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Research Article

Comparative Analysis of Nutritional Attributes in Karaerik and Kabuğu Yufka Grapevine Leaves Under Varying Bud Load

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Abstract: This study, investigated the effects of variety selection (*Vitis vinifera* cv. Karaerik and Kabugu Yufka) and bud load management (24, 36, 48, and 60 buds per vine) on the physiological and nutritional parameters of grapevine leaves over a two-year period. The research examined various leaf characteristics including dry matter content, ash content, acidity, pH, dietary fiber, vitamins C and E, total phenolic content, and macro and micromineral composition. The findings revealed significant differences among varieties across multiple parameters. Karaerik consistently demonstrated higher dry matter content, ash content, acidity, vitamin C levels, and generally superior macro and micronutrient concentrations. Conversely, Kabugu Yufka exhibited higher vitamin E content. Bud load treatments had varying effects, with some parameters, such as dry matter content and leaf acidity in the second year, showing significant responses to increased bud load. The study also observed year-to-year variations, with notable changes in vitamin C, total phenolic content, and mineral compositions between the two growing seasons. These findings' consistent superiority of Karaerik in several nutritional aspects suggests its potential for producing higher quality grape leaves for culinary or nutraceutical purposes. However, the higher vitamin E content in Kabugu Yufka leaves indicates that variety choice may depend on specific nutritional targets. The varied responses to bud load treatments highlight the importance of tailored management strategies for each variety to maximize desired leaf characteristics.

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1. Introduction

Grapes are among the few fruits with a remarkably diverse range of culinary applications, being processed into various products that play a significant role in both traditional and modern cuisine.

Examples of such grape-derived products include grape juice, pestil, bastık, molasses, köme, vinegar, rakı, wine, and köfter, each representing a distinct method of utilization. Beyond these products, vine leaves also hold considerable culinary value and can be consumed either fresh or vine leaves preserved (Cangi and Yagcı, 2017). In recent years, vine leaf production has developed into a distinct commercial sector within viticulture, expanding beyond conventional grape cultivation to include the specialized production of leaves for commercial purposes. This transformation has been driven, in part, by socio-economic changes, particularly the increasing participation of women in the workforce, which has led to a greater demand for convenient, ready-to-eat food products, including pickled vine leaves. Consequently, viticulture for leaf production has emerged as a profitable industry, further strengthened by expanding export opportunities that enhance its economic appeal (Yagcı et al., 2012). Moreover, in regions where viticultural practices are limited by specific climatic constraints, such as late spring frosts, critical temperature thresholds, and the increased frequency of extreme weather events, the cultivation of preserved vine leaves is considered a more sustainable and economically viable alternative to traditional grape production (Cangi and Yagcı, 2012). In addition, the increasing emphasis on health-conscious nutrition and functional food products has intensified interest in grapevine leaves, which are recognized as an excellent source of bioactive molecules, particularly phenolic compounds (Schoedl et al., 2012; Aguilar et al., 2016; Moldovan et al., 2020; Banjanin et al., 2021; Goicoechea et al., 2021; Maia et al., 2021; Yildiz et al., 2024). The growing recognition of their nutritional and health benefits has further underscored their potential as an alternative agricultural product, particularly in regions where ecological constraints pose challenges to grape cultivation.

This study systematically analyzed the effects of different bud load treatments on key quality parameters in the leaves of Karaerik and Kabugu Yufka grape varieties. The evaluated quality parameters included dry matter and ash content, titratable acidity, pH, leaf color, vitamin E and C content, dietary fiber content, total phenolic content, and the concentrations of various macro and microelements. The research was conducted in accordance with the agronomic and economic findings of previous studies carried out in the region (Kalkan et al., 2024a and 2024b). The primary objective was to provide a complementary assessment by examining the qualitative characteristics of the leaves of the selected cultivars. Furthermore, the integration of these qualitative assessments with agronomic performance and economic feasibility aimed to offer a more comprehensive understanding of vine leaf production in the region, thereby enhancing its potential as a sustainable and economically viable agricultural practice.

2. Material and Methods

2.1. Material

The study utilized two grapevine varieties, Karaerik and Kabugu Yufka, as plant material. Karaerik is characterized by thin, slightly wavy, five-lobed leaves with a bright green color, sparse pubescence, and prominent serrations. The petiole is of medium thickness, and the petiolar sinus is U- or V-shaped. Kabugu Yufka leaves are five-lobed, yellowish green in color, with sparse woolly pubescence. The petiole is of medium thickness, and the petiolar sinus is closed (Kalkan ve ark., 2024a) (Figure 1a and 1b).

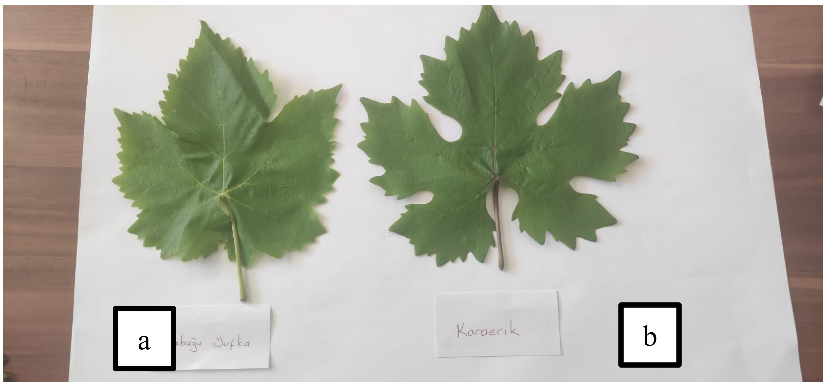

Figure 1. (a,b) Leaf images belong to Kabugu Yufka and Karaerik grape varieties.

2.2. Method

2.2.1. Data collection and analyses

Leaf harvesting for analysis commenced in the first week of June and concluded in the last week of July in both years. Leaves selected for sampling were the 4th, 5th, and 6th leaves on shoots that had reached two thirds of the size of a fully mature leaf from the tip, following the method described by Kılıç (2007) (Figure 2). A total of 25 leaves were collected for each treatment.

Figure 2. Leaves collected for pickling purposes (Photo: Kılıc, 2007).

2.2.2. Dry matter and ash content (%)

Dry matter content was determined by drying leaf samples in an oven at 105 °C until a constant weight was achieved. Ash content was measured by incinerating leaf samples in a muffle furnace at 500-600 °C until white ash was obtained (Dokuzlu, 2004).

2.2.3. Titratable acidity (%)

Titratable acidity was determined using the pH-metric method on an aqueous extract obtained from fresh leaves processed in a blender (Cemeroglu, 1992).

2.2.4. pH

Leaf samples were blended with a small amount of distilled water to form a puree. The pH was then measured by immersing a pH meter electrode in the puree (Cemeroglu, 1992).

2.2.5. Leaf color

Leaf color was measured using a Minolta colorimeter (Model CR-300) calibrated with a white standard plate (Y=92.40, x=0.3137, y=0.3195). Hunter color measurement parameters (L-brightness, a-red/green, b-yellow/blue) were recorded.

2.2.6. Vitamin C content

Ascorbic acid (Vitamin C) content was determined in fresh grape leaves using a modified method of Karhan et al. (2004) with High-Performance Liquid Chromatography (HPLC).

2.2.7. Vitamin E content

Vitamin E content was analyzed using Gas Chromatography-Mass Spectrometry (GC-MS) following the method described by Fiorentino et al. (2009).

2.2.8. Dietary fiber

Dietary fiber was determined using the AOAC Official Method 991.43 (Total, Soluble, and Insoluble Dietary Fiber in Foods, Enzymatic-Gravimetric Method, MES-TRIS Buffer, First Action 1991, Final Action 1994).

2.2.9. Mineral content

Concentrations of Ca, Fe, Mg, Mn, P, K, Zn, Cu, and Se were measured using Inductively Coupled Plasma Mass Spectrometry (ICP-MS). Vitamin E and mineral content analyses were conducted at the Chemistry Department, Faculty of Arts and Sciences, Erzincan Binali Yildirim University.

2.2.10. Total phenolic content

Total phenolic content (mg GAE/100 g) was determined using the Folin-Ciocalteu colorimetric method as described by Singleton and Rossi (1965).

2.3. Statistical analysis

Data were subjected to analysis of variance (ANOVA) using JUMP statistical software (version 7.0.1). Means were compared using the Least Significant Difference (LSD) test at a 5% significance level.

3. Results

3.1. Dry matter content in leaves of grape varieties

The effects of cultivar and bud load treatments on dry matter (DM) are given in Table 1. The effect of cultivars on % dry matter content was statistically significant (P<0.05) in both years. In the second year, treatments and variety x treatment interactions were found significant.

Table 1. Effect of variety and bud load on % dry matter in leaves

Year	Variety	Applications (bud/vine)				The main effect of variety
		24	36	48	60	
2021	Karaerik	28.20 ns	28.17	28.16	28.02	28.17 a
	Kabugu Yufka	28.00	27.70	27.15	26.48	27.38 b
	The effect of the treatment	28.10 ns	27.94	27.65	27.25	
2022	Karaerik	27.22 a	26.86 b	26.79 b	26.61 b	26.87 a
	Kabugu Yufka	26.13 c	26.10 c	26.03 c	25.18 d	25.86 b
	The effect of the treatment	26.67 a	26.48 ab	26.41 b	25.90 c	

The differences between the means indicated by different letters in the same column are statistically significant (p < 0.05). ns: not significant.

3.2. Leaf ash content in grape varieties

The effects of cultivar and bud load treatments on ash content are given in Table 2. While the effect of cultivars on ash content was found statistically significant (P<0.05), the difference between treatments was found significant in the second year.

Table 2. Effect of variety and bud load treatments on % ash in leaves

Year	Variety	Applications (bud/vine)				The main effect of variety
		24	36	48	60	
2021	Karaerik	1.58 ns	1.58	1.61	1.68	1.61 a
	Kabugu Yufka	1.45	1.50	1.55	1.63	1.53 b
	The effect of the treatment	1.52 ns	1.54	1.58	1.65	
2022	Karaerik	1.76 ns	1.70	1.69	1.66	1.70 a
	Kabugu Yufka	1.65	1.60	1.65	1.49	1.60 b
	The effect of the treatment	1.71 a	1.68 a	1.65 ab	1.57 b	

The differences between the means indicated by different letters in the same column are statistically significant (p < 0.05). ns: not significant.

3.3. Leaf acid content in grape varieties

The effects of cultivar and bud load treatments on acid content are given in Table 3. The effects of cultivar and bud load treatments on leaf acid content were statistically significant in both years. The effect of treatments was significant in the second year ($P<0.05$).

Table 3. Effect of variety and bud load treatments on % acid content in fresh leaves

Year	Variety	Applications (bud/vine) 24	36	48	60	The main effect of variety
2021	Karaerik	1.42 ns	1.50	1.46	1.54	1.46 a
	Kabugu Yufka	1.30	1.28	1.27	1.24	1.27 b
	The effect of the treatment	1.36 ns	1.39	1.34	1.39	
2022	Karaerik	1.23 ns	1.34	1.32	1.40	1.32 a
	Kabugu Yufka	1.24	1.20	1.37	1.38	1.29 b
	The effect of the treatment	1.24 c	1.27 bc	1.35 ab	1.39 a	

The differences between the means indicated by different letters in the same column are statistically significant ($p < 0.05$). ns: not significant.

3.4. Leaf pH value in grape varieties

The effects of cultivar and bud load treatments on pH values are given in Table 4. The pH values between varieties were statistically significant only in the first year ($P<0.05$). The differences in treatments and interactions were not statistically significant in both years.

Table 4. Effect of variety and bud load treatments on leaf pH in 2021 and 2022

Year	Variety	Applications (bud/vine) 24	36	48	60	The main effect of variety
2021	Karaerik	3.08	3.10	3.07	3.10	3.09 a
	Kabugu Yufka	3.06	3.06	3.06	3.04	3.06 b
	The effect of the treatment	3.07	3.08	3.07	3.07	
2022	Karaerik	3.32	3.30	3.28	3.28	3.30 ns
	Kabugu Yufka	3.29	3.33	3.30	3.30	3.30
	The effect of the treatment	3.30 ns	3.31	3.29	3.29	

The differences between the means indicated by different letters in the same column are statistically significant ($p < 0.05$). ns: not significant.

3.5. Leaf dietary fiber content in grape varieties

The results of the effect of cultivar and bud load on dietary fiber content are given in Table 5. The effect of cultivar and bud load treatments on leaf dietary fiber content in the first year was found statistically significant among cultivars, mean values, and cultivar x bud load interaction. In the second year, only the effect of cultivars was found statistically significant ($P<0.05$).

Table 5. Effects of bud load and variety on dietary fiber content (g 100 g^{-1}) in leaves

Year	Variety	Applications (bud/vine) 24	36	48	60	The main effect of variety
2021	Karaerik	11.03 d	11.55 b	11.25 c	11.90 a	11.43 a
	Kabugu Yufka	10.42 h	10.82 f	10.60 g	10.95e	10.70 b
	The effect of the treatment	10.73 d	11.19 b	10.93 c	11.43 a	
2022	Karaerik	13.97 ns	13.88	13.68	13.13	13.67 a
	Kabugu Yufka	11.79	11.68	12.28	10.65	11.60 b
	The effect of the treatment	12.89 ns	12.78	12.98	11.89	

The differences between the means indicated by different letters in the same column are statistically significant ($p < 0.05$). ns: not significant.

3.6. Vitamin C content in leaves of grape varieties

The effects of cultivar and bud load treatments on vitamin C content in leaves are given in Table 6. The effects of cultivar and bud load treatments on the amount of vitamin C in fresh leaves were found to be statistically significant among cultivars in both years (P<0.05). The mean values were not statistically significant in the cultivar x bud load interaction.

Table 6. Effect of variety and bud load on vitamin C content (mg 100 g^{-1}) in fresh leaves

Year	Variety	Applications (bud/vine)				The main effect of variety
		24	36	48	60	
2021	Karaerik	105.4 ns	97.50	117.8	106.5	106.79 a
	Kabugu Yufka	92.70	84.48	87.42	94.74	89.84 b
	The effect of the treatment	99.05 ns	90.99	102.6	100.6	
2022	Karaerik	130.47 ns	131.67	134.64	132.50	132.32 a
	Kabugu Yufka	112.73	116.76	117.49	121.38	117.09 b
	The effect of the treatment	121.60 ns	124.22	126.07	126.94	

The differences between the means indicated by different letters in the same column are statistically significant (p < 0.05). ns: not significant.

3.7. Vitamin E content in leaves of grape varieties

The data obtained for the effects of cultivar and bud load on vitamin E content in fresh leaves are given in Table 7. The effects of cultivar and bud load treatments on vitamin E content in leaves were found to be statistically significant in both years, among cultivars and in the cultivar x bud load interaction (P<0.05).

Table 7. Effect of variety and bud load on vitamin E content (mg 100 g^{-1}) in fresh leaves

Year	Variety	Applications (bud/vine)				The main effect of variety
		24	36	48	60	
2021	Karaerik	7.32c	8.69c	9.17c	7.30c	8.12 b
	Kabugu Yufka	21.82 a	17.03 b	19.27 ab	17.18 b	18.82 a
	The effect of the treatment	14.57 ns	12.86	14.22	12.24	
2022	Karaerik	15.38 c	15.73 c	12.14 c	13.98 c	14.31 b
	Kabugu Yufka	20.80 b	20.53 b	24.99 a	20.10 b	21.69 a
	The effect of the treatment	18.09 ns	18.13	18.57	17.04	

The differences between the means indicated by different letters in the same column are statistically significant (p < 0.05). ns: not significant.

3.8. Total phenolic content in grapevine leaves

The data obtained regarding the effects of cultivar and bud load treatments on total phenolic matter contents are given in Table 8. In the first year, total phenolic matter content between varieties was found to be statistically significant (P<0.05). There was no difference in the second year.

Table 8. Effect of variety and bud load on total phenolic matter content in leaves (mg GAE 100 g^{-1} DM)

Year	Variety	Applications (bud/vine)				The main effect of variety
		24	36	48	60	
2021	Karaerik	4093.6 ns	4002.9	3864.5	3930.7	3972.9 a
	Kabugu Yufka	3632.4	3340.3	3726.8	3744.8	3611.0 b
	The effect of the treatment	3863.0 ns	3671.6	3795.7	3837.7	
2022	Karaerik	3222.9 ns	3212.7	3019.1	3068.4	3130.8 ns
	Kabugu Yufka	2825.6	2815.3	2848.5	2912.4	2850.5
	The effect of the treatment	3024.26 ns	3014.0	2933.7	2990.4	

The differences between the means indicated by different letters in the same column are statistically significant (p < 0.05). ns: not significant.

3.9. Some macro mineral composition of grapevine leaves (K, Mg, P, Ca)

The effects of cultivar and bud load treatments on some macronutrients are given in Table 9. In terms of potassium content, cultivar x treatment interaction in the first year and differences between cultivars in the second year were found to be statistically significant. In terms of magnesium content, the differences between cultivars were found significant in both years. In terms of calcium content, only the differences between treatments were statistically significant (P<0.05). In terms of phosphorus content, the effect of cultivar and bud load treatments on phosphorus content in leaves was statistically significant between cultivars in the first year, but no difference was found in the second year.

Table 9. Effects of variety and bud load on some macro element amounts (ppm) in leaves

	Year	Variety	Applications (bud/vine) 24	36	48	60	The main effect of variety
Potassium	2021	Karaerik	2706.4 bc	2796.9 a-c	2810.7 a-c	2552.4 c	2716.5 ns
		Kabugu Yufka	2683.4 bc	2932.2ab	2581.1c	3002.0 a	2797.4
		The effect of the treatment	2694.7 ns	2695.9	2860.0	2777.2	
	2022	Karaerik	9196.9 ns	9189.7	8705.3	10050.9	9196.9 a
		Kabugu Yufka	8516.4	8698.3	8307.3	7948.8	8516.5 b
		The effect of the treatment	8856.6 ns	8944.0	8506.3	8999.9	
Magnesium	2021	Karaerik	2035.3 ns	2073.0	2297.0	2377.4	2195.6 b
		Kabugu Yufka	2783.5	2802.5	2736.4	2848.6	2793.0 a
		The effect of the treatment	2409.4 ns	2437.7	2516.6	2613.0	
	2022	Karaerik	2339.9 ns	2249.9	2636.0	2499.1	2339.9 b
		Kabugu Yufka	2746.1	2834.7	3029.1	2923.6	2746.1 a
		The effect of the treatment	2543.0 ns	2542.9	2832.6	2711.4	
Calcium	2021	Karaerik	1046.4 ns	1095.8	1030.2	1126.9	1074.8 ns
		Kabugu Yufka	1063.5	1049.2	1077.3	1085.7	1068.9
		The effect of the treatment	1055.0 ns	1072.5	1053.7	1106.3	
	2022	Karaerik	999.19 ns	905.8	1095.48	846.27	961.70 a
		Kabugu Yufka	850.97	805.03	791.90	818.76	850.97 b
		The effect of the treatment	925.08 ab	865.45 bc	943.69 a	832.51c	
Phosphorus	2021	Karaerik	3627.7 ns	3676.2	3884.3	3753.6	3735.5 a
		Kabugu Yufka	3202.2	3554.1	3369.7	3538.1	3416.0 b
		The effect of the treatment	3415.0 ns	3615.1	3627.0	3646.0	
	2022	Karaerik	3616.9 ns	3484.0	3666.1	3646.1	3603.2 ns
		Kabugu Yufka	3602.3	3209.0	3406.9	3553.3	3442.9
		The effect of the treatment	3609.6 ns	3346.5	3536.5	3599.7	

The differences between the means indicated by different letters in the same column are statistically significant (p < 0.05). ns: not significant.

3.10. Some micromineral composition of grapevine leaves (Fe, Zn, Mn, Cu, Se)

The effects of cultivar and bud load treatments on some micronutrient amounts are given in Table 10. The effects of cultivar and bud load treatments on iron content in leaves were found to be statistically significant in the first year, while zinc content was found to be statistically significant between cultivars in both years (P<0.05). In terms of manganese content, it was found statistically significant only for the cultivars in the first year, but there was no difference in the second year. The effect on copper content was not statistically significant. On the other hand, the effect on selenium content was not found to be statistically significant (P<0.05) in the first year, while it was found to be significant in the second year among the varieties and treatments.

Table 10. Effects of variety and bud load on some microelement amounts (ppm) in leaves

	Year	Variety	Applications (bud/vine)				The main effect of variety
			24	36	48	60	
Iron	2021	Karaerik	71.89 ^{ns}	61.73	67.57	62.52	65.92 a
		Kabugu Yufka	53.55	58.63	60.07	52.69	56.24 b
		The effect of the treatment	62.72 ^{ns}	60.18	63.82	57.61	
	2022	Karaerik	146.51 ^{ns}	167.41	150.19	131.14	148.814 ^{ns}
		Kabugu Yufka	127.77	126.96	159.91	138.34	138.2
		The effect of the treatment	137.14 ^{ns}	147.19	155.05	134.74	
Zinc	2021	Karaerik	129.8 ^{ns}	130.1	129.9	120.7	127.6 a
		Kabugu Yufka	117.2	105.7	104.2	115.3	110.6 b
		The effect of the treatment	123.5 ^{ns}	117.9	117.0	118.0	
	2022	Karaerik	113.38 ^{ns}	113.33	103.95	99.64	107.58 a
		Kabugu Yufka	97.51	94.23	89.61	76.24	89.40 b
		The effect of the treatment	105.45 ^{ns}	103.78	96.78	87.94	
Manganese	2021	Karaerik	30.59 ^{ns}	30.88	30.20	30.90	30.44 a
		Kabugu Yufka	24.40	26.Şub	28.27	30.39	27.27 b
		The effect of the treatment	27.50 ^{ns}	28.45	29.24	30.24	
	2022	Karaerik	38.22 ^{ns}	31.50	38.61	35.01	35.84 ^{ns}
		Kabugu Yufka	33.44	32.77	31.36	31.54	32.28
		The effect of the treatment	35.83 ^{ns}	32.14	34.98	33.27	
Copper	2021	Karaerik	9.36 ^{ns}	Eki.51	Ağu.41	9.Eyl	9.33 ^{ns}
		Kabugu Yufka	Ağu.75	Eyl.49	Ağu.83	Eki.32	Eyl.34
		The effect of the treatment	9.06 ^{ns}	10.0	Ağu.62	Eyl.70	
	2022	Karaerik	15.73 ^{ns}	14.79	14.76	17.00	15.57 ^{ns}
		Kabugu Yufka	15.34	16.Ağu	16.Ağu	14.61	15.53
		The effect of the treatment	15.54 $^{n\ s}$	15.44	15.42	15.81	
Selenium	2021	Karaerik	0.059 ^{ns}	0.057	0.054	0.059	0.057 ^{ns}
		Kabugu Yufka	0.057	0.049	0.055	0.057	0.055
		The effect of the treatment	0.058 ^{ns}	0.053	0.054	0.053	
	2022	Karaerik	0.072 ^{ns}	0.057	0.057	0.061	0.062 a
		Kabugu Yufka	0.055	0.069	0.061	0.039	0.056 b
		The effect of the treatment	0.064a	0.063a	0.059b	0.050c	

The differences between the means indicated by different letters in the same column are statistically significant ($p < 0.05$). ns: not significant.

4. Discussion

The results provided valuable insights into the effects of variety selection and bud load management on certain chemical parameters in grapevine leaves. The findings demonstrated significant variety-dependent variations and, in some cases, bud load-induced changes in leaf composition across two consecutive growing seasons. Regarding dry matter content, our results indicated that Karaerik consistently exhibited higher dry matter content compared to Kabugu Yufka across both years, with values ranging from 26.61% to 28.20% for Karaerik and 25.18% to 28.00% for Kabugu Yufka (Table 1). Kılıc (2007) reported that the lowest and highest dry matter content varied between 28.01-29.49% (8 buds/vine) in the goblet system and 26.22- 27.03% (24-16 buds/vine) in the cord system in terms of bud load and training systems. Gulcu and Demirci (2011) reported that the dry matter content of the Narince variety was 24.09%, the Yapıncak variety was 18.48% and the Tekirdağ Cekirdeksiz variety was 24.18%; Coban (2023) reported that the total dry matter content of Sultani Cekirdeksiz grape variety was 26.1%. The differences are thought to be due to factors such as variety-specific characteristics, environmental conditions, and viticulture practices (Koundouras et al., 2006; Kepenekci, 2007).

On the other hand, the ash content in our study ranged from 1.58% to 1.76% for Karaerik and 1.45% to 1.65% for Kabugu Yufka (Table 2). Sat et al. (2002) reported ash content in different grape varieties between 1.52 (Karaerik) and 2.15 (Hacıtesbihi). Coban (2023) reported that ash content varied in fresh grapevine leaves in May and July. Ovayurt and Soylemezoglu (2023) determined the amount of ash in different grape varieties between 0.48% (Yapıncak) and 1.57% (Tekirdağ Cekirdeksizi). Kılıc

(2007) reported that training systems and bud load applications affected the ash content of grapevine leaves. In our study, ash content in leaves decreased in the second year in parallel with the increase in bud load. The data obtained regarding the ash content of the varieties are generally similar to the literature. It is thought that the differences are due to the variety, bud load, year, and leaf removal times depending on the reports of the above researchers.

In our study, the % acidity values determined in fresh leaves were between 1.23-1.54 in the Karaerik grape variety and between 1.20-1.38 in the Kabugu Yufka variety depending on the year and treatments, which is similar to the previous studies. As a matter of fact, Basoglu et al. (2004) determined % acidity between 1.20 and 1.50 in fresh leaves of the Sultani Cekirdeksiz grape variety, and Kılıc (2007) determined % acidity between 1.29 and 1.62 in Narince variety according to the bud load applications. The researcher reported that acidity values were low at low bud load in the first year of the study and acidity increased with high bud load. Ovayurt and Soylemezoglu (2023) determined % acidity between 1.92 (Narince) and 2.08 (Yapincak) in fresh leaves of different varieties. On the other hand, researchers have reported that elevation (Koundouras et al., 2006) cultivation system (Kepenekci, 2007), variety (Sensoy and Balta, 2010; Kamiloglu and Ustun, 2014; Celik and Ates, 2025), soil, climate, topographical features (Demiray, 2006; Bayram et al., 2016) and cultural treatments (Bahar et al., 2018) affect acidity.

The pH values in our study ranged from 3.07 to 3.32 for Karaerik and 3.04 to 3.33 for Kabugu Yufka (Table 4). Academic studies on pH values in fresh grapevine leaves are quite limited. In the studies, the findings of pH values are mostly related to the leaves processed in brine. Sat et al. (2002) determined the pH values of fresh grapevine leaves as 3.39 in the Hacı Tesbihi variety, 3.31 in the Kabugu Yufka variety, 3.43 in the Agrazaki variety and 3.46 in Karaerik variety. Ovayurt and Soylemezoglu (2023) reported that pH values in fresh leaves of different grape varieties were determined between 3.1 (Emir and Narince) and 3.24 (Sultani Cekirdeksiz). In general, it can be said that the treatments did not have a stable effect on pH values. Similarly, in a study conducted by Kılıc (2007), it was determined that there was no statistical difference between bud load and pH.

On the other hand, our study found dietary fiber content ranging from 11.03% to 13.97% for Karaerik and 10.42% to 12.28% for Kabugu Yufka (Table 5). These results are in agreement with the findings of Celik (2014), who reported 11 g of dietary fiber per 100 g of fresh grapevine leaves, and Cangi et al. (2019) who found 10.5 g 100 g^{-1} in Narince leaves. Our values are also comparable to those reported by Ovayurt and Soylemezoglu (2023) for various varieties (12.06 to 14.01 g 100 g^{-1}). The consistency of our findings with previous studies suggests that dietary fiber content in grapevine leaves may be relatively stable across different varieties and growing conditions.

The vitamin C content in our study ranged from 97.5 to 132.5 mg 100 g^{-1} for Karaerik and 87.42 to 121.38 mg 100 g^{-1} for Kabugu Yufka (Table 6). Sat et al. (2002) determined vitamin C in fresh grapevine leaves as 54.00 mg/100g in the Hacıtesbihi variety, 100.29 mg/100g in the Karaerik variety, 61.75 mg 100 g^{-1} in the Kabugu Yufka variety and 77.08 mg 100 g^{-1} in Agrazaki grape variety. Vitamin C content in the leaves of the varieties may vary depending on whether the leaves are fresh or pickled. As a matter of fact, Sat et al. (2002) reported that the vitamin C levels of pickled leaves were significantly lower compared to fresh leaves and this decrease may be due to the processing technique. In addition, Franke et al. (2004) reported that vitamin C contents may vary with species, cultivar, and part analyzed.

Our study also found vitamin E content ranging from 7.30 to 15.38 mg 100 g^{-1} for Karaerik and 17.03 to 24.90 mg 100 g^{-1} for Kabugu Yufka (Table 7). Studies on the determination of vitamin E content in grapevines are mostly limited to wine and berry contents. Studies on vitamin E content in fresh grapevine leaves are almost nonexistent. Cangi et al. (2019) determined the vitamin E content in pickled Narince grapevine leaves as 6.96±3.37 mg 100 g^{-1}. Vitamin E contents in fresh grapevine leaves are higher than the findings of Cangi et al. (2019). This shows that vitamin E values are different in fresh and pickled grapevine leaves.

On the other side, the total phenolic content in our study ranged from 3019.1 to 4093.6 mg 100 g^{-1} for Karaerik and 2815.3 to 3744.8 mg 100 g^{-1} for Kabugu Yufka (Table 8). These values are generally higher than those reported by Ovayurt and Soylemezoglu (2023) for various varieties (1780 to 3130 mg GAE 100 g^{-1}). The higher phenolic content observed in Karaerik (a black variety) compared to Kabugu Yufka (a white variety) is consistent with the findings of Yang and Xiao (2013) who reported higher phenolic content in black grape varieties. As noted by Nadal and Arola (1995), De La Orts et al. (2005) and Sonmez Yildiz et al. (2023) factors such as variety, ecological conditions, maturity levels, and cultural practices can influence phenolic content in grapevines. Our findings support this notion and provide additional evidence for variety-specific differences in phenolic content.

Macronutrient contents in leaves of Karaerik and Kabugu Yufka cultivars varied under different bud load treatments across cultivars, years, and, in some cases, in response to bud load management treatments (Table 9). The potassium content in the Karaerik grape variety ranges from 2552.4 to 10050.9 ppm, while in the Kabugu Yufka variety, it ranges from 2581.1 to 8698.3 ppm. The magnesium content in the Kabugu Yufka variety is between 2736.4 and 3029.1 ppm, whereas in the Karaerik variety, it ranges from 2035.3 to 2636 ppm. The calcium content in the Kabugu Yufka variety is between 2736.4 and 3029.1 ppm, while in the Karaerik variety, it ranges from 2035.3 to 2636 ppm. The phosphorus content in the Karaerik grape variety is between 3484 and 3884.3 ppm, while in the Kabugu Yufka grape variety, it ranges from 3202.2 to 3666.1 ppm. In general, our study found that phosphorus, potassium, and calcium levels were higher in the Karaerik variety, whereas magnesium content was higher in the Kabugu Yufka variety (Table 9). Aydin et al. (2005) determined the phosphorus content to be 0.11%, potassium content to be 0.54%, calcium content to be 2.02%, and magnesium content to be 0.33% in the leaf blade during the berry set period of the Yuvarlak Cekirdeksiz grape variety. Kara and Bacevli (2012) identified the phosphorus content in the fresh leaves of rootstock cuttings as ranging from 2594.5 ppm (41 B) to 3702.7 ppm (140 Ru); potassium content from 5523.3 ppm (140 Ru) to 7859.5 ppm (110 R); calcium content from 8098.7 ppm (110 R) to 11593.3 ppm (41 B); and magnesium content from 1991.4 ppm (110 R) to 3216.2 ppm (99 R). Tangolar et al. (2019) found the phosphorus content in the Early Sweet variety during full bloom to range between 0.26% and 0.38%, potassium content between 0.50% and 0.55%, calcium content between 1.06% and 1.48%, and magnesium content between 0.13% and 0.19%. Esetlili et al. (2020) reported the phosphorus content in the fresh leaves during the flowering period of the Cabernet Sauvignon grape variety to range between 0.19% and 0.34%, potassium content between 0.98% and 1.44%, calcium content between 2.14% and 3.11%, and magnesium content between 0.44% and 0.61%. Coban (2023) found the phosphorus content to be 0.22%, potassium content to be 1.36%, calcium content to be 2.3%, and magnesium content to be 0.55% in the fresh leaves of the Sultani Cekirdeksiz grape variety during May. The findings for the fresh leaves of the Karaerik and Kabugu Yufka varieties in this study are generally consistent with the results reported by Aydin et al. (2005), Coban (2023), Tangolar et al. (2019), and Esetlili et al. (2020).

Micronutrient contents in leaves of Karaerik and Kabugu Yufka cultivars varied under different bud load treatments across cultivars, years, and, in some cases, in response to bud load management treatments (Table 10). The iron content in the leaves of the Karaerik grape variety ranged from 61.73 to 138.34 ppm, while in the Kabugu Yufka grape variety, it ranged from 52.69 to 159.91 ppm. The zinc content in the Karaerik variety ranged from 99.64 to 130.1 ppm, and in the Kabugu Yufka variety, it ranged from 76.24 to 117.2 ppm. Manganese levels in the Karaerik variety ranged from 30.20 to 38.61 ppm, while in the Kabugu Yufka variety, it ranged from 24.40 to 33.33 ppm. Copper content in the Karaerik variety was between 8.41 and 17 ppm, and in the Kabugu Yufka variety, it was between 8.75 and 16.08 ppm. The selenium content in the leaves of the Karaerik variety ranged from 0.054 to 0.072 ppm, and in the Kabugu Yufka variety, it ranged from 0.039 to 0.069 ppm. In general, the Karaerik variety exhibited higher levels of iron, zinc, manganese, and selenium. Under low bud load conditions, selenium and zinc levels were higher, whereas these values decreased with an increase in bud load (Table 10). Aydin et al. (2005) reported that the manganese content in the leaf blades of the Yuvarlak Cekirdeksiz variety during the fruit-setting period was 48 ppm, iron content was 217 ppm, and copper content was 29 ppm. Kara and Bacevli (2012) determined the copper content in the fresh leaves of rootstocks 41 B, 110 R, and 1103 P to range from 8.3 ppm (140 Ru) to 13.2 ppm (41 B), iron content from 580.7 ppm (41 B) to 1575.0 ppm (110 R), manganese content from 31.8 ppm (99 R) to 127.0 ppm (140 Ru), and zinc content from 15.2 ppm (140 Ru) to 28.2 ppm (99 R). Tangolar et al. (2019) found that in the Early Sweet variety at full bloom, the leaf samples contained iron levels ranging from 83.2 to 57.7 mg kg^{-1}, manganese levels from 82.6 to 63.4 mg kg^{-1}, and zinc levels from 16.9 to 14.9 mg kg^{-1}. Esetlili et al. (2020) reported the iron content in the Cabernet Sauvignon variety to range from 144 to 242 mg L^{-1}, zinc from 33 to 44 mg L^{-1}, manganese from 87 to 140 mg L^{-1}, and copper from 20 to 38 mg L^{-1}. Licina et al. (1997) measured selenium content in vine organs as 0.07 µg/g in roots, 0.12 µg g^{-1} in stems, shoots, and leaves, and 0.02 µg g^{-1} in grapes. Liu et al. (2019) determined selenium content in grapevine plants as 0.935±0.014 g in roots, 0.426±0.009 g in stems, 1.193±0.061 g in leaves, and 1.081±0.055 g in shoots. The micronutrient levels in the leaves of the grape varieties in this study are somewhat similar to the findings of the aforementioned researchers, but generally, the element levels were either lower or higher. These differences are likely attributed to various factors, including soil, grape variety, timing of leaf sampling, and the cultural practices applied. Indeed, Kacar and Katkat (2010) reported that numerous factors, such as the plant species, age, root growth, the physical, chemical, and biological properties of the soil, the types and quantities of available elements in the soil, agricultural practices, and climatic conditions, significantly influence the nutrient content of plants.

Conclusion

The Karaerik grape variety has stood out in terms of dry matter content, with the 24 and 36-bud vine training systems being the most prominent among the applied treatments. The Karaerik variety has also shown higher levels of ash content and acidity. In general, it was found that the applications had no significant stable effect on pH values. The dietary fiber and vitamin C contents were higher in the Karaerik variety. Although no statistical differences were found between the treatments, the 48 and 60 bud/vine systems yielded higher vitamin C values. The vitamin E content in fresh leaves was found to be higher in the Kabugu Yufka variety, while the Karaerik variety was noted for its higher total phenolic content. Overall, iron, zinc, manganese, and selenium levels were higher in the Karaerik variety. In treatments with lower bud load, selenium and zinc levels were higher, whereas these values decreased as the bud load increased.

Ethical Statement

Ethical approval is not required for this study as it is not a retrospective study.

Conflict of Interest

The authors declare that there are no conflicts of interest.

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Author Contributions

N.N.K, O.T.A and Z.K: Chemical analyses, A.B: Manuscript writing, R.C: Statistical analysis, S.A: Disease control, B.K and D.K: Literature review.

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