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Olive cultivars suitability for high-density orchards

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Abstract

A new olive orchard type, based on high-density planting, was introduced in Tunisia in 2000 by some investors, using mainly 'Arbequina', the most utilized cultivar up to that time in Spain and in some other countries. Limited cultivar choice is in fact considered one of the main inconvenients for using high planting densities in olive. Therefore, a comparative trial was set up in 2003 to evaluate the suitability of four olive cultivars ('Arbosana', 'Arbequina i-18', 'Chemlali' and 'Chetoui') to a planting density of 1250 trees ha^{-1}. The results showed that the local cultivars 'Chemlali' and 'Chetoui' were more vigorous than 'Arbosana'. However, 'Arbosana' and 'Arbequina i-18' presented the highest fruit yield in comparison to the local ones. Furthermore, 'Arbosana' showed the highest accumulated fruit yield after the first five harvests and the highest crop efficiency (0.56-1.52 kg m^{-3} of tree canopy). Also, 'Arbosana' and 'Arbequina i-18' presented the lowest alternate bearing indexes (0.38 and 0.44, respectively) during that period of time. Significant differences among cultivars for oil content and fatty acid composition were observed. The oleic acid content was high in 'Arbosana' and 'Chetoui' (69.4-66.7%) and intermediate to low in 'Arbequina-i18' and 'Chemlali' (64.9-56.1%). The high vigour and low production of the studied Tunisian cultivars show that it is not advisable to use them in high-density orchards. 'Arbosana' was the most adapted cultivar to this new planting density system in this trial.

Additional keywords: hedgerow; *Olea europaea* L; oil content; oil quality; olive yield; super-intensive; vigour.

Resumen

Adaptación de cultivares de olivo a plantaciones de alta densidad

Un nuevo tipo de olivar, en alta densidad, fue introducido en Túnez en el año 2000. El cultivar estándar en estas plantaciones fue 'Arbequina', el más utilizado hasta ese momento en España y otros países. Una de las principales limitaciones para el uso de altas densidades de cultivo en olivo es la escasa disponibilidad de cultivares de bajo vigor. Por ello, se estableció un ensayo en 2003 para evaluar la adaptación de cuatro cultivares ('Arbosana', 'Arbequina i-18', 'Chemlali' y 'Chetoui') a una densidad de plantación de 1250 árboles ha^{-1}. Los resultados obtenidos mostraron que los cultivares tunecinos 'Chemlali' y 'Chetoui' son más vigorosos que 'Arbosana'. Sin embargo, 'Arbosana' y 'Arbequina i-18' presentaron la mayor producción de aceitunas en comparación con los tunecinos. 'Arbosana' mostró la mayor producción acumulada de aceitunas después de las primeras cinco cosechas y la mayor eficiencia productiva (0,56-1,52 kg m^{-3} de copa). Además, 'Arbosana' y 'Arbequina i-18' presentaron los menores índices de alternancia (0,38 and 0,44, respectivamente) durante ese período de tiempo. Se observaron también diferencias significativas entre los cultivares estudiados con respeto al contenido y la composición acídica de aceite. El contenido en ácido oleico fue alto en 'Arbosana' y 'Chetoui' (69,4-66,7%) e intermedio-bajo en 'Arbequina i-18' y 'Chemlali' (64,9-56,1%). El alto vigor y baja producción de los cultivares tunecinos estudiados muestran que no es recomendable utilizarlos en plantaciones de alta densidad. 'Arbosana' ha sido el cultivar mejor adaptado a la densidad de plantación utilizada en este ensayo.

Palabras clave adicionales: calidad de aceite; contenido de aceite; *Olea europaea* L; plantación super-intensiva; rendimiento de oliva; seto; vigor.

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Abbreviations used: D1 (canopy width in the inter row sense); D2 (canopy width in the row sense); FAME (fatty acid methyl ester); H (canopy height); IA (alternate bearing index); NMR (nuclear magnetic resonance); SPSS (Statistical Package of the Social Sciences); TCSA (trunk cross-section area).

Introduction

The olive high-density system started to develop in Spain in 1991 with 1000 to 1250 'Arbequina' trees ha^{-1} (Planas *et al.,* 1997). Since this date, the choice of both cultivar and planting density was a matter of debate. However, nowadays high density orchards cover more than 80,000 ha in the world and more than 3,500 ha in Tunisia (Rius and Lacarte, 2010).

The main advantage of these hedgerow orchards is the use of over-the-row mechanical harvesters, which reduce harvest costs in comparison to manual and even trunk-shaking harvest. In fact harvesting enterprises advertise their work as able to harvest 1-ha of hedgerow olive orchard in just 2.0-2.5 hours, almost without any more hand labour than the harvester driver. Also, these high-density orchards allow for higher yield per hectare during the first years after planting (De la Rosa *et al*., 2007; Leon *et al*., 2007; Pastor *et al*., 2007; Tous *et al*., 2008), compared to the so-called intensive model (200 to 300 trees ha^{-1}) (Pastor and Humanes, 1990; Tous *et al*., 1999; Pastor *et al*., 2005).

The limited cultivar choice when deciding to establish a high density planting olive orchard remains as one of the main inconvenient. Indeed, to guarantee the success of this new olive orchard model, only low-vigour cultivars should be used. However, olive is characterized by the high vigour of even its low-vigour cultivars (Del Rio *et al*., 2002; 2005a), especially in areas where the annual growing season is very long, like Andalusia in Southern Spain and any others of lower latitude, specially the South regions of North-African countries or the North-Eastern ones of Argentina. Furthermore, dwarf olive cultivars and rootstocks did not exist by 2003 (Del Río *et al*., 2005a).

In 1998 'Arbequina i-18', 'Arbosana' and four more cultivars of moderate vigour (Tous *et al*., 2005a) were planted in a trial at 2469 trees ha^{-1} in Spain (Tous *et al*., 2003; 2008). Some more trials have been or are still under study in Spain and other countries to determine the behaviour of several cultivars at high planting densities, from around 800 to almost 2600 trees ha^{-1} (Godini *et al*., 2006; De la Rosa *et al*., 2007; Leon *et al*., 2007; Pastor *et al*., 2007; Camposeo and Godini, 2009).

Also, mutual shading between contiguous rows is considered as another drawback of this new olive orchard model. Connor (2006) has studied the importance of the planting arrangement (row orientation, height and width, canopy slope and alley width) for assuring that the whole tree receives all the radiation needed to achieve good productivity. Moreover, this difficulty may become aggravated if adequate training and pruning programs are not applied, giving rise to significant productivity decreases after a certain number of years (Pastor *et al*., 2005), still not observed in other trials at the 5th (Tous *et al*., 2008), 6th (De la Rosa *et al*., 2007) and 7th year after planting (León *et al*., 2007), probably due to different amount of water applied in the irrigation programs. Moreover, the establishment of a high-density orchard requires a high investment, evaluated in about € 6000 ha^{-1} in Tunisia and higher investments in Italy and Spain, figures representing 2-3 times more than for an olive orchard of about 300 trees ha^{-1} in Spain (Pastor, 2006; Tombesi, 2006; Tous *et al*., 2006).

In 2002 'Arbosana' had joined 'Arbequina' in commercial hedgerow orchards, also in experimental trials, because of its low vigour (Tous *et al*., 2005a; Godini *et al*., 2006). Therefore the aim of this trial was to study the behaviour of 'Arbequina i-18' and 'Arbosana' in comparison to local cultivars 'Chemlali' and 'Chetoui' grown under high density planting system.

Material and methods

The experiment was planted in Takelsa (Northern of Tunisia, 36°47' N; 10°37' E) with 'Chemlali' and 'Chetoui' as local cultivars and 'Arbequina i-18' and 'Arbosana' from Spain. The climate in this area is typically Mediterranean, with an average rainfall about 500 mm year^{-1}. The mean, maximum and minimum temperatures are 18.4, 23.5 and 13.2°C, respectively.

In April 2003, the trees (self-rooted plants, 50 cm tall) were planted in a sandy soil, over 2 m deep, alkaline pH (7.8) and low in organic matter (0.2%). The planting density used in this trial was 1250 trees ha^{-1}, with 2 × 4 m spacing. Rows were planted in the North-South direction. After planting, a trellis system was placed in the orchard and each tree was tied to a stake, for facilitating the central leader training. During the first 2-3 years, trees were lightly pruned by eliminating vigorous lateral branches (between rows) to allow for better incident sun radiation on the basal parts of the trees and to maintain the apical dominance of the main shoot. Irrigation applied during the last five reported years varied between 1500 and 2000 m^3 ha^{-1}. The fertilization program was based essentially on N, P and

K. Potassium was applied since the third year after planting. Since 2008 (after the third harvest) three phytosanitary treatments against *Fusicladium oleagineum* were applied yearly.

The experiment was designed as randomized complete block with three replicates. Each block is composed of two rows of ten trees each. All measurements were carried out on all the experimental trees except in those at the ends of the block lines (16 trees per block, *i.e.* four trees per cultivar and block).

Growth measurements and fruit yield

Trunk girth and tree height at 20 cm above soil level were measured after harvest until seven years (seven growing seasons) after planting time (January 2010). The trunk cross-section area (TCSA) was calculated thereafter as shown by Del Rio *et al.* (2005a). Canopy volume of each tree was also calculated by considering the tree as a parallelepiped and consequently by using the formula [1]:

$$\text{Canopy volume} = D_1 \times D_2 \times H \qquad [1]$$

where D_1, D_2 are the widths in the inter-row and in-row senses, respectively and H is the height of the trees.

Since the third to the seventh years after planting all trees were harvested separately except those at the border of each block. Crop efficiency (kg m^{-3} of canopy) was also determined.

Alternate bearing index

Based on the five harvested crops, the alternate bearing index of each experimental tree was calculated (Hoblyn *et al*., 1936). This alternate bearing index *IA* was calculated according to formula [2]:

$$IA = \frac{\sum \sqrt{\left[(C_{i+1} - C_i) / (C_{i+1} + C_i)\right]}^2}{n-1} \qquad [2]$$

where n is the harvest number; and C_1 and C_{1+1} are the crop yield of two successive crops.

Fruit characteristics

Three fruit samples of 3 kg each were taken from each block and cultivar at a ripening index ranging from 3 (reddish or purple skin) to 4 (black epidermis) on a scale of 0 to 7 (Ferreira, 1979). The average fruit weight was determined by weighting three samples of 100 fresh fruits. Then these samples were dried in a forced-air oven at 105°C until reaching a constant weight (Del Rio and Romero, 1999). Dried samples were weighted to determine their moisture contents and then their oil percentages referred to dry weight were determined in an nuclear magnetic resonance analyser, model Oxford 4000 (Del Rio and Romero, 1999). These fruit characteristics were studied from the second to the fifth harvests.

Fatty acid composition

At the first, second and fourth harvests olive oils were extracted from the fruit, using the laboratory oil mill Abencor (MC2, Sevilla, Spain), consisting of a hammer mill, a thermobeater and a paste centrifuge (Martinez *et al*., 1975). Fatty acid methyl ester (FAME) composition of oils was determined according to the EU Regulation (EC, 2002). Chromatographic separation was performed using a Shimadzu apparatus.

Statistical analysis

Analysis of variance and mean separation tests were performed to determine significant differences among cultivars and among years for fruit and oil characteristics for each cultivar using SPSS (Statistical Package of the Social Sciences) base 13.0 software (Chicago, IL, USA).

Results

Seven years after planting ‘Chemlali’ and ‘Chetoui’ presented similar and higher tree height and canopy volume than ‘Arbosana’ and ‘Arbequina-i18’ (Table 1), which are therefore less vigorous. Indeed canopy volume of ‘Arbequina-i18’ and ‘Arbosana’ were 21 and 34% less than that obtained by ‘Chemlali’ (Table 1). Canopy widths in the inter-row sense were significantly different only for ‘Chemlali’ and ‘Arbosana’ (Table 1). No significant differences were obtained in the tree height/canopy width ratio, while the TCSA was similar and higher for ‘Chemlali’ and ‘Chetoui’

Table 1. Tree height, canopy volume, canopy width in the inter row sense, TCSA and height/canopy width ratio of the compared cultivars seven years after planting. Data are means ± SE

Variety	Tree height (m)	Canopy volume (m^3 $tree^{-1}$)	Canopy width (m)	TCSA (cm^2)	Height/canopy width ratio
Chemlali	3.24 ± 0.07 a	17.0 ± 0.88 a	2.51 ± 0.07 a	329.6 ± 20 ab	1.31 ± 0.04 a
Chetoui	3.04 ± 0.10 ab	14.9 ± 1.6 ab	2.39 ± 0.11 ab	350.5 ± 26.6 a	1.24 ± 0.05 a
Arbequina i-18	2.78 ± 0.06 bc	13.4 ± 0.8 bc	2.30 ± 0.37 ab	281.1 ± 19.4 c	1.22 ± 0.03 a
Arbosana	2.62 ± 0.15 c	11.3 ± 0.5 c	2.15 ± 0.07 b	299.7 ± 14.0 b	1.24 ± 0.03 a

The same letters within the column indicate no significant differences among cultivars (Duncan, $p < 0.05$).

Table 2. Yield (kg $tree^{-1}$), accumulated yield (kg $tree^{-1}$), estimated accumulated yield (kg ha^{-1}) and alternate bearing index of the compared cultivars since three to seven years after planting. Data are means ± SE

Variety	Yield (years after planting)					Cumulative yield		Alternate bearing index
	3	4	5	6	7	Measured (kg $tree^{-1}$)	Estimated (kg ha^{-1})	
Arbosana	3.75 ± 0.25 a	7.58 ± 0.7 a	4.23 ± 0.3 a	13.27 ± 0.7 a	7.38 ± 1.1 a	36.21 ± 2.52 a	45262.5 a	0.38 ± 0.03 c
Arbequina i-18	2.03 ± 0.25 b	6.84 ± 0.6 ab	3.08 ± 0.2 b	9.74 ± 0.7 b	6.44 ± 0.8 a	28.13 ± 2.07 b	35162.5 b	0.44 ± 0.02 c
Chemlali	1.98 ± 0.4 b	4.66 ± 0.76 b	1.09 ± 0.3 c	7.23 ± 0.8 bc	1.95 ± 0.6 b	16.91 ± 2.08 c	21137.5 c	0.69 ± 0.04 b
Chetoui	0 c	7.07 ± 0.7 ab	0 d	6.39 ± 1.4 c	4.94 ± 1.9 ab	18.40 ± 1.18 c	23000 c	0.88 ± 0.04 a

The same letters within the column indicate no significant differences among studied cultivars (Duncan, $p < 0.05$).

than for 'Arbosana' and 'Arbequina i-18', with also significant difference among the Spanish cultivars (Table 1).

Three cultivars started producing harvestable crops three years after planting, but 'Chetoui' bear one year later. 'Chetoui' also showed a significantly higher biennial bearing habit, as shown by the alternate bearing index, higher than for 'Chemlali', and significantly higher than those observed in 'Arbequina i-18' and 'Arbosana' (Table 2). 'Arbosana' was the most productive cultivar every year until the seventh after planting, although the difference over the second, 'Arbequina i-18', was significant only the third, fifth and sixth years (Table 2). 'Arbosana' also showed significantly higher accumulated yield (kg $tree^{-1}$) than 'Arbequina i-18', which showed the same difference with the Tunisian cultivars (Table 2). In fact this value was almost 29% higher in 'Arbosana' than in 'Arbequina i-18' and 105% higher than the average of those of 'Chetoui' and 'Chemlali'. The crop efficiency of 'Arbosana' was higher than those of the other cultivars along the years of the study (Figure 1).

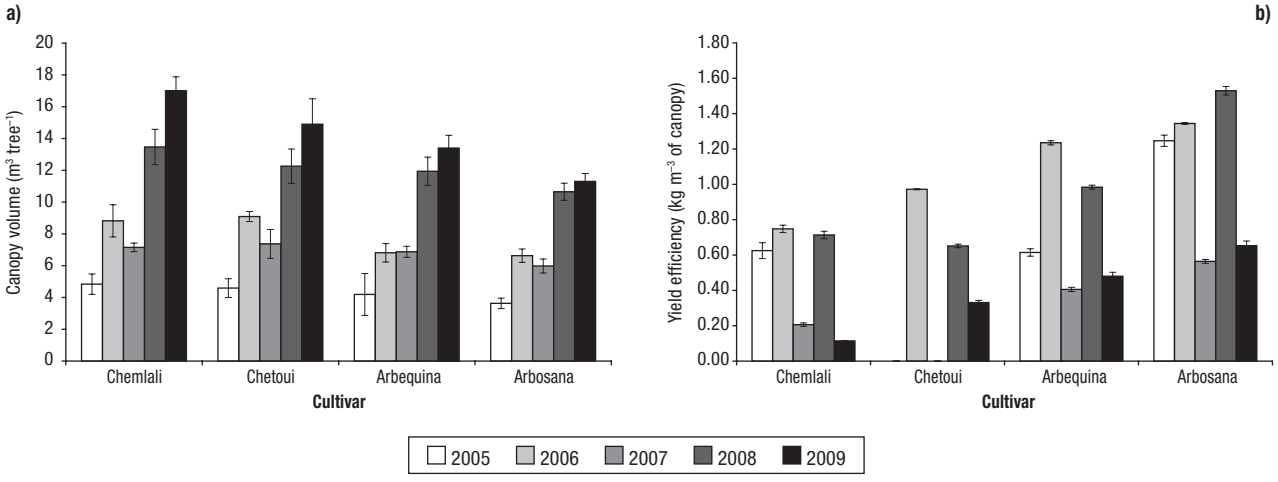

Figure 1. Canopy volume (a) and yield efficiency (b) of the compared cultivars during the first five producing years of the study.

Table 3. Oil content on dry weight basis (nuclear magnetic resonance, NMR), moisture content and fruit weight of the compared cultivars during the last four recorded harvests, one less for 'Chetoui'

Variety	Fruit oil content NMR (%)	Fruit moisture (%)	Fruit weight (g)
Chetoui	53.17 a	53.17 b	2.46 a
Arbosana	50.06 ab	61.6 a	1.88 b
Arbequina i-18	49.77 ab	53.6 b	2.06 b
Chemlali	43.34 b	56.5 b	1.11 c

The same letters within the column indicate no significant differences among studied cultivars (Duncan, $p < 0.05$).

Fruit weight average varied significantly among cultivars: 'Chetoui' > 'Arbosana' = 'Arbequina' > 'Chemlali' (Table 3). A significant difference for oil content on dry weight basis was also observed between 'Chetoui' and 'Chemlali', with values of 53.2% and 43.4%, respectively. However, no significant difference was observed among years for each studied variety (data not shown).

Significant differences among cultivars were observed in the oil acidic compositions. 'Arbosana' and 'Chetoui' showed the highest oleic acid contents (68.3-69.4% and 66.7-68.2%, respectively) while 'Chemlali', 'Arbequina' and 'Arbosana' showed similar and significantly higher palmitic acid contents than 'Chetoui' (Table 4). 'Arbosana' showed the smallest values in linoleic acid in comparison to the other cultivars.

Discussion

The smallest canopy values of 'Arbosana' and 'Arbequina i-18' should be related to their significantly smaller tree height as tree girth does not differ except with 'Chemlali' (Table 1). The high tree height and canopy width of this cultivar make it quite unsuitable to the hedgerow orchard, designed to be harvested with a straddle harvester. It should be noted that tree height has not been affected by any pruning yet, either manual or mechanical.

The smallest canopy volume of 'Arbosana' also agrees with the results of another trial up to the 5th year after planting, where 'Arbosana' and 'Arbequina i-18' are compared to 'Canetera', 'Joanenca', 'Koroneiki' and 'Fs-17' grown at 1469 trees ha^{-1} (Tous *et al*., 2003; 2008). That behaviour of those two Spanish cultivars compared to the most planted in Tunisia also confirms their classification as very low- and low-vigour cultivars, respectively (Tous *et al.*, 2005a). But the canopy volumes per hectare of 'Arbequina i-18' and 'Arbosana' are higher in our trial, 24% and 20%, respectively. This could be explained by our trees being two years older when providing the compared data, by the planting densities used, almost double in Tarragona (East Spain), and by the location, giving rise to longer growing season in our trial, as Takelsa is located 4° 20' to the South of Tarragona. As it was foreseen when designing the trial, it is advisable to reduce the density at the pace the growing season lengthens because of decreasing latitude.

Table 4. Fatty acid composition (oleic, palmitic and linoleic acid percentages) of the compared cultivars at the first (2005), second (2006) and fourth (2008) recorded harvests except for Chetoui (second and fourth). Data are mean of 3 replicates ± SE

	Arbosana	Chétoui	Arbequina i-18	Chemlali
Oleic acid (C18:1)				
2005	68.3 ± 0.17 a	–	61.3 ± 0.23 b	56.1 ± 0.49 c
2006	68.6 ± 0.24 a	66.7 ± 1.22 a	64.9 ± 0.35 b	61.6 ± 0.74 c
2008	69.4 ± 0.006 a	68.2 ± 0.54 a	62.3 ± 0.07 b	62.7 ± 0.05 b
Palmitic acid (C16:0)				
2005	16.5 ± 0.2 b	–	18.1 ± 0.09 a	19.8 ± 0.11 a
2006	15.9 ± 0.8 ab	12.9 ± 0.54 b	16.9 ± 0.23 a	17.2 ± 0.12 a
2008	16.7 ± 0.04 a	14.1 ± 0.63 b	17.8 ± 0.10 a	17.5 ± 0.26 a
Linoleic acid (C18:2)				
2005	9.6 ± 0.37 c	–	13.9 ± 0.18 b	17 ± 0.44 a
2006	11.0 ± 0.32 b	16.9 ± 0.84 a	14.0 ± 0.0.2 ab	16.6 ± 0.21 a
2008	8.4 ± 0.01 b	14.2 ± 0.23 a	14.5 ± 0.15 a	14.1 ± 0.23 a

The same letters within the line indicates no significant differences among cultivars (Duncan, $p < 0.05$).

Our 'Arbosana' smallest canopy width in the inter-row sense has been also reported (Tous *et al*., 2008), although much smaller than in our trial, 1.46 versus 2.15 m. This also suggests that longer growing-season locations need more distance among trees and rows. But still pruning is needed to maintain the hedgerow thickness small enough to allow for using the over-the-row harvesters.

The similar height/canopy width ratios of the compared cultivars (Fig. 1B) allow to classify them as open growth habit seven years after planting, since every value is lower than 1.4 (Tous *et al*., 2003). That report has classified 'Arbosana' accordingly the fourth year after planting, but the other cultivars behave like semi-erect ('Arbequina i-18'), or even erect ('Joanenca'). With results of one more year, Tous *et al*. (2008) classify all their cultivars as erect-growth type, perhaps due to the planting density being almost 100% higher than ours (2469 vs. 1250 tree ha^{-1}). The relative smaller density at Takelsa does not force the trees to grow upright looking for light, at least yet.

The small TCSA values shown by 'Arbequina i-18' and 'Arbosana' trees seven years after planting (Table 1) confirm their behaviour in other comparative trials five (Tous *et al*., 2008) and three growing seasons after planting (Camposeo and Godini, 2009).

The result of 'Chetoui' starting fruiting one year later than the other cultivars is already known in its area of origin (Trigui and Msallem, 2002), while the three years taken by 'Arbosana' and 'Arbequina i-18' have been already reported at higher densities (Pastor *et al*., 2005; Godini *et al*., 2006; De la Rosa *et al*., 2007; Tous *et al*., 2008; Camposeo and Godini, 2009), showing that this is a genetic value not influenced by tree density. The first crop of 'Arbosana' and 'Arbequina i-18' in our trial is about the same than in Tarragona, Spain (Tous *et al.,* 2008) and Bari, Italy (Godini *et al*., 2006; Camposeo and Godini, 2009), but smaller than in Córdoba, Spain (De la Rosa *et al*., 2007), most likely due to different soil and climatic conditions.

The precocity of entry into bearing should however take into account not only how many years after planting the first crop is harvested, but also the accumulated crop of the first three harvests, as it has been shown that the time after planting a cultivar enters into bearing is not always correlated to the importance of its subsequent first harvests (Del Río *et al*., 2005a). In our trial, the accumulated yield during the first three harvests is higher in 'Arbosana' (15.6 kg $tree^{-1}$) and 'Arbequina i-18' (11.9 kg $tree^{-1}$) than in 'Chemlali' and 'Chetoui' (7.7 and 7.2 kg $tree^{-1}$, respectively), even worse for 'Chetoui' as it produces only one of the three considered years. Furthermore, 'Chetoui' and 'Chemlali' showed the highest alternate bearing index, 0.88 and 0.69, respectively (Table 2). The low yields of local cultivars during these first three years may also be due to the heavier lateral pruning needed to maintain them in hedgerow growth because of their higher vigour.

The accumulated production of the first three years is also higher in Takelsa than in Tarragona, Spain (Tous *et al.,* 2008) for 'Arbosana' (9.2 kg $tree^{-1}$) and similar for 'Arbequina i-18' (10.2 kg $tree^{-1}$) but much higher in the trial of Córdoba, Spain (De la Rosa *et al*., 2007, 23.0 kg $tree^{-1}$ for 'Arbosana' and 24.8 kg $tree^{-1}$ for 'Arbequina i-18'). Besides the different soil and climatic conditions, our results would have been better if the severe *Fusicladium oleagineum* attack at the third harvest year (2007) would have not taken place. Indeed the accumulated yields during the first five harvests of 'Arbequina i-18' and 'Arbosana' in our trial were not much smaller than those obtained in Cordoba if taking into account our smaller density, 1250 *vs.* 1975 (De la Rosa *et al*., 2007). As mutual shading has not started yet, our hedgerow results at a moderate density also agree with others using the same cultivar and densities lower than 1,000 trees ha^{-1} (Pastor *et al*., 2005, 2007). Although with a reduced sample, our results (Table 3) also confirm that cultivar is the main source of variation in olive fruit weight and oil content (Del Rio *et al*., 2005b). The average fruit weights of the four recorded crops are quite similar to other previously reported results (Trigui and Msallem, 2002; De la Rosa *et al*., 2007; Tous *et al*., 2008). However, those of 'Arbosana' and 'Arbequina i-18' show a light tendency to be a little higher when going from Tarragona, Spain (1.6 and 1.8 g) to Córdoba, Spain (1.9 and 1.8 g) and Takelsa, Tunisia (1.9 and 2.1 g), also confirming that certain traits of some cultivars do change with the environment (Tous and Romero, 1994). The quite low oil content of 'Chemlali' (Table 3) may be explained by the fact that this cultivar is not well adapted to the Northern Tunisian region, as is not its area of origin (Trigui and Msallem, 2002). However, when elaborating the oil in the olive mill attention should be paid to the only bad trait shown by 'Arbosana' in this trial, its highest fruit moisture content.

The acidic composition of 'Arbosana' (Table 4) adds another important trait to its good suitability for Tunisian environmental conditions as it presents oleic and palmitic percentages higher and lower, respectively, than those allowed by the rules agreed upon at the International Olive Council. 'The oleic acid contents

of 'Chetoui' and 'Chemlali', respectively fair and bad, also confirm previous local results (Grati-Kammoun and Khlif, 2001). The cultivar has already been held responsible for most (70-80%) of the variation in the concentration of the main fatty acids (Uceda *et al*., 2005; Tous *et al*., 2005b).

On the other hand 'Chetoui' presents a little better oleic acid and a little worse palmitic acid content than in the world olive germplasm bank of Córdoba (Uceda *et al*., 2005), separated by just 1° 10' of latitude from Takelsa. Besides that, our oleic and palmitic acids contents of 'Arbosana' and 'Arbequina i-18' are a little worse than those obtained in the high-density cultivar trial of Córdoba, Spain (De la Rosa *et al*., 2007) as they tend to decrease and to increase, respectively, some more if compared to the germplasm bank of Catalonia, Spain (Tous *et al*., 2005b), separated by 4° 20' of latitude from our trial. These results also confirm that some cultivars do change with the environment (Tous and Romero, 1994; Ben Temime *et al*., 2004; Tous *et al*., 2005b; Uceda *et al*., 2005) and the fruit load (Barone *et al*., 1994) in different fruit and oil characteristics.

In summary, 'Arbosana' and 'Arbequina i-18' showed a good suitability for high density orchards in the area of Takelsa, especially 'Arbosana', mainly due to their low vigour, high crop efficiency and less alternate bearing when compared to the Tunisian cultivars. 'Arbosana' also showed high oleic acid and low linoleic acid contents. The use of the Tunisian cultivars 'Chetoui' and 'Chemlali' in high-density planting orchards is not advisable due to their high vigour, lower productivity and highest alternate bearing indexes.

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