HortScience 59(4):498–502. 2024. https://doi.org/10.21273/HORTSCI17653-23

‘Sultana’: A New Olive Cultivar for Hedgerow Orchards

Pedro Valverde
Department of Agricultural, Food and Environmental Sciences, Marche Polytechnic University, Ancona, Italy; and Department of Agronomy (Excellence Unit “María de Maeztu” 2020–23), ETSIAM, University of Córdoba, Córdoba, Spain

Concepción Muñoz, Diego Barranco, and Carlos Trapero
Department of Agronomy (Excellence Unit “María de Maeztu” 2020–23), ETSIAM, University of Córdoba, Córdoba, Spain

Keywords. comparative trial, cultivar description, high productivity, low vigor, new cultivar, olive breeding, olive oil

In the late 1990s, a superhigh density (SHD) system was developed in Spain for olive tree cultivation, and the system quickly spread to other olive-growing areas, now covering more than 400,000 ha worldwide. This new system is characterized by a large number of plants per hectare (>1500), and the canopy can be mechanically harvested by straddle harvesters as a hedgerow. SHD orchards require low-vigor cultivars; however, this characteristic is infrequent in olive germplasm (Connor et al. 2014; Díez et al. 2016). Currently, two traditional cultivars, Arbequina and Arbosana, which are low-vigor and highly productive, are present in most SHD olive orchards worldwide. Therefore, developing alternative olive cultivars for SHD orchards is needed for the olive-growing sector. The Olive Breeding Program of the University of Córdoba, Spain, was initiated in 1991 with the aim of developing new olive cultivars to improve the main agronomical characteristics, such as oil content (Rallo et al. 2018), and other traits, such as disease resistance (Valverde et al. 2023). However, the concomitant development of SHD orchards has made the development of low-vigor and highly productive cultivars necessary for these and later breeding programs. As a result, cultivars with such characteristics as ‘Sikitita’ (‘Picual’ × ‘Arbequina’) (Rallo et al. 2008) or ‘Lecciana’ (‘Arbosana’ × ‘Leccino’) (Camposeo et al. 2021) were developed.

Received for publication 23 Dec 2023. Accepted for publication 22 Jan 2024.
Published online 5 Mar 2024.
We thank BALAM Agriculture S.L. and especially its R&D department for the work they conducted. We also thank those responsible for allowing experiments to be developed on their commercial farms, especially Cándido Medina (Espeluy trial) and Pedro García (Utrera and Jédula trials). Additionally, we acknolwedge the work done by José Antonio Torres Aguilera and his team for characterizing the olive oil of ‘Sultana’.
P.V. is the corresponding author. E-mail: p.valverde@staff.univpm.it or pedrovalverde@uco.es.

In Mar 2022, the University of Córdoba registered the new olive ‘Sultana’. This new olive was explicitly developed to be the cultivar of choice for SHD olive systems. ‘Sultana’ comes from a directed crossing performed in Spring 2013 between the cultivars Arbosana and Sikitita, used as female and male genitors, respectively. To corroborate the crossing and identify the new cultivar by DNA markers, paternity tests were performed using 12 microsatellite (SSR) markers (Table 1) commonly used in olive germplasm identification (Trujillo et al. 2014).

‘Sultana’ and other seedlings were planted in 2014 and then evaluated under field conditions until 2020. The experimental plot was located on the experimental farm of the University of Córdoba, Spain. The following traits were monitored: tree height and width, trunk diameter, flowering time, flower load, fruit load, and oil content. ‘Sultana’ was precocious, flowering for the first time in Spring 2016; only 8.1% of the seedlings of the same cohort flowered 2 years after planting. ‘Sultana’ was selected and clonally propagated in Winter 2018 according to the data from the three previous harvests.

In Aug 2019, the first trial with blocks and repetitions to compare the performance of ‘Sultana’ against ‘Arbequina’ and ‘Arbosana’ was established. The trial was located at the “El Valenciano” experimental field owned by the Spanish company BALAM Agriculture S.L., the main collaborator in the development of the Sultana cultivar. ‘Sultana’ was planted and evaluated under commercial conditions both on the “El Valenciano” experimental farm and on the farms of other collaborators. In all the trials in which the ‘Sultana’ olive was evaluated, the plants were established under hedgerow conditions (SHD).

Morphological Description

The morphological description of ‘Sultana’ was conducted following the descriptive parameters proposed by the International Union for the Protection of New Varieties of Plants (UPOV Code OLEAA_EUR). The main morphological characteristics of the cultivar were tree and growth habits (Fig. 1), leaf characteristics, fruit and stone characteristics (Fig. 2), and time of fruit ripening (Fig. 3), described as follows.

Table 1. Allelic profiles of ‘Sultana’ and its genitors, cultivars Arbosana and Sikitita, for 12 SSR markers.[i]

SSR locus	Sultana	Arbosana	Sikitita
ssrOeUA-DCA3	237/241	229/241	237/241
ssrOeUA-DCA9	182/204	192/204	182/182
ssrOeUA-DCA-11	134/178	134/140	140/178
ssrOeUA-DCA16	122/144	122/124	124/144
ssrOeUA-DCA18	172/176	164/176	164/172
UDO-43	175/212	175/208	175/212
GAPU-59	210/210	210/220	210/220
UDO-11	116/166	116/119	116/116
UDO-19	129/129	129/129	129/129
UDO-24	185/203	203/203	185/185
GAPU 71B	127/141	118/141	121/127
GAPU 101	189/217	183/189	183/217

[i] SSR markers were described by Trujillo et al. (2014).
SSR = simple sequence repeat.

Tree
1. Vigor: weak.
2. Growth habit: drooping.
3. Canopy density: dense.
4. Fruiting shoot: number of lateral shoots: medium.

Leaf blade
5. Length: long.
6. Width: medium.
7. Length/width ratio: slightly elongated.
8. Intensity of green color on the upper side: medium.
9. Curvature of the longitudinal axis: straight.
10. Twisting: absent or weak.

Inflorescence
11. Length: medium.
12. Width: medium.

Flower
13. Attitude of the corolla lobe: reflexed.

Fruit
14. Length: medium.
15. Width in position B: medium.
16. Weight: medium.
17. Shape in position A: ovate.
18. Ratio of length to width at position A: moderately elongated.
19. Immature fruit: intensity of green color: light.
20. Immature fruit: size of lenticels: large.
21. Immature fruit: number of lenticels: medium.
22. Over color at full maturity: black.

Fig. 1. Three-year-old ‘Sultana’ trees at the BALAM Agriculture experimental field.

Fig. 2. Fruit characteristics of 'Sultana' and its genitor cultivars Arbosana and Sikitita.

Fig. 3. Evolution of fruit ripening in cultivar Sultana.

23. Symmetry in position A: weakly asymmetric.
24. Shape of the apex at position A: truncate.
25. Nipple: absent or weak.
26. Shape of the base at position A: rounded to truncated.
27. Bloom of surface: medium.

Stone

28. Shape in position B: elliptic.
29. Length/width ratio: moderately elongated.
30. Length: medium.
31. Width in position B: medium.
32. Weight: medium.
33. Symmetry in position A: strongly asymmetric.
34. Symmetry in position B: symmetric.
35. Number of grooves on the basal end: between 7 and 10.
36. Distribution of grooves on the basal end: weakly grouped around the suture.
37. Shape of the apex at position A: acute.
38. Mucron: present.
39. Shape of the base in position (A): rounded.
40. Rugosity of surface: weak.
41. Time of fruit ripening: very early.

Agronomical Traits

The main agronomical description of 'Sultana' was performed at the experimental farm "El Valenciano." The comparative experimental orchard was planted in Aug 2019 and included the new cultivar Sultana; Arbequina and Arbosana were used as control cultivars. The experimental design had four blocks with four plants per cultivar and block. The tree spacing was 5.0 × 2.0 m (1000 trees/ha), and the plants were oriented north–south. The evaluated agronomic characteristics included tree vigor, fruit morphology, fruit production, oil content, and oil composition and quality.

Vigor and tree canopy volume. Vigor was evaluated for 4 years (2019–23) in winter by measuring height, canopy width, and trunk diameter. Here, we present 2023 data, and according to these measurements, 'Sultana' exhibited the lowest vigor, with an average height of 233.3 cm, whereas 'Arbequina' and 'Arbosana' exhibited 315 and 272.8 cm, respectively. Similarly, 'Sultana' had the lowest canopy width, with an average of 191.1 cm, compared with the 227.5 and 217.8 cm canopy widths shown by the two control cultivars (Arbequina and Arbosana), which were not significantly different. Consequently, with the vigor parameters, we calculated the canopy volume and found the smallest canopy volume for 'Sultana', with an average value of 6.3 m^3, followed by 'Arbosana', with 10.1 m^3, and 'Arbequina', with 13.2 m^3. No significant differences were observed when we compared trunk diameter among the three cultivars, with average values close to 75 mm. The low vigor observed in 'Sultana', in addition to facilitating harvesting, reduces pruning needs, which allows a reduction in management costs (Table 2).

Olive oil content, production, and fruit characteristics. Along with tree vigor, production in terms of fruits and oil was the main characteristic considered to indicate 'Sultana' as a promising new olive cultivar. Fruit production was evaluated during two harvest seasons, 2022 and 2023, during which the fruits of each tree were collected and weighed in November (Fig. 4). The fruit oil content was evaluated via nuclear magnetic resonance (Miho et al. 2020) for each block and cultivar in three harvest seasons, 2021, 2022, and 2023. Moreover, the fruit maturity indices were determined according to the following scale: 0 = green fruit, 1 = yellow fruit, 2 = veraison, 3 = purple fruit, and 4 = black fruit.

The production in terms of kilograms of fruit per hectare was greater for 'Sultana' in 2022 and 2023 (7855.1 and 9627 kg) than for 'Arbequina' (7127.8 and 5493.0 kg), but was not significantly different from that of 'Arbosana'. On the other hand, the production of olive oil in 'Sultana' in 2022 was 1622.3 kg/ha (Table 3), with no significant differences compared with that in cultivars Arbequina and Arbosana. In the 2023 harvest, 'Sultana' produced 1426.2 kg of oil per hectare (Table 3), which was not significantly different from that of 'Arbosana', but both cultivars were significantly more productive than 'Arbequina'.

The fruits were weighed to determine the average weight of the three cultivars. On average, 'Sultana' had a greater fruit weight than the control cultivars. No significant differences were detected between 'Sultana' and 'Arbequina' in 2023, probably due to

Table 2. Variables were monitored to characterize the tree vigor of the cultivars Sultana, Arbequina, and Arbosana. The trees were 4.5 years old and were grown in the "El Valenciano" experimental field.

Cultivar	Tree ht (cm)	Canopy width (cm)	Trunk diam (mm)	Canopy volume (m^3)
Sultana	233.33 c	191.11 b	73.56 a	6.33 c
Arbosana	272.78 b	217.77 a	73.67 a	10.09 b
Arbequina	315.00 a	227.50 a	77.00 a	13.20 a

The data are the means of 12 replicated plants per cultivar. Rows with common letters for the same variable do not significantly differ according to Fisher's protected least significant difference test at $P = 0.05$.

Fig. 4. Mechanical harvesting of 2.5-year-old trees of 'Sultana' at "El Valenciano," Carmona, Sevilla.

Table 3. Fruit production per hectare, average fruit weight, maturity index, oil content and oil production per hectare in 'Sultana' and the control cultivars Arbequina and Arbosana for the 2021, 2022, and 2023 harvest seasons at the "El Valenciano" experimental field.

Cultivar	Yr	Fruit/ha (kg)	Avg fruit wt (g)	Fruit ripening (0–4)	Olive oil on fresh matter (%)	Olive oil on dry matter (%)	Production (kg olive oil/ha)
Sultana	2023	9626.9 a	2.6 a	1.5 b	14.8 b	36.5 b	1426.2 a
Arbosana		10,205.0 a	1.9 b	1.0 c	14.0 b	38.7 ab	1434.4 a
Arbequina		5493.0 b	2.4 a	2.7 a	17.7 a	42.4 a	959.9 b
Sultana	2022	7855.1 ab	1.8 a	2.0 a	20.5 a	46.2 a	1622.3 a
Arbosana		9583.3 a	1.3 b	1.0 b	17.8 a	44.2 a	1709.7 a
Arbequina		7127.8 b	1.3 b	2.7 a	20.2 a	46.4 a	1445.0 a
Sultana	2021	—	2.5 a	3.3 a	21.5 a	46.3 a	—
Arbosana		—	1.2 b	1.0 b	17.4 b	41.3 b	—
Arbequina		—	—	1.4 b	20.0 ab	45.9 a	—

The data are the means of 12 replicated plants per cultivar. Rows with common letters for the same variable do not significantly differ according to Fisher's protected least significant difference test at $P = 0.05$. For the calculation of fruit and oil production per hectare, 1000 trees are considered because the plantation framework is 5 × 2 m.

Table 4. The 'Sultana' fruit morphology included fruit length, width, and weight; stone weight; and percentage of pulp collected from the "El Valenciano" experimental field (Carmona, Sevilla) in 2021, 2022, and 2023.

'Sultana', "El Valenciano"	2021	2022	2023	Avg
Fruit length (cm)	14.1	17.5	21.9	17.9
Fruit width (cm)	7.2	13.3	15.9	12.1
Fruit weight (g)	2.5	1.83	2.6	2.3
Stone weight (g)	0.4	0.5	0.5	0.5
Pulp weight/fruit weight (%)	84.3	71.0	82.1	79.2

the greater fruit load of 'Sultana' (Table 3). The morphology of the 'Sultana' fruits was described for three harvest seasons: 2021, 2022, and 2023. The average fruit length was 17.9 cm, and the width was 12.1 cm. The average fruit weight was 2.3 g, and the stone weight was 0.5 g; thus, the percentage of pulp over the total weight was 79% (Table 4).

Along with the precommercial trial established at the "El Valenciano" experimental farm, three parallel experimental plantations were established in southern Spain to evaluate the performance of 'Sultana' and other cultivars in different environments. The main and common characteristics of these fields are as follows: fields were planted in Spring 2021, had a tree spacing of 4.0 × 1.5 m (1666 trees/ha), and had an annual irrigation dose of 1500 $m^3 \cdot ha^{-1}$. These orchards are located in southern Spain, specifically in Espeluy (Jaén), Utrera (Sevilla), and Jédula (Cádiz), with an experimental design of three blocks and three plants per cultivar and block. The Jédula trial included larger plants with complete rows and at least 20 plants per cultivar and block. Fruit production, fruit oil content, and weight were evaluated in 2023 in the three orchards, whereas Utrera was evaluated for an additional year (2022). In these trials, 'Sultana' had a greater oil content and average fruit weight than did the cultivars Arbequina and Arbosana (Fig. 5); these latter characteristics facilitate machine harvesting. In addition, 'Sultana' exhibited an earlier ripening date in all the experimental trials than did the control cultivars.

Oil Composition and Quality

The oils of 'Sultana' and 'Arbequina' were extracted in 2023 using an experimental mini olive oil mill (Abencor mill) to assess their fatty acid profile and stability via the Rancimat method (at 100 °C) (Miho et al. 2020). For this, 2 kg of fruit from each block of the trial located at "El Valenciano"

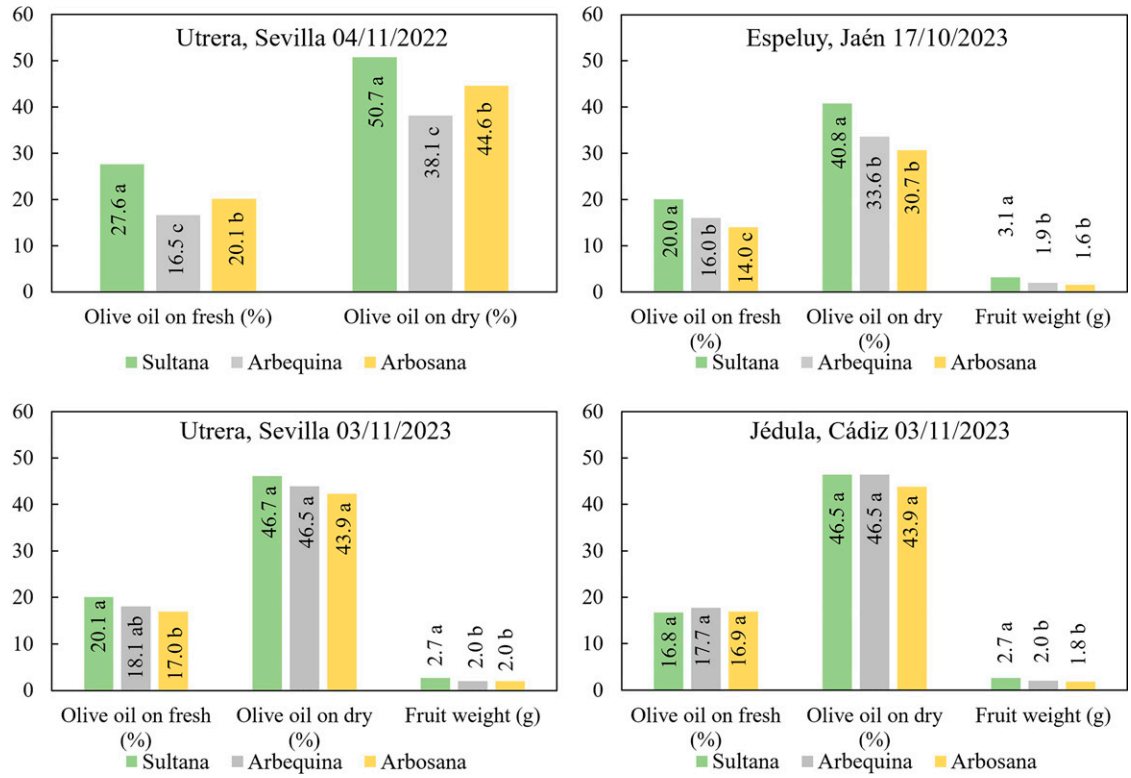

Fig. 5. Olive oil content in fruit as a percentage of fresh (left columns) and dry matter (central columns) and fruit weight (right columns) in the Espeluy, Utrera, and Jédula experimental fields in 2023 and olive oil in fresh and dry matter in Utrera in 2022. For the Utrera and Espeluy experimental fields, the data are presented as the means of nine replicated plants per cultivar. Columns with common letters do not differ significantly according to Fisher's protected lease significant difference (LSD) test at $P = 0.05$. For the Jédula experimental field, the data are the means of at least 60 replicated plants per cultivar. Columns with common letters do not differ significantly according to Fisher's protected LSD test at $P = 0.05$.

Table 5. Stability and fatty acid composition of the 'Sultana' and 'Arbequina' olive oils extracted in Nov 2023 from the "El Valenciano" experimental field.

Stability[i] and fatty acids (%)	Sultana	Arbequina
Stability	42.03 a	20.50 a
Oleic acid	67.27 a	53.99 b
Palmitic acid	16.81 b	19.09 a
Linoleic acid	9.59 b	20.37 a
Palmitoleic acid	2.17 b	2.81 a
Stearic acid	2.16 a	1.70 b
Linolenic acid	0.72 b	0.83 a
Arachid acid	0.49 a	0.37 b
Eicosenoic acid	0.32 a	0.25 b
Behenic acid	0.18 a	0.11 b
Lignoceric acid	0.10 a	<0.10 a
Myristic acid	0.02 a	0.02 a
Margaric acid	<0.10 a	0.10 a
Margaroleic acid	<0.10 b	0.24 a
Lauric acid	<0.10 a	<0.10 a
Erucid acid	<0.10 a	<0.10 a
Trans-oleic isomer	0.02 a	<0.01 a
Trans-linoleic and translinolenic isomers	0.02 a	0.04 a

[i] Rancimat hours at 100 °C.

Data are the means of three replicated samples per cultivar; each sample was harvested from three trees. Rows with common letters for the same variable do not significantly differ according to Fisher's protected least significant difference test at $P = 0.05$.

were collected. First, the oil extraction of 'Sultana' fruits was notably easier than that of 'Arbequina'. 'Sultana' had more than double the stability of Arbequina; however, the differences were not significant because of the high variability between blocks (Table 5). Similarly, oleic acid was also significantly greater in 'Sultana' than 'Arbequina', at 67.2% and 54.0%, respectively (Table 5).

The organoleptic profile of 'Sultana' virgin oil was extracted and characterized from both green and ripe fruits (Fig. 6). 'Sultana' green fruits produce highly fruity, intense, and complex virgin oil, with hints of white and tropical fruits such as pineapple, melon, and mango in the olfactory phase. In addition, herbaceous backgrounds of wildflowers and aromatic plants such as basil, cinnamon, and vanilla are also clearly perceptible. In the mouth, all the complexities detected by the nose were reaffirmed. It is a noble and balanced oil with a surprisingly spicy finish and an aftertaste of fresh fruit and custard. On the other hand, 'Sultana' ripe fruits produce virgin oil with intense fruitiness from aromatic plants and wildflowers. In the nose and in the foreground, fennel and fresh thyme stand out, with a green background of mint. In the mouth, it is round and complex, with an extremely sweet entry and a fair and balanced bitter and spicy taste, suggesting retronasal aromas of green almond and banana peel.

Conclusions

'Sultana' is a new cultivar developed for hedgerow orchards that joins the limited catalog of cultivars suitable for hedgerow orchards. 'Sultana' is notable for its high production and compact size. Its weeping habit and low vigor, which are lower than those of 'Arbequina' and 'Arbosana', make it suitable for narrow planting designs such as 4 × 1.5 m. However, the optimal design varies according to management, soil type and edaphoclimatic conditions. The reduced vigor of 'Sultana' makes its plantations easier to manage, reducing the need for pruning and, therefore, costs. In addition, 'Sultana' combines low tree vigor with larger fruits than 'Arbosana', allowing easy mechanical harvesting. The extra virgin oils from 'Sultana' differ from those from 'Arbequina' in terms of composition and organoleptic profile, thus increasing the diversity of olive oils in SHD olive systems.

References Cited

Camposeo S, Vivaldi GA, Montemurro C, Fanelli V, Cunill Canal M. 2021. Lecciana, a new low-vigour olive cultivar suitable for super high density orchards and for nutraceutical EVOO production. Agronomy. 11:2154. https://doi.org/10.3390/agronomy11112154.

Connor DJ, Gómez-del-Campo M, Rousseaux MC, Searles PS. 2014. Structure, management and productivity of hedgerow olive orchards: A review. Sci Hort. 169:71–93. https://doi.org/10.1016/j.scienta.2014.02.010.

Díez MC, Moral J, Cabello D, Morello P, Rallo L, Barranco D. 2016. Cultivar and tree density as key factors in the long-term performance of super high-density olive orchards. Front Plant Sci. 7:1226. https://doi.org/10.3389/fpls.2016.01226.

Miho H, Moral J, López-González MA, Díez CM, Priego-Capote F. 2020. The phenolic profile of virgin olive oil is influenced by malaxation conditions and determines the oxidative stability. Food Chem. 314:126183. https://doi.org/10.1016/j.foodchem.2020.126183.

Rallo L, Barranco D, de la Rosa R, León L. 2008. 'Chiquitita' olive. HortScience. 43(2):529–531. https://doi.org/10.21273/HORTSCI.43.2.529.

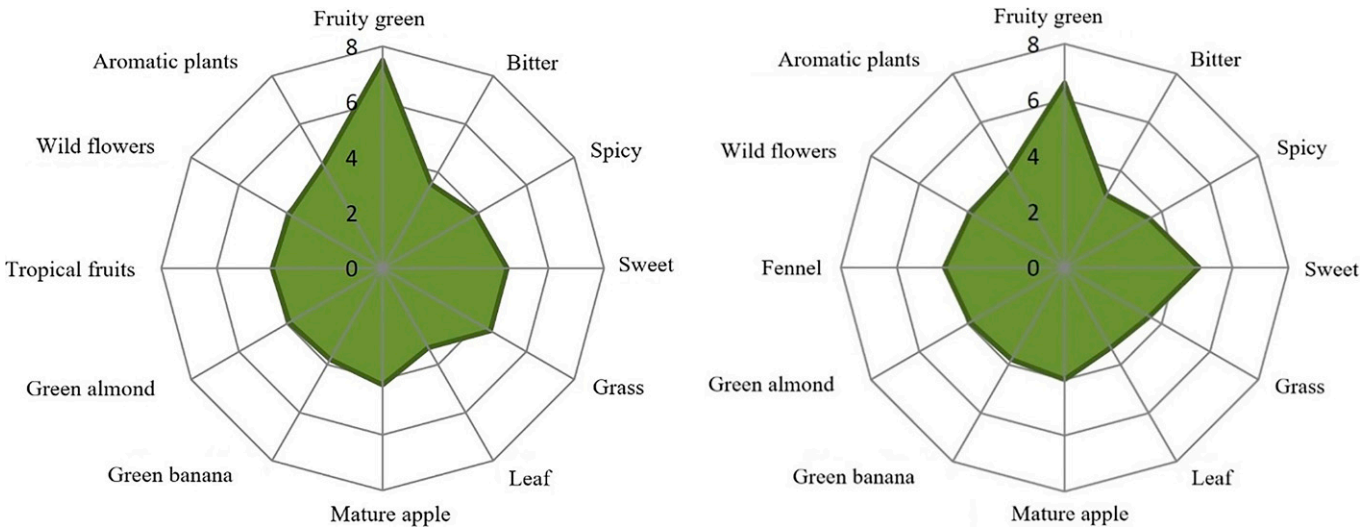

Fig. 6. Organoleptic profile of olive oil from the cultivar Sultana. (**Left**) Oil profile extracted from green fruit. (**Right**) Oil profile extracted from ripe fruit.

Rallo L, Barranco D, Díez CM, Rallo P, Suárez MP, Trapero C, Alfaro FP. 2018. Strategies for olive (*Olea europaea* L.) breeding: Cultivated genetic resources and crossbreeding, p 535–600. In: Al-Khayri J, Jain S, Johnson D (eds). Advances in plant breeding strategies: Fruits. Volume 3. Springer, Cham. https://doi.org/10.1007/978-3-319-91944-7_14.

Trujillo I, Ojeda MA, Urdiroz NM, Potter D, Barranco D, Rallo L, Diez CM. 2014. Identification of the Worldwide Olive Germplasm Bank of Córdoba (Spain) using SSR and morphological markers. Tree Genet Genomes. 10:141–155. https://doi.org/10.1007/s11295-013-0671-3.

Valverde P, Barranco D, López-Escudero FJ, Díez CM, Trapero C. 2023. Efficiency of breeding olives for resistance to Verticillium wilt. Front Plant Sci. 14. https://doi.org/10.3389/fpls.2023.1149570.