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Review

An Overview of Olive Cultivation in Turkey: Botanical Features, Eco-Physiology and Phytochemical Aspects

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Abstract: Global climate change, especially global warming, is affecting olive production efficiency as well as its product quality. The size and water content of fruit varies depending on the olive fruit yield along with the region, climate, and geographical position as well as agricultural applications. Anthropogenic activities also affect its ecology to a great extent. The plant prefers areas with mild winters and short rainy seasons but is facing long and dry summers, sunny habitats, well drained dry, poor, loamy, clayey-loamy, slightly calcareous, pebbly and nutrient-rich soils, with a pH around 6–8. It is resistant to drought but suffers much from harsh winters and air pollutants, which affect its production. Although the olive plant tolerates temperatures between −7 °C to 40 °C, the optimum temperature demanded for growth, development, and fruit yield is 15–25 °C. The annual precipitation demand lies between 700–850 mm. An important part of the composition of its fruit consists of water and oil or the "liquid gold". Main ingredients are additionally fat-soluble vitamins, minerals, organic sugars, and phenolics. Phenolic substances are responsible for many beneficial health effects as well as the taste and aroma of olive fruit. Oleuropein stands out due to its inhibition of oxidation of low density lipoproteins and its hypoglycemic and cholesterolemic effects. It is also a component that protects the olive tree against various parasites and diseases, one of the reasons why olive is recorded as the "immortal tree". Olive trees are cultivated in different regions of Turkey. A series of changes occur in morphological, physiological, and biochemical features to overcome different types of stress. In this review, information about the botanical aspects, eco-physiology, and pharmaceutical features of the oil, fruit, and leaves has been evaluated.

Keywords: cultivation; eco-physiology; olive; pharmaceutical aspects; Turkey

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1. Introduction

Genus *Olea* is represented by 30 species in the world and almost 80 different names are used globally. The most popular species is *Olea europaea*, widely distributed in the Mediterranean region and the only species economically important worldwide [1]. Olive trees are mainly found in the coastal areas of the eastern Mediterranean basin, the contiguous coastal areas of Southern Europe, Northern Iran (at the south end of the Caspian Sea), Western Asia, and North Africa [1].

The origin of the tree is said to lie in upper Mesopotamia and Southwest Asia [2,3]. Some regard it as Hatay, Gaziantep, and Kahramamaraş. The distribution is said to have followed in three ways: first via Egypt to Tunisia and Morocco, second via the Anatolian side of the Aegean Islands, Greece, Italy, and Spain. Third is over Iran to Pakistan and China [2,3].

2. Botanical Features

Olea europaea is in general a short and thick tree or shrub, up to 10 m in height. The flowers are numerous, bisexual, or functionally unisexual. The most important part of this tree is the fruit, an ovoid—green before ripening but blackish-violet after it ripens—normally 1–2.5 cm long, and smaller in wild plants than in the cultivated forms [1]. These trees can live up to 1000 years of age. The fruit is produced when the trees reach an age of 3–4 years, but the desired yield is obtained from trees that are 12–20 years old. It maintains its productivity up to 100 years of age and if rejuvenated by pruning, fruit production can last for many more years [4].

The wood of these trees is very strong and normally used for durable furniture production as well as some types of handcrafts, but is also preferred as firewood in some places as it burns even when wet [5,6].

The olive tree is a monoecious plant with perfect and imperfect flowers, dependent on wind for self- or cross-pollination. Cultivated plants are normally pollinated by neighboring cultivars or even the wild form, that is, *Olea sylvestris* [1]. The leaves show hypostomatic character and stomatal density varies among different cultivars [6]. Even under 100% light intensity both net photosynthesis and transpiration increase because of the morphological changes in leaves. These trees adapt to a high light intensity by increasing stomatal density, cuticular thickness and numbers of palisade parenchyma layers [7]. Thermophillic features of mesomorphic leaves show that daily water potential varies due to fast changes in the leaf turgor. The trees protect themselves from drought with stomatal closures during peak daytime hours, effectively bringing down levels of water loss [8–13].

3. Ecological Features

The olive orchards in Turkey are generally located on the coastal zone, where Mediterranean climatic conditions prevail. The yield from trees is generally 11.7 kg/tree. This is very low compared to other countries. For example, the yield in Italy is 50 kg/tree [14]. Major factors affecting the yield are natural such as; geomorphology, altitude, exposure and slope, climate, soil, water conditions, periodicity, and the age of trees; in addition to human-based factors such as the maintenance, irrigation, pruning, time, and type of harvest [14].

3.1. Geomorphological Features

Altitude is also an important factor that affects olive yield, closely related to temperature and precipitation, and it plays an important role in the identification of cultivation areas. In general olive trees are distributed between 0–800 m altitudes in Turkey. These elevations provide favorable conditions for their cultivation particularly in the Mediterranean, but their occurrence decreases towards the north. In the Aegean Region, the cultivation is mainly observed at 600 m, but also occurs at 800 m in the Mediterranean, and 450 m in the Marmara [14]. In some cases, distribution areas steer away from the ecological optimum. The olive groves established by grafting wild olive trees exceed the upper limits. The upper limits for wild olives are approximately 210 m higher than the upper limit of cultivated trees. At 180 m the fruit yield is 19.4 kg, but this decreases to 9.1 kg at 500 m elevation [14].

Slope: Nearly 75% of the olive groves in Turkey grow on slopy areas with little soil depth, effectively lacking irrigation facility. Only 8% of the olive cultivation area is irrigable and this is closely related to the yield. The recent olive groves are mostly found on marginal and sloping areas, although such areas have several disadvantages such as a low water holding capacity and low soil depth. Rainwater flows down at higher speeds in these areas and permeates even less into the soil as the slope increases. The yield too decreases in such areas [14]. In the Aegean region, the average slope of olive groves is 28%. Almost 30% of olive groves are found in the area and have a slope of 26% or more. The yield per tree decreases by 33% in the areas with a 30% slope. The highest yield per tree is 24.3 kg in areas with slope level varying between 0 to 2%. At a slope of 15% the yield per tree is 14.6 kg, which goes down to 8.0 kg when the slope is 30%, and 4.5 kg at 45% slope. However, these interrelationships change with latitude and climatic features. Approximately 27% of the olive orchards near İzmir, Aydın, and Manisa are level or almost level (0–5%), but 22% show little slopy features (6–15%), almost 20% are moderately sloped (16–25%), and 30% are found on extremely sloped areas (26% and more). The lowest yield is 2.9 kg per tree which is observed in areas with a 55% slope [14].

3.2. Climatic Features

The olive orchards found in the Mediterranean basin show good adaptation to its subtropical climatic features, where summers are long and dry [15,16]. The olive cultivation in Turkey is generally characterized by climatic factors like temperature and precipitation, which affect plant growth and development [17]. Annual and monthly temperature averages are very important for the vegetative and generative development of olives. The flower bud also needs cool periods for its formation [18].

Temperature: It is effective on the growth behavior of olives. In Turkey, olive orchards are found in the Marmara, Aegean, Mediterranean, and Southeast Anatolian regions. These orchards prefer south facing slopes in areas where the climate is not favorable, in order to maximize the light that olives need for favorable production and growth performance. In hot and arid climates, the exposure of the slope is not important [14]. The annual average temperature in olive growing areas depicts that 14.5 °C is the lowest limit for its cultivation. The coastal areas of South Marmara, Aegean region and the rift valleys, Mediterranean coast and western parts of Southeastern Anatolia are recorded as the suitable areas for olive cultivation [14].

Another important point is the relationships between monthly average temperatures and the phenological stages of the olive trees. The tissue of the olive tree generally dies at −5 °C and below these levels, the leaves, shoots, twigs, and stems freeze [14,19]. These trees can tolerate temperatures up to −7 °C in general [14], depending on variables such as the variety of the tree, intensity, frequency, air humidity, wind speed, soil moisture, soil temperature, and other features. Damage in the form of defoliation, browning of the annual shoots, cracks in the shells, and even drying is observed. If the temperature is lower than −7 °C, leaves are lost and slender branches dry up, resulting in severe yield losses [19]. At −10 °C and below the death of the entire tree occurs [20]. However, some varieties have been reported to tolerate frost up to −18 °C [21].

The olive cultivation areas in Turkey as a rule experience low temperatures during January, when temperatures can vary between 4.4–10 °C. However, olive trees meet their chilling requirements between −7 to 7 °C [14]. Therefore, we do not come across any problems in South Aegean and the Mediterranean olive cultivation areas [14]. Temperatures between 5–10 °C are required by these trees in February and March. These ranges are common at all places on the coast where olive cultivation is important. In spring, the average temperatures are higher in the Mediterranean but lower in the Marmara region. As such, vegetative activities like the formation of new shoots and flowering begin earlier in Mediterranean areas, which leads to the development of fruit. In areas where temperatures exceed 30 °C in summer, the photosynthesis activity decreases, negatively affecting fruit formation. The main temperature requirement for olive yield during this period is between 20–25 °C. Therefore, north Aegean and South Marmara regions show favorable conditions for the fruit's development, compared to Mediterranean areas in Turkey [14]. Drought in the region and high temperatures during the vegetation period also adversely affect olive fruit production, and an increase in temperature also increases photosynthetic activity. Usually, the enzymes involved in photosynthesis begin to get denatured from 30 °C onwards and the photosynthesis rate decreases. Above 35 °C, the stomata start closing up, which limits the exchange of gases for photosynthesis thereby negatively affecting growth [22,23]. At 40–45 °C, photosynthesis completely stops [24]. In view of this, olive cultivation is subsequently problematic in the Southeastern Anatolian region and its economical production is practiced only under marginal conditions [14].

Efe et al. [25] have studied the effects of temperature on phenological and pomological characteristics of different olive genotypes in Turkey. These researchers have found that extremely high and low temperatures produce negative effects on olive growth, quality, and yield. Low temperatures have been found to cause excessive shedding of leaves, cracking of bark, and death of thick branches, while high temperatures reduce the size of olive fruit.

Precipitation: The annual rainfall need for olive plantations varies between 700–850 mm. The winter and spring rains entering the soil are valuable for good blooming and the increased fruit production rate of flowers [24]. In the temperate regions, olive trees are generally large with tall stems and strong vegetative parts, particularly if there is high rainfall or summer irrigation is provided [26]. If water stress occurs in the shoot growth period, shoot development decreases [27,28], and if it occurs during fruit set, the olive production rate will also decrease [29,30].

In the Aegean, Marmara, and Southeastern Anatolian regions, annual precipitation is lower compared to average values required in olive growing areas. However, in some parts of the South Aegean and Mediterranean regions it is above average. Seasonal precipitation distribution is more important for olives than the total amount of precipitation. In some parts of the Mediterranean summer, precipitation is generally very low but the total annual precipitation is rather high. Olive production is negatively affected by summer drought [14]. The olive growing areas in Turkey generally receive enough precipitation in spring when olives produce new shoots, buds, and flowers. In general, in summer months a water deficiency is observed in all olive growing areas. This is the time when fruit formation and development occurs. In the Mediterranean and Southeast Anatolia during the summer months, the precipitation is very low and temperatures are high, which in turn increases negative effects due to low precipitation. During autumn the water deficit problem disappears to a large extent, followed by more rain. However, in some parts of the inland areas, water deficit problems continue. During the last part of autumn, fruit matures following the completion of physiological activities. In December, olive trees show a reduction in their activities to the lowest levels, which continues through January and February—following the harvest period starting in October. Winter precipitation has little effect on the quality of olive fruit. Its effects are more indirect, with rainwater filling the ground water for the next season's growth. In the South Aegean and Western Mediterranean regions, winter temperatures are reasonably favorable. These allow for the continuation of physiological activities without interruption. This may be the reason why the largest olive fruit is produced in these areas [14].

3.3. Soil Characteristics

Olive trees tend to avoid heavy textured clayey soils with too much water, but prefer clayey-loam, sandy loamy, and loamy soil with a moderate moisture around the root zone. Although the taproot grows deep into the soil, the fibrous roots are shallow. Therefore, deep soil ploughing is not useful for olive groves, because fibrous roots grow closer to the surface, especially in clayey soil. The soils generally show a pH range of (slightly acidic) 6.5–7.8 (slightly alkaline). If pH values are lower or higher, the quality and yield of olives decreases [14].

3.4. Hydrographic Factors

The majority of olive groves in Turkey are situated in areas with more than 15% slope, and as such, due to topographic conditions the possibilities for irrigation are weak, but nearly 8% of the groves that face irrigation problems only encounter them during intensive summer droughts. It is thus important that the slope of orchards should be suitable for irrigation. With this in mind, the location of waterways are important because ground water is of great value for olive cultivation in irrigable areas. Water collected from different types of waterways and dams is drawn by water pumps and used for irrigating olive groves. The water from the natural Iznik and Marmara Lakes is also used in olive growing areas for irrigation. The area of irrigated groves in the Mediterranean and Southeast Anatolia has significantly increased lately [14].

4. Olive Cultivations in Different Regions of Turkey

The countries surrounding the Mediterranean basin are the major table olive producing areas and oil production here accounts for nearly 98% of global production [31]. Currently almost 2000 cultivars have been recorded from the basin, all exhibiting enormous diversity based on pit size and fruit morphology [32,33]. The varieties differ depending on the regions and districts vis-a-vis the climate, soil, and geomorphological features. Some are more suitable for olive oil extraction and others are consumed as table olives. In Turkey, not enough data is currently available concerning the number of varieties because of a dearth in studies regarding this topic, however the number of varieties is estimated to be over 400. The cultivation is done in 36 provinces (Figure 1). Nearly 119 varieties cultivated in Turkey are "registered" by National Olive and Oliveoil Council of Turkey [14,34]. Out of these, 30 are very common, the rest are grown in more limited areas (Figure 2). The well-known varieties cultivated for oil are Ayvalık, Memecik, Kilis yağlık, Nizip yağlık, and Yağ Çelebi. Records from 2012 have revealed that at that time, there were approximately 162 million olive trees in Turkey. This figure has increased during the last two decades and every year new groves are established (Table 1). Tekirdağ, Çanakkale, Bursa, Bilecik, Balıkesir, İzmir, Aydın, Manisa, Muğla, Denizli, Eskişehir, Isparta, Burdur, Antalya, Mersin, Karaman, Adana, Osmaniye, Kahramanmaraş, Hatay, Gaziantep, Adıyaman, Siirt, Mardin, Şırnak, Şanlıurfa, Yalova, Kocaeli, Sakarya, Zonguldak, Bartın, Kastamonu, Samsun, Sinop, Giresun, Trabzon, and Artvin are the olive growing provinces [14].

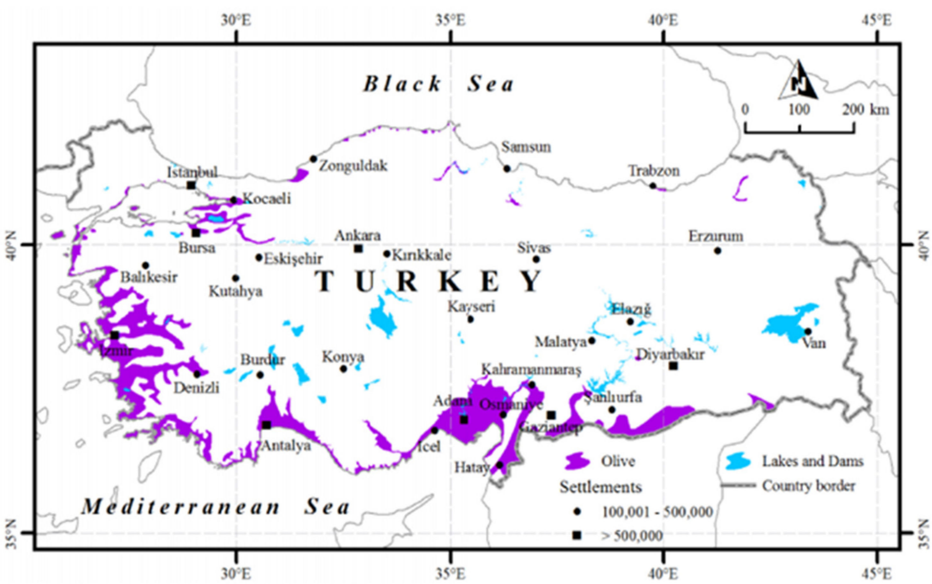

Figure 1. Olive plantation areas in different provinces in Turkey (modified from Efe et al. [14]).

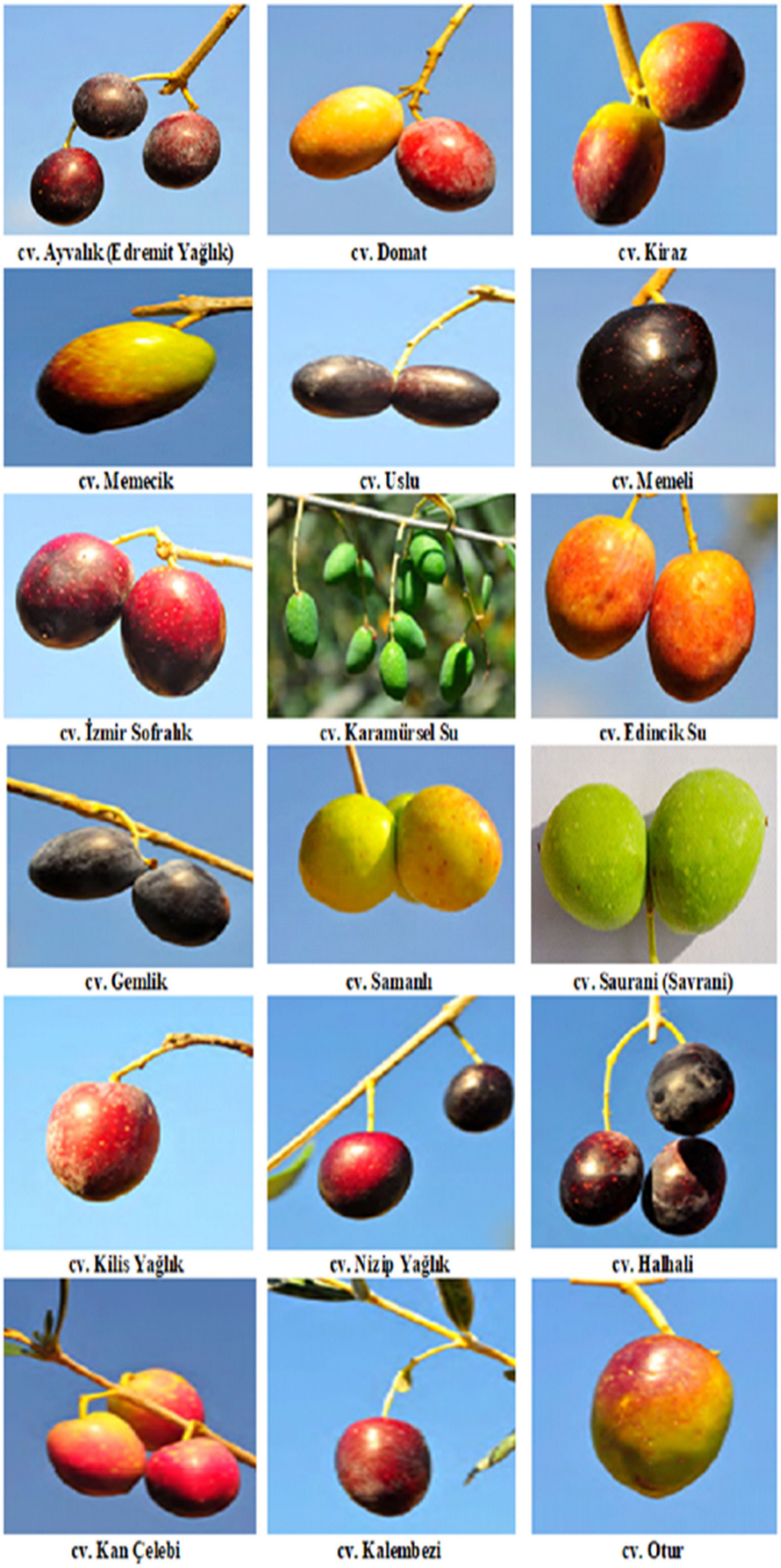

Figure 2. Some of the olive varieties cultivated in Turkey (modified from Efe et al. [14]).

Table 1. Data on the number of olive trees, their yield, table olives, and oil producing olives from different provinces of Turkey—2013 and 2019 (modified from Efe et al. [14] and UZZK [34]).

Provinces	Productive Trees	Production (ton)	Olive Oil (ton)	Olive/Olive Oil (kg)
Balıkesir	10.492.272	**153.965** (35.046 for table olive, 118.919 for olive oil)	23.792	5
Çanakkale	4.476.547	**62.581** (6.752 for table olive, 55.829 for olive oil)	11.673	4.8
Manisa	9.941.050	**195.940** (101.844 for table olive, 94.097 for olive oil)	16.178	5.8
Aydın	21.710.646	**142.958** (37.210 for table olive, 105.749 for olive oil)	20.737	5.1
Muğla	13.544.649	**63.442** (5.400 for table olive, 58.043 for olive oil)	11.609	5
Denizli	581.358	**13.293** (7.643 for table olive, 5.650 for olive oil)	1.130	5
İzmir	14.154.970	**83.468** (8.955 for table olive, 74.514 for olive oil)	14.965	5
Bursa	8.915.205	**113.913** (92.103 for table olive, 21.809 for olive oil)	4.926	4.4
Tekirdağ	1.011.471	**12.364** (10.822 for table olive, 1.542 for olive oil)	385	4
Gaziantep	3.048.000	**30.480** (6.096 for table olive, 24.384 for olive oil)	6.096	4
Adana	948.612	**14.229** (5.691 for table olive, 8.538 for olive oil)	1.707	5
Hatay	8.679.016	**130.185** (36.037 for table olive, 94.148 for olive oil)	18.829	5
Antalya	2.328.254	**23.283** (6.754 for table olive, 16.529 for olive oil)	3.306	5
Mersin	4.272.022	**42.720** (12.816 for table olive, 29.904 for olive oil)	5.980	5
Kilis	1.646.000	**16.460** (3.292 for table olive, 13.168 for olive oil)	3.292	4
Osmaniye	875.760	**13.136** (5.254 for table olive, 7.882 for olive oil)	1.576	5
Şanlıurfa	23.940	**414** (88 for table olive, 328 for olive oil)	82	4
Kahramanmaraş	735.080	**8.374** (2.161 for table olive, 6.213 for olive oil)	1.228	5.1
Mardin	235.245	**5.156** (5.156 for table olive)	0	0

Olive orchards are generally established in some parts of the Marmara, Aegean, Mediterranean, and Southeastern Anatolia regions. A large part of the table olives are produced in the Marmara region, and almost 80% of these are known as the Gemlik variety. The Ayvalık and Memecik olives used for olive oil extraction are cultivated in the Aegean region, which supplies approximately 50% of all olive production in Turkey. The best-known varieties of olives are grown in the Mediterranean and Southeast Anatolian regions. These are mostly used for olive oil extraction. The oil content in the olives also differs. The most widely known varieties are; Ayvalık (Edremit), Gemlik, Uslu, Domat, Çelebi (Eşek Zeytini) varieties in the north of Aegean Region; Memecik, Domat, Yamalak Sarısı, Erkence, Tavşanyüreği, Manzanillo varieties in South Aegean region; Gemlik, Karamürsel Su, Domat, Samanlı varieties in the Marmara region; Tavşanyüreği, Kan Çelebi, Büyük Topak Ulak (Çilli), Uslu, Gemlik varieties in Western Mediterranean; Sarı Ulak, Büyük Topak Ulak, Halhali, Gemlik, Ayvalık varieties in the Eastern Mediterranean and Nizip Yağlık, Kilis Yağlık, Halhali, Edincik Su, Tavşanyüreği varieties in the Southeastern Anatolia region. The black table olive varieties are Gemlik, Uslu and Edincik Su; whereas, the green table olive varieties and stuffed types are Domat and Yamalak Sarısı. Ayvalık (Edremit) and Memecik varieties are classified as green olives, pink scratched, and black table olives also used for olive oil. More than 80% of the olives cultivated in the Marmara area are used as black table olives [14].

Efe et al., [14] have given the list of olive tree varieties grown in the different regions of Turkey. These are as follows:

Aegean Region: Olive groves in the Aegean region extend 150–200 m inland from the shores around Büyükmenderes, Küçükmenderes, Gediz, and Bakırçay river valleys. They are cultivated in Çanakkale (Ayvacık-Küçükkuyu), Balıkesir (Edremit, Havran, Burhaniye, Gömeç, Ayvalık), Manisa, İzmir, Aydın, and Denizli provinces. The well-known varieties are "Ayvalık" (Edremit) in the vicinity of Edremit Bay and "Memecik" in İzmir, Aydın, and Muğla. The Gemlik variety is famous in the Marmara region. It is cultivated in various parts of this region under the names; Ak Zeytin, Aşıyeli, Çakır, Çekişte, Çilli, Dilmit, Erkence, Girit, Eşek (Ödemiş), Hurma Kaba, Hurma Karaca, İzmir Sofralık, Karayaprak, Kiraz, Memeli, Taşarası (Aydın), Tavşanyüreği, Sarıyaprak, Yağ, Yerli Yağlık, and Yamalak [14].

Marmara Region: An intensive cultivation is observed in the southern coasts of Marmara, especially in the provinces of Kocaeli, Yalova, Bursa, Balıkesir, Çanakkale, and Tekirdağ. Olive orchards are found especially in Mudanya, Gemlik, İznik, Erdek, and around Edincik as mono-cultivar. These orchards are mixed up with other agricultural activities near Gölcük, Karamürsel, Yeniçiftlik, Yalova, Bandırma, Marmara Island, Eceabat, Biga, Lapseki, Bozcaada, Gökçeada and Gelibolu. The most common variety found here is Gemlik followed by Edincik Su, Beyaz Yağlık, Çelebi (İznik), Çizmelik (Tekirdağ), Erdek Yağlık, Eşek Zeytini (Tekirdağ), Samanlı, Karamürsel Su, and Siyah Salamuralık [14].

Mediterranean Region: Major cultivated areas found here include the provinces of Antalya, Isparta, İçel, Adana, Osmaniye, Hatay, Kahramanmaraş, and Karaman. Hatay has the biggest share in olive cultivation, followed by Antalya, İçel, and Adana provinces. A majority of the olive groves in the region are transformed from forests however some have been established by grafting the wild olive shrubs. The most important and common variety in the region is "Halhali". It is mainly cultivated in Hatay and the production is suitable for consumption as table olives as well as oil. Çelebi (Silifke), Büyük Topak, Elmacık, Küçük Topak Ulak, Halhali (Hatay), Karamani, Sarı Haşebi, Sarı Ulak, Ulak, Saurani, Sayfi varieties are cultivated in the region [14].

Southeastern Anatolia Region: The most common provinces are Gaziantep, Kilis, Adıyaman, Şanlıurfa, Mardin, and Şırnak. The commonly cultivated olive varieties here are; Kilis Yağlık, Nizip Yağlık, Halhali (Derik), Eğriburun (Nizip), and Kan Çelebi'dir. Other ones are; Belluti, Eğriburun (Tatayn), Halhali, Çelebi, Hamza Çelebi, Hirhali Çelebi, Hursuki, İri Yuvarlak, Kalem Bezi, Mavi, Melkabazi, Tespih Çelebi, Yağ Çelebi, Yağlık Çelebi, Yağlık Sarı Zeytin, Yuvarlak Çelebi, Yuvarlak Halhali, Yün Çelebi, and Zoncuk [14].

Black Sea Region: The distribution of olive trees in this region is confined to the areas sheltered from northern winds in Zonguldak, Kastamonu, Sinop, Ordu, Samsun, Trabzon, and Artvin provinces. The main varieties found here are; Butko, Görvele, Marantelli, Patos, Otur, Sati, Samsun Salamuralık, Samsun Tuzlamalık, Samsun Kırmızı Tuzlamalık, Samsun Yağlık, Sinop No.1, Sinop No.2, Sinop No.4, Sinop No.5, Sinop No.6, and Trabzon Yağlık [14].

5. Eco-Physiological Features

In Turkey, several studies have been carried out to determine the physiological and biochemical changes in olive trees under various abiotic and biotic (disease, pests, allelopathy, etc.) stress conditions—especially abiotic conditions like drought, cold, freezing, mineral deficiency, and pollution—and find out the ways to reduce or eliminate stress [35–37]. All these factors are regarded as adverse conditions for olive cultivation and growth, because this plant is a tree unique to the Mediterranean climate [35].

5.1. The Olive Trees and Low-High Temperature Stress Studies in Turkey

The areas of the Mediterranean Basin between the latitudes of 30–45° are considered as olive production zones [38,39]. The most important stress that limits olive yield and fruit quality in this zone is low temperature [36]. The losses in yield are significant due to the effect of untimely freezing or extremely cold winter temperatures [37].

In Turkey, it has been reported that many olive trees suffered from severe frost damage, especially in the Marmara region in 1983, 1985, and 1987 [40], and many were damaged by low temperature effects in the Mudanya District of Bursa in 2010 [41].

Resistance to freezing varies from plant to plant as it occurs through a synergistic interaction of genetic structure and environmental factors [42,43]. The tree's age, developmental period, feeding status, and some other factors can also determine the extent of frost damage [44].

As with other abiotic stresses, freezing damage in plant cells is caused by increased reactive oxygen species (ROS) and oxidative stress. ROS can lead to damage of plant cells and tissues [45]. The ability of plant cells to be removed from ROS is an important indicator of environmental stress tolerance [46]. Plants with tolerance react to low temperatures by increasing the amount of enzymatic and non-enzymatic antioxidants [47]. ROS are also actively involved in the signaling and function of antioxidant systems in the cell [45]. Cansev et al. investigated the mechanism of cold tolerance by applying artificial low temperatures to the olive trees [48]. They found that by increasing cell membrane stability with daily gradual temperature reduction, a tolerance was created through complex mechanisms, including antioxidant enzyme metabolisms. These researchers also state that the olive plants gain cold resistance by increasing the secondary metabolite production and antioxidant capacity. These researchers examined the total phenolic content and antioxidant capacities after applying artificial low temperatures to the leaves of the cold acclimated (in January) and non-acclimated (in July) Gemlik variety olive [49]. Many researchers [47,48,50] have shown that low temperatures are a limiting factor in olive cultivation, but high temperatures too affect the yield and quality. High-temperature stress negatively affects olive plants by damaging leaf cell membranes and reducing leaf water content, particularly when the temperature exceeds 35 to 40 °C. These high temperatures reduce the rate of photosynthesis and stop vegetative growth [51].

According to Benlloch-González et al. [23] olive plants are very efficient in regulating water and potassium transportation when only the atmosphere surrounding the aerial part is warmed up; but, an increase in the soil temperature decreases root K^+ uptake and transport to the aerial parts results in the reduction of shoot water status and growth. Many authors have reported that K^+ starvation inhibits the effect of water stress on stomatal closure in the olives and enhances water loss through transpiration [23].

5.2. The Studies on Water Scarcity in Turkey's Olive Trees

The effects of climate change, especially global warming, have been amplified in recent years due to industrialization, overpopulation, uncontrolled urbanization, and poor agricultural practices. It is anticipated that the plant communities in the Mediterranean region will face more severe water stress in future because global climate change will increase potential evapotranspiration [52]. Water scarcity is among the most important abiotic stresses affecting sustainable agriculture [53,54]. Drought caused by a lack of water in the soil or atmosphere has important eco-physiological effects on the survival of the plant, crop productivity, and quality [55]. Lack of water also restricts mineral uptake and transport, causing nutritional disorders [56,57].

Olive trees are known as drought-resistant species because 85% of the areas where olives are cultivated in the world are not irrigated, generally 100–200 kg/da production loss occurs in these areas every year. Under arid conditions, olive trees can stop crown growth and increase photosynthesis and transpiration, thereby creating drought resistance. However, water stress during growth periods has a negative impact on production and development, resulting in significant changes in fruit quality, maturity, and fat content [24,58]. These plants grow in different environments and are known for their resistance to water stress, especially during summer, when they face scarce precipitation and high temperatures [59,60]. The response to water stress has been shown to be quite unpredictable, because of high intraspecific genetic diversity [61]. Although these plants are considered as drought-resistant, the number of irrigated cultivars is increasing, and balance between irrigation and productivity is a major issue because water is a scarce commodity in most olive growing countries [60,62]. Dell'Amico et al. [63] have reported no decrease in the fruit volume of table olives in low water stress conditions under minimum values of −1.8 MPa. The decrease in the yield of fruit has been recorded with values around −3.5 MPa during pit hardening [64,65]. However, a reduction in fruit growth has been found at values higher than −3.0 MPa [66,67].

There are several protective mechanisms that are found in olive plants against drought, heat, and high irradiation levels; but the extreme water-limited habitats as a result of climate change could lead to negative results on mineral uptake, carbon assimilation, canopy dimension, oxidative susceptibility, phenology, growth and reproduction processes and, finally on crop yield [68]. The water requirements of annual crops in the Mediterranean olive-growing areas range extensively due to the diverse microclimates, soils, and rainfall patterns. In addition, though olive trees are accepted as to be resistant to drought, irrigation does improve the physiological performance of these trees, together with higher stomatal conductance, better water status, photosynthetic rates, as well as the crop yield [68]. The irrigation has also been shown to have negative effects on oil yield and quality. The oil percentage in the fruit is reported to decrease as a function of increased amounts of water applied, which affects the total amount of phenolic compounds [68,69]. The phenolic compounds containing hydroxyl groups are known to be synthesized in response to stress conditions [70]. An increase in the amount of secondary metabolites (such as phenolic compounds) in plants against water stress can be interpreted as the plant's response to stress [71]. These compounds are also thought to be the compounds responsible for antioxidant activity [72]. The most important phenolic compounds synthesized in olive plants are tyrosol, oleuropein, hydroxytyrosol, propanoic acid, coumaric acid, flavonoids, luteolin, and apigenin [73,74]. The number and concentration of phenolic compounds in olives shows variability depending on the ecology and climate of the growing area [75,76], and agricultural and cultural practices such as irrigation [77], harvesting, and crop processing [78,79].

In Turkey, the irrigation of olive plantations is done by canal waters, but for future safety and water shortage problems studies are investigating the potential uses of reclaimed waters and the effect of such waters on different varieties of olive trees [80–84]. Their investigations have revealed that wastewater treated appropriately could serve as an alternative irrigation water source for olive trees in water scarcity areas. An increased concentration of sodium, phosphorus, potassium, and nitrogen in soils irrigated with treated wastewater has been reported [84]. The quantity of water used in the irrigation of olive plants affects the yield of fruit, the oil content, as well as the olive oil quality [85–89]. Even the use of moderate saline water for irrigation leads to an increase in fruit productivity and oil yield when compared to high salinity and control waters [90].

Highly saline irrigation waters generally reduce the yield of olives, the weight of the fruit, and the oil content, and increase the moisture content of fruit [91]. This is the reason that the olive tree is accepted as a moderately salt-tolerant plant [89,92]. Any increase in the Na content following irrigation with treated wastewater leads to a decrease in the K content, which is of common occurrence and widely reported in these plants [93–96].

The study conducted using irrigated and non-irrigated Kilis Yaglik and Gemlik olive varieties also revealed that more flavanol is synthesized in leaves under non-irrigated conditions; the irrigation and cultivar determine the flavanol content (1.04 mg/g) in olive leaves [97].

5.3. Heavy Metal Pollution and Olive Trees—Case Study from Turkey

Heavy metal pollution is one of the major abiotic stresses which causes serious environmental and health problems [98]. Tuna et al. [99] have investigated the heavy metal content of olive leaves in the vicinity of three thermal power plants. They analyzed these for cadmium, cobalt, chromium, copper, iron, manganese, nickel, lead, and zinc. The average concentrations reported by these workers were 0.3, 2.2, 2.0, 6.9, 242, 42, 3.9, 8.3, and 22 mg/kg, respectively. These findings were significantly higher than non-polluted control sites. They also reported that olive tree leaves can be evaluated for biomonitoring and assessment of environmental pollution in the Mediterranean regions that are full of olive orchards; especially Aydın province [99]. Sahan and Basoglu [100] examined the accumulation of lead, cadmium, iron, copper, and zinc in the olives collected from areas near high traffic roads and industrial areas. They pointed out that high concentrations of copper, zinc and lead may in fact be due to the industrial activities and heavy traffic. Zincircioğlu [101] has reported that the amount of copper and zinc is very high in the Akhisar district of Manisa in some garden soils where olive groves are found but the amounts of cadmium, lead and arsenic were below the pollution limits. Ünal et al. [102] have determined chromium, lead, zinc, and copper concentrations in their studies conducted on olive leaves collected from a factory in Izmir Kemalpasa industrial zone, using three different points on the highway, and a clean area as control, which was 7 km away from the Kemalpasa industrial zone and highway. Their study found concentrations were high compared to the control group, but copper concentrations were low at the cement factory and roadside point.

In a study investigating the effects of dust emulsions on the growth and yield of trees in the olive plantations adjacent to a cement plant, Sheikh et al. [103] have reported that the leaves of olive trees in the polluted area were covered with cement cover, but there were no visible signs of injury. However, polluted trees showed a decrease in growth (50%) and fruit yield (55.6%) compared to non-polluted ones. This reduction has been explained as being due to the shading effect of cement cover on the leaves and the changes that cement plant wastewater creates in the soil.

The heavy metal pollution in 64 orchards with cv. Gemlik table olive trees has been investigated by Gürel and Başar [104] in the towns of Iznik, Orhangazi, Gemlik, Mudanya, and Nilüfer of Bursa, Turkey. Total amounts of nickel and chromium have been reported as being quite high in the soils. Cadmium, cobalt, and copper concentrations are reported as being slightly greater than the permissible ranges (Cu $\leq$ 100 mg/kg, Co $\leq$ 50 mg/kg and Cd $\leq$ 3 mg/kg) in some of the soils analyzed. The concentrations in general were not reported as being at toxic levels in different parts of the plant. An accumulation of copper in the soil, leaf, and fruit samples has been reported by Gürel and Başar [104]. The reason being a mixture of copper oxychloride and copper sulfate^{+} slaked lime known as Bordeaux mixture is widely used as a pesticide in Bursa [104].

5.4. Olive Tree Diseases and Pests in Turkey

The most important causes of olive fruit losses in these trees are due to diseases, pests, and weeds. They cause nearly 30% damage, out of which 15% is due to pests [105]. Unfortunately, harmful and natural enemy populations have increased with an increase in olive growing areas in Turkey—144 harmful species have been identified [106]. In Turkey, Olive branch cancer (*Pseudomonas savastanoi* pv. Savastanoi), Verticillium Wilt *(Verticillium dahliae)*, Peacock Spot Disease *(Spilocaea oleaginea = Cycloconium oleaginum*), Anthracnose (*Colletotrichum gloeosporioides* (syn. *Gloeosporium olivarum*)) diseases, and Olive fruit fly (*Bactrocera oleae*), Olive moth (*Prays oleae*), Olive shelled louse (*Parlatoria oleae*), Olive black scale (*Saissetia oleae*), Olive leaf moth (*Palpita unionalis*), Olive cottony scale (*Philippia oleae*), Mealybug (*Euphyllura straminea*), Bark beetle (*Phloeotribus scarabaeoides*), Olive gall midges (*Lasioptera berlesiana*), Plant bug (*Calocoris trivialis)*, *Agalmatium flavescens*, *Coenorrhinus cribripennis* pests are primary biotic stress factors that cause major economic losses. Subsequent significant olive pests are the Leopard moth (*Zeuzera pyrina*), Olive stem midge (*Resseliella oleisuga*), Bark beetle (*Hylesinus oleiperda*), Mealybug (*Pollinia pollini*), Olive leaf moth (*Palpita unionalis*), Olive thrips (*Liothrips oleae*), and Olive leaf wart (*Dasineura oleae*) [107]. The olive fruit fly is the main pest among all olive pests [108].

The olive fly [*Bactrocera oleae* (Gmelin) (Diptera: Tephritidae)] causes significant damage in olives and is accepted as the main pest in Turkey as well as in other countries where olive groves are distributed [109]. It is a pest for all olive trees, but the damage is more extensive in table olives [109,110].

Verticillium dahliae Kleb causes partial drying of branches and/or complete drying of trees in all countries where olive cultivation is done. The wilt resulting from this fungus is regarded as the most important disease of olive trees [111].

In Turkey, "Sinop No. 1", "Eğriburun Nizip", "Erkence", "Eğriburun Tatayn", "Girit Zeytini", and "Marantelli" were highly resistant, 11 domestic cultivars ("Sarı Habeşi", "Yağlık Çelebi", "Zoncuk", "Dilmit", "Şam", "Hurma Karaca", "Erdek Yağlık", "Melkabazı", "Yün Çelebi", "Kan Çelebi", and "Siyah Salamuralık"), two foreign cultivars ("Arbequina" and "Frantoio") and one wild clonal rootstock ("D36") are resistant; ten domestic cultivars ("Ak Zeytin", "Yağ Çelebi", "Saurani", "Butko", "Gemlik", "Otur", "Yağ Zeytini", "Belluti", "Sinop No. 2", and "Samanlı"), three foreign cultivars ("Leccino", "Chemlali", and "Ascolana") and one wild clonal rootstock ("D9") are moderately susceptible to *Verticillium dahliae* [112].

Sensitivity and tolerance of some olive varieties in Turkey: Kefalonya and Ithaca are sensitive to olive fly; Pikoual is resistant to olive anthracnose, but susceptible to olive fly, olive moth and olive worm, ringed spot and *Verticillium* wilt; Ayvalık is partly cold resistant, sensitive to *Verticillum* wilt; Uslu is sensitive to *Verticillium* wilt; Gemlik is partly cold resistant, moderately sensitive to *Verticullum* wilt; Domat and Memecik are moderately sensitive to *Verticillium* wilt; and Eşek zeytini (Ödemiş) is very resistant to the *Verticillium* wilt [111].

5.5. Olive Waste Management in Turkey

During olive oil production, two types of waste are formed—olive-mill wastewater (OMW) and olive pomace. Generally, the methods applied for the disposal of this waste in Turkey include; direct discharge into sewerage, evaporation in lagoons, use in agricultural irrigation and establishment of individual expansion of factory facilities [113]. According to 2015 statistics, from a total of 1,700,000 tons of olives produced, 1,300,000 tons of olives have been processed for olive oils, and about 175,000 tons of olive oil produced [114]. According to TUIK [114] the average amount of olives processed has been 1,030,956 tons and a total of 1,909,800 tons of waste has been produced in one year, including 650,000 tons of olive pomace and 1,259,800 tons of olive-mill wastewater [114].

Turkey approximately generates 650,000 tons per year of olive pomace from its olive oil production, whereas global production is around 2 million tons per year [115,116]. Solid olive pomace is reported to possess a good potential for use as fuel, with high organic content, a heating value (≈22 MJ/kg) close to that of lignite [117], low sulfur content (approximately 1.5%), and high energy density per unit volume. The fuel pellets made of oil pomace can also be used in industrial boilers and domestic boilers following the removal of any residue oil via hexane extraction [118]. A report prepared lately suggests that Turkey has a 50-MW potential of olive-pomace-based biofuel [115,119]. However, it can be evaluated for other purposes as well, such as in the cosmetics industry [120], functional foods [121], biodiesel production [122], adsorbent production [123], the extraction of phenolic compounds [124], the production of fodder additives upon the removal of olive seeds [125], and composting [115,126].

Olive-mill Wastewater (OMW) is the liquid waste resulting from the olive oil extraction process [127,128]. In Mediterranean olive oil producing countries, annual OMW generation varies between 7 × 10^6 and 30 × 10^6 m^3 [128,129]. The OMW is a significant source of environmental pollution in all olive-oil-producing countries. The OMW is rich in polyphenols, organic matter, salt, and low molecular weight organic acids [128,130,131]. The olive pomace or olive cake and OMW has serious impacts on the environment due to odor, impenetrable film (causing negative impact for oxygen transfer), discoloring of natural waters, and toxicity as being a great threat for aquatic life [115,132]. If plant roots are in a long contact with OMW, the phytotoxic substances in OMW affect the structure of the root membrane and modify its functions (including metabolic efficiency and stability) [128]. Much concern is being shown regarding this and attempts are being made for an effective treatment and safe disposal of OMW in the environment [128,133]. OMW, also known as "black water", is produced from three-phase olive mills. It is characterized in the form of a brown-black color, with a peculiar odor, acidic pH, high electrical conductivity, and a very complex redox system. The most important point is that this waste presents high values for most pollution parameters, and also contains large amounts of mineral nutrients, suspended solids, and high concentrations of aromatic organic compounds, such as; simple phenols and polyphenols [134,135]. However, the presence of a high amount of organic compounds and plant nutrients can also qualify it as a low-cost fertigation source. This could be used particularly in Mediterranean countries characterized by water-deficient environments and soils poor in organic matter [134,135]. Ahmali et al. [136] have reported that a mixture of OMW and urban wastewater has good fertilizer potential even after treatment by constructed wetland systems which ensure a high reduction of toxic phenolic compounds.

Several authors have pointed out that OMW disposal in nature causes serious environmental problems due to its antibacterial effects and phytotoxicity [128,133,137–140]. However, in spite of all these investigations and suggestions, there is few data available on the effects on plant photosynthesis [128,138,139,141–143]. OMW treatment in general leads to a reduction in fresh and dry biomass production, as well as net photosynthetic rate and water use efficiency. The photosynthetic activity in this connection has been studied in different plants such as tomato, spearmint, peppermint, chickpea, lettuce, maize, spinach, and wheat [128,134,138,139,144–150]. The plant roots have been noted to be more sensitive to phytotoxicity than shoots. The responses to OMW treatment also vary depending on plant species and developmental stage [128].

Ergül et al. [151] have reported that adapted *Trametes versicolor* FPRL 28A INI can treat OMW efficiently without any dilution or pretreatment or without any addition of nutrients. Ergül et al. [152] have suggested that through sequential batch applications starting with adapted *Trametes versicolor* FPRL 28A INI and consecutive treatment with *Funalia trogii*, a significant amount of total phenolics can be effectively removed when compared to co-culture applications. According to Pekin et al. [153] there is a large number of olive mills on the Aegean coast of Turkey and the total phenolics in their effluents are less than 3 g L^{-1}. They have stressed that sludges from industrial wastewater treatment plants in the region could be used efficiently to biodegrade these effluents after simple dilution, while producing biogas [153]. Several investigations have been undertaken in Turkey on olive oil waste utilization, mostly regarding olive pomace—for practical purposes—with the utilization as fuel being the most common purpose [115,154,155].

6. Olive Ingredients

Olive fruit and its oil are the most important components of traditional Mediterranean nutrition. Throughout history, olives have been associated with a healthy and long life. One of the reasons why olive is used as both food and medicine is its perfect ingredient composition. The composition of the fruit varies according to the cultivar, degree of maturity, harvest time, and growing and processing conditions. The fruit consists of approximately 50% water, 22% fat, 1.6% protein, 3% sugar, 5.8% cellulose, 1.5% mineral substance, 2% polyphenols, 0.7% organic acid and its salts, 0.8% pectic substances and others [156]. It is one of the fruits with the richest fat and fatty acid composition. Fat content increases as the fruit ripens [157,158], the highest proportion of fatty acids belongs to oleic acid, constituting 70–80% [157,158]. Oleic acid is a monounsaturated fatty acid, since it is not prone to oxidation and it contributes to antioxidant effect and stability [159]. The amount of oleic acid in fruit composition is followed by palmitic acid, linoleic acid, stearic acid, palmitoleic acid, linolenic acid, and myristic acid [157,160]. Since linoleic and linolenic acids cannot be synthesized in the human body, they are in the group of essential fatty acids (EFA) and must be taken from diet. In addition, the consumption of monounsaturated fatty acids (oleic acid, linoleic acid) causes a decrease in plasma LDL (low-density lipoprotein) levels and an increase in HDL (high-density lipoprotein) levels, thereby lowering the risk of cancer and heart diseases [161]. This is one of the reasons why the Mediterranean nutrition model is so popular [162]. Olive fruit taken with a daily diet provide an essential fatty acid supplement and have a positive effect on blood cholesterol levels. Some of the olive proteins are water-soluble, some are insoluble. For this reason, although the protein content of processed fruit decreases, it does not lose its nutritional value due to the amino acids it contains [163].

The mineral substances of olives are important for their toxicological and medicinal effects. Metal content varies during ripening, but does not exceed toxic limits. Olive fruit contains mineral substances like; phosphorus, potassium, magnesium, and iron [163]. It has been reported that the highest mineral amount in olive is magnesium and the lowest is cobalt [164]. The former is one of the vital minerals for the human body, as it plays an important role in intercellular communication and many enzyme activations. Since it is not produced in the body, it has to be taken via diet. Due to unhealthy eating habits, magnesium deficiency is common today. For this reason, foods like olive fruit with high magnesium content have increased in importance. The compounds responsible for the medicinal effects of olive fruit can be listed as mainly phenolic compounds, hydroxycinnamic acid derivatives, vitamins, hydrocarbons, and sterols.

In addition to the information already given, fresh olive leaves are rich in oleuropein and hydroxytyrosol. They also contain polyphenols and flavonoids such as luteolin, rutin, caffeic acid, catechin, and apigenin. In olive oil and olive leaf extract we also find elenolic acid. Olive leaf extract shows anti-inflammatory, antioxidant effects and has positive effects on diabetes as well as cardiovascular diseases. The tea prepared from the leaf is generally safe even at high doses. The olive fruit and oil together are well known as antioxidants, and beneficial for dry skin because of the fatty acid content, some of which comes from the emollient squalene. Olive oil also contains essential fatty acids good for dry skin, including oleic, palmitic, and linoleic acids and phenolic compounds which provide antioxidant benefits [165].

6.1. Phenolics

The phenolic components of olives vary according to the cultivars, maturity, harvest time, and growing conditions. Phenolic substances are the main components of olives and are responsible for their medicinal values [166]. These are secondary metabolites synthesized during aromatic amino acid metabolism in plants [167]. They particularly affect the color, taste, and stability of fruit and vegetables. Since they are browned by oxidation, they make the desired color change in processed olive technology [168]. Phenolic acids, phenolic alcohols, flavonoids, and secoiridoids are the phenolic components of olive. Phenolic substances protect plants against environmental stress conditions and pathogens, and play an important role in physiological and biochemical events. Although the phenol content and composition of phenolic compounds in olive fruit depends on fruit maturity and cultivar, it has been reported that it lies between 1–3% [169]. There is a close relationship between phenol content and the altitude at which the olive trees are growing—the amount is reported to decrease in olives cultivated at high altitudes [170].

Phenolic acids are the components with a carboxyl group attached to the phenol ring, and are divided into two groups as hydroxy benzoic and hydroxycinamic acids. Olive phenolic acids are caffeic acid, coumaric acid, ferulic acid, vanilic acid, and gallic acid [171]. In addition to its antioxidant effects, phenolic acids are also effective on the color of olive fruit and sensory characteristics [172]. The antioxidant activities of phenolic acids and their esters depends on the number of hydroxyl groups in their structure. As the number increases, antioxidant activity becomes stronger [171].

Phenolic alcohols in olive are tyrosol and hydroxytyrosol (Figure 3). The amount of tyrosol varies depending on the cultivars of olive fruit. Some researchers have suggested that hydroxytyrosol is the degradation product of oleuropein and increases as the concentration of oleuropein in the fruit decreases during ripening stages [173]. The phenolic alcohols are among the powerful natural antioxidants. High antioxidant activity of hydroxytyrosol depends on o-dihydroxyphenyl. It is also reported that hydroxytyrosol provides additional antioxidant protection by strengthening endogenous defense systems by activating different cellular signaling pathways [174].

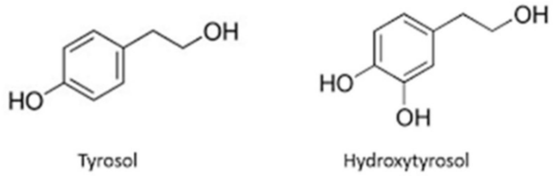

Figure 3. Chemical structures of two phenolic alcohol compounds isolated from olive fruit (modified from Hashmi et al. [1]).

Flavonoids are low molecular weight polyphenolic compounds found in many plants. They are known as substances responsible for pigments in plants. Many bioactivities have been detected by in vivo, in vitro tests and epidemiological studies have been reported. Olive flavonoids include flavones (Luteolin-7-glycoside, Luteolin-5-glycoside, Apigenin-7-glycoside) anthocyanins (Cyanidine-3-glycoside, Cyanidine-3-rutinocyte, Cyanidine-3-caffeglycoside, Cyanidine-3-cafferutinocyte) and flavonols (Quercetin-3-routine) [175,176]. Delphinidin glycoside (Delfinidin-3-ramnoglycoside-7-xylocyte) has also been detected in some olive species [177]. All flavonoids show antioxidant activity due to the 3–4 dihydroxy configuration and are medicinally important, especially having an effect on the color and stability of the fruit.

Phenolic acids, phenolic alcohols, and flavonoids are found in many plants belonging to different families, but the secoiridoids are found only in the Oleaceae family. The substances grouped under the class of secoiridoids are distinguished from others in that they contain elenolic acid or elenolic acid derivatives [167]. The ingredients of olive in the secoiridoid structure are oleuropein, demetiloleuropein, ligstroside, and nüzhenide (Figure 4) [178]. The main component of olive is oleuropein, which is in the structure of secoiridoid. It is the glucosidic ester of elenolic acid and hydroxytrosol, found in the fruit and all tissues, giving the olive its unique taste, and is not found in any other fruit [165,179]. The water soluble oleuropein is found in high amounts in unprocessed olives, mainly in unripe fruit, the quantities exceed 140 mg/g and it has several beneficial effects on health [165,179]. Its amount decreases during fruit ripening due to enzymatic and chemical reactions, however the amount of hydroxytyrosol increases [180]. The demetil oleuropein is structurally similar to oleuropein which increases during the blackening of olives but contains tyrosol instead of hydroxytyrosol [181]. Another substance in the secoiridoid structure is ligstroside, found in high amounts in young olives, but its amount decreases with maturity. Oleuropein, demethyloleuropein, and ligstroside can be found in the flesh, skin, and seed of the olive fruit, while nüzhenide is only found in the seed [176]. It has beneficial effects on health and is one of the reasons why unprocessed olive seeds became important as pharmaceutical raw materials. A hydroxycinnamic acid derivative verbascoside is formed by binding glucose and rhamnose to the hydroxytrosol and hydroxycinnamic acid molecule [182]. Vinha et al. [176] have observed that the amount of verbascoside is low in the species in which oleuropein amounts are high and in the early stages of fruit.

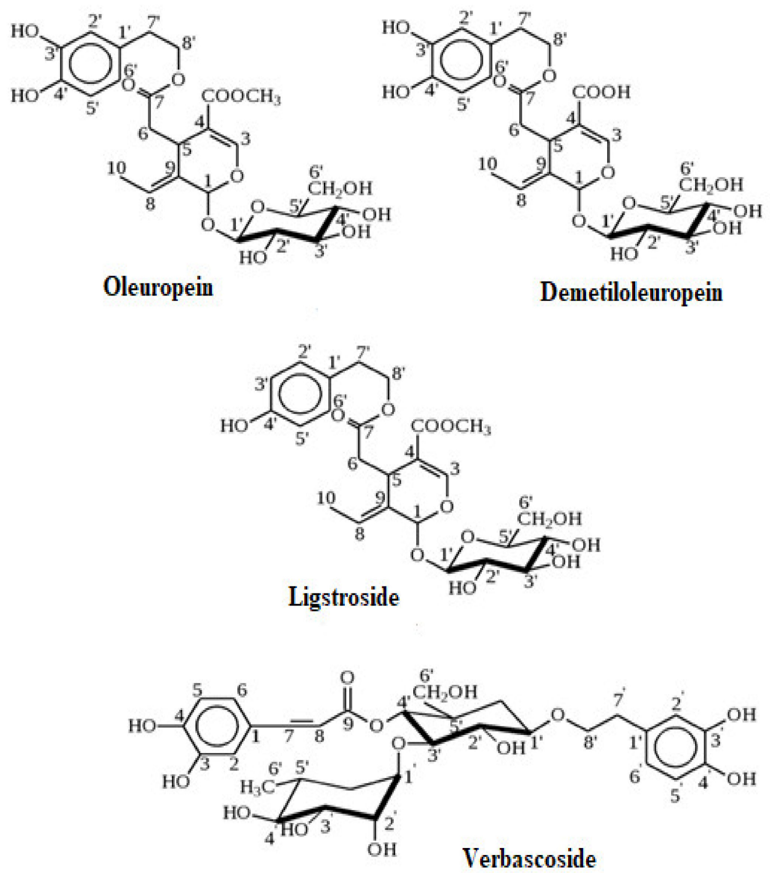

Figure 4. Chemical structures of some of the secoiridoid compounds isolated from olive fruit (modified from Hashmi et al. [1]).

Data published by Sun et al. [183], has enlightened the fact that oleuropein, a polyphenolic compound in olive oil and the leaves of the olive tree, has several health benefits. Oleuropein and its metabolite, hydroxytyrosol, are reported to show powerful antioxidant activity, probably responsible for the anti-inflammatory as well as disease-fighting activities of olive oil. It is well known for its blood-pressure-lowering effect. It has been shown to have an ability to protect the hypothalamus from oxidative stress, and these effects are clear if supplementation takes place either before or after the onset of hypertension. Other findings have revealed it to be cardioprotective, anti-inflammatory, antioxidant, anti-cancer, anti-angiogenic and neuroprotective, and reduces oxidative damage in a region of the brain that is most affected by neurodegeneration in Parkinson's disease. It also prevents the toxic aggregation of both amyloid beta and tau, proteins involved in Alzheimer's disease, a potent inhibitor of human epidermal growth factor receptor 2 (a protein that is frequently over-expressed in breast cancer cells), and has a chemo-preventative effect on colitis-associated colorectal cancer. Some reports implicate autophagy and the inhibition of mammalian target of rapamycin (mTOR) through the protective effects of oleuropein, suggesting that protective effects from various disorders occur via shared molecular mechanisms. However, olive oil may exacerbate low blood pressure in individuals who already have low blood pressure, could interact with other pharmaceutical drugs designed to lower blood pressure or regulate diabetes. The benefits of oleuropein suggest that future studies are needed for a more comprehensive understanding involving the diverse protective effects of oleuropein [183].

Polyphenols are well known for their health promoting features. These are found in different parts of plant—including olive oil—but olive oil also contains some unique phenolic compounds, found only during the malaxation process. Yorulmaz et al. [184] have studied 101 samples from 18 cultivars during two crop years from the west, south and south-east regions of Turkey. They have reported the main phenolics of Turkish olives as; tyrosol, oleuropein, p-coumaric acid, verbascoside, luteolin 7-O-glucoside, rutin, trans cinnamic acid, luteolin, apigenin, cyanidin 3-O-glucoside, and cyanidin 3-O-rutinoside [184]. In general, even though higher amounts of oleuropein and trans cinnamic acid have been reported, luteolin is the predominant one in almost all oil samples. The values in Southeast Anatolian oils are lower than other areas. In the varieties like Uslu, Memecik, Gemlik, Edremit, Erkence, Mersin yaglik, Saurani, Antalya yaglik, Nizip yaglik, Kilis yaglik, Domat, Celebi, Kalamata, Sari ulak, Halhali, Sarı hasebi, Girit, and Gulumbe, the phenolic compounds found are listed as; tyrosol, oleuropein, p-coumaric acid, verbascoside, luteolin 7-O-glucoside, rutin, trans cinnamic acid, luteolin, apigenin, cyanidin 3-O-glucoside, and cyanidin 3-O-rutinoside. Oleuropein and trans cinnamic acid are present in higher amounts among all phenolics [184].

6.2. Vitamins

Olive fruit contains fat-soluble vitamin E. It is divided into two groups as tocopherols and tocotrienols. Both groups have four isomers (α, β, γ, δ). The most common tocopherol in olive oil is α-tocopherol which is the most active form [185]. Of tocopherol content, 95% is α-tocopherol, 2% is others [186]. α-tocopherol is highly resistant to oxidative degradation and has a strong antioxidant effect. High levels of polyunsaturated fatty acids are required for the absorption of vitamin E into the body but the amount of polyunsaturated fatty acids in olives is low. Even with relatively low concentrations, α-tocopherol taken with daily olive consumption protects the body against oxidative damage and lipid peroxidation [187].

6.3. Hydrocarbons and Sterols

Squalene is the main compound in the hydrocarbon structure in olive (Figure 5). It is triterpenic and is an intermediate product in cholesterol biosynthesis [188]. Although it is common throughout the body, it is found in high levels in skin sebum [189].

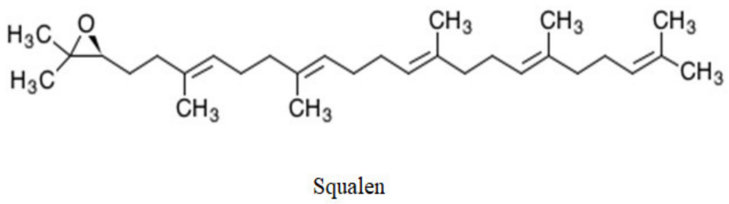

Figure 5. Chemical structure of squalene isolated from olive fruit (modified from Hashmi et al. [1]).

Olive phytosterols are betasitosterol (96%), campesterol (3%) and stigmasterol (1%) (Figure 6). Phytosterols compete with cholesterol and inhibit cholesterol reuptake from the intestines thus having a cholesterol-lowering effect [190].

Sterols constitute the majority of the unsaponifiable fraction in olive oil, the main sterols being β-sitosterol, Δ(5) -avenasterol, campesterol, and stigmasterol, most of them showing high variability. The extracts are reported to contain much higher concentrations of olive polyphenol hydroxytyrosol than olive oil or olives. In industrial product "hytolive", a 100 mg dose is reported to contain the hydroxytyrosol equivalent of 500 mL of extra virgin olive oil. Total sterols in olive oils range from 358 mg/kg in cv. Sarı Hasebi to 1092.33 mg/kg in cv. Halhalı [191].

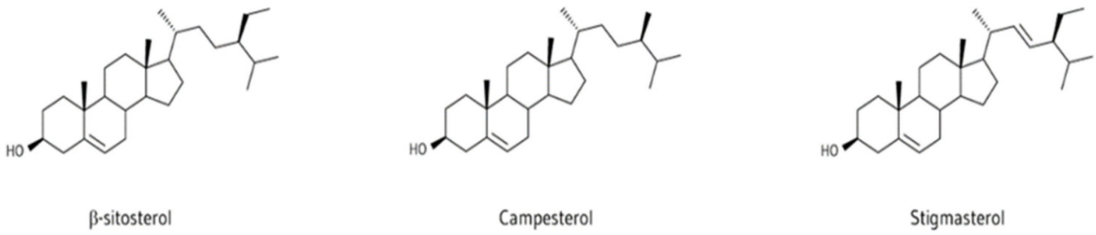

Figure 6. Chemical structures of some of the sterol compounds isolated from olive fruit (modified from Hashmi et al. [1]).

Volatile compounds such as ethers, aliphatic, and aromatic hydrocarbons, alcohols, phenolic compounds, aldehydes, ketones, and fatty acids are the main flavor components of olives [156,192]. Flavor components play an important role in determining the quality of olives. Flavor components are formed as a result of the controlled oxidation of oils. The volatile ingredient content of olives varies depending on the activity of the lipoxygenase enzyme in the fruit. Volatile compounds reach the highest concentration in the period when the olive is half black and full black in color. In addition, volatile components undergo changes during storage [193]. It has been stated that the amount of aldehydes and esters in particular decreases during ripening [193]. Most flavor compounds have high antibacterial effects [194]. They protect the olive plant against many fungi, bacteria, and pathogen attacks [194]. Due to these ingredients, olives are one of the trees with the highest natural resistance and are even called “immortal trees”.

The phytochemical research carried out on *O. europaea* has led to the isolation of several compounds cited above as well as a few other types of secondary metabolites which are present in almost all parts of the olive tree [1,195–198]. The therapeutic utilities of *O. europaea* indicate its use in traditional medicine as well. It has been known to reduce blood sugar, cholesterol, and uric acid; has been used to treat diabetes, hypertension, inflammation, diarrhea, respiratory and urinary tract infections, stomach and intestinal diseases, asthma, hemorrhoids, rheumatism, and has been used as a laxative, mouth cleanser, and as a vasodilator in various countries [1,199–201]. The ethnomedical uses of *O. europaea* in the treatment of different diseases and infectious disorders of bacterial, fungal, and viral origin have been validated in several experimental studies [1,195,196,202]. Currently it is thought that the olive leaves left in boiled water for 10 min and consumed as tea has a protective impact against the current COVID-19 outbreak.

7. Conclusions

Turkey is a country heavily affected by global warming [203]. Global warming and rising carbon dioxide levels will affect olive trees directly as well as indirectly by changing the diversity, frequency, and life cycles of insects and pests [204]. Olive cultivation in Turkey is usually carried out on slopes or very difficult terrain, and such plants will suffer from high temperatures and lack of water following the future scenarios of global warming [205]. Olive trees growing especially in arid and semi-arid regions too will be affected in particular by global climate change and water stress [206]. If agricultural production in general goes down, this will have serious consequences on the economies of olive producing countries as well.

Olive fruit harvesting is a difficult task if the trees are tall, as the production costs increase. The harvesting of smaller trees is done by hand, stick, or mechanical vibrator. The average age for the olive trees in Turkey is high (around 75 years), they are tall, and the maintenance of suitable varieties in suitable areas is necessary to increase the yield. There are also non-native olive varieties cultivated in Turkey. Italy tops the list among olive producing countries with highest number of registered olive varieties. The non-native varieties to be cultivated in Turkey should be tried according to the ecological conditions of the area. The adaptability should be tested, which is an important step also from an economical point of view [14].

The ecological conditions of the soil and climate in Turkey are highly suitable for olive production. Both oil and table olives possess a great economic input. However, the sector is directly affected by developmental problems. The raw material production is strongly controlled by the oil industry. Major problems faced at present are related to oil producers who are highly important in the development of this sector. An evaluation of the problems of olive growers shows that they face a serious situation related to the high input prices, low demand, low government support, together with the lack of information on latest research developments on cultivation techniques.

In all 119 olive cultivars are registered in Turkey. There are nearly 180 million trees and 2 million tons of olives are produced annually together with 190.000 tons of olive oil and 410.000 tons of table olives. Export of olive oil is 55.000 tons, export of green and black table olives is 70.000 tons [34,114]. However, the olive production is facing problems like harvesting methods, long waiting periods for oil squeezing from ripe olives, deficiencies in storage systems, harvesting with poles (which increases the periodicity and leads to 70% loss in productivity), and also government payments, because help varies with the types of olives cultivated [34].

Much encouragement has been given for the "Gemlik" variety cultivation with higher payments made; which has lead towards the cultivation of this variety outside its natural areas. The plantation of varieties outside their ecological niches proves detrimental for some varieties, which ends up with a non-profitable production. The insufficient watering and distribution of olive trees on slopy areas is also less effective and the plantations on slopes suffer from erosion [14,25].

The solutions for all of these problems are; (**a**) mechanical harvesting to bring down losses due to periodicity; (**b**) modernization of maintenance problems; (**c**) sapling production on the basis of varieties in a balanced way; (**d**) importance should be given to the regional adaptational features as well as regional geographical characteristics; (**e**) the preference should be given to the cultivation of varieties in their own geographical areas; (**f**) fertilizer applications should be done following full soil analysis of the plantation areas; and (**g**) a drip irrigation system should be preferred which proves to be healthier.

Our suggestion is that the farmers need to be supported, they should be informed yearly on the latest developments in harvesting, maintenance, storage and organizational matters. Their net income and productivity should increase which can be possible only through an efficient marketing system of organic products. If the right precautions and knowledge transfer is passed on to the farmers, they can supply an adequate quantity and quality of olive fruit for oil production. The olive oil industry can accordingly make major contributions to the economy of the country with a high added value.

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