

Comparison of pomological and biochemical characteristics of “Sarı Lop” fig cultivar grown in different ecological regions

Original Article

Abstract:

“Sarı Lop” fig (*Ficus carica* L.), whose fruits are of very high quality, is the world-famous dried fig cultivar most grown in Turkey. It is intensively cultivated in the Aegean region of Turkey, especially in the provinces of Aydın and İzmir. This study compared the pomological and biochemical characteristics of “Sarı Lop” fig fruits grown in four provinces with different regional ecologies in Türkiye (Aydın, Bursa, Isparta, and İzmir). Fruit samples were harvested at commercial maturity, ensuring homogeneity in ripeness and health. Morphological traits, including fruit weight, length, and width, as well as peel color parameters (L^* , a^* , b^*), were measured. Biochemical analyses were performed to determine pH, titratable acidity (TA), total soluble solids (TSS), total phenolic content (TPC), total flavonoid content (TFC), and antioxidant activity (AA). Significant variations were observed among provinces, with Aydın and İzmir figs exhibiting larger size, higher TSS, and elevated TPC, TFC, and AA levels, whereas Isparta and Bursa fruits showed comparatively smaller size and lower biochemical contents. These results indicate that the ecology of the region where figs are grown may have an effect on fruit quality and biochemical contents. The study underscores the importance of considering regional cultivation ecology in fig production and breeding programs aimed at improving fruit quality, nutritional value, and functional properties.

Key words:

Antioxidant, *Ficus carica* L., phenolic content, pomological traits, region

Apstrakt:

Poređenje pomoloških i biohemijskih karakteristika sorte smokve „Sarı Lop” uzgajane u različitim ekološkim regionima

„Sarı Lop” smokva (*Ficus carica* L.), čiji su plodovi veoma visokog kvaliteta, svetski je poznata sorta suve smokve koja se najviše gaji u Turskoj. Intenzivno se uzgaja u egejskom regionu Turske, posebno u provincijama Ajdin i Izmir. Ova studija je uporedila pomološke i biohemijske karakteristike plodova sorte „Sarı Lop” uzgajanih u četiri provincije sa različitim regionalnim ekološkim uslovima u Turskoj (Ajdin, Bursa, Isparta i Izmir). Uzorci plodova su ubrani u komercijalnoj zrelosti, uz obezbeđivanje ujednačenosti u pogledu zrelosti i zdravstvenog stanja. Merene su morfološke osobine, uključujući masu, dužinu i širinu ploda, kao i parametri boje kore (L^* , a^* , b^*). Biohemijske analize su sprovedene radi određivanja pH vrednosti, titrabilne kiselosti (TA), ukupnih rastvorljivih čvrstih materija (TSS), ukupnog sadržaja fenola (TPC), ukupnog sadržaja flavonoida (TFC) i antioksidativne aktivnosti (AA). Zabeležene su značajne razlike između provincija, pri čemu su smokve iz Ajdina i Izmira imale veće plodove, viši TSS i povećane vrednosti TPC, TFC i antioksidativne aktivnosti, dok su plodovi iz Isparte i Burse bili manji i sa nižim biohemijskim vrednostima. Ovi rezultati ukazuju na to da ekologija regiona u kojem se smokve gaje može uticati na kvalitet plodova i njihov biohemijski sastav. Studija naglašava značaj uzimanja u obzir regionalne ekologije u proizvodnji smokava i programima oplemenjivanja, sa ciljem poboljšanja kvaliteta plodova, nutritivne vrednosti i funkcionalnih svojstava.

Ključne reči:

Antioksidans, *Ficus carica* L., sadržaj fenola, pomološke osobine, region

Introduction

The fig (*Ficus carica* L.), an important component of the Mediterranean diet and a symbol of health and longevity (Trichopoulou et al., 2006), has recently attracted considerable attention as an exotic fruit in

Western and Northern European countries where its cultivation is not feasible (Polat & Çalışkan, 2008). The increasing global interest in figs can be attributed to several factors, including their historical and cultural recognition as a “sacred fruit” their higher

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nutritional value compared to many other fruit species (Aksoy et al., 2007), their richness in crude and reducing fibers, minerals, and polyphenols, as well as their lack of fat and cholesterol (Vinson, 1999). Moreover, figs have high commercial value due to their versatile uses.

The fig is a deciduous fruit species with a long history of domestication, dating back to ancient times in Anatolia. It is considered one of the earliest domesticated fruit species. Historical records indicate that the fig was first cultivated in the Arabian Peninsula and the Middle East (Aksoy, 1991). Türkiye is regarded as the center of origin of the fig, from which it spread to Syria and Palestine, and subsequently to China and India via the Middle East. In more recent times, America, southern and southwestern Africa, and eastern Australia have become new centers of fig cultivation, while California has experienced the second evolutionary phase in the cultural history of fig cultivation following Anatolia (Stover et al., 2007).

Türkiye holds a leading position globally in both dried and fresh fig production and trade (Uzundumlu et al., 2018). The “Sarı Lop” cultivar predominates in dried fig production, while “Mor Güz” and “Bursa Siyahı” are the primary cultivars for fresh consumption. The cultivation of the “Sarı Lop” cultivar is concentrated mainly in the Aydın and İzmir provinces. According to the Turkish Statistical Institute (TÜİK, 2024), Türkiye’s total fig production in 2024 was 375,000 tons, approximately 66% of which was produced in Aydın province.

The fruits, leaves and roots of fig tree have long been used in traditional medicine for the treatment of cardiovascular, respiratory (such as sore throat, cough, and bronchial disorders), and gastrointestinal (including colic, indigestion, loss of appetite, and diarrhea) ailments, owing to their anti-inflammatory and antispasmodic properties (Konak et al., 2015; Veberic & Mikulic-Petkovsek, 2016). These therapeutic effects are mainly attributed to their rich secondary metabolites, particularly polyphenols, essential oils, and alkaloids. The major polyphenols identified in figs include phenolic acids (hydroxycinnamic and hydroxybenzoic derivatives) and flavonoids (flavan-3-ols, anthocyanins, and flavonol glycosides), which are known for their strong antioxidant capacity (Hssaini et al., 2021). Polyphenols act as electron or hydrogen donors, neutralizing reactive free radicals and preventing oxidative cellular damage (Singh et al., 2021). Figs exhibit high antioxidant potential, especially in dark-colored cultivars where antioxidants are mainly concentrated in the edible peel. The predominant phenolic compounds in fresh figs include chlorogenic acid, catechin, epicatechin, rutin, cyanidin-3-O-

rutinoside, luteolin-8-C-glucoside, quercetin-3-O-glucoside, and kaempferol-3-O-glucoside, which serve as effective free radical scavengers and reducing agents beneficial to human health (Singh et al., 2022).

The pomological and biochemical characteristics of fig fruits are significantly influenced by ecological parameters such as climate conditions, altitude, soil structure, humidity, and other environmental factors of the growing region (Medda et al., 2022; Ahmad, 2023; Zhou & Qiao, 2024). These environmental variations can modulate physiological processes and metabolic pathways during fruit development, thereby affecting fruit quality, nutritional composition, and, particularly, polyphenolic content (Elmeknassia et al., 2025a, b). In this context, the present study aims to compare the pomological and biochemical characteristics of fruits of the “Sarı Lop” cultivar grown in four provinces with different regional ecologies in Türkiye (Aydın, Bursa, Isparta, and İzmir).

Materials and methods

Materials

In this study, fruit samples of the “Sarı Lop” fig cultivar (*F. carica* L. cv. “Sarı Lop”) were used as the plant material. The samples were collected from four major fig-producing regions of Türkiye, Aydın, Bursa, Isparta, and İzmir during the September 2025 growing season. According to Arca and Çitiroğlu (2025), both Aydın and İzmir provinces exhibit a hot-summer Mediterranean climate (Köppen–Geiger), are classified as semi-arid to slightly humid according to Thornthwaite, and fall within the humid category under the Akdeniz classification. In contrast, Bursa generally has a mild climate influenced by the Marmara Sea. According to the De Martonne–Gottman method, Isparta is characterized by a climate type ranging between semi-arid and humid (Dursun & Babalık, 2021). In addition, average September climate data for the provinces of Aydın, Bursa, Isparta, and İzmir for the period 1940–2025 are presented (**Tab. 1**) (Anonymus, 2025). In the study, 10 healthy trees were selected from fig orchards identified in each province. From these trees, 10 fruits were collected from different parts of each tree, resulting in a total of 400 fruits. The 100 fruits collected from each province were divided into four replicates, and the analyses were conducted accordingly. All sampling was performed within the same harvest season and from orchards with similar agronomic practices.

Fruits from each region were harvested at the commercial ripening stage, ensuring uniform maturity and selecting only healthy specimens

Table 1. Long-term (1940–2025) average September climatic parameters of Aydın, Bursa, Isparta, and İzmir provinces.

Climate Statistics	AYDIN	BURSA	ISPARTA	İZMİR
Average Temperature (°C)	23.80	20.40	19.00	23.80
Average Maximum Temperature (°C)	32.20	27.30	26.60	29.30
Average Minimum Temperature (°C)	16.90	13.80	11.10	18.80
Average Sunshine Duration (hours)	8.20	7.90	9.30	10.10
Average Number of Rainy Days	1.95	5.07	3.73	1.94
Average Monthly Total Precipitation (mm)	16.90	42.70	18.50	15.50

without mechanical damage or visible disease symptoms. The collected samples were transported to the laboratory under cold chain conditions and stored at +4 °C until pomological and biochemical analyses were performed.

Methods

The fruit weight (g) was determined using a precision digital balance (HZK-210FA). For each location, thirty fruit samples were selected and weighed. The fruit length (cm) and width (mm) were measured as described by Kılıç et al. (2022). Following harvest, the fruits were cleaned, peeled, and filtered prior to analysis. The pH of the fruit juice was measured using a digital pH meter (ADWAN AD12). The titratable acidity (TA) was determined according to the method described by Balıkcı et al. (2021). For this purpose, 10 mL of fruit juice was diluted with distilled water to a final volume of 100 mL, and the solution was titrated with 0.1 N NaOH using a burette (BRAND Titrette) until the pH reached 8.1. The amount of TA was calculated as citric acid. Color parameters were evaluated using a colorimeter (CR-400, Minolta, Japan). The total soluble solid (TSS) content was determined with a handheld refractometer (HI 96801) as reported by Kılıç et al. (2022).

The total phenolic content (TPC) of fig fruit extracts was determined using the Folin–Ciocalteu method described by Singleton and Rossi (1965). Homogenized fruit pulp was extracted for 1 h with an acetone–water–acetic acid solution (70:29.5:0.5, v/v/v). After adding Folin–Ciocalteu reagent and allowing the mixture to react for 8 min, 7% sodium carbonate was added. The reaction mixture was incubated for 2 h at room temperature, and absorbance was measured at 750 nm using a spectrophotometer (Model T60U, PG Instruments, USA). Results were expressed as mg gallic acid equivalents (GAE) per 100 g fresh weight.

The total flavonoid content (TFC) was determined according to the procedure of Dewanto

et al. (2002), as modified by Çelik et al. (2023). The extract was sequentially treated with 5% NaNO₂, 10% AlCl₃·6H₂O, and 1 M NaOH. After incubation, absorbance was recorded at 510 nm using a UV spectrophotometer (Model T60U, PG Instruments, USA). Results were expressed as mg catechic acid equivalents (CE) per 100 g fresh weight.

The antioxidant activity (AA) of fig fruit extracts was evaluated using the DPPH radical scavenging assay (Kumaran & Karunakaran, 2006). A 100 µL aliquot of extract was mixed with 2 mL of 0.1 mM DPPH solution and incubated for 30 min at room temperature. Absorbance was then measured at 517 nm using a UV spectrophotometer (Model T60U, PG Instruments, USA).

The data obtained from the study were analyzed using analysis of variance (ANOVA) in Minitab 17. Tukey's multiple-comparison test was subsequently applied to identify statistically significant differences among the mean values at the $p < 0.05$ significance level. Principal Component Analysis (PCA) was performed using PAST 4.06b.

Results and discussion

The fruit's physical characteristics of the fig cultivar "Sarı Lop" obtained from different regions are presented in **Fig. 1**. Significant differences were observed among provinces in terms of average fruit weight, fruit width, and fruit length. Figs collected from Aydın and İzmir exhibited larger and heavier fruit sizes, whereas those from Bursa and Isparta were relatively smaller.

The fruit chemical characteristics of the fig cultivar "Sarı Lop" obtained from different regions are presented in **Fig. 2**. The analysis revealed variations in pH, TA, and TSS across provinces. While pH values showed only slight differences, TA was higher in fruits from Aydın province. The highest TSS values were recorded in figs from İzmir and Aydın provinces.

The peel color values of the fig cultivar "Sarı Lop" obtained from different regions are presented

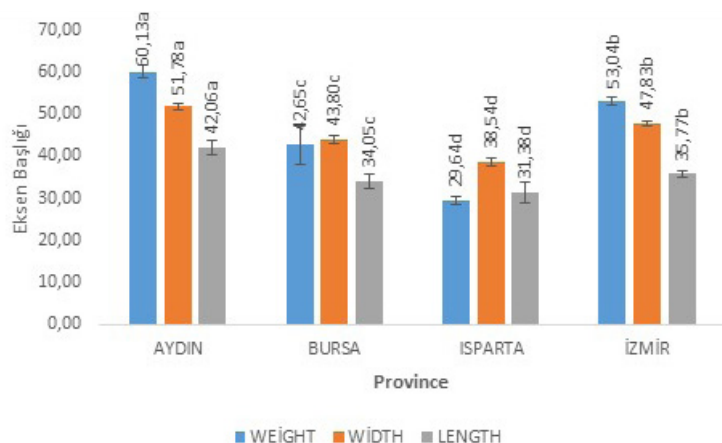


Fig. 1. Fruit weight (g), fruit width (mm) and fruit length (mm) of the "Sarı Lop" fig variety supplied from different provinces

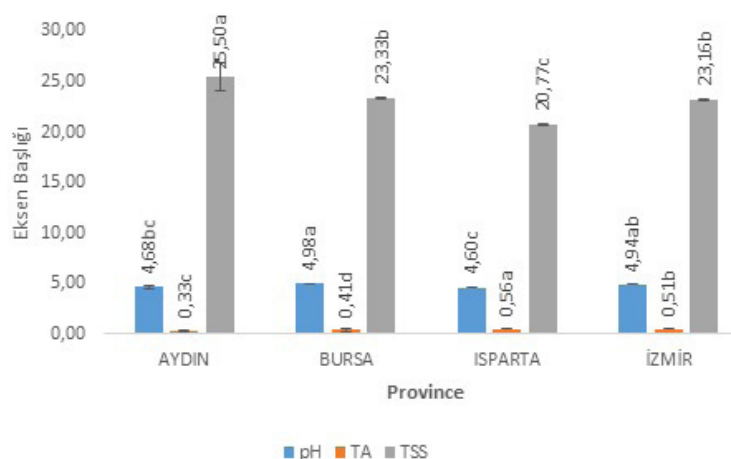


Fig. 2. Chemical characteristics of fig cultivar "Sarı Lop" obtained from different provinces. TA: Titrable Acidity (%); TSS: Total Soluble Solids (%)

in **Fig. 3.** Color parameters (L^* , a^* , b^*) showed considerable variation among locations. The lowest L^* value was observed in fig fruits collected from İzmir, while the highest L^* value was recorded in those obtained from Aydın. Conversely, the lowest a^* value was found in fruits from Aydın, whereas the highest a^* value was detected in fruits collected from İzmir. Examination of the b^* values revealed that the highest values were obtained from Aydın and Bursa, while the lowest value was observed in fruits from Isparta.

The biochemical contents of fig cultivar "Sarı Lop" obtained from different regions are presented in **Fig. 4.** Significant differences were detected in TPC, TFC, and AA. The highest TPC and AA values were observed in fruits from Aydın and İzmir, which experience more hot, sunny conditions than the other provinces. Conversely, lower levels of phenolic contents and antioxidant activity were recorded in figs from Bursa and Isparta. The TFC

values showed a pattern similar to that of TPC and AA, indicating a strong correlation among these biochemical parameters. Considering the long-term average September climatic data presented in **Tab. 1**, it is evident that the regional variations in TPC, TFC, and AA are closely associated with environmental factors. Higher temperatures, lower precipitation, and adequate sunshine duration in Aydın and İzmir likely promoted the synthesis of phenolic compounds, resulting in higher biochemical values in these regions. In contrast, relatively lower temperatures and higher moisture conditions in Bursa and Isparta may have limited phenolic accumulation. These findings indicate that temperature and water availability play a decisive role in secondary metabolite production and directly influence the biochemical composition of fig fruits (Prinsloo & Nogemane, 2018).

PCA revealed clear relationships between climatic variables, particularly temperature parameters, and the pomological and biochemical traits of fig fruits (**Fig. 5**). The first principal component (PC1) was mainly associated with TPC, with a strong positive loading and clear separation from the other variables, indicating that TPC is a dominant contributor to overall variability.

Temperature-related variables, including average, maximum, and minimum temperatures, clustered in the same direction as several quality traits, such as TFC, TSS, fruit length, and fruit width, suggesting a positive association between thermal conditions and these traits. This pattern indicates that higher temperatures promote metabolic activity, enhance the accumulation of soluble solids and flavonoid compounds, and stimulate fruit growth.

In contrast, precipitation (average monthly total precipitation) was positioned in the opposite direction of temperature-related variables along PC2, indicating a negative association between moisture availability and temperature-driven metabolic processes. Similarly, AA and fruit weight were located closer to precipitation and minimum temperature, suggesting that these parameters may be influenced by water availability and cooler conditions rather than by high temperature alone.

Moreover, pH, TA, and color parameter (a^*) were

grouped on the negative side of PC1, indicating an inverse relationship with phenolic accumulation and temperature-related variables. The proximity of these variables to the origin suggests that their contribution to total variance is moderate compared to TPC and temperature-driven traits.

Overall, the PCA results demonstrate that temperature is a key driving factor influencing biochemical composition, particularly phenolic and flavonoid accumulation, whereas precipitation and moisture conditions modulate antioxidant activity and certain fruit quality traits.

Significant differences were observed in fruit weight, width, and length values of “Sarı Lop” figs obtained from four provinces. Samples from Aydın and İzmir exhibited larger, heavier fruits. This was thought to result from the more arid and warmer climatic conditions of these regions, which likely enhanced carbon assimilation and water balance during fruit development. Similarly, An et al. (2025) reported that figs cultivated in warmer regions accumulated higher levels of dry matter. Khadivi et al. (2025) and Herre et al. (2008) also emphasized that fruit size was closely associated with ecological conditions. Mlinarić et al. (2016) stated that elevated temperature and solar radiation promoted cell expansion in fruit tissues, positively influencing fruit size. Gozlekci (2011) likewise noted pronounced variations in pomological traits among figs grown in different ecological regions. The findings of the present study were consistent with these reports, indicating that environmental factors played a decisive role in shaping the morphological characteristics of fig fruits.

Significant differences were also observed in the chemical properties of figs among provinces. TA values were higher in samples from Aydın, whereas TSS were highest in figs from Aydın and İzmir. These results suggested that elevated temperatures and longer exposure to sunlight promoted the accumulation of organic acids and sugars. Kucuker et al. (2023) reported that organic acid content increased under warmer climatic conditions, and TSS rose with fruit ripening. Veberic et al. (2008) also indicated that figs grown in regions with longer sunlight exposure contained higher sugar and phenolic contents. Sedaghat et al. (2018)

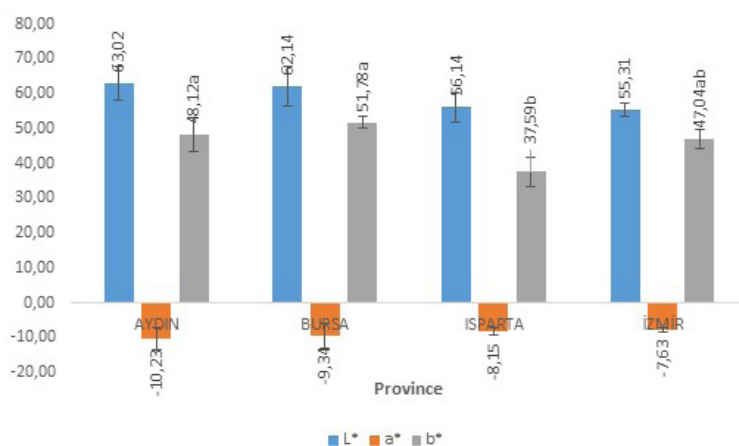


Fig. 3. L*, a*, and b* values of fruit peel of fig cultivar “Sarı Lop” obtained from different provinces.

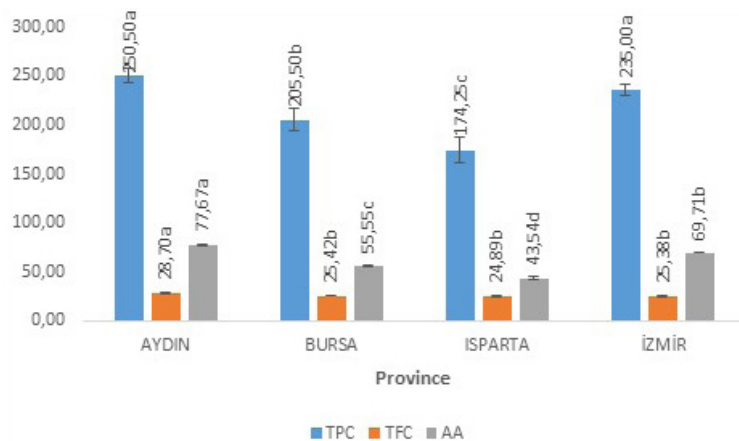


Fig. 4. Biochemical contents of fig cultivar “Sarı Lop” obtained from different provinces. TPC: Total Phenolic Content (mg GAE/100g); TFC: Total Flavonoid Content (mg CE/100g); AA: Antioxidant Activity (% inhibition)

emphasized that ecological differences determined the acid–sugar balance in figs. Similarly, Kishor et al. (2023) and Medda et al. (2022) demonstrated that warm climates enhanced sugar accumulation and improved fruit taste profiles. These findings supported the notion that the observed chemical variations were influenced by environmental factors.

As is known, fruit peel color is influenced by environmental temperature, sunlight exposure, and ripening stage; particularly, higher temperatures also stimulate anthocyanin and carotenoid synthesis (Espley & Jaakola, 2023). In the study, marked differences were found in peel color parameters. While figs from Aydın province showed higher b* (yellowness) values, Isparta province provided the lowest value. These results may be related to the higher levels of phenolic composition in figs grown in Aydın province (Fig. 4.), as well as to ecological conditions. Indeed, Polat and Çalışkan (2008)

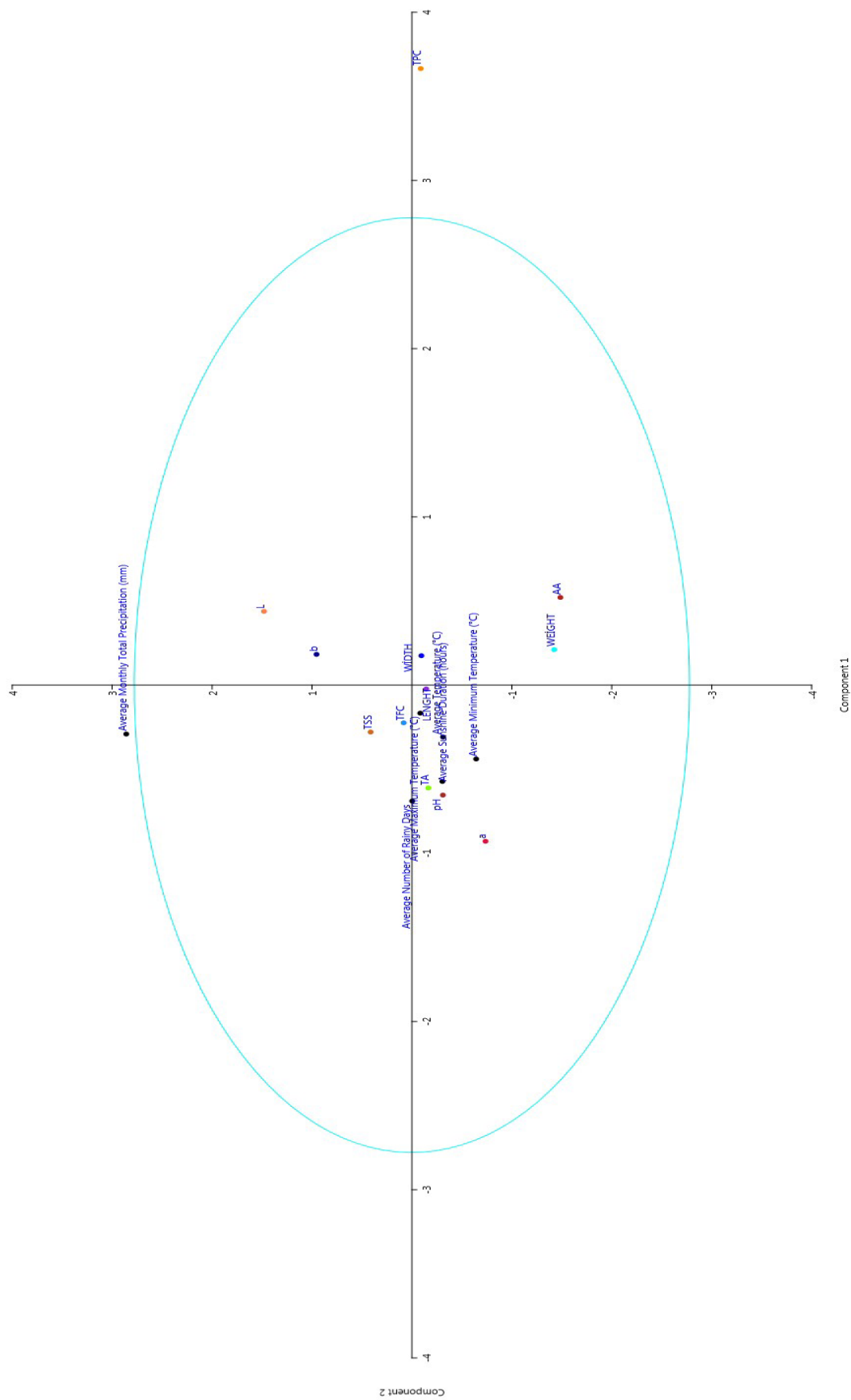


Fig. 5. Multivariate relationships between pomological and biochemical characteristics of "Sari Lop" fig fruits in different growing regions and climatic parameters.

noted that color differences varied with regional temperature. Hssaini et al. (2021) documented a strong correlation between peel color and phenolic compounds. Wang et al. (2017) indicated that environmental temperature stimulated the production of phenolic pigments. Also, Kamiloglu and Capanoglu (2015) emphasized the effect of sunlight exposure on color and phenolic composition.

Significant differences were also detected in total TPC, TFC, and AA among provinces. The highest values were recorded in figs from Aydın and İzmir, indicating that hot and sunny conditions promoted phenolic compound synthesis. Hssaini et al. (2021) reported that most phenolic compounds in figs consisted of hydroxycinnamic acids and flavonoid derivatives, and that their levels increased in warmer regions. Francini et al. (2021) demonstrated that environmental stress enhanced polyphenol accumulation. Zhang et al. (2023) showed a positive correlation between phenolic content and antioxidant activity. Veberic et al. (2008) reported that phenolic profiles varied with ecological factors. Francini et al. (2021) reported that increased temperature and sunlight stimulate phenolic metabolism, and Feng et al. (2013) emphasized that sunlight exposure and peel tissue are crucial for polyphenol synthesis. Overall, these findings supported the close relationship between environmental conditions and the phenolic content and antioxidant capacity of fig fruits.

Conclusion

The present study clearly demonstrates that temperature is the most critical environmental factor influencing the pomological and biochemical quality of "Sarı Lop" fig fruits. Regions characterized by higher average and maximum temperatures, such as Aydın and İzmir, exhibited superior fruit quality in terms of size, total soluble solids, and particularly phenolic and flavonoid contents. This can be attributed to enhanced metabolic activity and increased secondary metabolite synthesis under warm and high-radiation conditions. Among the studied regions, Aydın and İzmir emerged as the most favorable production areas due to their optimal combination of high temperatures, sufficient shine duration, and low precipitation, which collectively promote both fruit development and biochemical accumulation. In contrast, relatively cooler and more humid conditions in Bursa and Isparta limited these quality attributes. From a practical perspective, these findings suggest that fig cultivation for high-quality and nutritionally rich fruit production should be preferentially conducted in regions with warm, sunny, and moderately dry climatic conditions. Furthermore, in less favorable regions, agronomic

practices such as controlled irrigation, canopy management, and site selection to increase light exposure and reduce excess moisture may improve fruit quality. Collectively, these findings indicate that the functional and quality attributes of figs are closely linked to cultivation ecology, underscoring the need to account for regional environmental conditions in fig production and breeding programs aimed at enhancing fruit quality and nutritional value.

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