined, it was seen that the difference between cultivars was significant and there was an increase compared to the control among applications. Solhjoo et al. (2017) reported that fruit weight increased with $CaCl_2$ solution applied to Red Delicious apple trees, which is consistent with our results. When the average fruit weights were examined, it was seen that Golden Delicious had 163 g of fruit weight and Red Chief had 97 g of fruit weight. The Red Chief apple cultivar reached higher values in terms of the width, length and weight of apples compared to the Golden Delicious cultivar. In terms of firmness, the difference between the applications was found to be significant. It was determined that fruit firmness increased with potassium and calcium applications compared to the control, and the highest firmness value was determined with the application of both nutrients. Dilmaghani et al. (2005), who studied Golden Delicious apple trees grafted on M9 rootstock supplied potassium (KCl) and calcium ($CaCl_2$), reported positive correlations between potassium and soluble solid content, and calcium and fruit flesh firmness. Shen et al. (2016) reported that fruit flesh firmness increased with potassium application.

In Table 5, data on the effects of foliar K and Ca applications on fruit skin color of both apple varieties are given. When the effects of cultivar* application, application and cultivars on L, a and b values were examined, significant differences were found between the cultivars, and no statistical difference was found between the cultivar* interaction or single applications of the nutrients. Yellow Golden Delicious and red Red Chief apple cultivars were used in the study. When the effect of applications on fruit skin color was examined in connection with the fruit skin color, the L value of Golden Delicious was 74, while the fruit acceptance color L value of Red Chief cultivar was 62. When the fruit skin color was examined in terms of the a value, -18 value was obtained for Golden Delicious and -2 value – for Red Delicious. When the b values were examined according to the average values, it was found that the Golden Delicious variety scored 43 and the Red Delicious variety scored 28 for this parameter. As seen in Table 5, yellow-colored apples have higher values than red-colored apples, and the values decreased

Table 5

The effect of foliar K and Ca applications on fruit color of apples from different apple cultivars

Color	Variety	Application				Mean
		control	K	Ca	K+Ca	
L	Golden D.	74	75	74	75	74*a**
	Red Chief	62	61	62	62	62*b*
	mean	68	68	68	68	
a	Golden D.	-18	-19	-18	-19	-18*b**
	Red Chief	-1	-2	-2	-2	-2*a*
	mean	-9	-11	-10	-10	
b	Golden D.	42	42	43	43	43*a**
	Red Chief	28	28	28	28	28*b*
	mean	35	35	36	36	

The differences between capital letters indicate applications; lowercase letters indicate the differences between the varieties.

* The difference between the means shown with different letters in the same column and in the same row is significant (P<0.05).

as the red color intensity of the apple peel increased. Kucukyumuk, Erdal (2022) observed similar results in their study in which they examined the colors of yellow and red apple varieties. Raese, Drake (2000) and Solhjoo et al. (2017) reported that fruit skin color of the Red Delicious apple cultivar increased with Ca leaf fertilization. The results are consistent with previous studies.

Table 6 shows the effect of K and Ca applications of both apple cultivars on the SPAD values. While the effects of the cultivar*application interaction and applications on the SPAD values were not statistically significant, the effect of the cultivars on SPAD was found to be statistically significant. According to the general averages, it was determined that the SPAD values induced by the application of nutrients were higher than in the control. Among the cultivars, the Red Chief SPAD value (56) was higher than that of the Golden Delicious apple cultivar (49).

Table 6

The effect of foliar K and Ca applications on SPAD in different apple cultivars

	Variety	Application				Mean
		control	K	Ca	K+Ca	
SPAD	Golden D.	47	50	48	50	49*b***
	Red Chief	55	55	56	56	56*a*
	Mean	51	53	53	53	

** The difference between the means with different letters in the same column and in the same row is significant (P<0.01).

CONCLUSION

In this study, it was determined that even if there was sufficient potassium and calcium in the soil, 1% Ca + 1% K application to the leaves could increase fruit quality and yield. Although calcium was found in excess in the soil, no calcium toxicity was observed in apple leaves during this experiment. Foliar calcium and potassium fertilization is needed even there are no deficiency symptoms on apple trees, as it improves the flesh firmness of apples. The yield was increased by applying K and Ca, both singly and combined. Among the quality parameters, it was determined that the K+Ca application was more effective than the separate application of K and Ca in terms of fruit firmness. Fertilizing should be done according to the results of soil analysis and leaf analysis, as well as a plant variety.

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