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‘Farga’ Olive

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Abstract

‘Farga’ olive is an old and important cultivar grown in southeastern Spain for oil production (17,000 ha). Yet, scarce research has been conducted on its horticultural and oil characteristics. ‘Farga’ trees are vigorous and resilient, having an open growth habit and dense canopy. The cultivar shows late and alternate bearing. ‘Farga’ rooting by semi-hard wood cuttings is difficult. ‘Farga’ is hardy and tolerant to moderate winter frost and is sensitive to peacock spot and olive fly, and resistant to bacterial tuberculosis. Due to high fruit removal force the tree is unsuited to harvest by shaking. ‘Farga’ identification using 9 microsatellites gave a unique allelic DNA profile. ‘Farga’ oil composition regarding fatty acid is highly monounsaturated (78% oleic acid) with low polyunsaturated content (7.5% linoleic acid). ‘Farga’ olive oil is highly stable and shows medium to high polyphenol content, rich in apigenin. Total sterols is medium-low, being β-sitosterol the most abundant. The EVOO profile of ‘Farga’ is mid to high fruited with green notes, with a tendency to produce oils with a large equilibrium. It is an EVOO highly interesting as a varietal or to produce blended oils.

‘Farga’ olive (*Olea europaea* L.) is a traditional Spanish cultivar producing high oil quality. During a survey of olive cultivars carried out between 1987 and 1998, ‘Farga’ cultivar was located by Research & Technology Food & Agriculture (IRTA) in northeastern Spain (Catalonia and Valencia Regions). It is considered one of the early domesticated olive cultivars growing in these regions. ‘Farga’ is an old native cultivar of unknown parentage cultivated in the southern Tarragona and northern Castelló provinces. It is considered that ‘Farga’ was already known by Arabs who lived in this area before the reconquest of Iberian Peninsula by Christians (Cavanilles, 1797). The cultivated area of ‘Farga’ is estimated around 17,000 ha, being an important element of the landscape of its growing region (Tous, 1990; Tous and Romero-Aroca, 1993; Íñiguez et al., 2001; Ninot et al., 2015). In addition, ’Farga’ has been used to assemble the first olive draft genome reported worldwide (Cruz et al., 2016). The assembled draft genome of *O. europaea* provides a valuable resource for the study of the evolution and domestication process.

‘Farga’ is a very resilient olive and has been cultivated in its original area for centuries. There are many ‘Farga’ olive trees over 800 years old within traditional olive orchards (Arnan et al., 2012) and are the base of several olive conservation parks in this region used for recreation. Currently, Extra Virgin Olive Oil (EVOO) from these ancient trees is produced under audit schemes, marketed under several brands and receives a premium price due to its exclusivity.

Although partial information about this cultivar has been reported previously (Tous and Romero, 1993; Rallo et al. (2005); Íñiguez et al. (2001) and López-Cortés et al. (2013)), the increasing interest on it, jointly with new results from our group when studying the monumental ‘Farga’ trees from south Catalonia justify a more detailed description of ‘Farga’ cultivar in its original area.

Source of data. Data presented in this article comes mainly from the Catalan Olive Germplasm Bank sited at IRTA’s facilities in Mas de Bover (Cosntantí, Spain). This trial was planted in 1992 including 30 Catalan cultivars in a randomized block design with three replications and one tree per cultivar and block (Tous, Romero and Plana, 2005). Trees are spaced 7 x 5 m with drip irrigation. In the case of olive oil composition, some additional samples from other experimental orchards from IRTA were included, in order

to present values from a wider area (Tous et al., 2005).

The vigor and crop data refers to the first fifteen years of the study (1992-2007). Fruit characteristics come from samples taken from trees, with similar maturity index (fruits between reddish to black) in the full bearing period (2001-2007).

The fruit removal force was measured during two years, in mature olive trees from conventional orchards in Tarragona, using a manual dynamometer and single fruits were weighed in the laboratory.

The olive oil samples were obtained by the ABENCOR system in the laboratory of IRTA. The sensorial profile was developed from samples collected from 2008 to 2014. Sterol composition was studied in samples harvested from 2014-15 in adult trees from Tarragona, from three orchards having the three cultivars (two samples per orchard and cultivar). Polyphenol profiles were studied in 2009-2010 from samples from trees planted in IRTA's experimental trials in three different growing areas of Tarragona (Constantí, Mora d'Ebre and Tivenys). Fatty acid composition, total polyphenol content and oil stability values were obtained from fruit harvested from the Catalan collection in Constantí (period 2000-2007), but 'Farga' values include additional samples from monumental olive trees in southern Tarragona where this cultivar is widespread.

For our study 'Arbequina' and 'Picual, two important and largely grown Spanish cultivars, were compared to 'Farga' with some reference cultivars (Barranco and Rallo, 1993). Data from these cultivars come from the same trials.



Figure 1. Maturing olives of 'Farga'

Description and Performance. 'Farga' trees are vigorous having an open growth habit and dense canopy (Fig. 1). Plants are difficult to propagate by rooting semi-hard wood cuttings. The cultivar is nonprecocious

Table 1. Cumulative yield, yield efficiency, and tree size parameters of three olive cultivars after 15 years of growth at the Catalan Olive Germplasm Bank in Mas de Bover (Cosntantí, Spain). Table 3. Fatty acid composition, total polyphenol content and oil stability for three olive cultivars growing at the IRTA Mas de Bover Station from 10 years).

Cultivar	Cum. Yield (kg/ha)		TCSA (cm^2)	Canopy volume (m^3)	Cum. yield /TCSA (kg/cm^2)	Cum. yield /volume (kg/m^3)
	Years 6-15	Years 1-15				
'Farga'	2259 ± 889	24267 ± 9363	698 ± 230	48.3 ± 11.0	0.12 ± 0.01	1.72 ± 0.29
'Arbequina'	5453 ± 2226	63816 ± 22412	270 ± 115	25.2 ± 10.2	0.84 ± 0.09	9.02 ± 0.58
'Picual'	5416 ± 887	59939 ± 12677	620 ± 44	30.9 ± 3.1	0.34 ± 0.05	6.87 ± 1.74

Table 2. Fruit weight, Fruit removal force/fruit weight, Flesh/pit ratio and Oil content of three olive cultivars.

Cultivar	Fruit removal force[z]/ Fruit weight (g/g)	Fruit weight[y] (g)	Flesh/Pit[y] (g/g)	Oil yield[y] (% wet basis)	Oil yield[y] (% dry basis)
'Farga'	216	2.00 ± 0.20	3.02 ± 0.21	13.4 ± 3.4	44.3 ± 4.9
'Arbequina'	168	1.25 ± 0.32	2.92 ± 0.80	23.0 ± 1.92	49.5 ± 2.6
'Picual'	130	2.91 ± 0.76	3.91 ± 0.76	23.1 ± 3.08	48.7 ± 3.7

[z] Data from two years with mature trees in the Tarragona area
[y] Mean values (2004-2006) from the IRTA's Catalan collection

and alternate bearing, resulting in low production and yield efficiency when compared to the other two cultivars (Table 1). Leaves are elliptical in shape, short, and narrow. Full bloom occurs in mid-May at the IRTA olive collection in Constantí, Tarragona (112 m above sea level, Latitude: 41.17130, Longitude: 1.16774), showing little variation in bloom date from year to year. 'Farga' is a male-sterile cultivar characterized by the rare E3.1 chlorotype (Mariotti et al., 2010).

The fruit ripens in early Oct. from the basal to the apical zone (Fig. 1) and has a high fruit removal force to fruit weight ratio (FRF/W=216 g/g) which makes it unsuitable for harvest by shaking. 'Farga' fruits are small in size with a mean fruit weight of 2.0 g., elongated in shape and slightly asymmetric (Fig. 2). The tip is rounded, the cross section at maximum diameter is circular and the olive base is trunked. Oil content is medium (44.3% on dry weight basis), slightly lower than 'Arbequina' (Table 2).

Stone size is medium, elongated, and asymmetric. The surface is slightly rough, with 7-10 uniformly distributed fibrovascular grooves. The tip and base of the stone is pointed and ends in a nipple. The flesh to pit ratio is 3.02, similar to 'Arbequina' but smaller than 'Picual'.



Figure 2. Fruit of 'Farga'

'Farga' is hardy and tolerant to moderate winter frost. It is sensitive to peacock spot (*Spilocaea oleaginea* Hughes), olive fly (*Bactrocera oleae* Gmelin), *Verticillium*, antracnose (*Colletotrichum* spp) and it is considered resistant to bacterial tuberculosis (*Pseudomonas savastanoi*).

Oil composition and oil sensory profile. Fatty acid composition is highly monounsaturated (78% oleic acid) with low polyunsaturated fatty acid (PUFA) content (7.5% linoleic acid). 'Farga' olive oil has a high stability and medium to high polyphenol content, rich in apigenin (Table 3 and 4). Total sterols is medium-low (1271 mg/kg), campesterol and stigmasterol are higher than in other cultivars and β-sitosterol is the most abundant (Table 5).

'Farga' is one of the three olive cultivars for which the oil has the Protected Designation of Origin (PDO) "Baix Ebre - Montsià" and the other two are 'Morrut' and 'Sevillenca'. The EVOO profile of 'Farga' is mid to high fruited with green notes (cut grass and notes of green banana or green walnuts, green tomato or artichoke leaves), with a tendency

Table 3. Fatty acid composition, total polyphenol content and oil stability for three olive cultivars growing at the IRTA Mas de Bover Station from 10 years).

	'Farga'	'Arbequina'	'Picual'
C16:0 (%)	11.59 ± 3.35	15.20 ± 1.37	11.94 ± 1.08
C16:1 (%)	1.23 ± 1.24	2.06 ± 0.54	1.18 ± 0.27
C17:0 (%)	0.11 ± 0.01	0.13 ± 0.03	0.10 ± 0.04
C17:1 (%)	0.10 ± 0.08	0.27 ± 0.04	0.14 ± 0.04
C18:0 (%)	1.64 ± 0.23	1.71 ± 0.28	2.98 ± 0.26
C18:1 (%)	73.33 ± 9.60	67.98 ± 2.77	76.81 ± 3.40
C18:2 (%)	11.17 ± 4.72	11.46 ± 1.42	5.40 ± 2.43
C18:3 (%)	0.57 ± 0.18	0.71 ± 0.11	0.91 ± 0.09
C20:0 (%)	0.17 ± 0.07	0.36 ± 0.06	0.30 ± 0.04
C20:1 (%)	0.13 ± 0.05	0.29 ± 0.04	0.21 ± 0.03
SAT (%)	12.45 ± 4.97	17.15 ± 1.34	13.80 ±1.10
INSAT (%)	87.55 ± 4.97	82.85 ± 1.34	86.20 ± 1.10
MUFA (%)	69.43 ± 21.53	70.28 ± 2.40	70.80 ±1.02
PUFA (%)	10.90 ± 5.62	12.17 ± 1.44	15.40 ± 2.46
Total polyphenols[z] (mg/kg)	201.7 ± 63.0	244.3 ± 85.4	413.8 ± 135.3
Stability[y] (h 120ºC)	17.5 ± 1.1	9.0 ± 3.3	27.8 ± 1.1

[z] By Folin-Ciocalteau method

[y] Oil stability determined by Automated 617 Rancimat Method (Frank et al., 1982)

Table 4. Polyphenols profiles for three olive cultivars growing at the IRTA Mas de Bover Station (N=5).

Polyphenol (mg/kg oil)	'Farga'	'Arbequina'	'Picual'
Hydroxytyrosol	0.17 ± 0.16	0.34 ± 0.39	1.46 ± 1.03
Tyrosol	5.72 ± 5.89	1.96 ± 0.67	2.11 ± 0.74
Vanillic	1.31 ± 0.49	1.19 ± 0.24	0.95 ± 0.39
Vanillin	0.27 ± 0.13	0.26 ± 0.05	0.32 ± 0.06
ρ-coumaric	1.60 ± 0.65	1.88 ± 0.19	2.51 ± 0.96
3,4-DHPEA-AC	59.40 ±45.32	367.90 ± 136.08	67.78 ± 9.35
Ferulic	0.19 ± 0.11	0.26 ± 0.04	0.20 ± 0.04
3,4-DHPEA-EDA	64.35 ± 66.06	113.70 ± 85.61	496.00 ± 216.52
Pinoresinol	5.47 ± 5.27	4.83 ± 2.02	3.18 ± 5.50
ρ-HPEA-EDA	0.00 ± 0.01	6.82 ± 18.86	105.38 ± 61.48
Lignan	224.30 ± 121.48	198.17 ± 42.53	37.98 ± 33.38
ρ-HPEA-EA	60.45 ± 59.31	64.24 ± 15.61	298.82 ± 162.88
3,4-DHPEA-EA	414.85 ± 250.15	236.84 ± 95.38	1000.37 ± 684.87
Luteolin	3.34 ± 1.55	4.10 ± 1.15	3.25 ± 1.04
Apigenin	2.04 ± 1.75	3.54 ± 1.07	0.69 ± 1.04

Table 5. Sterols profile and total sterols for three olive cultivars.

Sterols	'Farga'	'Arbequina'	'Picual'
Cholesterol (%)	0.13 ± 0.09	0.10 ± 0.01	0.10 ± 0.01
Campesterol (%)	3.89 ± 0.31	3.47 ± 0.37	3.57 ± 0.21
Stigmasterol (%)	1.14 ± 0.46	0.82 ± 0.35	0.82 ± 0.18
Apparent β-sitosterol (%)	94.01 ± 0.39	94.67 ± 0.67	94.90 ± 0.15
Δ7-Stigmastenol (%)	0.22 ± 0.06	0.12 ± 0.04	0.18 ± 0.04
Δ7-Avenasterol (%)	0.40 ± 0.05	0.43 ± 0.08	0.30 ± 0.00
Total sterols (mg/kg oil)	1271 ± 206	1464 ± 95	1601 ± 100

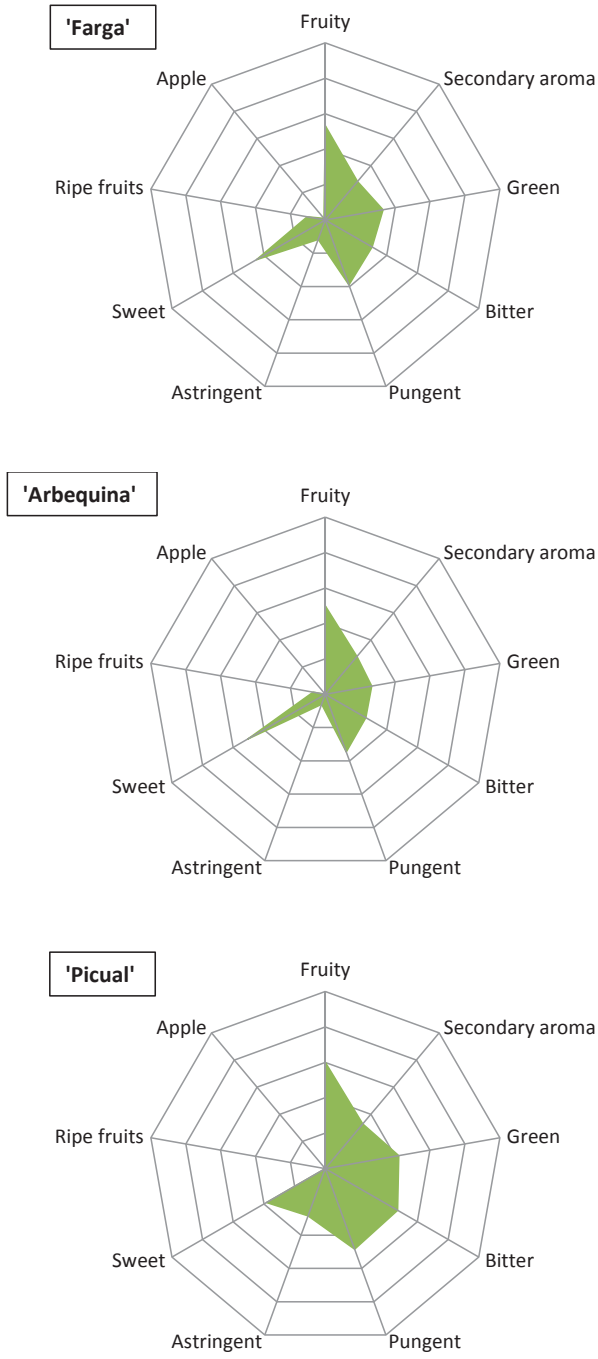


Figure 3. Sensory profile of 'Farga' olive oil, compared with 'Arbequina' and 'Picual'.

Table 6. Allelic profile (in bp) of the 9 microsatellite markers used for three olive cultivars.

Cultivar	Molecular Makers (SSR) (bp)								
	DCA03	DCA04	DCA07	DCA08	DCA09	DCA10	DCA11	DCA16	DCA18
'Farga'	243:249	170:192	154:154	135:167	179:192	145:160	128:143	122:150	165:169
'Arbequina'	236:247	136:166	137:150	143:143	190:211	168:168	143:143	122:146	167:177
'Picual'	243:253	136:136	154:170	141:145	190:198	160:162	143:180	124:154	169:175

to produce oils with a large equilibrium between sweet, bitter and pungent, including a final weak astringency (Fig. 3). It is an EVOO highly interesting as a varietal or to produce blended oils ("coupages") and with a medium to long shelf life, mainly when an early olive harvest is made.

Cultivar identification by molecular markers. The nine microsatellites used to identify 'Farga' within IRTA's olive cultivar germplasm collection were DCA3, DCA4, DCA7, DCA8, DCA9, DCA10, DCA11, DCA16 and DCA18 (Sefc et al., 2000). Also using these polymorphic DNA loci it was possible to clearly distinguish this cultivar from the other locally cultivated in the region and as well as 'Arbequina' and 'Picual' (Table 6).

Availability. Cuttings and trees are available from commercial olive nurseries in the south of Tarragona and Castelló (Spain).

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Table 7. Sensorial profile for three olive cultivars grown at the IRTA Mas de Bover Station (N=10 years), (Official Extra Virgin Olive Oil Tasting Panel of Catalonia)

	'Farga'	'Arbequina'	'Picual'
Fruity	5.32 ± 0.64[z]	4.99 ± 0.61	6.00 ± 0.68
Secondary aroma	2.83 ± 0.28	2.78 ± 0.27	3.29 ± 0.45
Green	3.31 ± 0.33	2.66 ± 0.77	4.21 ± 0.81
Bitter	3.05 ± 0.62	2.64 ± 0.58	4.71 ± 1.11
Pungent	3.90 ± 0.51	3.46 ± 0.71	4.84 ± 0.82
Astringent	1.17 ± 0.80	0.60 ± 0.72	2.84 ± 1.00
Sweet	4.49 ± 0.34	5.06 ± 0.14	3.83 ± 0.62
Ripe fruits	1.04 ± 0.81	0.70 ± 0.91	0.00 ± 0.00
Apple	0.12 ± 0.37	0.00 ± 0.00	0.00 ± 0.00

[z] Values are means and standard deviations for intensity on a scale of 0 to 10; where 0 is absence of the attribute and 10 is the maximum intensity.

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About The Cover:

'Fraga' olive tree, estimated to be 350 years old. 'Fraga' is a traditional Spanish cultivar that produces high quality oil.