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The role of sumac (*Rhus* spp.) in ecosystem resilience against climate change

Akide ÖZCAN[1]*, Mehmet SÜTYEMEZ[2], İlker Büşah AYAZ[3], Huri TAŞCI[4]

[1]Department of Organic Farming, Goksun Vocational School, Kahramanmaras Sutcu Imam University, Kahramanmaras
[2]Department of Horticulture, Faculty of Agriculture, Kahramanmaras Sutcu Imam University, Kahramanmaras
[3]Department of Horticulture, Institute of Science, Kahramanmaras Sutcu Imam University, Kahramanmaras
[4]Pistachio Research Institute, Republic of Türkiye Ministry of Agriculture and Forestry, Gaziantep

*Corresponding author: akideozcan@ksu.edu.tr; ozcanakide46@gmail.com

Akide ÖZCAN: https://orcid.org/0000-0001-7182-3811
Mehmet SÜTYEMEZ: https://orcid.org/0000-0003-2417-8009
İlker Büşah AYAZ: https://orcid.org/ 0000-0002-9574-8788
Huri TAŞCI: https://orcid.org/ 0000-0002-9474-3272

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ABSTRACT: This study was conducted to demonstrate the contribution of the highly adaptable sumac plant to economic sustainability and its importance in protecting agricultural ecosystems resilient to climate crisis. Sumac (*Rhus* spp.) is a perennial plant species renowned for its remarkable adaptability to arid climatic conditions. This resilience positions sumac as a valuable species for alternative agriculture and ecosystem restoration, particularly in the context of escalating environmental challenges such as climate change and desertification. Various sumac species are naturally distributed across diverse regions of the world, with Anatolia being one of the primary centers of its occurrence. Beyond its ecological significance, sumac holds considerable importance due to its wide-ranging applications in the food and health sectors. Sumac, widely consumed in its spice form, is also extensively utilized in traditional medicine due to its well-documented antioxidant, antimicrobial and anti-inflammatory properties. Moreover, it is among the plant species employed in natural dye production. The cultivation of sumac presents a viable economic alternative, particularly for low-yield, sloping, or degraded lands. Its economic returns and potential for land utilization enable significant contributions to rural development, even in regions where the cultivation of many other agricultural crops is scarcely feasible. Furthermore, sumac's role in reducing carbon emissions, a growing global concern, is noteworthy. Owing to its photosynthetic capacity and biomass production in arid environments, sumac functions as a natural carbon sink. In sum, sumac is a plant species that is highly tolerant to drought. Due to its versatile applications and environmental benefits, it holds strategic importance from both economic and ecological perspectives.

Keywords: Sumac, climate crisis, forest fires, reforestation

İklim değişikliğine karşı ekosistem dirençliliğinde sumağın (*Rhus* spp.) rolü

ÖZET: Bu çalışma, adaptasyona, ekonomik sürdürülebilirliğe ve iklim krizine dirençli tarımsal ekosistemlerin korunmasında sumak bitkisinin önemini ortaya koymak amacıyla yürütülmüştür. Sumak (*Rhus* spp.), kurak iklim koşullarına olağanüstü uyum sağlamasıyla bilinen çok yıllık bir bitki türüdür. Bu dayanıklılık, özellikle iklim değişikliği ve çölleşme gibi artan çevresel zorluklar karşısında, sumak bitkisini alternatif tarım ve ekosistem restorasyonu için değerli bir tür konumuna getirmektedir. Çeşitli sumak türleri doğal olarak dünyanın çeşitli bölgelerine dağılmış olup, Anadolu bu türlerin başlıca merkezlerinden biridir. Ekolojik öneminin ötesinde, sumak gıda ve sağlık sektörlerindeki geniş kapsamlı uygulamaları nedeniyle büyük öneme sahiptir. Baharat formunda yaygın olarak tüketilen sumak, antioksidan, antimikrobiyal ve antienflamatuar özellikleri nedeniyle geleneksel tıpta da yaygın olarak kullanılmaktadır. Ayrıca, sumak doğal boya üretiminde kullanılan bitki türleri arasındadır. Sumak bitkisinin yetiştiriciliği, özellikle düşük verimliliğe sahip, eğimli ya da bozulmuş arazilerde ekonomik bir alternatif sunmaktadır. Ekonomik getirileri ve arazi kullanım potansiyeli, birçok tarımsal ürünün yetiştirilmesinin neredeyse imkânsız olduğu bölgelerde bile kırsal kalkınmaya önemli katkılar sağlamaktadır. Bununla birlikte, sumak bitkisinin küresel ölçekte giderek önem kazanan karbon emisyonlarının azaltılması konusundaki potansiyeli dikkat çekicidir. Kurak ortamlarda fotosentez kapasitesi ve biyokütle üretimi sayesinde sumak, doğal bir karbon yutağı olarak değerlendirilebilir. Özetle, sumak kuraklığa dayanıklı bir bitki türüdür. Çok yönlü kullanım alanları ve çevresel faydaları sayesinde hem ekonomik hem de ekolojik açıdan stratejik öneme sahiptir.

Anahtar Kelimeler: Sumak, iklim krizi, orman yangınları, ağaçlandırma

INTRODUCTION

The rapid increase in urban population and the rapid growth of cities are causing the rapid depletion of ecological and natural resources. The increase in cities and the decrease in green areas are also making the effects of global climate change more pronounced (Ekren et al., 2024). In recent years, agricultural production has been adversely impacted by rising temperatures driven by global climate change, alterations in precipitation patterns, and the increasing frequency and intensity of extreme weather events (Kadıoğlu et al., 2017). Furthermore, the incidence of natural disasters (including floods, storms, heatwaves, extreme weather conditions, and forest fires) is projected to escalate as a consequence of ongoing climatic shifts (Davarcıoğlu & Lelik, 2018; Soltekin et al., 2021; Karadaş & Altınkaya, 2025).

Water scarcity and the intensification of extreme weather events driven by climate change are projected to exert increasingly detrimental effects on agricultural systems. As these challenges escalate in the coming years, global food security is expected to be increasingly compromised, with reduced access to safe and sufficient food supplies (IPCC, 2023). As rainfall decreases, the amount of irrigation water needed by plants will increase due to both higher summer temperatures and increased evaporation/transpiration. Even with irrigation, it is predicted that there will be declines in summer crop yields, particularly because plants will be exposed to higher and extreme temperatures during their flowering and grain formation periods (Kadıoğlu et al., 2017).

Despite all these predictions, sumac (*Rhus coriaria* L.) stands out as a drought-resistant species that grows in semi-arid regions of Anatolia and can be cultivated with low inputs.

Sumac is taxonomically classified within the genus *Rhus* L., belonging to the family *Anacardiaceae*, order *Sapindales*, group *Dialypetalae*, class *Dicotyledonae*, subclass *Angiospermae*, and division *Spermatophyta* (Köroğlu, 1989; Rayne & Mazza, 2007). The family *Anacardiaceae* comprises 81 genera and approximately 800 species distributed worldwide (Zannou et al., 2025). In Türkiye, the species *Rhus coriaria*, belonging to the genus *Rhus*, grows naturally and is widespread. Sumac are plants with resinous bark that grow naturally in tropical and temperate regions in the form of shrubs or small trees. The sumac plant is 1-3 m tall. Its young branches, covered with brown puberulent, are flexible. Leaves are opposite or spirally arranged, simple or pinnately compound, auriculate or non-auriculate. Leaves are generally 15-27 cm long, imparipinnate, with 9-15 leaflets, elliptical to broadly shaped, very short-stalked or stalkless, with the underside sparsely puberulent and strigillose along the veins on the underside. The inflorescences are 20-25 cm long, with a dense and erect panicle structure. They have small, greenish, and inconspicuous flowers. The sepals are puberulent and green. The petals are greenish-white, 3-4.5 mm long, slightly longer than the sepals, and ciliate at the margins. There are three small bracts at the base of each flower. There are five stamens with an egg-shaped ovary. The flowers are racemose, actinomorphic, hermaphroditic, or erect (Köroğlu, 1989). The active flowering period is between June and July. The fruit is flattened spherical in shape, with a diameter of 5-6 mm. Unripe fruits start out green and turn dark red as they ripen (Köroğlu, 1989; Güvenç et al., 2017).

Additionally, it contributes to the ecosystem in terms of soil conservation and carbon sequestration. The climate crisis is one of today's most urgent global issues and poses serious threats to food security, water resources, and ecosystems. Both adaptation and mitigation strategies are crucial in combating this crisis. The agricultural sector is one of the sectors most affected/to be affected by climate change, but it also has the potential to play a key role in the solution. This review article examines the importance of sumac (*Rhus spp*.) cultivation in the context of combating the climate crisis from a multifaceted perspective.

Resistance to Drought and High Temperatures, Soil Health, Erosion Control, and Evaluation of Marginal Lands

Sumac's natural resistance to drought and high temperatures facilitates the adaptation of agricultural systems to the adverse conditions brought about by climate change. In regions where water resources are decreasing and temperatures are rising, while the cultivation of traditional plant species becomes difficult, drought-tolerant plants such as sumac offer an alternative solution. This can help farmers stabilize their incomes and ensure food security. Sumac's water efficiency makes it a more sustainable option compared to traditional irrigated crops. Sumac is a plant that can grow in calcareous soils and requires little water (Şahin, 2020). Sumac's exceptional drought tolerance represents a critical agronomic advantage in the context of increasing water scarcity associated with climate change.

The number of wildfires is rapidly increasing due to high temperatures. These fires are causing serious damage to the region's flora and fauna. The *R. coriaria* (sumac) species exhibits significant resistance to fire due to the high moisture content in its leaves and stem. This characteristic may help the plant ignite later, particularly in situations like forest fires, thereby slowing the spread of the fire. It has been demonstrated that *R. coriaria* exhibits a certain delay period against fire due to its high moisture content, and this feature can be taken into account in firefighting strategies (Yılmaz, 2017). Neyisci (2011) investigated the ignition delay times of *Rhus coriaria* L. at different temperature levels. Ignition tests conducted at 750°C revealed that the plant ignites in 4.93-2.50 seconds during dry seasons and in 4.23-2.52 seconds during rainy seasons. The moisture content of *R. coriaria* L. was reported to be 118% during dry seasons and 55% during rainy seasons. Thanks to its fire resistance, it is also preferred for roadsides and lane edges (Yılmaz, 2016). Sumac is relatively resistant to fire because it can sprout again after fires, and can therefore be used in afforestation efforts in areas with a high risk of drought-induced fires. Due to this characteristic of the sumac plant, it has the potential to be used not only in firefighting but also in the much faster rehabilitation of post-fire areas.

Global warming and decreasing rainfall amounts are causing temperatures on Earth to rise and droughts to occur. Scientists are working diligently on drought-resistant species, varieties, and breeding improvement studies to mitigate the effects of drought on agriculture.

Water scarcity continues to increase worldwide every day. This water scarcity poses a major risk not only to humans directly but also to all living things on earth. In agricultural activities, it emerges as a limiting factor in determining many key components such as irrigation type, rootstock, and variety selection. Promoting the cultivation of *R. coriaria* L. in limited irrigation areas around the world will encourage producers. It will also provide indirect contributions such as preventing erosion by afforesting idle lands with drought-resistant plant species.

Afforestation, shrubbery, and grassing in karst areas susceptible to severe erosion are good land-use management strategies (Dindaroglu et al., 2023). The sumac's extensive and deep root system plays an effective role in preventing erosion by firmly holding the soil. Especially on sloping lands and in areas with intense wind erosion, sumac cultivation reduces soil loss and preserves soil fertility. Furthermore, sumac's leaf fall and organic matter contribution can improve soil structure, increase water retention capacity, and enhance soil health by supporting microbial activity. These characteristics offer a natural solution to soil degradation problems caused by climate change. *R. typhina* L. was introduced to the China Botanical Garden in 1959 and has been frequently used in the rehabilitation of degraded fields in most mountainous areas of northern China. This use has determined its tolerance to most exposures, even in poor soils with strong growth (Wang et al., 2008). Sumac species (*Rhus*) are a plant family of great importance in combating erosion due to their extensive root systems. With the climate crisis, the rapid and economical restoration of areas damaged by increasing fires is a priority. Sumac provides rapid propagation through root suckers. The idea that invasive species have a higher growth rate than native species and tolerate a wider range of conditions requires more careful examination in various community species (Mills et al., 2012). Since sumac species are also classified as invasive plants, they may be preferred for reforestation of damaged forested areas. Agroforestry practices based on land capability classes play a pivotal role in addressing global challenges such as climate change, land degradation, and biodiversity loss. Considering the effects of wind erosion, the use of windbreaks in agricultural areas is of great importance. The effectiveness of windbreaks depends on the combined evaluation of installation principles (factors such as height, continuity, permeability, direction, and length). The species should be fast-growing in their youth, capable of reaching tall heights, not spreading their crowns, long-lived, with deep root systems, branching from the base, suitable for pruning, highly flexible, and able to fix atmospheric nitrogen (e.g., juniper, acacia, etc.). Care should also be taken to select species, especially shrubs and bushes, that have medicinal and aromatic properties or can produce non-wood forest products, and that have characteristics suitable for creating habitat areas for wildlife. Sumac can be preferred as a windbreak in areas with strong and prevailing winds (Turna et al., 2024).

Figure 1. *R. coriaria* L. tree

Staghorn sumac (*R. typhina* L.) is good for supporting poor park soils with medium alkalinity. This species, which is important in the context of climate change, shows good resistance to drought and frost (Timiş-Gânsac & Dincă, 2020). *R. typhina* L. is an exotic ornamental shrub valued for its exceptionally decorative leaves and fruits. Additionally, this species can be used in windbreak strips (Popov et al., 2017) or agroforestry systems (Kachova & Dincă, 2015). Sumac's ability to grow in poor and marginal lands creates new opportunities for communities farming on unproductive or low-yield soils. This reduces pressure on existing agricultural areas while allowing abandoned or unproductive lands to be economically utilized. Thus, it can contribute to rural development and improved income distribution. Sumac (*R. coriaria* L.) is a species that grows naturally in various habitats, such as dry, rocky, and stony areas, roadside slopes, and forested areas, at elevations between 600 and 2000 meters. It has a high tolerance to air pollution in urban areas. This ecological flexibility allows it to grow spontaneously on vacant lots and roadsides, while its ability to adapt to low temperatures and limited water conditions enables it to thrive in a wide range of ecosystems (Öztaş Kurt & Gül, 2024). This feature makes sumac an important tool in the afforestation of erosion-worn surface soils, the rehabilitation of mining sites, and various conservation-oriented afforestation projects (Brinkman, 1974; Humphrey, 1983; Köroğlu, 1989; Rowe & Blazich, 2002; Gezer & Yücedağ, 2006; Göktürk et al., 2006). Although *R. laurina* is relatively sensitive to drought, it is quite successful in rapid recovery after fire, forming an active root system after sprouting (DeSouza et al., 1986). At the end of the sumac's first growing season, only 17% of *R. laurina* seedlings were affected by herbivores (Frazer & Davis, 1988). This also supports the proliferation of sumac compared to other forest plants.

R. typhina L. adapts to temperate climatic conditions; it has a long growing season, requires summer heat and fertile soils, and is resistant to dust and smoke. It can also thrive in sandy and poor soils, along riverbanks, or in less saline soils. It is a light-loving species and sprouts vigorously (Clinovschi, 2005). This species is resistant to drought and frost, tolerates pollution and shade well despite its preference for light, and tends to be an invasive plant (Timiş-Gânsac & Dincă, 2020). Sumac are also used in agricultural activities. It is an important plant species, especially for afforestation of barren areas (mining areas, erosion, areas affected by natural disasters, etc.) (Göktürk et al., 2006). Its most important feature for use in afforestation is its ability to grow in dry, rocky, gravelly areas up to an altitude of 1900 meters (Baytop, 1999). Sumac cultivation will increase the income and welfare levels of people living in the region by utilizing areas in rural areas that are not suitable for other agricultural production, as well as creating new employment opportunities.

Biodiversity and Ecosystem Services

Sumac is an important source of nectar and pollen for bees and other pollinators during its flowering period. The species known as sumac has a wide range of ethnobotanical uses. It is commonly cultivated as a 'Bee Plant' and is one of the most preferred honey plants in beekeeping (Yılmaz, 2017). This contributes to the conservation of biodiversity and ensures the continuity of ecosystem services. The decline in pollinator populations poses a serious threat to global food production. Cultivating pollinator-friendly plants such as sumac can increase the resilience of agricultural ecosystems. Furthermore, sumac provides shelter for other plant and animal species in its natural habitat, supporting overall ecosystem health. In cold temperate regions under sumac invasion, SNB (Soil N_2-fixing bacterial communities) have greater diversity and richness, mainly due to the higher plant nutrient content (especially leaf nitrogen) in cold temperate regions compared to warm temperate regions. This situation may stem from the fact that the cold temperate region's deer antler sumac can provide more nutrients to the soil ecosystem and possibly meet nutritional requirements by supporting higher SNB diversity and richness. In particular, changes in the structure of SNB under deer antler sumac invasion in different climate zones may play an important role in its successful spread across most of northern China (Wu et al., 2019).

Fruits in forested areas are important for feeding wildlife. Managers need to consider this when selecting tree species for forest reforestation, understanding the amount of fruit produced by each species, how fruit production changes seasonally, and how it changes as young forests mature. Fleshy fruit is an important food source for both game animals and wildlife other than game animals, and can be particularly important for migratory birds in the fall and for resident birds and mammals in the winter. Fruit availability is highest in summer and early fall and lowest in winter. American holly (*Ilex opaca*), sumac (*Rhus* species), and greenbrier (Smilax species) retain their fruits during the winter months, but their distribution is irregular (Greenberg et al., 2007). Sumac fruits are an important food source for wildlife during the winter season.

Sumac species contribute to the ecosystem in many ways. The opportunities offered by cities compared to rural living areas have accelerated migration from villages to cities. With migration, the existing transportation capacities of cities have been filled, and the horizontal and vertical expansion of urban areas has increased (Sakal, 2007). As people migrated to city centers to take advantage of living opportunities, the need for employment and production arose. Production facilities and factories were established to meet this need. Urban vehicle traffic and the use of various fuels have increased. This use has greatly affected the city's air quality, temperature, and all biological life in the city by increasing CO_2 and other harmful gas emissions (Dascher, 2014; Kahveci & Acar, 2021; Martínez-Zarzoso & Maruotti, 2011). Some sumac species are used as ornamental plants along roadsides. Although not like trees, shrub-like sumac plants also contribute to carbon sequestration by absorbing carbon dioxide (CO_2) from the atmosphere through photosynthesis. Large-scale sumac cultivation projects offer a small but meaningful mitigation potential that could help reduce carbon emissions. Especially with the decline of forested areas and the expansion of agricultural land, practices that increase carbon sequestration within agricultural systems are of great importance. However, reducing the canopy cover and controlled burning can also promote suitable conditions for species that are more fire-resistant than mesophytes, such as sassafras (Sassafras albidum (Nutt.) Nees) and sumac (*Rhus* spp. L.) (DeSelm et al., 1991; Arthur et al., 2012). EGS (early growing season) fires generally support sumac establishment or fail to control it (Evans, 1983; Nippert et al., 2021; Turner et al., 2025). Therefore, one species with a high ability to resprout after fire is *Rhus* spp. L. Climate change and the associated increase in carbon emissions have heightened the importance of sustainable agricultural policies. The agricultural sector is considered both a source of greenhouse gas emissions and a potential carbon sink; in this context, low-emission crop production systems are gaining prominence.

Economic Potential and Sustainable Development

Sumac's role in combating the climate crisis is not limited to environmental benefits; it also has significant potential in terms of economic sustainability. While sumac fruits are traditionally used as a spice, its leaves and bark are also valued in the medical and dye industries. Known for its antioxidant, anti-inflammatory, and antimicrobial properties, sumac has a wide range of uses, from the food industry to cosmetics. Sumac is used in Kahramanmaraş province in the form of a paste, while in neighboring provinces, it is used by soaking sumac fruit in water to obtain its sourness (Aldıoglu, 2022). This product diversity creates additional income sources for farmers, increasing their economic stability. Furthermore, converting sumac into value-added products (e.g., sumac juice, sumac oil, sumac tea) can contribute to regional economies. Sumac is a famous spice made from the fruits of a shrub of the same name in the Middle East. To obtain spice from the plant, the fruit is dried and ground into a fine red-purple powder. The red fruits are sharp and flavorful, containing malic acid found in apples. As a spice, it is delicious when used in meat marinades or salad dressings. Sumac comes from a shrub native to the Mediterranean and dates back to ancient times (Zargari, 1992). The Romans used sumac fruits as a souring and flavoring agent before citrus fruits reached the region. In a study conducted in Kahramanmaraş by Çelik and Özkaya (2022), a large proportion of consumers stated that they also consume sumac and sumac juice as tea. Sumac still grows wild around the Mediterranean; its main sources today are Türkiye and the Middle East. There are many varieties of sumac, and some are poisonous. However, Native Americans traditionally used sumac to make a refreshing drink and also used both its leaves and fruits in tobacco mixtures (Matloobi & Tahmasebi, 2019).

A study conducted by Kamalinejad et al. (2019) showed that sumac water extracts can inhibit microbial growth in ground meat during refrigerated storage. Since sumac is commonly used as a spice in foods such as red and white meat, applying its extracts to these foods not only improves sensory properties but also extends shelf life. Sumac extracts can be used as natural food preservatives (El Khatib & Salame, 2019). Meanwhile, these extracts may have health-promoting effects on consumers due to their potential antimicrobial activities. Sumac is preferred not only for adding flavor to dishes but also for its antimicrobial effect on foodborne pathogenic microorganisms. This allows the foods it is used in to retain their freshness and be stored for longer periods (Tiryaki, 2010).

The most important phenolic acids and flavonoids are catechin, ferulic acid, gallic acid, apigenin, gentisic acid, chlorogenic acid, p-coumaric acid, caffeic acid, isorhamnetin, quercetin, cinnamic acid, taxifolin, epicatechin, kaempferol, P-hydroxybenzoic acid, vanillic acid, vanillin, anisic acid, pyrogallol, sinapic acid, syringaldehyde, syringic acid, and benzoic acid. The organic acids in sumac are malic acid, citric acid, tartaric acid, and fumaric acid. The fatty acid composition of sumac fruits is myristic acid, palmitic acid, palmitoleic acid, stearic acid, oleic acid, linoleic acid, and linolenic acid. The vitamin content of sumac fruit is thiamine, riboflavin, pyridoxine, cyanocobalamin, nicotinamide, biotin, and ascorbic acid (Khoshkharam et al., 2020). The sour taste also stems from the presence of organic acids such as malic acid, citric acid, and tartaric acid (Chakraborty et al., 2009; Heydari et al., 2019). Sumac fruit is a primary source of phytochemical compounds that are nutritionally and medically important, including phenolics, anthocyanins, organic acids, and antioxidant (Table 1). A total of 26 volatile compounds suitable for use in commercial food products were clearly identified. Sumac fruit was also found to be a good source of xylose that could be used for commercial xylitol extraction (Ozcan et al., 2021). These findings emphasize that sumac fruit has valuable raw material potential for industrial applications beyond being merely a spice.

Table 1. Phytochemical Composition and Antioxidant Properties of Sumac (*R. coriaria* L.)

Phenolic acids (mg/g)	**Amount**	**References**
Ferulic acid	0.001-0.034	Zannou et al., 2025
Gallic acid	0.29-12.04	Karadaş et al., 2020
Chlorogenic acid	0.005-1.160	Zannou et al., 2025
p-coumaric acid	0.002-0.410	Zannou et al., 2025
Caffeic acid	0.001-0.100	Zannou et al., 2025
Vanilic acid	0.007-0.022	Zannou et al., 2025
Syringic acid	0.002-0.010	Zannou et al., 2025
Benzoik acid	0.09-0.81	Kosar et al., 2007
Organic acids (µg/g)		
Malic acid	1357.40-2804.11	Ferk et al., 2007; Kossah et al., 2011; Ozcan et al., 2021
Citric acid	48.25-96.50	Ozcan et al., 2021; Zannou et al., 2025
Tartaric acid	1.20-2.15	Zannou et al., 2025
Fumaric acid	0.41-3.40	Zannou et al., 2025
Oxalic acid	0.49-3.92	Ozcan et al., 2021
L- Ascorbic acid	4.03-42.70	Ozcan et al., 2021; Zanoou et al., 2025
Flavonoids (mg/g)		
Catechin	0.024-1.300	Zannou et al., 2025
Quercetin	0.010-0.136	Zannou et al., 2025
Epicatechin	0.035-0.193	Zannou et al., 2025
Kaempferol	0.032-0.170	Zannou et al., 2025
Total antioxidant (%)	1.55-78.05	Fereidoonfar et al., 2019; Belew et al., 2021; Ozcan et al., 2021
Total anthocyanins (mg/L)	10.27-120.80	Fereidoonfar et al., 2019; Ozcan et al., 2021

The health benefits of sumac for humans are as follows: It is rich in vitamin C, a powerful antioxidant that may help prevent diseases such as diabetes, cardiovascular diseases, and cancer. Sumac fruit is a spice containing anti-inflammatory properties that can help combat inflammatory diseases, colds, and flu. Studies have proven it to be effective in regulating cholesterol levels and treating diabetes by lowering blood sugar. Sumac is an antimicrobial and antifungal spice that can help treat skin inflammation and disorders. It has also been studied for its effectiveness in fighting bacteria such as Salmonella and for its use in safely disinfecting fruits and vegetables. It can increase breast milk production and relieve menstrual cramps. Sumac is a diuretic, meaning it helps flush toxins from the body through urine and has been used traditionally. It can be used to treat urinary tract infections and digestive problems (Khoshkharam et al., 2020). The fruit and seeds are used in the treatment of burns with egg yolk (Tabata et al., 1994). Supplements (capsules) and essential oils are produced from different parts of sumac (Alsamri et al., 2021). The root portion of the sumac plant, known as the yellow root or yellow wood, is used to dye thread yellow (Aslan, 2017). Its leaves and branches are used in fabric dyeing to obtain black color (Koçyiğit, 2005). The seeds, roots, and stem wood are used for dyeing purposes (Demir et al., 2010). This fruit is used for medicinal purposes in animal diseases (Cansaran & Kaya, 2010). In Anatolian villages, it is used for mouth sores and diarrhea in animals (Koyuncu & Köroğlu, 1991). The plant is crushed and used internally to heal wounds (Sezik, 1991). Sumac is evaluated as a food supplement, food coloring, natural food preservative, and animal feed additive, in addition to its use as a spice in foods (Sakhr & El Khatib, 2020; Pakseresht et al., 2023; Ostadrahimi et al., 2025).

CONCLUSIONS

Global warming, extreme weather events, drought, and water scarcity—the effects of climate change—pose a very serious threat to agricultural production and, consequently, food security. This situation highlights the need to shift toward plant species that require less water and resources, are drought-resistant, and provide environmental benefits. Sumac is a plant species native to the Middle East and Mediterranean climate, tolerant to drought and offering various ecological benefits. Sumac is also economically attractive; thanks to its diverse uses in spices, dyes, medicine, and pharmacology, it can contribute to rural development. Thus, it can create a sustainable model that combines both ecological and economic benefits. This study was conducted with the aim of contributing to the development of climate-resilient agricultural systems by evaluating the potential of sumac in terms of adaptation and economic sustainability within the scope of current literature. Although sumac has high potential in combating the climate crisis, there are some challenges to its widespread cultivation. These include difficulties in transitioning from seed to seedling, the fact that appropriate cultural practices have not yet been fully optimized, and the need to develop market demand. However, these challenges also present significant opportunities for research and development. Sumac is a species that leaves a relatively low carbon footprint on the environment due to its low input requirements, drought resistance, and fire-resistant structure. When used in particularly barren, agriculturally unsuitable areas, its indirect environmental benefits, such as soil protection and carbon sequestration, increase. Compared to other industrial crops (such as corn, cotton, and rice), sumac has a significantly lower carbon footprint. Sumac cultivation, especially in degraded and marginal areas, is highly valuable in terms of environmental sustainability.

Thanks to its deep root system, it can use soil water more efficiently, making it an ideal plant for regions experiencing water scarcity. Additionally, its ability to grow in poor soils and marginal lands offers a significant advantage in terms of erosion control and the rehabilitation of degraded lands. Sumac also has a wide tolerance to soil pH, which facilitates its adaptation to different soil types. Genetic breeding studies enable the development of higher-yielding and disease-resistant sumac varieties, while modern agricultural techniques (e.g., drip irrigation, soil sensors) can further increase sumac's water use efficiency. Furthermore, greater public awareness of sumac's benefits and uses will increase market demand, paving the way for its widespread cultivation. Sumac is considered an important plant species in terms of climate change adaptation, ecosystem resilience, and sustainable land management. Therefore, its characteristics in terms of plant ecophysiology need to be elucidated in future studies.

AUTHOR CONTRIBUTIONS

Akide Özcan: Designing the research, writing and reviewing the manuscript and supervising. **Mehmet Sütyemez:** Writing and reviewing the manuscript and supervising. **İlker Büşah Ayaz:** Writing and reviewing the manuscript and supervising. **Huri Taşcı:** Writing and reviewing the manuscript and supervising

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The author declares no conflict of interest.

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This study does not require any ethics committee approval.

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