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THE EFFECTS OF DIFFERENT CROP LOADS ON YIELD, QUALITY, AND SUGAR FRACTIONS IN EARLY SWEET (*Vitis vinifera* L) TABLE GRAPE

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Abstract: The quality of the grapes taken from the vines varies depending on many factors. Grape quality is one of the critical determining factors in the crop load left on the vine. The aim of this study was to investigate the effects of three different crop load levels (36 (T1), 75 (T2), and 105 (T3) bud vine^{-1}) on yield, quality, and sugar fractions of Early Sweet (Vitis vinifera L.) table grape variety grown in Alaşehir district of Manisa/Türkiye. As two years average, the heaviest clusters, berry weight, and soluble solid content (733.0g, 4.41g, 18.05%) were determined in T1 crop load level while the lowest weight clusters and berry weight (580.7g, 388g, 17.42%) were obtained from T3 crop load level. The opposite of these findings was observed in titratable acidity values. In the research; the highest amount of table grapes per vine was obtained at T2 treatment in both years. The mean total glucose values for both years varied between 45.70% (T1), 45% (T2), and 37.90% (T3), respectively. Fructose content ranged between 41.50% (T1) and 41% (T3), and sorbitol content was 2.17% (T1), 2.05% (T2), and 2.17% (T3). Galactose content was negligible in all crop load treatments and ranged between 0.54% and 0.56%. The result is also T2 treatment (75 bud vine^{-1}) can be recommended to 'Early Sweet' grape growers as the most effective treatment that provides the highest amount of marketable grapes in terms of yield-quality balance.

Keywords: Early sweet grape, Crop load, Grape quality, Sugar fraction

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1. Introduction

Grapes are one of the most consumed grapefruits in the world. The history of viticulture dates back to 5000 BC. The Anatolian region called Asia Minor is the homeland of the grapevine (Uzun and Bayır, 2008; Senthilkumar et al., 2015). In the world, 7,085,350 hectares of vineyard area are used for fresh grape production. Türkiye has 393.420,000 hectares of vineyards and 3.650,000 million tons of fresh grape production (Anonymous, 2022). The most crucial region in Türkiye in terms of both vineyard area and grape production is the Aegean region. This region alone has 31-38% of the vineyard area and accounts for 50% of the grape production.

Pruning is the most important cultural practice in viticulture. It is the only way to maintain and increase productivity in vineyard farming, to maintain vitality, and to ensure the balance between development and yield (Winkler et al., 1974). The crop load of the vine can be regulated by the number of buds left on the vine during winter pruning or by cluster thinning during the growth period (Pehlivan and Uzun, 2001). In this respect, winter pruning is the primary process determining crop load yield and grape quality. Determining the optimal pruning and crop load for a grape variety's region is crucial for sustainable viticulture (Benavente et al., 2014). Various studies have been carried out in our country and in the world to determine the appropriate pruning levels of different grape varieties (Dardeniz and Kısmalı, 2005; Söyler et al., 2020). Early Sweet is the earliest commercial, seedless, white grape cultivar, excellent eating quality, with a muscat flavor. This grape cultivar is highly desired and famous worldwide. In this respect, the cultivation area in our region has tended to increase in recent years. However, it has been observed that growers perform different pruning procedures on this cultivar and face problems such as not achieving the desired quality.

High sugar concentration in grapes is particularly desirable and is a critical component of edible eating quality, defining ripeness and harvest time. This parameter is often used to evaluate grape berry quality in literature (Gehan et al., 2020). Prior research indicates that grape berries contain significant amounts of glucose and fructose, with their values being similar to each other. Additionally, the glucose and fructose content and proportions can vary widely among grape berries, depending on factors like the grape variety used and the growing conditions of the vineyards (Petrisor et al., 2019). The content and composition of sugar have a significant influence on the taste, color, and other nutritional components of grapes.

The crop load given to the vines is the most important factor affecting the quality of the grapes, sugar content, sugar-acid balance, and ripening time (Sabır et al., 2010; Ashraf and Farag, 2022). The content and composition of sugar have a great influence on the taste, color, and other nutritional components of grapes. Sugar is an important nutrient in grapes and a sign of ripeness (Gehan et al., 2020).

This study aimed to investigate the effect of different levels of crop load on yield, quality, and sugar fractions in Early Sweet (*Vitis vinifera* L.) table grapes.

2. Materials and Methods

2.1. Plant Material and Study Site

The research was carried out at the grapevine of Early Sweet (*Vitis vinifera* L.) in the Alaşehir-Manisa/Türkiye in 2021-2022 years. The climate in this region is semi-arid with hot dry summers and cold rainy winters. The average yearly temperature is 18.0 ^{0}C and the total amount of annual rainfall is about 635 mm. Early Sweet's vines are highly vigorous when planted on their roots, 6 years old. The planting distances were 3.1 m between the rows and 1.6 m on the rows and vines were trained onto a Y trellis system. A drip irrigation system was used, and the soil structure of these vineyards is the loamy alluvial soil, and the routine cultural processing such as soil management, and fertilizers.

2.2. Applications

Winter pruning was carried out in mid-February in both years. The trial design was performed as four treatments:

T1 - 10 buds (3 Long-cane, 2 spurs-cane with 3 buds each), a total of 36 buds per vine,

T2 – 12 buds (5 long, 5 spurs with 3 buds each), a total of 75 buds per vine,

T3 – 15 buds (6 long, 5 spurs with 3 buds each), a total of 105 buds per vine.

2.3. Methods of Analysis

At harvest (June 25, when SSC reached 16 °Brix), vines in each treatment plot were weighed to determine fresh grape yield per vine (kg vine^{-1}). Five clusters (g) per vine were randomly selected and weighed on a digital balance.

For each cluster, 12 berries were randomly sampled from the shoulder, middle, and tail. Fresh fruits were weighed using a digital balance to determine fruit weight (g). The soluble solid content (SSC) of juices was determined as % using a handheld temperature-compensated refractometer (Atago Pal-1, Japan). The titratable acidity (TA) by titrating 10 mL juice with 0.1 N NaOH to pH 8.1 was expressed as g tartaric acid L^{-1}. The pH of berry juices was determined with a pH meter (Mettler Toledo MP220, Zurich, Switzerland).

Marketable table grapes, the amount of marketable table grapes was determined according to Turkish Standards 101 table grape standard (Anonymous, 2002). The percentage of overall yield was calculated

2.4. Sugar Fractions of Analysis

For sugar fractions of analysis, we followed the methods described by Melgarejo et al. (2000). One hundred g of berries were crushed with a Heidolph SilentCrusher M (Germany). Seven grams of samples that contained skin and pulp of berries were homogenized with a homogenizator (A-10 Analytical Mill, Tekmar Ohio, USA) after the addition of 50 mL 0.009 N H_2SO4. We centrifuged 1 milliliter of whole fruit extract at 10,000 revolutions per minute for 2 minutes at 4^{o}C. Then we passed the supernatants through a SEP-PAK C18 cartridge. HPLC readings were taken using a µbondapak-NH2 column along with 85% acetonitrile as the liquid phase, and a refractive index detector (IR). We performed chromatographic separation on an Agilent 1100 series HPLC using a DAD detector (Agilent, Waldbronn, Germany). Using the sugar fractions, we calculated the sugar contents, and the results are expressed as percent.

2.5. Statistical Analysis

The experiment was laid out according to completely randomized blocks with three replicates and each replication had six vines. The data collected underwent statistical analysis using the SPSS statistical software package (version 20.0; SPSS Inc., Chicago, IL, USA). Differences between means were evaluated through ANOVA analysis of variance and determined by the Duncan multiple comparison test ($P<0.05$).

3. Results and Discussion

The effects of different levels of crop load left at pruning on the yield of fresh grapes and average cluster and berry weight, percentage of marketable table grapes, SSC (%), titratable acidity (g 100 mL^{-1}), and SSC/TA ripening index were found to be statistically significant in both years ($P<0.05$). However, pH was found statistically non-significant in 2021 and 2022. As a result of the variance analysis, three distinct groups were identified (Table 1).

3.1. Yield

Yield includes the total amount of fresh grapes. The highest yield was obtained from 105 buds vine^{-1}, a group (T3) while the lowest yield was 36 buds vine^{-1}, c group (T1) in both years. After analyzing the effect of crop load left on the vine during pruning, it was discovered that the vine productivity increased as the crop load left on the vine increased. In other words, when the total number of buds left per vine in winter pruning increased from 36 to 105 buds in both years, the yield increased by about 49.4%. These results are similar to the results reported in previous studies by Harikanth et al. (2015), Kumar et al. (2017), and Popović et al. (2023) that the yield of fresh grapes increases with an increasing number of buds left in pruning.

3.2. Cluster Weight

Average cluster weight, is a very important parameter for the quality of table grapes. The Average cluster weight was found between 508.20 and 740.0 g.

Table 1. The effects of different crop load levels on yield and quality properties

	Treatment, 2021			Treatment, 2022		
	T1	T2	T3	T1	T2	73
Yield, kg vine^{-1}	20.2±2.21c*	28.75±2.50b	41.50±3.0 a	22.1±2.00 c	27.25±2.20 b	42.10±2.50 a
Cluster weight g	750.5±25.8 a	704±30.0b	580.2±30.3 c	725.5±24.10a	770±28.0 b	581.20±28.3c
Berry weight g	4.40±0.20 **a	4.26±0.15b	3.86±0.12 c	4.42±0.15 a	4.25±0.15 b	3.90±0.12 c
TSS %	18.10±1.45 a	17.90±2.10b	17.50±1.90 c	18.00±1.45 a	17.75±.1.90 b	17.35±1.90 c
TA g tartaric acid 100^{-1} ml	0.61±0.10 a	0.64±0.12b	0.66±0.10 c	0.60±0.10 c	0.63±0.12 ab	0.66±0.10 a
TSS/TA	29.6±1.80 a	27.9±1.42b	26.5±1.51 bc	30.00±1.60 a	27.73±1.25 b	26.28±1.32 c
pH	3.88±0.1ns***	3.87±0.15ns	3.80±0.10 ns	3.75±0.12 ns	3.70±0.15 ns	3.68±0.10 ns
M. grape**** %	79.1 b	86.9 a	53.6 c	76.9 b	88.0 a	47.5 c

*a, b= Mean values (means ± SEM**) followed by the same letter in each rows are not significantly different (P>0.05), **SEM: standard error of mean, ***ns= non-significant, T1= 36 buds vine^{-1}, T2= 75 buds vine^{-1}, T3= 105 buds vine^{-1}, ****Markatable grape= total fresh yield (kg)/table grapesx100.

As two years average, the heaviest clusters and berry weight (733.0 g) were determined in treatment T1 (36 buds vine^{-1}, a group) while the lowest weight clusters (580.7 g) were obtained in treatment T3 (105 buds vine^{-1}, c group) (Table 1). Previous studies (Fawzi et al., 2010; Pehlivan and Uzun, 2015; Popović et al., 2023) in similar research in different grape varieties are also consistent with the assertion that excessive crop load reduces cluster weight.

3.3. Berry Weight

The berry weight was found between 3.86 and 4.42 g. As the number of pruned buds increased, the number of clusters increased, and cluster weight and berry weight decreased in the grapevine. As a two-year average, the highest berry weight was observed in T1 (4.41 g, a group) and followed by T2 (4.25 g, b group) and T3 (3.88 g, c group), respectively (Table 1). This result is convenient for Zhu-mie et al. (2010), Gil et al. (2013), Benavent et al. (2014), and Popović et al. (2020).

3.4. SSC (%)

As the number of buds left per vine increased, the SSC (%) values decreased although the yield increased. Increased exposure of fruit to light has been associated with increased accumulation of soluble solids. The highest SSC (%) value (18.05±1.45, a group) was observed in the T1 treatment, and the lowest value (17.42±1.67, c group) was obtained from the T3 treatment. Somkuwar and Ramteke (2010), Kök et al. (2013), and Söyler et al. (2020) reported that the more the severity of pruning, the lower the percentage of berry drop and fruit increased and acidity decreased when pruning severity increased in Thompson Seedless cultivar. This is consistent with our findings.

3.5. TA

The Titratable acidity was found between 0.61 and 0.66 g 100 ml^{-1}. The highest TA value (0.66±0.10, a group) occurred in the T3 treatment and the lowest value (0.60±0.10, c group) was determined in the T1 treatment (Table 1). According to Gaser et al. (2017) and Gehan et al. (2020), an increase in crop load results in a higher yield of fresh grapes and acidity values.

3.6. SSC/TA

The effect on the SSC/TA ratio in the juice was similar in both seasons studied. Maturation is delayed as the level of buds left in pruning increases. Because the increase in yield causes an increase in acidity and a decrease in SSC. Also, the highest SSC/TA ratio value (29.80) was found in the T1, and the lowest value (26.65) was obtained in the T3 (Table 1). Studies on different grape varieties yielded similar results by Fawzi et al. (2010), Ashraf and Farag (2022), and Popović et al. (2023). Maturation of table grape (Vitis vinifera L.) extends from a period of almost 40 days from véraison to harvest. During this phase of fruit development, the most significant physiological changes occur, allowing for the accumulation of sugar, acid, phenolic compounds, and an increase in weight.

3.7. Marketable Table Grapes

When the effect of different crop load levels on marketable table grapes was analyzed (Table 1), the highest amount of table grapes was obtained from T2 (86.9%, 88%) in both years. This was followed by T1 (79.1%, 76.9%) and T3 (53.6%, 47.5%) treatment levels, respectively. This result showed the importance of correct crop load in winter pruning.

3.8. Sugar Fraction

The effects of different levels of crop load left during pruning on α-Glucose (%), β-Glucose (%), Total Glucose (%), Sorbitol (%), and Glucose/Fructose were found statistically significant in both years (P<0.05). However, it was found statistically non-significant when Fructose (%) and Galactose (%) were considered (P>0.05) (Table 2).

Grapes contain sugar, which is a crucial nutrient and a sign of ripeness (Petrisor and Chirecanu, 2019). The sugar in grapes is mainly made up of glucose and fructose (Zhang et al. 2021). In analyzing fresh grape samples, glucose, α, and β anomers were determined separately. The total amount of glucose was calculated by adding up α-glucose and β-glucose. As presented in Table 2. total glucose was higher than fructose for T1 and T2 treatment samples and vice versa for T3. The mean total glucose values for both years varied between 45.70 % (T1), 45 % (T2), and 37.90 % (T3), respectively.

Table 2. The effects of different crop load levels on sugar fraction

	Fructose (%)			α-Glucose (%)			β-Glucose (%)		
	2021	2022	Mean	2021	2022	Mean	2021	2022	Mean
T1	41.80	41.20	41.50	17.00 ^{a}	17.20 ^{a}	17.10 ^{a}	29.60 ^{a}	27.60 ^{a}	28.60 ^{a}
T2	41.25	40.75	41.00	16.40 ^{b}	16.80 ^{ab}	16.60 ^{b}	28.80 ^{b}	28.00 ^{a}	28.40 ^{a}
T3	41.50	40.50	41.00	14.30 ^{c}	14.00 ^{c}	14.15 ^{c}	23.40 ^{c}	24.10 ^{b}	23.75 ^{b}
LSD $_{0.05}$	ns	ns	ns						
	Sorbitol (%)			Galactose (%)			Total Glucose (%)		Glucose/Fructose
	2021	2022	Mean	2021	2022	Mean			Mean
T1	2.15 ^{a*}	2.20 ^{a}	2.17 ^{a}	0.54	0.54	0.54	45.70 ^{a}		1.101 ^{a}
T2	2.00 ^{b}	2.10 ^{b}	2.05 ^{a}	0.56	0.54	0.55	45.00 ^{ab}		1.097 ^{b}
T3	2.00 ^{b}	2.15 ^{ab}	2.07 ^{b}	0.55	0.53	0.54	43..90 ^{c}		0.924 ^{c}
LSD $_{0.05}$				ns**	ns	ns			

*a, b= Mean values (means ± SEM**) followed by the same letter in each rows are not significantly different (P>0.05), **SEM: standard error of mean, ***ns= non-significant, T1= 36 buds vine^{-1}, T2= 75 buds vine^{-1}, T3= 105 buds vine^{-1}.

Fructose content ranged between 41.50 % (T1) and 41 % (T3), and sorbitol contents were 2.17 % (T1), 2.05 % (T2), and 2.17 % (T3). Galactose content was negligible in all of the different crop load treatments and it ranged between 0.54 % and 0.56 % (Table 2). It has been observed that grapes accumulate sugar primarily as glucose and fructose, according to Davies (1996) and Zhang et al. (2021). During harvest, fructose and glucose are found near each other, which aligns with the findings of this study. Additionally, the concentration of other sugars in grape berries tends to be relatively low. They typically undergo hydrolysis and become reducing sugars during transportation from the grape leaves to the berries. The findings are comparable to those of Abd El-Ghany (2006), Gaser et al. (2017), and Coelho et al. (2018). They observed that vines with longer pruning (overload) units had lower total chlorophyll leaf content and sugar accumulation compared to vines with shorter pruning (underload) units.

As a result, these other sugars may only be present in small amounts, Petrisor and Chirecanu (2019) also found that the content of sucrose and other sugars was very low (or even undetectable) in all grape varieties and that the glucose/fructose ratio in grape berries ranged from 1.0 to 1.06 with some varieties having fructose content slightly higher than glucose.

4. Conclusion

Pruning (crop load) is considered one of the most important vinicultural practices for grape production. Furthermore, pruning severity (bud load) is extremely important to obtain optimum yield and quality for sustainable viticulture in any grape variety.

Our research discovered that increasing the crop load (number of buds per vine) during winter pruning led to higher fresh grape yield. However, we also observed a decrease in grape quality characteristics and an increase in non-standard products and we found that the loss for table grapes ranged from 33.1% to 40.5%.

According to the results of present study, T2 treatment (12 buds-5 cane-long, 3 buds 5 cane-spurs; total 75 bud vine^{-1}) can be recommended to ‘Early Sweet’ table grape growers as the most effective treatment that provides the highest amount of marketable table grapes with yield-quality balance.

Author Contributions

The percentage of the author contributions is presented below. The author reviewed and approved the final version of the manuscript.

	H.Ç.
C	100
D	100
S	100
DCP	100
DAI	100
L	100
W	100
CR	100
SR	100
PM	100
FA	100

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The author declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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