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Article

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Posted Date: June 13th, 2025

DOI: <https://doi.org/10.21203/rs.3.rs-6785870/v1>

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Additional Declarations: No competing interests reported.

Version of Record: A version of this preprint was published at Scientific Reports on October 1st, 2025.
See the published version at <https://doi.org/10.1038/s41598-025-15206-2>.

Phenolic profile in leaves of Autochthonous Grapevine Cultivars (*Vitis vinifera* L.) from Turkey distinct of Isparta

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Abstract: In the current age, nutrition is a widely discussed topic, with foods rich in antioxidants being advocated to support healthy living. Phenolic compounds, which are used in treating various diseases due to their antimicrobial properties, have health-promoting properties. Consequently, producing extracts from grape varieties with high phenolic content for use in pharmaceuticals, food supplements, and cosmetics is essential for health and the economy. It is well established that grape leaves are rich in phenolic compounds. However, they are not currently utilised to their full potential and are considered mainly waste. This study was conducted in vineyards in Isparta, located in Turkey's Mediterranean Region, in 2018. The study utilised four autochthonous leaf varieties: two red (*Vitis vinifera* cv. Burdur Dimriti and *Vitis vinifera* cv. Siyah Gemre) and two white (*Vitis vinifera* cv. Razaki and *Vitis vinifera* cv. Tilki Kuyruğu). Total phenolic and flavanol content, as well as the presence of other phenolic compounds, were determined in the grape leaves. The study's findings indicated significant variations in the phenolic content of different grapevine leaf varieties. Total phenolic content ranged from 3.25 to 7.38 mg CE/g, while total flavanol content ranged from 67.66 to 120.24 mg CE/g. Phenolic compounds identified in the leaves included ferulic acid, gallic acid, caffeic acid, chlorogenic acid, catechin, quercetin, epicatechin, rutin, p-coumaric acid, o-coumaric acid, protocatechuic acid, hesperidin, vanillin, kaempferol, luteolin, and tannic acid, which were found to vary among the varieties.

Key Words: Flavanol, Grapevine, Grape leaves, Phenolic Compounds, Polyphenols,

1 **Introduction**

2 Grapes are among the most extensively cultivated fruits globally. Turkey is considered to be
3 among the foremost grape-cultivating nations worldwide. Turkey's viticultural history spans
4 millennia, and the country is widely regarded as the grape's ancestral home. It is evident that
5 the country has experienced a considerable degree of cultivation over centuries, and as a
6 consequence, it is now characterised by a rich genetic diversity. The cultivation of grapes is
7 widespread throughout Turkey, and the fruit is consumed in various forms. While they are
8 primarily valued for salads, drying, and winemaking, traditional consumption methods are also
9 widely practised in Turkey (Candar et al., 2021). The consumption of grape leaves has been a
10 practice for many years, both in their fresh state and in the form of pickles. In Turkey, stuffed
11 grape leaves made with pickled leaves are considered a traditional dish. Gürkan (2014)
12 demonstrates that analogous culinary preparations are also favoured in Greece, Albania,
13 Bulgaria, the Balkans, France, and Spain.

14 In recent years, there has been an increased focus on healthy living, leading to a greater
15 emphasis on plants rich in phenolic compounds and antioxidants. These secondary metabolites
16 are found in various parts of plants and perform different functions within them. They have
17 been demonstrated to play a role in the plant's defence mechanisms and to possess protective
18 properties against various stress conditions, such as UV radiation, pathogens, and diseases
19 (Taware et al., 2010; Kedrina-Okutan et al., 2019). Phenolic compounds have a variety of
20 applications in the study of various characteristics of plants, including bitterness, astringency,
21 aroma, the colouration of flowers and fruits, taxonomic differentiation, growth and
22 development, rooting, and graft incompatibility mechanisms. The properties above include
23 antioxidant, antimutagenic, anticarcinogenic, anti-aging, and antimicrobial characteristics
24 (Nassiri-Asl, 2009; Devi and Singh, 2017; Fayek et al., 2017).

25 Grapes are among the most notable fruit types in terms of their phenolic compound content.
26 The substantial secondary metabolite content of the grape plant is a salient feature that
27 distinguishes it from numerous other plants. Resveratrol, a polyphenol found in grapes, is also
28 available in tablet form. Research has indicated the presence of phenolic compounds in various
29 parts of the grapevine, including leaves, shoots, fruit flesh, peel, and seeds (Hallaç Türk et al.,
30 2018; Saez et al., 2019; Goufo et al., 2020). Consequently, identifying grapevine varieties with
31 elevated phenolic compound content and the subsequent production of extracts for utilisation

1 in pharmaceuticals, food supplements, and cosmetics is of significant importance from both
2 health and economic standpoints. The initial studies on determining the phenolic profile of
3 grapevines focused primarily on wine, seeds, seed husks, and pulp. However, in recent years,
4 there has been an increase in studies on grapevine leaves. Scientific studies have demonstrated
5 that grape leaves are abundant in phenolic acids, tannins, anthocyanins, and flavonoids
6 (Fernandes et al., 2013; Lima et al., 2016; Jaradat et al., 2017; Kedrina-Okutan et al., 2019).
7 The use of grape leaves in traditional medicine to treat various diseases has a long history, as
8 evidenced by numerous studies (Pari and Suresh, 2008; Devi and Singh, 2017). It is well
9 established that grape leaves are endowed with a plethora of pharmacological properties,
10 including but not limited to antioxidant, antidiabetic, liver-protective, cholesterol-lowering,
11 antibacterial, anti-ageing, antiviral, anti-carcinogenic, collagen-preserving, hair-growth-
12 promoting, antifungal, anti-inflammatory, and cell damage prevention properties (Dani et al.,
13 2010; Devi and Singh, 2017; Salehi et al., 2019; Duangjan et al., 2021). Over the past two
14 decades, the potential of grape leaves in terms of phenol provision has attracted the attention of
15 numerous pharmaceutical companies, which have invested significant economic resources in
16 research to identify a safe and effective source of phenols.

17 The utilisation of by-products resulting from the processing of grapes for commercial purposes,
18 encompassing fresh and processed produce, remains a relatively underutilised practice in
19 Turkey. After the harvest, the leaves are permitted to stay on the vines. Evidently, the utilisation
20 of grapevine leaves is inadequate, and they are predominantly regarded as a by-product.
21 Determining phenolic compounds in post-harvest leaves can generate opportunities for their
22 utilisation in the food, pharmaceutical, and cosmetic industries. Moreover, the potential
23 therapeutic applications of grape leaves, in conjunction with their utilisation as a functional
24 food, underscore the necessity for re-evaluating this product within the paradigm of sustainable
25 agricultural development (Acero et al., 2025).

26 This study aimed to ascertain the phenolic compound content of leaves from four indigenous
27 grape varieties cultivated in vineyards in Isparta, which is located in the Mediterranean Region
28 of Turkey. This was undertaken to identify their potential as a valuable resource for the food
29 and pharmaceutical industries and to facilitate their re-evaluation.

Materials and Methods

The present study was conducted in 2018 in vineyards in the province of Isparta, in the Mediterranean Region of Turkey. Four varieties of leaves were utilised as materials in the study: two coloured varieties (*Vitis vinifera* cv. Burdur Dimriti, *Vitis vinifera* cv. Siyah Gemre) and two white varieties (*Vitis vinifera* cv. Razaki and *Vitis vinifera* cv. Tilki Kuyruğu). The vines of the varieties had been cultivated for 20 years and had grown on their roots. The Goble training system was implemented in the vineyards. As the available climate data demonstrated, the total precipitation in 2018 was 399.8 mm, which is lower than the long-term average of 543.6 mm. Concurrently, the average temperature was recorded as 13.8 °C, higher than the long-term average of 12.2 °C. The monthly precipitation and temperature data are presented in Figure 1.

The soil in the designated trial area is characterised by a predominantly clay-textured composition, exhibiting a neutral reaction with a pH value of 7.01. Electrical conductivity measurements indicate a low level of conductivity (0.09 dS/m), suggesting conditions that are not saline. The calcium carbonate content was found to be 2.96%, and the organic matter content was found to be 1.01%. Nutrient analysis indicates the presence of phosphorus at a high level (41 ppm), while potassium is present at a low level (68.7 ppm). The analysis revealed that calcium (1960 ppm) and magnesium (195.3 ppm) were found at moderate levels.

The Burdur Dimriti grape variety utilised in the present study is a table grape variety distinguished by a red-purple colouration, a medium berry size (3.8 g), a round shape, and the presence of seeds. The buds open in the first and second weeks of April, and flowering occurs in the second week of June. The Burdur Dimriti grape variety, which reaches maturity in late July, continues to ripen through late August and September. The Siyah Gemre grape variety is a table grape characterised by its dark purple colouration, medium size (7.8 g), round shape and seed-bearing nature. The buds open in the second week of April, and flowering occurs in the second week of June. The Black Gemre grape variety, which reaches maturity in the second week of August, continues to ripen until the end of September. The Tilki Kuyruğu variety is a table grape characterised by its yellow-green colour, medium size (4.7 g), cylindrical shape, and the presence of seeds. The buds open in the third week of April, and flowering occurs in the second week of June. The Tilki Kuyruğu grape variety, which reaches maturity in the third week of August, is ready for harvest in early October. The Razaki grape variety is a table grape characterised by its light yellow-green colour, medium size (5.5 g), elongated elliptical shape,

1 and seeds. The buds open in the third week of April, and flowering occurs in the second week
2 of June. The Razaki grape variety, which reaches maturity during the last week of August,
3 continues to ripen until the end of September or the beginning of October.

4 Healthy, green grapevine leaves were collected from five individual plants of each variety
5 during the whole ripening stage of the grape. It is imperative to emphasise that meticulous
6 attention was devoted to consistently ensuring that the leaves were positioned and orientated.
7 Furthermore, the leaves located between the sixth and twelfth nodes from the base of the stem
8 were collected in September 2018.

9 After collection, the leaves were placed in ice boxes to prevent water loss and kept in ice boxes
10 until they reached the laboratory. The leaves transferred to the laboratory were stored in a deep
11 freezer at -18 °C until the analysis period for phenolic compound analysis. Fresh leaves were
12 utilised for the extraction of phenolic compounds. To achieve this objective, 1 g of leaf samples
13 was collected and homogenised with 70% methanol containing 0.1% HCl for one minute. The
14 samples were then extracted in an ultrasonic water bath for 30 minutes on each occasion. After
15 filtration, the extracts were employed in the analysis of phenolic compounds.

16 The total flavanol content was determined by the DMAC (dimethylamino cinnamaldehyde)
17 method, as described by Arnaus et al. (2001). Spectrophotometric readings were obtained at a
18 wavelength of 640 nm. For the purpose of this experiment, a DMAC solution was prepared and
19 subsequently added to the leaf extracts. Subsequently, the mixture was subjected to rigorous
20 mixing, after which readings were taken following a period of 10 minutes. The total flavanol
21 content was determined as catechin equivalents in milligrams per gram (mgCE g⁻¹) of fresh
22 weight.

23 The total phenolic compound content was determined using the Folin-Ciocalteu colorimetric
24 method as described by Singleton and Rossi (1965). After adding distilled water and Folin-
25 Ciocalteu to the leaf samples extracted in methanol, the mixture was thoroughly stirred, and
26 saturated Na₂CO₃ was added after 30 seconds. Subsequently, the samples were subjected to a
27 secondary mixing process. Thereafter, they were permitted to stand in a state of repose at
28 ambient temperature for two hours. Subsequently, the samples were analysed at a wavelength
29 of 765 nm using a spectrophotometer. The results were calculated as catechin equivalents (CE)
30 in milligrams per gram (mg g⁻¹) of fresh weight. The phenolic compound analysis was

conducted using HPLC DAD (Agilent Tech. Inc., CA, USA), per the methodology established by Göktürk Baydar et al. (2011). Acetic acid and methanol were utilised as the mobile phase in analyses employing a gradient program. In the analysis of leaf samples, a comprehensive array of phenolic acids was analysed, including ferulic acid, gallic acid, caffeic acid, chlorogenic acid, catechin, quercetin, epicatechin, rutin, p-coumaric acid, o-coumaric acid, protocatechuic, hesperidin, vanillin, kaempferol, luteolin, and tannic acid. Quantitative analyses of the detected phenolic compounds were performed in triplicate.

The data obtained in the study were then subjected to variance analysis by the randomised block design. The statistical test known as Duncan's was utilized to ascertain the disparities in mean values. Pearson correlation analysis, principal component analysis (PCA) and heatmap analysis were performed using the RStudio V4.3.1 programme (RStudio Team, 2023; R Core Team, 2023, Vienna, Austria). The 'devtools', 'RColorBrewer' and 'pheatmap' packages were used for the heatmap analysis; the 'metan' package was used for the correlation analysis; and the 'FactoMineR', 'factoextra' and 'pca3d' packages were used for the principal component analysis.

Results and Discussion

Significant differences were identified between varieties in all characteristics examined in the study. The results of the analyses demonstrated that the total phenolic compound content ranged from 3.25 to 7.38 mg CE g⁻¹ (Figure 2). An analysis of the data concerning the total phenolic compound content of the leaves of the two coloured and two white grape varieties employed in the study demonstrated that the highest total phenolic compound content was obtained from the white grape varieties Tilki Kuyruğu and Razakı. The present study found that the concentration of total phenolic compounds in the sample was consistent with the data previously reported on whole leaves (Lima et al., 2016; Kedrine-Okutan et al., 2019; Acero et al., 2025). Lima et al. (2016) reported that white grape varieties exhibited higher total phenolic content in their leaves. This finding emerged from a comprehensive study that examined the antioxidant levels and phytochemical composition of leaves from 10 distinct grape varieties, of which six were white and four were red. White and red grapevine varieties showed values between 11.2 and 15 mg GAE 100 m g⁻¹ of total phenols. The total phenol content of white varieties is marginally higher than that of red varieties (6.03 mg GAE g⁻¹ and 7.38 mg GAE g⁻¹, respectively). This outcome has been corroborated in other studies that have compared white and red grapevine leaf varieties

in terms of their phenolic content (Fernandes et al., 2013; Koesis et al., 2015).

In contrast, Hallaç Türk (2009) ascertained the total phenolic content in leaf samples extracted from Barış, Italia, Tekirdağ Seedless, Trakya Ilkeren and Yalova İncisi grape varieties at varying periods, determining it to be within the range of 5.88-10.57 mg g⁻¹ dry matter in the form of catechins. Dani et al. (2010) observed percentages of 20.2 and 19 mg/100 g of GAE mg⁻¹ in this plant's leaves from Brazil's organic crops. The results obtained in this study indicate that the total phenolic content is not equivalent to that reported in other studies. As demonstrated in the relevant literature, the sampling time of leaves, in addition to the extraction method, variety, weather, ultraviolet (UV) radiation and soil, have been shown to alter the concentration of active ingredients in plants (Kocsis et al., 2015; Bodo et al., 2017; Selka et al., 2019).

The total flavanol content in the leaves of the varieties utilised in the study ranged from 67.66 to 120.24 mg C g⁻¹ (Figure 3). The total flavanol content indicates the total phenolic content, which is slightly higher in white and red varieties. The highest total flavanol content was determined in the leaves of the Razaki grape variety. In contrast, the lowest total flavanol content was found in the leaves of the Burdur Dimriti grape variety. Similarly, Lima et al. (2016) found total flavonols ranged from 76 to 108 mg CE g⁻¹ in different grape varieties. In a separate study, the total flavonoid content of grape leaves from five different grape varieties ranged between 5.08 and 7.22 mg g⁻¹ (Güler and Candemir, 2014). Conversely, Acero et al. (2025) observed percentages of 7.05 mg CE 100 g⁻¹ of total flavonoids. About the content of flavonols, the results of the present study are consistent with those obtained in other grapevine leaf varieties (Lima et al., 2016).

The study revealed the following phenolic compound analyses: ferulic acid (0.47–1.60 µg.g⁻¹), gallic acid (0.77–6.1 µg.g⁻¹), caffeic acid (8.35–44.93 µg.g⁻¹), chlorogenic acid (30.54–80.47 µg.g⁻¹), catechin (99.8–549.2 µg.g⁻¹), quercetin (24.61–30.57 µg.g⁻¹) and epicatechin (74 µg.g⁻¹). The concentrations of rutin, p-coumaric acid, o-coumaric acid, and proanthocyanidin ranged from 27–121.2 µg.g⁻¹, 103.9–386.7 µg.g⁻¹, 0.73–1.35 µg.g⁻¹ and 3.21–6 µg.g⁻¹, respectively. The concentrations of the analytes were as follows: hesperidin (21 µg.g⁻¹), vanillin (0.98–2.25 µg.g⁻¹), kaempferol (11.26–14.88 µg.g⁻¹), luteolin (3.21–5.76 µg.g⁻¹), and tannic acid (0.91–1.18 µg.g⁻¹). The highest concentrations of ferulic acid, caffeic acid, tannic

acid, p-coumaric acid, o-coumaric acid, hesperidin, and luteolin were found in Tilki Kuyruğu. In contrast,lic acid, vanillin, kaempferol, chlorogenic acid, and catechin were found in Siyah Gemre (Figures 4 and 5). Quercetin, rutin, and proanthocyanidin were detected in Razaki, while epicatechin was identified in the Burdur Dimriti grape variety (Figures 4 and 5). As demonstrated in previous studies (Lima et al., 2016; Pantelic et al., 2017; Pintac et al., 2019; Maia et al., 2019), the present study's findings are from preceding research. The results indicate that the varieties exhibit varying richness levels in different phenolic compounds.

In their 2019 study, Maia et al. (2019) identified the presence of bioactive compounds, including caffeic acid, quercetin, resveratrol, kaempferol, and catechin, in Pinot Noir grape leaves. The authors further reported that such leaves could be used as a source of bioactive compounds for both human and animal nutrition (Maia et al., 2019). Pintac et al. (2019) identified 28 phenolic compounds in four red and four white grape varieties collected post-harvest. The quantity of these phenolic compounds was found to vary depending on the grapevine variety. Furthermore, it was reported that the phenolic compounds present in the highest amounts in the leaves were flavonoids, ellagic acid, and chlorogenic acid. In a separate study undertaken by Pantelic et al. (2017), it was ascertained that the leaves of 22 distinct grape varieties cultivated in Serbian vineyards exhibited a high concentration of phenolic acids, flavonols, and flavan-3-ols. Fernandes et al. (2013) reported that leaves from 20 different grape varieties, including 10 white and 10 red varieties, grown in Portugal contained trans-kaftaric, trans-kumarol tartaric acid, myricetin-3-O-glucoside, quercetin-3-O-galactoside, and kaempferol-3-O-glucoside, with the last two compounds being present in the highest amounts.

Lima et al. (2016) reported that white grape varieties exhibited higher leaf antioxidant potential than red varieties, with quercetin levels ranging from 39 to 54 mg g⁻¹. Kocsis et al. (2015) and Kolb et al. (2001) researched the effects of sunlight on leaf phenolic composition. As demonstrated in the research by Kocsis et al. (2015) and Kolb et al. (2001), there was an observed alteration in the phenolic compounds in both shaded and unshaded grapevine leaves. The disparities observed in the studies are hypothesised to be attributable to diversity, geographical location, and climatic conditions. The synthesis and quantity of phenolic compounds in plant tissues vary due to many factors. Many factors have been reported to influence the composition and amount of phenolic compounds. The factors to be considered include grape variety and type, grape development stage and age, grape tissue and parts, ecological factors, cultural practices, and stress conditions (Kocsis et al., 2015; Bodo et al.,

2017; Barreales et al., 2019; Selka et al., 2019).

The heat map, created using the phenolic compound data obtained in the study, revealed significant phenolic differences between the four grape varieties (Figure 6). Tilki Kuyruğu exhibited a distinctive profile, characterized by elevated concentrations of numerous phenolic compounds, including ferulic acid, caffeic acid, p-coumaric acid, hesperidin, luteolin, and tannic acid. Conversely, Razaki has garnered attention due to its high concentrations of flavonoid compounds, including rutin, quercetin, kaempferol, and proanthocyanidin. Furthermore, both white grape varieties exhibited elevated levels of total phenolic and flavanol content, a finding corroborated by visual analysis (Ali et al., 2010). In contrast, Siyah Gemre exhibited moderate levels of certain phenolic acids (gallic acid, catechin, chlorogenic acid), while Burdur Dimriti generally showed low content, except for epicatechin, which was present at high levels. The results of the vertical clustering indicate that the phenolic profiles of Tilki Kuyruğu and Razaki are similar to each other, while Burdur Dimriti is distinctly different. In the horizontal dendrogram, compounds such as chlorogenic acid, gallic acid, and vanillin were found to be concentrated in similar varieties, indicating that these compounds act together. This approach is consistent with studies suggesting that phenolic compounds should be evaluated through clustering (Revilla & Ryan, 2000). The application of a heat map facilitates comparative evaluation of the varieties in terms of their industrial use potential, with the results highlighting that the unprocessed leaves of Tilki Kuyruğu and Razaki could be an important resource for the development of functional products.

In this study, PCA (Principal Component Analysis) was employed to elucidate the variations of phenolic compounds that were the subject of evaluation (Figure 7). The application of PCA also enabled the visualization of the relationships between the various varieties. The initial two components (Dim1 and Dim2) account for approximately 80% of the total variance, suggesting that the phenolic variables employed in the analysis are adequate for differentiating between varieties. The direction and distance relationships between varieties and phenolic compounds are clearly visible in the biplot graph. Tilki Kuyruğu is located in the upper right quadrant and shows strong positive relationships with ferulic acid, caffeic acid, p-coumaric acid, hesperidin, tannic acid, and total phenolic content. This finding substantiates the hypothesis that this variety possesses a high degree of phenolic content and that the related compounds within this variety undergo aggregation. Razaki is located in the lower right region and is distinguished by its high flavonoid content, which is significantly correlated with flavonoid-characterized compounds, including quercetin, rutin, kaempferol, proanthocyanidin, and total flavanol. PCA has

heretofore been utilized to characterize phenolic compounds in grape varieties, with demonstrable efficacy documented (Li et al., 2011; Chamkha et al., 2003). Conversely, the Siyah Gemre and Burdur Dimriti varieties have been observed to be located in areas exhibiting a negative charge and have been found to demonstrate weak or inverse relationships with compounds such as chlorogenic acid, catechin, and gallic acid. This finding suggests that these two varieties possess reduced overall phenolic levels and divergent profiles in terms of compounds. When PCA results are evaluated in conjunction with heat maps and chemical analyses, Tilki Kuyruğu and Razaki are found to have a higher potential for functional product development.

Pearson's correlation analysis of the phenolic compounds identified in the leaf samples revealed that some compounds exhibited strong and significant correlations with each other (Figure 8). Notably, a very high positive correlation was observed between ferulic acid and tannic acid ($r = 0.98$; $p < 0.001$). Similarly, high positive correlations were observed between ferulic acid, caffeic acid, p-coumaric acid, luteolin, hesperidin and total phenolic content. These findings support the presence of these compounds at high concentrations in the Tilki Kuyruğu variety. This is consistent with literature investigating the structural and functional relationships of phenolic compounds (Anastasiadi et al., 2012; Kennedy et al., 2006). Conversely, negative correlations were found between total phenolic content and certain compounds, such as epicatechin, catechin, gallic acid, and chlorogenic acid. These compounds were found to be concentrated in varieties with lower total phenolic content. Negative correlations indicate that certain compounds dominate different varieties and can influence total content in different directions. Positive correlations between flavonoid compounds and total flavanols, for example, are consistent with the literature on flavonoid-rich varieties such as Razaki (de la Rosa et al., 2019). Furthermore, positive correlations between quercetin, rutin, kaempferol, and total flavanols corroborate the flavonoid richness of the Razaki variety. Overall, correlation analysis has provided important insights into phenolic compound patterns among varieties and into the identification of compounds that exhibit common variation.

Conclusion

In conclusion, an evaluation of the study's findings indicated that the levels of total phenolic compounds, total flavanols, and phenolic compounds varied according to the varieties. The

finding that grape leaves are particularly rich in phenolic compounds indicates their potential as a natural antioxidant source in the pharmaceutical and food industries as nutraceuticals. Furthermore, the presence of phenolic compounds in the leaves has been demonstrated to influence the resilience of grapevines to abiotic and biotic stress conditions. In this regard, the study is significant for identifying the differences between varieties and evaluating autochthonous grapevine varieties that have lost their original value due to urbanisation, which has led to their disappearance. Moreover, the study has emphasised the potential for utilizing leaves devoid of any post-harvest value. The findings of the study indicated that the leaves of the grape varieties Tilki Kuyruğu, Razakı, Siyah Gemre, and Burdur Dimriti possess considerable potential for utilisation as functional components within the food industry, pharmaceuticals, and cosmetics.

Acknowledgements

This study is derived from Ayse Aycan URCAN's Master's thesis.

Funding Declaration

This article was not supported by any funding.

Data availability

Data will be made available on request. Contacts: filizhallac@isparta.edu.tr (Filiz HALLAC TURK)

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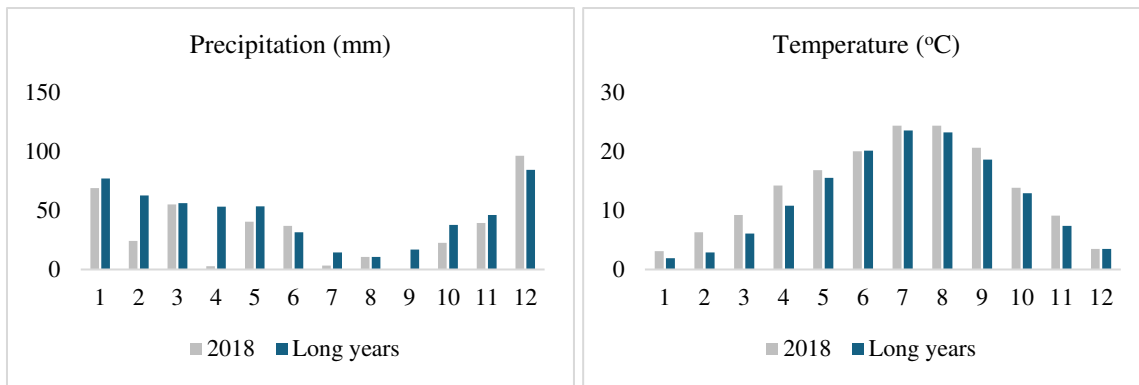


Figure 1. Monthly rainfall and temperature data for the test area.

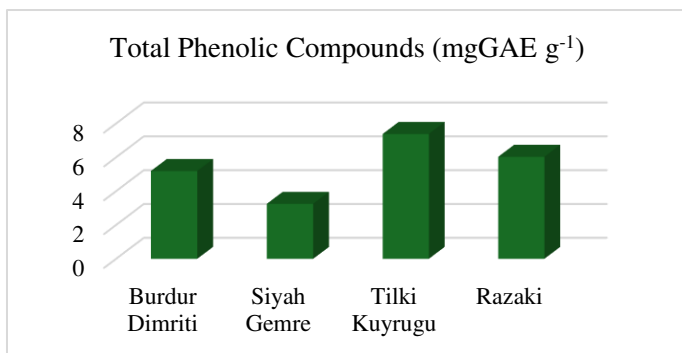


Figure 2. Total phenolic compound content obtained from grape leaves.

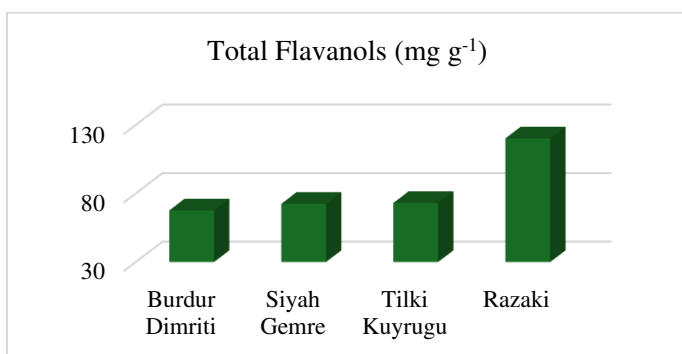


Figure 3. Total flavanol content obtained from grape leaves

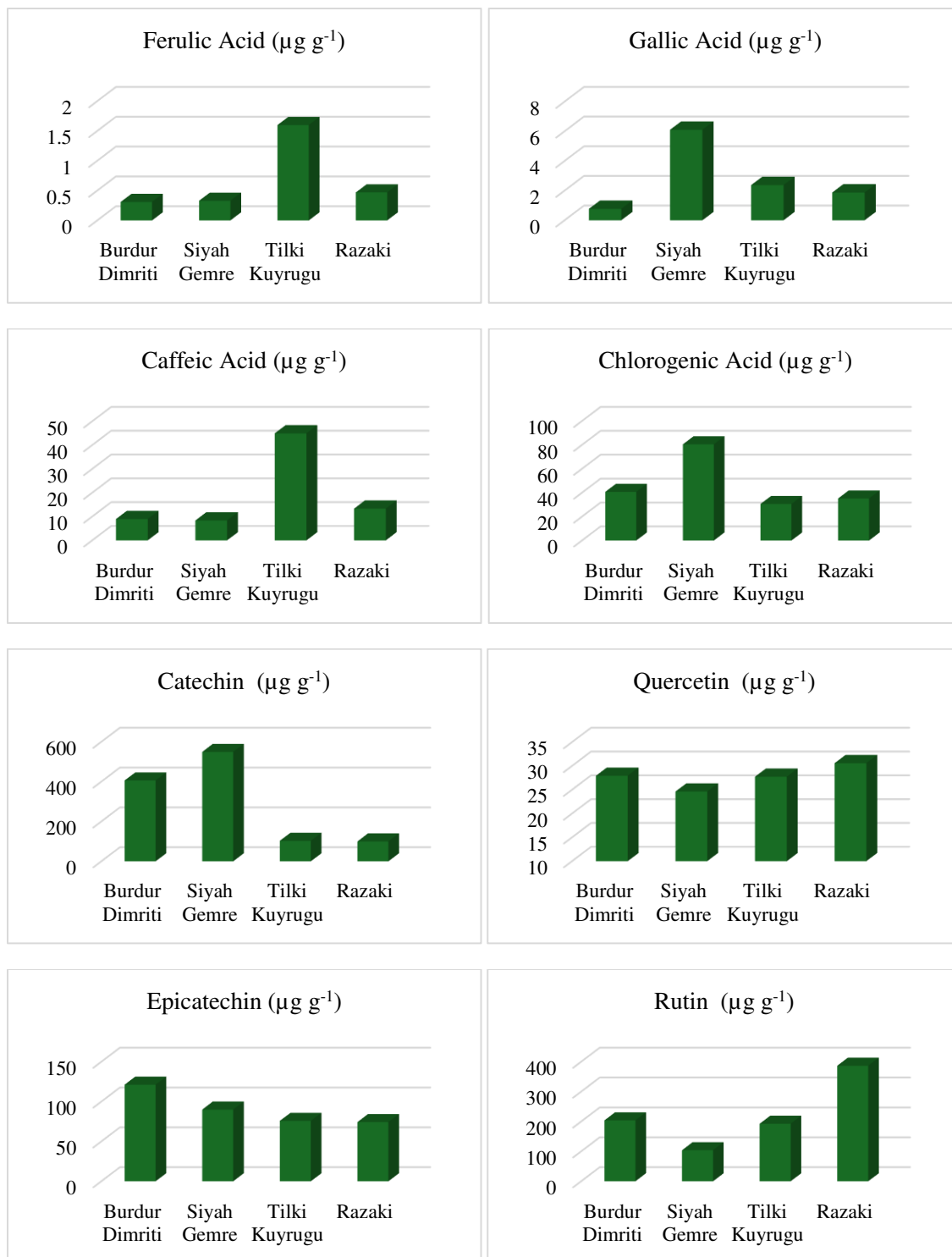


Figure 4. Ferulic acid, gallic acid, caffeic acid, chlorogenic acid, catechin, quercetin, epicatechin and rutin contents obtained from grape leaves.

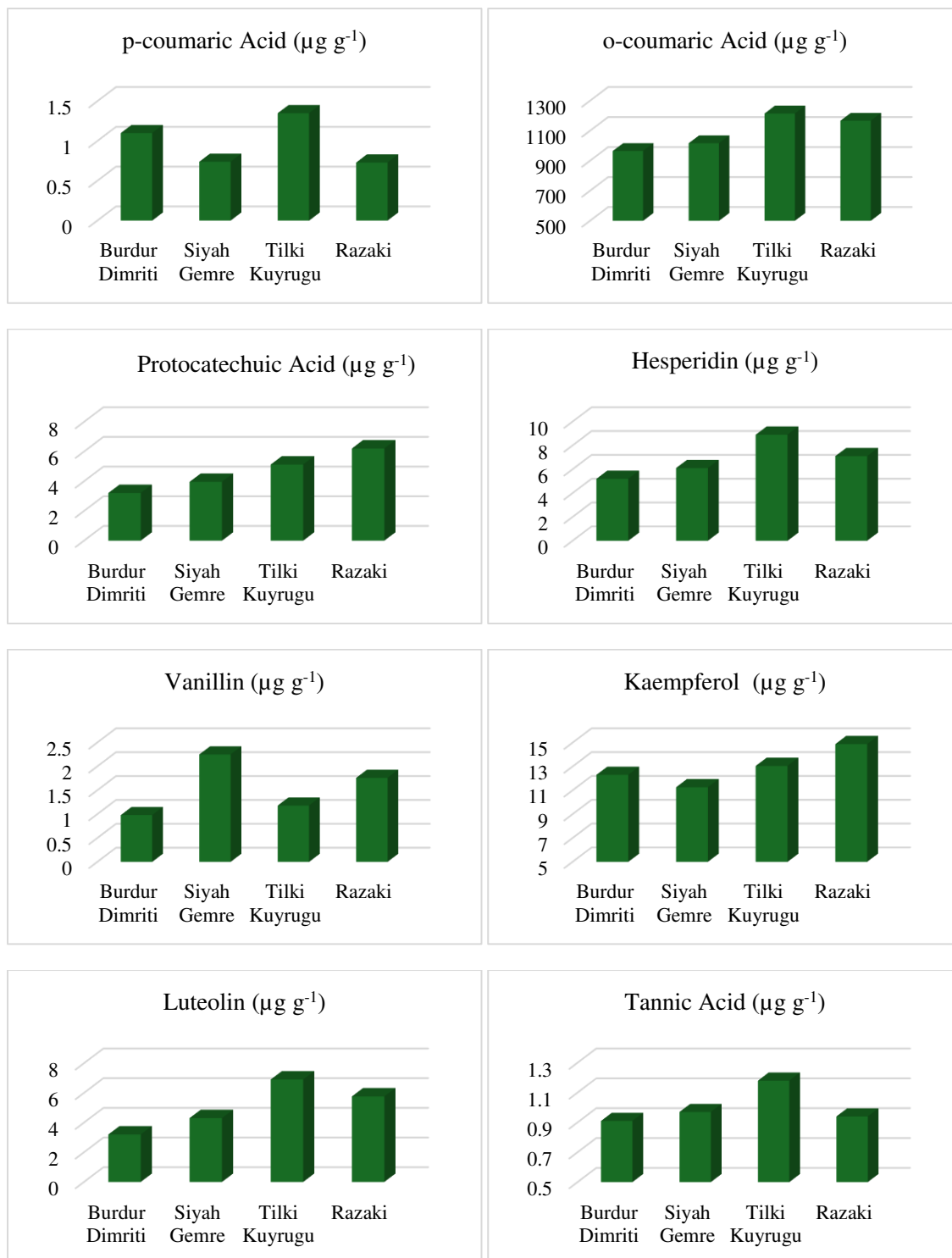


Figure 5. P-coumaric acid, o-coumaric acid, protocatechuic acid, hesperidin, vanillin, kaempferol, luteolin and tannic acid contents obtained from grape leaves.

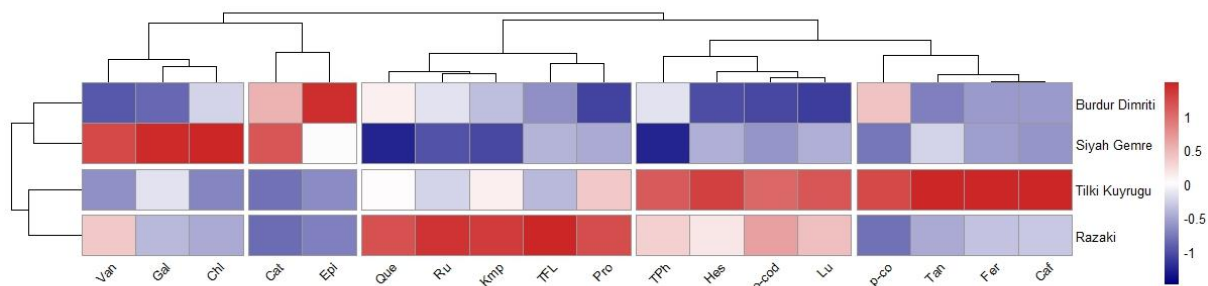


Figure 6. A heat map will be utilized to illustrate the concentrations of phenolic compounds in diverse varieties. Van: vanillin, Gal: gallic acid, Chl: chlorogenicacid, Cat: catechin, Epi: epicatechin, Que: quercetin, Ru: rutin, Kmp: kaempferol, TFL: Total flavanol, Pro: protocatechuicacid, TPh: Total phenolic compounds, Hes: hesperidin, o-cod: o-coumaric acid, Lu: luteolin, p-co: p-coumaric acid, Tan: tannic acid, Fer: ferulic acid, Caf: caffeic acid.

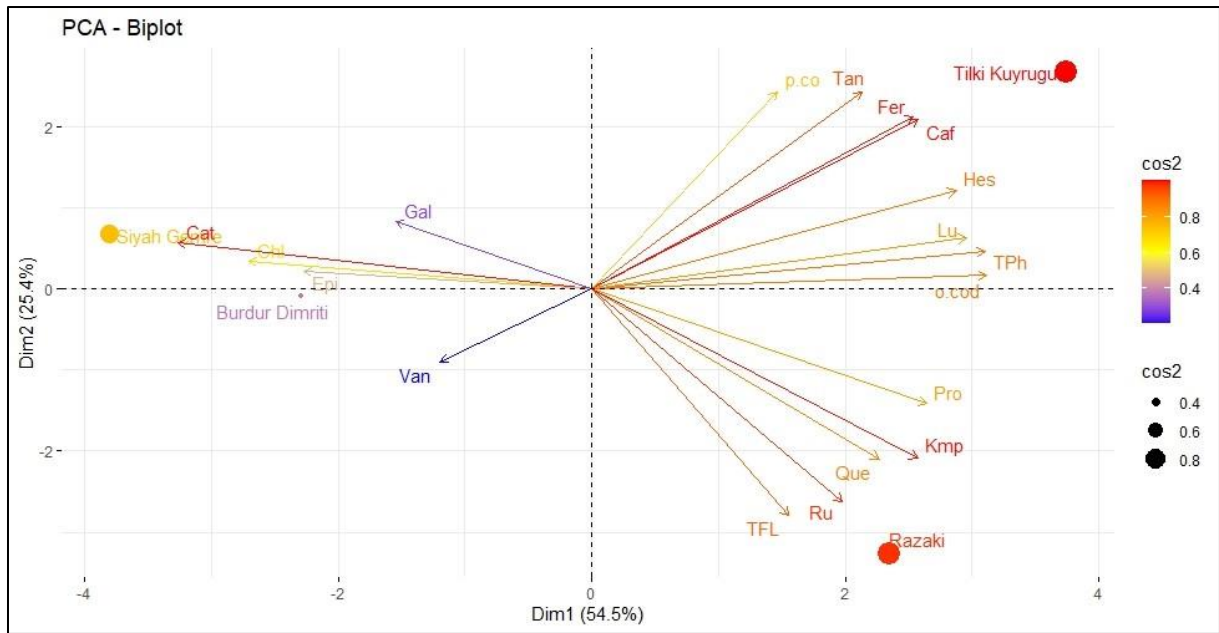


Figure 7. PCA (Principal Component Analysis) biplot graph of varieties according to phenolic compounds. Van: vanillin, Gal: gallic acid, Chl: chlorogenic acid, Cat: catechin, Epi: epicatechin, Que: quercetin, Ru: rutin, Kmp: kaempferol, TFL: Total flavanol, Pro: protocatechuic acid, TPh: Total phenolic compounds, Hes: hesperidin, o-cou: o-coumaric acid, Lu: luteolin, p-co: p-coumaric acid, Tan: tannic acid, Fer: ferulic acid, Caf: caffeic acid.

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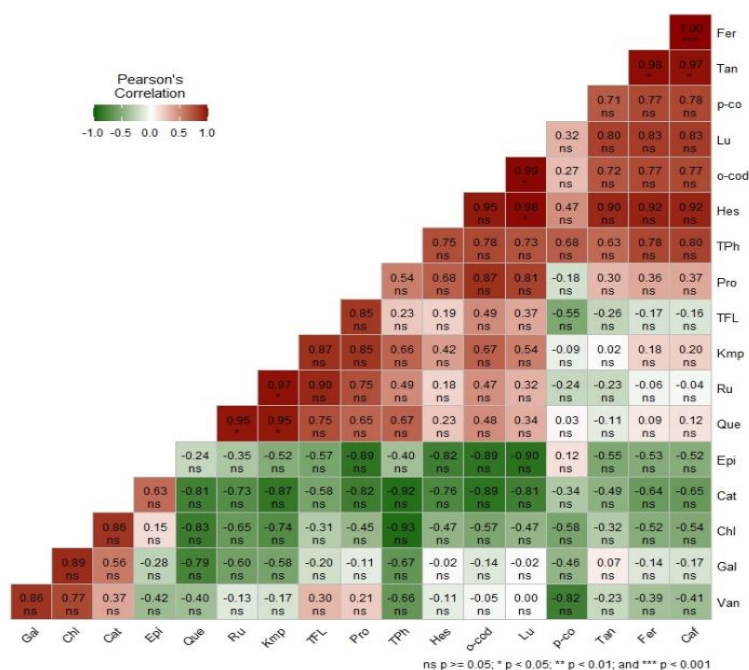


Figure 8. Pearson correlation matrix showing the relationships between phenolic compounds detected in grape leaves. The color scale represents the correlation coefficient, with red tones indicating a positive correlation and green tones indicating a negative correlation. ***, **, * and ns indicate $p < 0.001$, $p < 0.01$, $p < 0.05$, and non-significant levels, respectively.