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Fruit and oil Characteristics of Tunisian olive progenies obtained by controlled crosses

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Abstract – Thirteen olive progenies coming from controlled crosses on Tunisian olive cultivars (Meski and Chetoui) with autochthones and foreign cultivars were selected among 200 olive genotypes on the basis of their agronomic characteristics in a breeding program initiated in 1994. In this study, weight and flesh to seed ratio, oil content, specific absorption at ultraviolet light, free acid content, chlorophyll and carotenoid contents, total phenols and fatty acid composition of these progenies were determined and compared to their parents. The analysis of variance revealed significant differences among genotypes for all traits ($p<0.01$) except for UV extinction coefficients (K232 and K270). Some progenies showed superior features compared to their genitors.

Keywords: Fruit, oil characteristics, olive progenies, cross breeding

1. Introduction

The olive (*Olea europaea* L.) is the most important fruit tree in the Mediterranean Basin. It yields two products, table olives and olive oil, both of which are important components for the Mediterranean diet and are largely consumed worldwide. But there is a need to improve yield, quality and nutritional value of the olive product. The concept of quality on fruit products is wide, complex and dynamic (Ozdemir et al. 2018). This has encouraged olive research institutions in some producing-countries to perform several cross-breeding programs. Most of these programs have been focused on cross breeding among the main outstanding cultivars and selection within the progenies (Fontanazza et al. 1990; Trigui and Msallem 1995). Fatty acid composition, in particular high oleic acid content, has been considered one of the most important breeding objectives for olive oil (León et al 2008). Fruit weight, flesh and seed ratio and texture hardness were thought as an important physical quality attribute and has a great importance for table olive breeding programs (Rallo 2014). Nevertheless, the long juvenile phase, high heterozygosity and scarce information on trait heritability were the most limiting factors that have negatively affected olive breeding all over the world (De la Rosa et al. 2016). Thus, until recently, very few cultivars have been emergedfrom formal olive breeding programs and were selected empirically within their original area of cultivation (Marchese et al. 2016).

In the past few years, olive growing and olive oil production had shown an exponential increase in non-Mediterranean countries (FAOSTAT 2016). The emergence of the new olive producing areas and the increasing importance of the nutritional features of olive oil for consumers and markets have significantly boosted the development of new and more ambitious olive breeding programs (Lavee 2013). Thus, the objectives of most recent breeding programs are not only agronomic (Pérez et al. 2018). In fact, as part of an olive genetic improvement program carried out using intervarietal breeding to produce superior progeny, several analytical determinations were carried out in many works based on oil composition (Manaï et al. 2018; Mousavi et al. 2018). Evaluation of olive oil composition is considered as a compulsory task in any breeding program aiming at obtaining new olive cultivars (León et al. 2011).

The quality of virgin olive oil (VOO) is highly determined by its fatty acid composition (high monounsaturated oleic acid content) and minor compounds (León et al. 2018). Several authors have reported improved cultivars or advanced selections with enhanced oleic acid, tocopherol, total phenolic contents as well as peroxide and pigments values (De la Rosa et al. 2013; Manaï et al. 2018; Pérez et al. 2018).

The aim of this study was the fruit characterization of thirteen selected olive progenies and their oil content parameters determination. Progenies were selected from a Tunisian controlled crossing program, initiated in 1994, done on 'Meski' and 'Chetoui' cultivars using several autochthonous and Mediterranean varieties. Obtained results were compared with seven correspondent parents.

2. Materials and Methods

2.1. Plant material

Thirteen olive progenies and their genitors (Table 1) were evaluated during their maturity stage (2014-2015 crop season). Investigated progenies were selected from 200 descendants according to their high productivity and agronomic characteristics. Descendants were the result of two Tunisian olive cultivars 'Meski' (table olive) and Chetoui (oil olive) already crossed with autochthonous cultivars (Besbessi, Chemlali and Chetoui) and foreign cultivars (Agezzi-Egypt, Ascolana-Italy, Manzanille-Spain and Picholine-France) in order to obtain a new oil or a table olive variety meeting the international market requirements (Dridi et al. 2018).

Olive trees were planted with 6x3m of space in the experimental plot of the National Institute for Research in Rural Engineering Water and Forests (INGREF) of Oued Souhil (latitude NR 36 (27 '22 "), E10 longitude (42' 02")) (Nabeul/North of Tunisia).

Table 1. Evaluated olive progenies hybrids and their genitors

Hybrid	Crossing combination
17C	Chetoui x Agezzi
16D	Meski x Chetoui
10E	Meski x Chemlali
9F	Meski x Besbessi
14F	Meski x Besbessi
8H	Meski x Manzanille
22H	Meski x Picholine
16I	Meski x Picholine
22I	Meski x Picholine
23I	Meski x Picholine
12J	Meski x Chetoui
21K	Chetoui x Ascolana
IO2	Meski x Ascolana

2.2. Fruit analyses

Fresh olive fruits were randomly hand-picked from olive progenies and their parents at their perfect stage in order to provide an optimum oil yield and quality (3 to 4 maturation index) (Boskou 2006). The weight of both fruit and seed as well as the flesh to seed ratio were analyzed according to the International Olive Council standard method (IOC 1997).

2.3. Oil analyses

2.3.1. Oil content

Fruit weight was measured and then samples were dried at 105°C until complete dehydration. Dried samples were weighed to determine moisture content. Oil content was determined using NMR fat analyser (OXFORD 4000) and expressed as a percentage on both fresh and dry weight basis.

2.3.2. Oil extraction

Virgin olive oil was extracted from olive fruit descendants and genitors using an Abencor laboratory oil mill (MC, Ingenierias y sistemas, Sevilla, Spain) (Martinez-Suárez et al. 1975). This equipment consists of a three steps process: a hammer crusher, a thermo beater and a paste centrifuge. Three samples of olive paste (700 g) per genotype were analyzed. After centrifugation, the obtained oil through decantation was transferred into dark glass bottles, and stored at 4°C until further analysis.

2.3.3. Analytical methods

2.3.3.1. Quality parameters

Two regulated physicochemical quality parameters were determined: Free acidity and ultraviolet light specific extinction coefficients (K232 and K270). Free acidity, given as percentage of oleic acid, was determined by titration of an oil solution according to the procedure described by Wolff (1968).
The ultraviolet specific extinction coefficients K232 and K270 were established (Frías et al., 1999). The optic density readings using an UV-Visible Spectrophotometer (Shimadzu) were performed at the two wavelengths 232 and 270nm using pure cyclohexane as a blank.

2.3.3.2. Pigment content

The total chlorophyll and carotenoid compounds (mg/kg) were determined colorimetrically operating as described by Minguez-Mosquera et al. (1991). Olive oil samples were putted into quartz cuvette and absorbance values were taken at 630, 670 and 710 nm against carbon tetrachloride for Chlorophyll fraction and at 470 nm for carotenoid fraction.

2.3.3.3. Total phenols

Total phenol compounds were colorimetrically quantified (Marigo 1973). Oil (2.5 g) dissolved in 5mL hexane and extracted with 5mL of a 60:40 (v/v) methanol–water mixture. Total phenols were determined by adding 0.5 mL of Folin-Ciocalteu reagent with 1 mL of 30% Na2CO to the extract and measuring the absorbance at 726 nm 2 h later using a UV spectrophotometer (Shimadzu).

2.3.3.4. Fatty acid composition

The composition of fatty acids was evaluated after preparation of fatty acid methyl ester using a cold saponification (Stefanoudaki et al. 1999). In brief, 0.2 g of oil were vigorously mixed with 3 mL of hexane and 0.3 mL of a methanolic solution of KOH (2 N), for 1 min. The mixture was allowed to set for 5 min and analyzed by gas chromatography (GC) (Perkin Elmer Gas Chromatograph Clarus 580) equipped with a capillary column (RESTEK Rt-2560) (column temperature 180 °C) coupled to a flame ionization detector. Both the injector and detector were maintained at 250°C. The identification of fatty acids was done by comparing retention time with standard compounds and results were expressed as relative percentage of the total.

2.4. Statistical analyses

Results were reported as the mean values of three replications in each analysis. The results are shown as the mean values and standard deviation. Analysis of variance was applied with the Duncan multiple comparison test of the means ($p<0.01$) to determine the presence of significant differences among the samples. Statistical analysis was performed using the SPSS® 24.0 (IBM®) program.

3. Results and discussion

This study reports on fruit characteristics (fruit and stone weight and flesh to stone ratio). It also reports on oil content and chemical characteristics of virgin olive oil from thirteen selected progenies and their genitors. A high degree of variability and significant differences between genotypes were obtained for all fruit and oil characteristics analyzed except for UV extinction coefficients (K232 and K270) (Table 2).

Table 2. Descriptive statistics of fruit and oil olive samples from the studied olive progenies and their parents

Parameters	Minimum	Maximum	Mean	SD	CV (%)
FW (g)	1.00	6.52	3.59	1.69	47.08***
SW (g)	0.11	0.73	0.48	0.17	35.42***
FSR	3.31	9.23	6.28	1.94	30.89***
Oil content (%DM)	31.74	57.96	45.97	7.79	16.95***
Total Phenols (mg/kg)	162.83	803.29	393.61	165.65	42.08***
Carotenoids (mg/kg)	3.37	11.84	7.1	2.21	31.13**
Chlorophylls (mg/kg)	1.31	10.28	3.92	2.65	67.60***
Free acidity (%C18 :1)	0.20	0.61	0.38	0.14	36.84**
K232 (nm)	1.99	2.51	2.28	0.16	7.02
K270 (nm)	0.17	0.26	0.21	0.02	9.52
Palmitic acid, C16 :0 (%)	9.14	19.36	14.73	2.92	19.82***
Palmitoleic acid, C16 :1 (%)	0.35	2.55	1.16	0.62	53.45***
Stearic acid, C18 :0 (%)	1.81	3.69	2.39	0.41	17.15***
Oleic acid, C18 :1 (%)	55.72	78.62	66.33	6.71	10.12***
Linoleic acid, C18 :2 (%)	5.28	20.43	13.7	4.69	34.23***
Linolenic acid, C18 :3 (%)	0.13	1.00	0.72	0.23	39.08***
Arachidic acid, C20 :0 (%)	0.24	0.57	0.44	0.07	15.91***
Oleic/3917inoleica cid, O/L	2.85	14.91	5.86	3.22	54.95***
MUFAs	58	79	67.5	6.51	9.64***
PUFAs	6	21	14.33	4.82	33.64***
MUFAs/PUFAs	2.78	13.78	5.57	2.95	52.96***

***Highly Significant at P< 0.001
**Significant at P<0.01

3.1. Fruit characteristics

Fruit weight and flesh to seed ratio were used as descriptive fruit characters and thus are required for the new cultivar registration procedure for olive cultivar candidates in breeding studies (Medina et al. 2010; Ozdemir et al. 2016).

Fruit characters measurements of the new obtained olive genotypes and their corresponding genitors are given in Table 3. Significant differences among genotypes were observed according to fruit and stone weight (FW, SW) and flesh to stone ratio (FSR) (Table 2, 3).

The highest fruit weight value was obtained for the parent ‘Ascolana’ (6.52 g), a table olive variety, while the lowest one was obtained for the parent ‘Chemlali’ (1 g), an oil olive variety. The average value of this parameter was 3.59 g in all genotypes tested. A high degree of variability was obtained among the descendance, it varied between 1.11 g for the hybrid ‘21K’ (‘Chetoui’ x ‘Ascolana’) and 5.47 g for the hybrid ‘IO2’ (‘Meski’ x ‘Ascolana’). Similarly, the stone weight showed significant difference among genotypes. It varied between 0.11 and 0.73 g in ‘17C’ and ‘14F’ respectively with an average value of 0.48 g.

Flesh to stone ratio was important for all genotypes (average= 6.28). The highest value was obtained in the female parent ‘Meski’ (9.24) followed by ‘Ascolana (8.93). The majority of the studied genotypes (progenies and parents) (Ozdemir et al. 2016; Laaribi et al. 2014), showed that this parameter was high (Table 3). In general, a high percentage of pulps means a better commercial value for both table and oil production (Alfei et al. 2008).

Table 3. Mean values by genotype for olive fruit and oil characters

Genotype	FW (g)	SW (g)	FSR	Oil Content (%DW)	Total Phenols (ppm)	Carotenoids (ppm)	Chlorophylls (ppm)	Free acidity	K232	K270
17C	2.43±0.51d	0.11±0.19a	5.84±0.11de	58.16±1.60i	361.58±45.33cde	8.27±3.33bcde	9.45±3.09de	0.25±0.22ab	2.14±0.24	0.21±0.02
16D	1.14±0.24ab	0.13±0.22a	3.30±0.52a	43.61±0.81bc	372.74±30.05cde	6.88±1.63abcd	6.05±1.87bcd	0.40±0.10abc	2.37±0.11	0.24±0.04
10E	4.46±0.32fg	0.69±0.06ef	5.50±0.68cd	37.56±3.64a	281.97±27.03bcd	5.88±3.33abc	2.34±0.11ab	0.50±0.03bc	2.43±0.11	0.23±0.02
9F	4.33±0.58fg	0.66±0.13ef	5.88±0.57de	31.67±5.51a	162.83±31.99a	4.78±1.29ab	2.19±1.20ab	0.53±0.06bc	2.47±0.11	0.19±0.04
14F	4.67±0.47g	0.73±0.07f	5.33±0.58bcd	30.66±3.75a	342.74±17.56cde	8.03±4.67abcde	2.25±0.97ab	0.45±0.18abc	2.35±0.34	0.21±0.02
8H	4.05±0.37efg	0.68±0.07ef	5.00±1.00abcd	34.54±2.08a	194.41±14.99ab	4.87±1.53ab	1.87±0.56a	0.45±0.09abc	2.14±0.18	0.21±0.07
22H	3.93±0.60efg	0.42±0.05cd	8.67±2.08f	50.67±2.08fgh	392.18±72.28de	8.61±2.54bcde	4.89±2.32abc	0.20±0.10a	2.20±0.20	0.20±0.03
16I	2.23±0.15cd	0.37±0.03bcd	5.08±0.21abcd	54.33±1.53hi	316.35±68.39cde	7.83±3.01abcde	3.28±1.71ab	0.43±0.35abc	2.43±0.11	0.23±0.01
22I	4.60±0.33g	0.50±0.03cde	8.13±0.23f	43.83±2.84bcd	439.13±51.78e	7.00±1.36abcd	2.82±0.22ab	0.20±0.17a	2.17±0.29	0.18±0.03
23I	1.77±0.36bcd	0.36±0.09bcd	3.67±0.58ab	47.48±1.73fgh	803.29±100.77g	11.84±3.51e	10.28±5.52e	0.61±0.17c	2.15±0.15	0.21±0.06
12J	1.66±0.58abc	0.32±0.02bc	4.00±1.00abc	48.00±2.52fgh	406.08±80.86de	6.82±1.57abcd	2.31±1.25ab	0.61±0.20c	2.06±0.49	0.20±0.06
21K	1.11±0.16a	0.23±0.01ab	3.67±1.15ab	46.86±1.00efg	786.07±168.76g	8.21±0.96bcde	3.61±1.90ab	0.41±0.10abc	1.99±0.55	0.19±0.06
IO2	5.47±0.27h	0.66±0.01ef	7.33±0.58ef	48.63±1.15efg	318.84±18.33cde	4.21±1.28ab	2.11±1.13ab	0.42±0.10abc	2.07±0.37	0.20±0.01
Ascolana	6.52±0.17i	0.65±0.08ef	8.93±1.00f	52.10±1.15gh	341.88±22.99cde	9.67±2.05cde	1.71±0.62a	0.26±0.18ab	2.50±0.18	0.20±0.01
Besbessi	5.94±0.31hi	0.66±0.11g	8.33±1.53f	45.50±0.50cde	254.96±36.80abc	6.50±1.09abc	1.38±0.55a	0.25±0.07ab	2.31±0.10	0.20±0.01
Chemlali	1.00±0.03a	0.19±0.01ab	4.13±0.23abc	49.57±0.98efg	325.14±15.86cde	5.05±2.21abc	3.87±2.24abc	0.20±0.10a	2.40±0.43	0.18±0.02
Chetoui	3.36±0.19e	0.35±0.02bcd	8.33±0.58f	50.67±0.58fgh	608.02±92.03f	3.37±2.17a	6.06±2.74bcd	0.53±0.11bc	2.23±0.06	0.26±0.14
Manzanille	4.15±0.18fg	0.51±0.06cde	7.33±1.15ef	48.31±0.54efg	380.80±38.51cde	5.47±0.62abc	2.90±0.37ab	0.20±0.03a	2.47±0.15	0.21±0.01
Meski	5.36±0.80h	0.53±0.08de	9.24±1.12f	40.67±0.58b	434.30±78.28cde	11.18±3.41de	1.31±0.34a	0.20±0.06a	2.37±0.06	0.17±0.02
Picholine	3.73±1.70efg	0.14±0.24a	7.66±0.58f	47.00±1.00def	393.61±171.51e	7.48±1.29abcde	7.50±3.47cde	0.47±0.06abc	2.37±0.30	0.21±0.01

Within columns, values followed by the same letter are not significantly different at $P>0.05$.

3.2. Oil characteristics

3.2.1. Oil Content

Oil content (% on dry weight basis) ranged from 31.74 % to 58% with an average of 45.97%. Tous and Romero (1994) divided olives into three groups (based on oil percentage on dry weight basis) as high (>46%), moderate (38 - 46%) and low (< 38%). In the current research, according to the oil percentage on the basis of dry matter, only four of hybrid olive candidates (‘10E’, ‘9F’, ‘14F’ and ‘8H’) had the oil percentage less than 38%. Seven hybrids (‘17C’, ‘22H’, ‘16I’, ‘23I’, ‘12J’, ‘21K’ and ‘IO2’) were in ‘high class ‘, while two hybrid cultivars (‘16D’ and ‘22I’,) were in the ‘moderate’ oil percentage groups. Oil content on dry weight basis was previously reported in the evaluation of new genotypes obtained by cross breeding in several studies. Oil percentage ranged from 30% to 50% in 23 new olive genotypes obtained by breeding crosses in Turkey (Ozdemir et al. 2016), 30% to 53% in 52 new olive genotypes selected in Central Italy (Alfei et al. 2008), 41% to 52% in 7 advanced olive selections in Spain (De la Rosa et al. 2013).

The genotypes ‘17C’, ‘22H’, ‘16I’, ‘23I’ and ‘12J’ had greater percentage of oil content than their parents (‘Meski’, Picholine’ and ‘Chetoui’). Similar result has been previously reported in progenies from open pollination of cultivars showing higher values for characters such as fruit weight, oil content and stone/fruit ratio than their parents (Arias-Calderón et al. 2014).

3.2.2. Analytical parameters

For all studied genotypes, analytical parameters (Table 2) are within the ranges established for high designed 'extra virgin' olive oil (EVOO) according to IOOC.

3.2.3. Quality indices

All parameters were compliant with the IOC standards established for "extra virgin olive oil" (EVOO) category for all samples (acidity < 0.8%; K232≤ 2.5; K270 ≤ 0.22) except for 4 genotypes ('16D', '10E', '16I' and 'Chetoui') where K270 value slightly exceeded the limit.
Free acidity percentage ranged from 0.20 to 0.61% corresponding to an average value of 0.38. Specific absorbance of olive oils at 232 nm and 270 nm ranged from 1.99 ('21K') to 2.5 ('Ascolana') for K232 and from 0.17 ('Meski') to 0.26 for K270 ('Chetoui').

3.2.4. Pigment content

Chlorophyll and carotenoid contents revealed a range of concentrations between 1.31 and 10.28 mg/kg and 3.37 and 11.84 mg/kg respectively. Significant differences among genotypes were observed in their pigment contents. The hybrid '23I' showed higher chlorophyll and carotenoid contents compared to the other cultivars ($P < 0.05$) (Table 3). The lowest amounts of both chlorophyll and carotenoid were observed in 'Meski' and 'Chetoui' oils respectively. These components have been proposed to be used for genotype characterization and they are considered as relevant parameters for quality assessment. They are not only related to cultivar but also to oil extraction method (Minguez- Mosquera et al. 1991). In the current study, results highly suggest the genotype effect since the extraction method, the fruit ripeness and the pedoclimatic and agronomic conditions were constant.
The high pigment level can increase oil stability and quality because pigments are involved in autoxidation and photooxidation mechanisms (Minguez- Mosquera et al. 1991). Such components have also biological and healthy properties and occur in the oil at concentrations that are usually correlated with those of phenols (Ranalli et al. 1998).

3.2.5. Total phenols

The phenolic compounds contained in EVOOs are very important for nutritional value and commercial quality of VOO. Moreover, they are taken into consideration for assessment in the new cross breeding programs (Pérez et al. 2014).
A wide range of variation for total phenols content was observed among the genotypes evaluated in this work (CV= 42%) confirming that genotype plays a fundamental role in this parameter (Lodolini et al., 2017; Pérez et al 2018). In general, the concentration of total phenols usually ranges from 50 up to 500 mg/kg, but oils can be found with concentrations up to 800 mg/kg (Manaï et al. 2007). In the present study, the total phenol content varied significantly among genotypes and oscillated between 162 and 803 mg/kg. The highest content was observed in the hybrid '23I' obtained from 'Meski' x 'Picholine' crossing followed by the hybrid '21K' (Chetoui' x 'Ascolana'), while the lowest content was noted for the hybrid '9F' ('Mesk' x 'Besbessi').
Duncan multiple comparison procedure proved that the main group of genotypes is constituted by six hybrids ('17C', '16D', '14F', '16I', '22I' and 'IO2') beside four olive cultivars ('Ascolana', 'Chemlali', 'Manzanille' and 'Meski') that correspond to a range between 316 to 434 mg/kg (Table 3).

3.2.6. Fatty acid composition

Fatty acid composition is one of the key parameters used to characterize olive oils. The monounsaturated fatty acids (MUFAs) are the predominant fatty acids in olive oil, with oleic acid being the most abundant (55-83%) (León et al. 2018). As mentioned before, the monounsaturated profile is one of the most important factors that contribute to explain health benefits of olive oil in the Mediterranean Diet (Rallo et al. 2018) and is largely responsible for the oil stability during the storage.
Seven fatty acids, namely palmitic acid (C16:0), palmitoleic acid (C16:1), stearic acid (C18:0), oleic acid (C18:1), linoleic acid (C18:2), linolenic acid (C18:3) and arachidic acid (C20:0) expressed as a percentage of total fatty acid composition were analysed in this study. Total monounsaturated/polyunsaturated ratio (MUFAs/PUFAs) and oleic/linoleic acid ratio (O/L) were also calculated.
Olive oils derived from the thirteen selected progenies and their correspondent parents showed that fatty acid composition is within the limits recommended by the IOC for virgin olive oils (IOC, 2018) (Table

2). Differences between genotypes are highly significant (p<001). As proved in many previous studies, the fatty acid composition of olive oil is known to be strongly depended on the particular cultivar (Rodriguez et al. 2018).

Oleic acid (C18:1), palmitic acid (C16:0) and linoleic acid (C18:2) were the most abundant fatty acids in the olive oils studied (Table 2) with an average of 66.33%, 14.73% and 13.7% respectively. While palmitoleic (C16:1), stearic (C18:0), linolenic (C18:3) and arachidic (C20:0) acids were present in lower amounts. Oleic acid, the major MUFA, was present in a wide range of concentrations (55.72-78.62%). Generally, the progenies presented higher values of this acid than their genitors, especially for the hybrids '14F', '16I', '22I', '23I'and '21K' (C18:1> 70%) (Table 4). The levels of palmitic acid, the major saturated fatty acid, ranged from 9.14% for '14F' olive oil to 19.31% for the 'Chemlali' one. Concerning the linoleic acid, polyunsaturated fatty acid which is negatively correlated to the stability of virgin olive oil, the highest percentage was observed in 'Meski' oil (20.43%) whereas the lowest one was found in '23I' (5.28%), the progeny of 'Meski' and 'Picholine'. For the other fatty acids, palmitoleic (C16:1), stearic (C18:0), linolenic (C18:3) and arachidic (C20:0), although their amounts varied from one olive oil to other, they were quite small and within the range required for olive oil.

Monounsaturated fatty acids have great importance because of their nutritional implication and effect on the oxidative stability of oils. In this study, the MUFAs value ranged from 58 to 79% with an average of 67.5%. While the polyunsaturated fatty acids (PUFAs) average was 14.33%. The MUFAs/PUFAs ratio varied from 2.78 to 13.78. This ratio is used as an indicator of the tendency of olive oil to undergo autoxidation. Indeed, higher ratios correspond to a higher oxidative stability of the olive oil (Rallo et al. 2018). The highest ratio showed for the hybrid '23I' (13.45) due to its high oleic acid content (78.62%), followed by the hybrid '21K' (11.39) and the lowest ratio was noticed for the female parent 'Meski' (2.78) and the hybrid '10E' (2.92) (Table 4).

Another ratio was calculated from oleic and linoleic acid content (O/L). This ratio is used to characterize olive cultivars and has a marked relationship with stability (Manaï et al. 2007). The highest ratio was found in '23I' olive oil (14.91) which had the highest oleic acid content and the lowest level of linoleic acid (Table 4). This hybrid is distinguishable from the other studied olive hybrids due to its considerably higher C18:1/C18:2 and MUFAs/PUFAs ratios.

Table 4. Mean values of fatty acid composition (%) and calculated ratios in olive oils from thirteen selected progenies and their parents

Genotype	C16:0	C16:1	C18:0	C18:1	C18:2	C18:3	C20:0	O/L	MUFAs	PUFAs	MUFAs/PUFAs
17C	17.73±0.07j	0.35±0.01a	2.39±0.06ef	67.24±0.81ef	10.63±0.16def	0.63±0.04bc	0.45±0.01def	6.30±0.14fg	67.40±0.47fg	11.27±0.17c	5.98±0.13fg
16D	16.35±0.17k	1.22±0.02fg	2.48±0.03fgh	60.35±2.36bc	16.82±0.59hi	0.67±0.06bc	0.52±0.08gh	3.61±0.16abc	61.92±2.98bc	17.50±1.64f	3.54±0.15abcd
10E	18.75±0.03k	2.55±0.02j	2.32±0.03de	55.72±0.17a	19.19±0.19ijk	0.73±0.03bc	0.45±0.01cde	2.90±0.03a	58.27±0.20a	19.93±0.23fg	2.92±0.04ab
9F	16.79±0.02i	1.98±0.01i	2.49±0.15fgh	63.49±0.38cd	12.85±0.50fg	0.65±0.56bc	0.40±0.01bcd	4.94±0.22de	65.48±0.38def	13.83±0.52de	4.73±0.20de
14F	9.14±0.08a	0.58±0.03abc	1.93±0.04b	77.50±0.33j	8.78±0.11bcd	0.59±0.51b	0.44±0.03cde	8.82±0.14ij	78.09±0.31k	9.71±0.15bc	8.04±0.13hi
8H	17.90±1.46j	2.13±0.71i	2.41±0.16efg	60.33±2.38bc	15.67±0.25h	0.74±0.03bc	0.45±0.01cde	4.66±1.07cd	62.47±1.28bcd	16.42±0.46f	4.51±2.77cd
22H	12.24±0.31cde	0.65±0.01bcd	1.92±0.15b	63.28±0.55cd	19.65±0.22jk	0.88±0.09bc	0.38±0.04bc	3.22±0.03ab	63.94±0.07cde	20.53±0.23fg	3.11±0.03ab
16I	14.27±0.15g	1.07±0.13efg	2.16±0.04c	70.91±0.22gh	9.59±0.07cde	0.70±0.01bc	0.50±0.01efg	7.38±0.08gh	71.99±0.35cde	10.30±0.07bc	6.98±0.08gh
22I	12.12±0.16c	0.93±0.04def	2.32±0.02de	73.40±0.24hi	9.53±0.06cde	0.87±0.01bc	0.37±0.01b	7.70±0.03hi	74.34±0.28hi	10.41±0.06bc	7.14±0.01h
23I	12.46±0.39cd	0.45±0.02ab	1.80±0.02a	78.62±0.31j	5.27±0.23a	0.60±0.05b	0.21±0.03a	14.91±0.58l	79.08±0.34k	5.89±0.29a	13.45±0.58k
12J	14.54±0.02g	0.86±0.01cde	2.52±0.02gh	64.88±0.32de	15.59±0.08h	0.81±0.01bc	0.42±0.01bcd	4.15±0.02abcd	65.74±0.02k	16.41±0.08ef	4.00±0.02abcd
21K	12.95±0.01e	1.85±0.01i	1.92±0.03b	75.92±0.41ij	6.75±0.05ab	0.07±0.06a	0.50±0.05efg	11.24±0.07k	77.78±0.03ef	6.83±0.03a	11.39±0.05j
IO2	13.94±0.03f	1.36±0.01def	2.51±0.01h	68.44±0.05def	11.53±0.02gh	0.84±0.01bc	0.44±0.01fgh	5.93±0.01bcd	69.81±0.03ef	12.37±0.03ef	5.64±0.01bcd
Ascolana	13.59±0.03fg	0.93±0.01g	2.55±0.01fgh	65.45±0.02fg	15.24±0.07ef	0.85±0.02bc	0.51±0.03cde	4.29±0.02ef	66.38±0.03gh	16.09±0.09cd	4.12±0.02ef
Besbessi	16.43±0.01hi	0.87±0.01cde	2.27±0.02cd	61.40±0.15bc	17.09±0.05hij	0.80±0.02bc	0.42±0.02bcd	3.59±0.01abc	62.28±0.02bcd	17.90±0.05f	3.47±0.01abc
Chemlali	19.31±0.01k	1.95±0.01i	2.31±0.01de	58.40±0.19ab	16.55±0.10h	0.77±0.01bc	0.46±0.01def	3.52±0.03abc	6035±0.19ab	17.31±0.11f	3.48±0.03abc
Chetoui	11.06±0.05b	0.47±0.01ab	3.69±0.01j	63.68±0.27cd	19.39±0.14ijk	0.73±0.02bc	0.56±0.02h	3.28±0.03ab	64.16±0.28cdef	20.12±0.17fg	3.18±0.04ab
Manzanille	12.91±0.02e	1.14±0.01efg	2.95±0.01i	73.23±0.08hi	7.52±0.15abc	0.77±0.01bc	0.47±0.02defg	9.73±0.20j	74.38±0.08i	8.30±0.16ab	8.96±0.17i
Meski	16.17±0.05h	0.94±0.04def	2.26±0.01cd	58.32±0.05ab	20.43±0.01k	0.81±0.02bc	0.41±0.01bcd	2.85±0.01a	59.27±0.09ab	21.25±0.03g	2.78±0.01a
Picholine	12.84±0.02de	0.91±0.01def	2.48±0.10fgh	65.97±0.60def	15.93±0.62h	0.97±0.11c	0.42±0.01bcd	4.14±0.20abcd	66.89±0.61efg	16.90±0.67f	3.96±0.19abcd
Norm IOOC	7.5-20	0.3-3.5	0.5-5	55-83	2.5-21	≤1	≤0.6	-	-	-	-

4. Conclusion

The controlled crossing on 'Meski' and 'Chetoui' varieties provided new genotypes with significant differences in term of fruit and oil characters, showing better values than the genitors for almost the characters evaluated. Observed differences between studied hybrid genotypes could be due mainly to the genetic component as they are grown in the same field with similar cultural practices and the oil extraction and process was carried out under the same conditions. It would be interesting to study their behavior in other pedo-climatic conditions in order to confirm their performances then some of these progenies could be released as new olive cultivars.

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