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Effects of Selenium Treatments on Physical and Chemical Traits of Some Grape Cultivars

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Abstract

Selenium, which was initially among the harmful elements with its toxic effects, later attracted attention with its positive effects on human and animal health. The main source of selenium is plants. This study aimed to determine the effects of selenium treatments at different doses (0.4 ppm and 8 ppm) on grape bunches and berries in a number of table grape cultivars. White cultivars ('Victoria', 'Italia'), colored cultivars ('Alphonse Lavallée', 'Lival', 'Royal', 'Bilecik Irikarası', 'Cardinal', 'Prima', 'Trakya Ilkeren') and seedless cultivars ('Flame Seedless', 'Sultani Cekirdeksiz', 'Tekirdag Cekirdeksiz') were used in this study. Selenium treatments were applied three times 10, 20 and 30 days from the berry-set period as spray to the whole vine. Harvested grapes were analyzed for cluster and berry weight (g), cluster width-length (cm), berry width-length (mm), berry flesh firmness, berry color values, TSS and titratable acidity (g/l). In the results of study, it was determined that the effect of selenium varied according to grape cultivars, and there is an increase in the seed, skin and pulp with the increase in the amount of selenium applied. It was determined that there were changes in cluster length ('Flame Seedless', 8 ppm: 16.6 cm), cluster weight ('Royal', 4 ppm: 318 g), berry weight ('Victoria', 4 ppm: 10.8 g) and berry sizes in table grapes with selenium treatments. The amount of water-soluble dry matter caused a decrease in 'Cardinal' (control: 17.4%), 'Lival' (control: 17.8%), 'Royal' (control: 17.3%) cultivars, and an increase in 'Flame Seedless' (8 ppm 20.8%) cultivars with selenium treatments. There was no significant effect on other cultivars.

Keywords 'Alphonse Lavallé' · 'Flame Seedless' · Skin · Titratable acidity · 'Prima'

Introduction

Grape has an important place among the world's fruit species in terms of production and consumption quantities. Grapes are used in various forms such as table grape, wine grape and dried grape. Besides meeting basic food demands of people, grapes are highly preferred also for health purposes (Yang and Xiao 2013; Keskin et al. 2021, 2022). Today, besides the quantity, people are concerned about the quality and healthiness of the food they consume. In terms of health concerns, importance of the presence of selenium (Se) in foodstuffs has been demonstrated in recent studies conducted with various agricultural products (Hu et al. 2003; Hlušek et al. 2005).

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Se is an essential micronutrient for plants. It is available in two forms as of organic and inorganic. Plants are also the primary source of selenium. Selenium uptake, transport and distribution depend on several factors such as plant species, development stages, type of supplementation, physiological conditions (salinity and pH), presence of the other substances in the environment and transport capacity of the plant (Gupta and Gupta 2017; Zhao et al. 2005; Li et al. 2008).

Se creates competition in transport systems and biotic ligand sites, thereby inhibiting the upward displacement of elements (Jancsó et al. 2013; Barwinska-Sendra and Waldron 2017), leading to a significant reduction in Fe accumulation in lettuce and wheat (do Nascimento da Silva and Cadore 2019; Filek et al. 2019).

Selenium reduces the effects of free radicals formed as a result of stress factors in humans and animals. The effectiveness of vitamin E, known as an antioxidant, depends on the presence of very small amounts of the element selenium in the body (Kong et al. 2005; Ríos et al. 2008). In plants, it has a protective effect against many abiotic stress factors (cadmium, UV-B radiation, salinity, etc.) (Karimi et al. 2020; Zhao et al. 2020). Another factor that differentiates selenium, which is so important for humans, animals and plants, is that it has very close deficiency and toxicity limits (Holsinger and Smith 1992; Mandic et al. 1995; Navarro-Alarcon and Cabrera-Vique 2008). For example, the daily Selenium requirement for humans is 50–200 µg (Burtis et al. 2006), and this amount causes toxicity over 400 µg/day (Burtis et al. 2006). While the daily amount to be taken for zinc is 12 mg (Insel et al. 2006), the toxicity limit starts above 4000 mg (Neyzi and Ertuğrul 2002, 2010).

As a result of Se treatments in viticulture, it is reported that there is an increase in the amount of selenium, especially in fruit peel and seed (Zhao et al. 2020). However, there is not much information about the change in cluster and berry in the studies. The aim of this study is to determine the effects of the selenium micronutrient element, which is extremely important for human health, on the grain and cluster properties of table grapes by applying different concentrations.

Materials and Methods

Experimental Design

This study was carried out in 2017 in the vineyard of Central Black Sea Transitional Zone Agricultural Research Institute (40° 32′ 17.20″ N, 36° 45′ 09.53″ E), Turkey. Average planting density of 1900 vines per hectare (3.0 × 1.75 m between the vines and between the rows, respectively). A double cordon support system is used in the vineyard. 'Alphonse Lavallée', 'Italia', 'Lival', 'Victoria', 'Royal', 'Bilecik Irikarası', 'Cardinal', 'Prima', 'Trakya Ilkeren', 'Flame Seedless', 'Sultani Cekirdeksiz' and 'Tekirdag Cekirdeksiz' grape cultivars were used in this study. Cultivars are grown on 1103 Paulsen rootstock. Vineyard soils have a sandy-clay texture with an organic matter content of 1.18% and a pH of 7.78.

In this study, white cultivars ('Victoria', 'Italia'), colored cultivars ('Alphonse Lavallée', 'Lival', 'Royal', 'Bilecik Irikarası', 'Cardinal', 'Prima', 'Trakya Ilkeren') and seedless cultivars ('Flame Seedless', 'Cekirdeksiz', 'Tekirdag Cekirdeksiz') were used.

Measurement Methods of Grape Samples

Pruning, spraying, irrigation and soil tillage, cluster thinning, leaf removal, cluster tip cutting (Ateş and Kısmalı 2007) were performed as standard. Selenium treatments were applied three times at 10, 20 and 30 days from the berry-set period as spray to the whole vine (Zhu et al. 2017). Treatment doses were selected as 0 (control), 4 and 8 mgkg^{-1} Se (sodium selenate [Na_2SeO_4]).

Cluster samples were taken homogeneously from the cultivars reached to harvest maturity and brought to the laboratory. For physical properties; cluster and berry weight (g) were determined with a precise balance (Precisa BJ 1200C, Dietikon, Switzerland); cluster width-length (cm) were measured with a ruler; berry width-length (mm) were measured with a caliper. Berry flesh firmness was measured with a penetrometer with a 1.54 mm penetrating tip (PCE FM200, Marc-10, New York, USA); color parameters of L, a, b were measured with a digital color measuring device (HunterLab D25, Minolta, Tokyo, Japan). Total soluble solids (TSS) in the must was measured with a refractometer (Atago Master-93H, Schmidt + Haensch GmbH & Co., Berlin, Germany); titratable acidity (g/l) was determined in accordance with Cemeroğlu (1992).

Results

Berry Physical Characteristics

Analysis results for berry physical characteristics were presented as white cultivars ('Victoria', 'Italia'), colored cultivars ('Alphonse Lavallée', 'Bilecik Irikarası', 'Cardinal', 'Lival', 'Prima', 'Royal', 'Trakya İlkeren') and seedless cultivars ('Sultani Cekirdeksiz', 'Flame Seedless', 'Tekirdag Cekirdeksiz') (Figs. 1, 2 and 3).

Considering berry physical characteristics, 'Victoria' cultivar was found to be prominent for berry weight (10.8 g) and berry width-length (23.2; 31.5 mm) parameters at 4 ppm Se treatments. Regarding berry flesh firmness, Se treatments did not generated significant differences among the cultivars. For color parameters, 'Italia' cultivar had the greatest L value (35.7) and 'Flame Seedless' cultivar had the greatest a and b values (6; 3.89) at 4 ppm Se treatments.

Cluster Weight, Cluster Width-Length, TSS and Acidity

Effects of Se treatments on cluster weights varied with the cultivars. While there was no difference between experimental treatments in some cultivars ('Alphonse Lavallée ', 'Cardinal', 'Italia', 'Prima', 'Victoria'), at 4 ppm Se treatments were found prominent in some cultivars ('Bilecik Irikarası', 'Royal', 'Trakya Ilkeren', 'Sultani Cekirdeksiz') and at 8 ppm in the others ('Flame Seedless', 'Tekirdag Cekirdeksiz'). The 4 ppm Se treatments have made 'Victoria' cultivar prominent for cluster length (23.2 cm) and 'Trakya İlkeren' cultivar for cluster width (15.6 cm). In terms of must chemical properties, Se treatments generated significant differences in TSS and titratable acidity values of

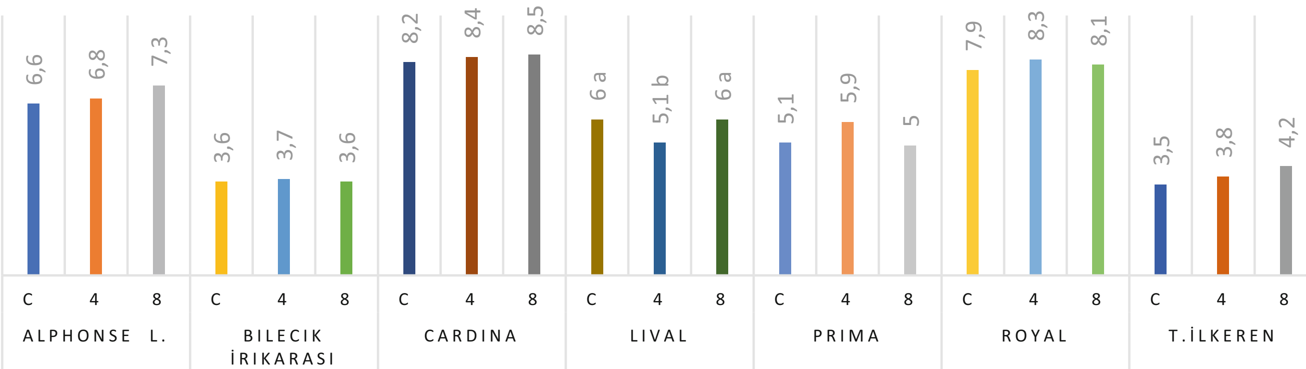

Fig. 1 Berry weight of colored cultivars (g)

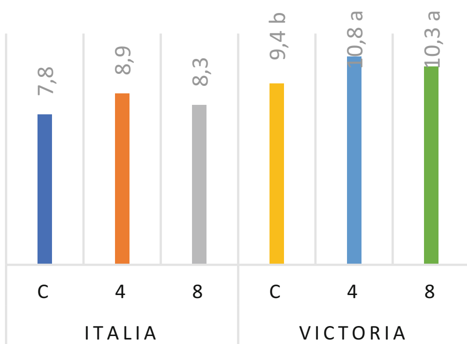

Fig. 2 Berry weight of white cultivars (g)

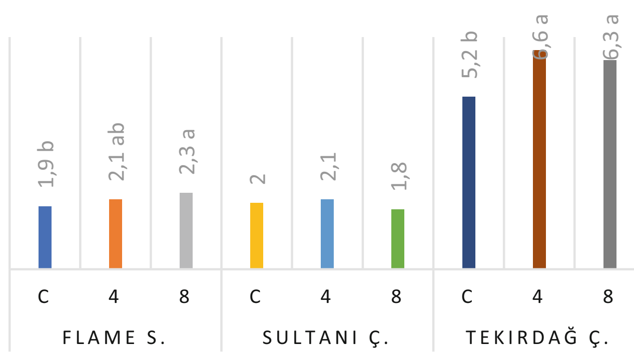

Fig. 3 Berry weight of seedless cultivars (g)

the cultivars. The highest TSS and titratable acidity values (20.8 brix; 7.47 g/l) were obtained from 'Flame Seedless' cultivar at 8 ppm Se treatments (Figs. 4, 5 and 6).

Discussions

Selenium Form and Type of Treatment

Distribution of Se forms is affected by soil properties like pH and thus, deficiency or availability of Se changes with soil properties. It was reported that foliar selenium treatments in the form of Na_2SeO_4 increased selenium contents in pears, grapes and peaches and this method was reported as an efficient, safe and cost-effective tool (Hu et al. 2002; Feng et al. 2015; Zhu et al. 2017). Therefore, in present study, foliar selenium sprays were performed in the form of Na_2SeO_4.

Berry Weight, Berry Width-Length, Berry Firmness and Berry Color Parameters

Previous studies with selenium treatments have mostly focused on chemical and phytochemical changes in berry and must, but studies on physical properties are highly limited. In this study, effects of selenium treatments on physical properties of clusters (cluster weight, cluster width-length) and berries (berry weight, berry width-length, berry firmness, berry color) were focused on (Tables 1 and 2).

In this study, increasing berry weights were detected with increasing selenium treatments. Prominent and significantly different cultivars included 'Victoria' (white cultivar), 'Flame seedless' (seedless cultivar) and 'Tekirdag Cekirdeksiz' (seedless cultivar) (Table 1). Yin et al. (2020) reported increasing berry weights in 'Red Barbara', 'Summer Black' and 'Hutai No.8' grape cultivars with selenium fertilization. As a result of the study, it can be that the L* value decreased and the color a* and b* values increased in many colored cultivars from Se treatments (Table 1). However, Se treatments did not have a significant effect on coloration in white cultivars (except 'Italia' cultivar). Zhu et al. (2019) reported positive effects of selenium treatments on berry coloration. Although there were differences between the cultivars in this study, generally similar results were obtained in terms of coloration. In table grapes, environment, cultivar characteristics and cultural practices significantly affect the quality (Ojeda et al. 2002; Marzouk and Kassem 2011; Locatelli et al. 2016; Zhu et al. 2019). Berry weight and coloration are important criteria in terms of marketing in table grapes. Although there are differences between the cultivars in terms of these characteristics, it can be that selenium treatments have a positive effect.

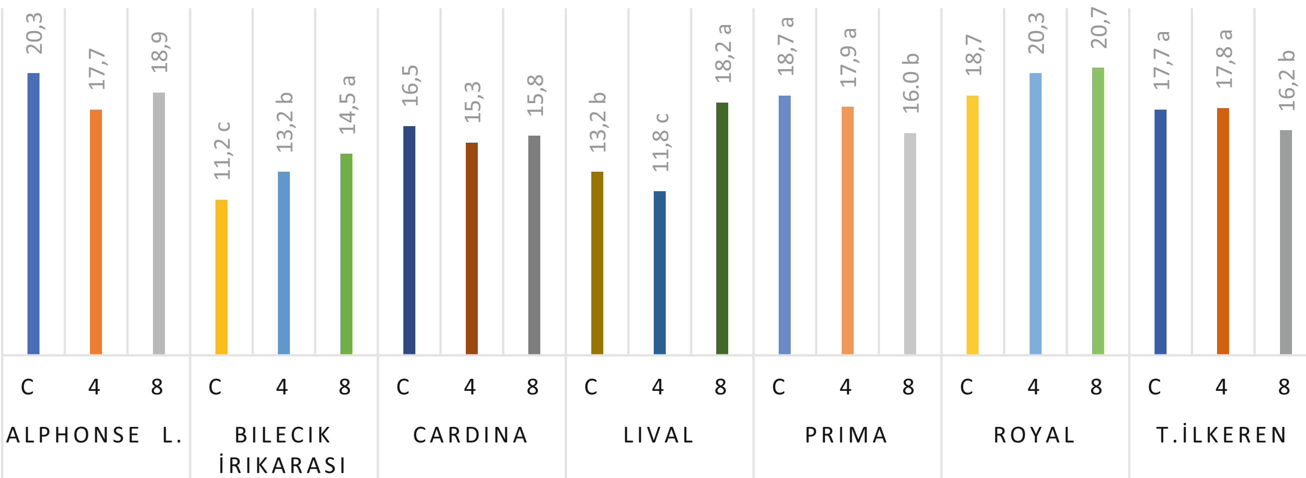

Fig. 4 Cluster length of colored cultivars (cm)

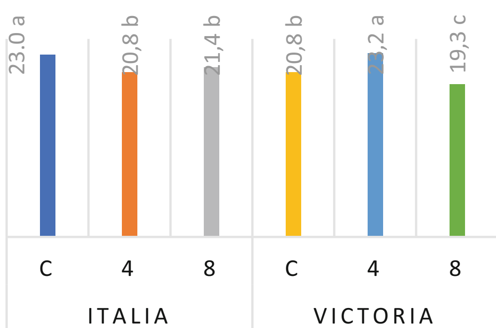

Fig. 5 Cluster length of white cultivars (cm)

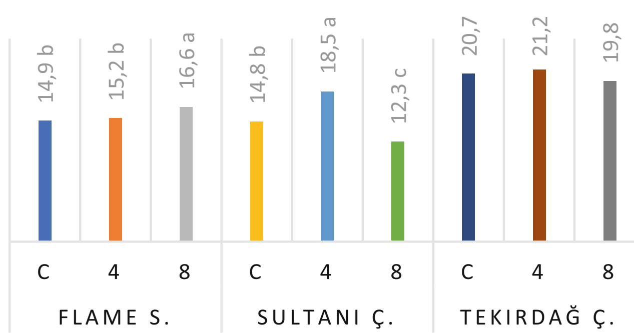

Fig. 6 Cluster length of seedless cultivars (cm)

Cluster Weight, Cluster Width-Length, TSS and Acidity

Today, as it was in all types of production, besides yield, quality is also a highly significant parameter in viticulture. There are several factors affecting quality of grapes and as these factors increase, quality control becomes more difficult. Chemical parameters of must (TSS (total soluble solids), pH, acidity, etc.) are very important parameters both in wine grapes and table grapes (Calo et al. 1996).

Effects of selenium treatments on TSS contents varied with the cultivars. The greatest increase in TSS was seen in 'Lival' and 'Flame Seedless' cultivars. Zhu et al. (2019) reported increasing TSS contents in five different table grape cultivars ('Hutai No.08', 'Crismon Seedless', 'Red Barbara', 'Summer Black') with selenium treatments, but indicated that such increases might vary based on cultivars. Selenium treatments affect the net photosynthesis rate in plants (Szczepaniak et al. 2013; Pacheco et al. 2014; Feng et al. 2015) and increase starch accumulation in leaves and fructose-1,6-biphosphatase activity (Owusu-Sekyere et al. 2013). It was reported that low selenium quantities increased photosynthesis and primary metabolism products; on the other hand, high concentrations inhibited photosynthesis and primary metabolism (Wang et al. 2012). Considering that photosynthesis products were largely represented by sugars, the increase in berry TSS contents could be explained by this phenomena.

Various treatments can be made to change the cluster morphology of seedless table grapes. Among these treatments, gibberellic acid (GA_3) is the most common (Creasy and Creasy 2009). Besides chemical treatments, grape cultivar, summer pruning, environmental conditions and cultural practices can also be effective on cluster morphology (Stoper et al. 2007). Present findings revealed that selenium treatments somehow showed a chemical thinning effect on clusters.

Conclusion

Selenium content in grapes increases with selenium fertilization. This means that people can meet some of their selenium needs with the consumption of fresh grapes. Although selenium treatments varied according to grape cultivars, they had a positive effect on cluster and berry properties. Thus, Se treatments also contributed to the marketing criteria of table grapes.

Table 1 The effect of selenium treatments on berry features and color

	Treatments	Cultivars											
		'Alphonse Lavallé'	'Bilecik İ. Karası'	'Cardinal'	'Lival'	'Prima'	'Royal'	'T.İlkeren'	'Italia'	'Victoria'	'Flame Seedless'	'Sultani Çekirdeksiz'	'Tekirdağ Çekirdeksiz'
Berry width	Control	20.8	16.4	22.8	20.4 a	18.7	22.1	16.6 c	19.6	21.2 b	15.3	12.6 b	18.8
	4 ppm	21	16.6	21.8	18.7 b	19.7	22.5	17.8 b	20.3	23.2 a	15.4	14.6 a	19.2
	8 ppm	22.1	16.5	22.7	19.3 b	18.5	22.5	19.0 a	21.1	23.1 a	15.9	12.2 b	19.7
	LSD (0.05)	N,S	N,S	N,S	0.9	N,S	N,S	N,S	N,S	1.1	N,S	1.4	N,S
Berry length	Control	22.8	18.5	24	20.9	20.6	23.4	15.9 c	24.1	29.2 b	12.9 b	15.6 b	19.2 b
	4 ppm	23.2	19.2	22.6	19.6	22.2	23.5	16.6 b	24.5	31.5 a	13.2 b	19.9 a	19.5 b
	8 ppm	23.1	18.7	24	20.8	20.8	22.3	18.3 a	25.2	31.2 a	15.1a	14.6 b	21.5 a
	LSD (0.05)	N.S	N.S	N.S	N.S	N.S	N.S	0.3	N.S	1.2	0.9	1.8	0.9
Berry hard-ness	Control	–0.08	–0.07	–0	–0.02	–0.07	–0.07	–0.07	–0.09	–0.57	–0.08	–0.08	–0.07
	4 ppm	–0.08	–0.03	–0	–0.03	–0.03	–0.08	–0.02	–0.1	–0.09	–0.08	–0.09	–0.07
	8 ppm	–0.03	–0.03	–0	–0.03	–0.03	–0.08	–0.03	–0.08	–0.03	–0.09	–0.07	–0.07
	LSD (0.05)	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
Color L	Control	21.0 a	21.7	24.6	24.2	22.3	22.1 b	23.6	33.4 b	38.9	21.2 b	41	24.5
	4 ppm	21.6 a	21.5	24.6	22.4	21.6	22.8 b	24.1	33.5 b	37.1	23.3 a	41.7	25.7
	8 ppm	19.7 b	21.1	23.4	23.4	22	23.8 a	24.2	35.7 a	38.7	22.4 a	41.4	25.3
	LSD (0.05)	0.8	N.S	N.S	N.S	N.S	0.7	N.S	0.5	N.S	1.2	N.S	N.S
Color a	Control	0.49 b	1.51 a	3.81	0.19	0.58 ab	0.11 c	1.02	–4.07	–5.68	5.50 b	–5.7	2.2
	4 ppm	0.21 c	1.19 ab	4.4	0.19	0.48 b	0.23 b	0.99	–4.07	–6.07	6.00 a	–5.09	2.38
	8 ppm	0.72 a	0.99 b	3.18	0.2	0.78 a	0.60 a	0.59	–4.38	–5.42	4.69 c	–5.71	2.33
	LSD (0.05)	0.2	0.4	N.S	N.S	0.2	0.1	N.S	N.S	N.S	0.4	N.S	N.S
Color b	Control	0.60 b	0.60 b	1.98	–0.22	0.51 c	0.22 a	0.57 a	8.5	11.41	3.57 a	11.69	0.19
	4 ppm	0.38 c	1.00 a	2.12	0.07	0.80 a	0.17 a	0.31 b	7.71	10.19	3.89 a	29.14	–0.37
	8 ppm	0.79 a	0.67 b	1.5	0.02	0.71 b	–0.40 b	0.48 a	8.4	9.93	2.58 b	12.02	0.18
	LSD (0.05)	0.1	0.2	N.S	N.S	0.1	0.2	0.2	N.S	N.S	0.7	N.S	N.S

The different lowercase letters indicate statically significant differences between the treatment ($p < 0.05$)

Table 2 The effect of selenium treatments on cluster features and must content

	Treatments	Cultivars											
		'Alphonse Lavallé'	'Bilecik İ.Karası'	'Cardinal'	'Lival'	'Prima'	'Royal'	'T. İlkeren'	'Italia'	'Victoria'	'Flame Seedless'	'Sultani Çekirdeksiz'	'Tekirdağ Çekirdeksiz'
Cluster weight (g)	Control	486	214 b	425	312	431	290 b	360 b	443	694	302 b	262 b	320 b
	4 ppm	417	256 a	456	364	470	318 a	428 a	417	703	313 b	343 a	373 a
	8 ppm	463	250 a	408	382	417	287 b	402 ab	459	717	368 a	265 b	388 a
	LSD (0.05)	N.S	31.8	N.S	N.S	N.S	16	46	N.S	N.S	10.8	13.4	21.3
Cluster width (cm)	Control	8.2	6.5 b	11.3	11.0	15.0 a	10.8	13.6 b	14.9	14.4	9.5 b	8.3 b	13.3 b
	4 ppm	10.3	6.3 b	15.3	11.3	13.3 b	11.2	15.6 a	11.7	14.3	10.0 b	11.7 a	15.2 a
	8 ppm	9.2	7.4 a	10.7	12	12.5 b	12.8	12.8 b	13.5	13	11.8 a	8.7 b	12.7 c
	LSD (0.05)	N.S	0.9	N.S	N.S	0.9	N.S	1.1	N.S	N.S	1.1	2.7	0.6
TSS (Brix)	Control	15.7	17.6	17.4 a	17.8 a	15.2	17.3 a	17.4	20	16	20.2 b	22.6	17.2
	4 ppm	15.2	17.9	15.7 b	17.2 b	16.2	16.1 ab	17.4	18.1	15.7	19.6 c	21.5	17.6
	8 ppm	15.9	17.5	16.1 b	18.0 a	15.7	15.3 b	17.5	17.4	15.7	20.8 a	20.8	17.8
	LSD (0.05)	N.S	N.S	0.7	0.2	N.S	1.3	N.S	N.S	N.S	0.4	N.S	N.S
Titratable acidity (g/l)	Control	6.51	8.3	4.47	5.81	7.27	6.90 a	6.20 b	4.98 b	4.43 b	7.10 a	7.10 a	6.31
	4 ppm	6.7	8.4	5.93	5.7	6.37	4.50 c	6.79 a	7.12 a	4.09 c	7.47 a	7.47 a	6.4
	8 ppm	6.7	8.13	5.39	5.6	6.58	5.82 b	6.33 b	7.02 a	5.00 a	6.47 b	6.47 b	6.59
	LSD (0.05)	N.S	N.S	N.S	N.S	N.S	0.4	0.3	0.2	0.3	0.5	0.5	N.S

The different lowercase letters indicate statically significant differences between the treatment ($p<0.05$)

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Conflict of interest S. Sucu and A. Yağcı declare that they have no competing interests.

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