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Assessment of Tunisian apricot local and hybrids cultivars for new breeding program

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ABSTRACT

Earlier, the fruit quality of local apricot varieties has been described summarily on the basis of morphological traits. Detailed characterization of the Tunisian cultivars was done using physical and chemical fruits traits. The aim of this work is to select among twelve early ripening cultivars, genotypes with high fruit quality as parents for new breeding program (creation of new cultivars: early, self-compatible, high fruit quality and resistant to main fungal diseases). A highly significant difference was obtained between the cultivars and between the years. Whereas, the fruit position had only significant influence on the flesh percentage in the fruit. Significant correlations were obtained between many fruit traits (physical and chemical). The fruit size (thickness, weight, length and width), flesh firmness, stone weight, juice and total soluble sugars percentages were of great interest for discrimination between the cultivars. The geographical origin was not a determinant criterion for cultivar clustering. The studied cultivars were divided into three groups: Bedri Ahmar and Bouk Ahmed (very small: 20-30g), Bouthani Ben Friha, Oueld El Oud, Hamidi, Adedi Ahmar, Sayeb and Asli (small: 31-40g). Fruits of Oud Hmida and the two hybrids Ouardi and Raki were classified as small/medium (41-45g). The results showed that Ouardi, Sayeb, Raki, Oud Rhayem and Oud Hmida have a high fruit quality. These cultivars were already used as parents for the new apricot breeding program.

Key words: Apricot (*Prunus armeniaca* L.), maturity date, fruit quality, local cultivars, hybrids cultivars.

INTRODCUTION

In Tunisia, the apricot production was about 30.000 tons during 2010-2011 with an increase of 28% comparing to the production in 2010. This production accounted for approximately 7% of the total fruit production (www.gifruits.com, 2011). This production is represented by early and season varieties which are cultivated in the north, the centre and the south of the country. The fruit quality of local and introduced varieties has been described summarily on the basis of morphological traits developed in local agro-ecological conditions (Carraut and Crossa-Raynaud, 1974; Lachkar and Mlika, 2006) in order to give farmers and consumers a possibility varietal choose. Apricot quality evaluation is generally based on diverse criteria as size, color, taste, flavor, texture, etc. and it seems not possible to have a preference for one of these parameters at the expense of others (Souty et al., 1990). Physical and chemical characteristics (Mellano et al., 2006), aroma and taste (Lunati, 2006) are very important for the consumer appreciation. The major criteria are sugars, acidity and firmness (Audergon et al., 1991a; Lurol et al., 2007). Actually, most breeding programs are focused on improvement of apricot flavor considering the roles played by principal acids and sugars in flavor expression (Bassi et al., 1996).

To overcome the insufficient information about the apricot Tunisian germplasm, the aim of this work is to give detailed characterization of some local early ripening cultivars using physical and chemical parameters of fruits at the maturity period. Results could permit to select genotypes with high fruit quality as parents for further breeding programs.

MATERIALS AND METHODS

1.1. Plant material

Twelve early local apricot cultivars (Oud Rhayem, Oud Hmida, Bouthani Ben Friha, Bedri Ahmar, Oueld El Oud, Hamidi, Bouk Ahmed, Adedi Ahmar, Ouardi, Sayeb, Asli and Raki, were selected for this study. They are maintained at INRAT-Mornag Resarch Station (36°7' latitude and 10°2' longitude) belonging to the higher semi-arid bioclimatic area, receiving 450 mm as average annual rainfall and having 12°C as average annual temperature.

Among these studied cultivars, five are originated from Testour (North-western of Tunisia): Oud Rhayem, Oud Hmida, Bouthani Ben Friha, Bedri Ahmar and Oueld El Oud and three are originated from Ras Jebel (North-eastern of Tunisia): Hamidi, Bouk Ahmed and Adedi Ahmar. Although, in earlier study, Hamidi was the main cultivar in Ariana region (almost 8 km far from the Tunis town, Tunisia) (Carraut and Crossa-Raynaud, 1974). Ouardi, Sayeb, Asli and Raki were the result of INRAT apricot breeding program (Mlika et al., 2002; Lachkar and Mlika, 2006) (Fig. 1). The two first hybrids “Ouardi and Sayeb” were obtained from crosses between Canino and Hamidi, whereas “Asli and Raki” were selected from crosses between Patriarca temprano and Scréara.

Three trees planted at 7m x 7m and receiving the necessary cultivation techniques, were randomly selected for each cultivar. During three consecutive years, (2007-2009) representative samples of 24 fruits by cultivar (6 fruits/orientation), were harvested on each tree at the maturity period and were analyzed for physical traits and chemical analysis.

1.2. Methods

The pomological fruit description was carried out according to UPOV (1979) and IPGRI (1984). Description was based on ten physical traits (fruit weight “FW”, fruit thickness “FTh”, fruit lenght “FL”, fruit width “FWi”, fruit thickness/width “FTh/FWi”, fruit lenght/width “FL/FWi”, flesh firmness “FlFir”, Flesh percentage “Fl%” and stone weight “SW”) and four chemical traits (juice percentage “J%”, pH, total soluble solids percentage “TSS%” and titratable acidity “TA”) (Vénien, 1998) (Table 1). Concurrently, maturity dates were recorded for the twelve cultivars during seven years (2003-2009).

1.3. Statistical analysis

To determine the effect of cultivar, fruit position and year on studied fruit traits, a multivariate analysis was carried out. The average values of each fruit trait were used to establish cultivars groups (Duncan test with 5%). Correlation between fruit traits were calculated and principal component analysis (PCA) and hierarchical clustering were performed using SPSS 11.0.

RESULTS AND DISCUSSION

1.4. Maturity dates

The follow-up of the maturity date of the local apricot cultivars over seven years showed important differences between some cultivars. According to the fruit maturity dates of the two early hybrids cultivars “Ouardi and Sayeb”, some cultivars were classified also as early (between the second and the fourth week of May): Oud Rhayem, Bedri Ahmar, Hamidi and Bouk Ahmed, others as mid-early (between the third week of May and the first week of June): Oud Hmida, Bouthani Ben Friha, Asli, Raki and Adedi Ahmar and the last one Oueld El Oud as late (between the fourth week of May and the second week of June) (Table 2). These results confirm those reported by Krichen et al. (2006). On the other hand, almost all local cultivars showed significant differences between years. However the four hybrids Ouardi, Sayeb, Asli and Raki, displayed similar maturity dates during the 7 years (Table 2).

The determination of the apricot harvest date is generally related to the some maturity physical, biochemical and physiological markers. These markers vary according to varieties, environmental conditions and cultivation techniques (Brown and Walker, 1990; Crisosto, 1994; Gouble et al., 2010; Lurol et al., 2007). Regularity of maturity dates is an interesting criterion allowing considering regular ones as parents in future breeding programs

1.5. Physical fruit traits

Data analysis using three classification factors (cultivar, fruit position and year) showed highly significant differences between cultivars for all studied traits (thickness, weight, length, width, thickness/width, length/width, flesh firmness,

flesh percentage and stone weight) (Table 3). The fruit weight varied between 26.7g (Bouk Ahmed) and 41.8g (Ouardi) (Table 3). According to IPGRI (1984), the studied cultivars were divided into three group (Table 3): very small (20-30g): Bedri Ahmar and Bouk Ahmed, small (31-40g): Bouthani Ben Friha, Oueld El Oud, Hamidi, Adedi Ahmar and the two hybrids Sayeb and Asli, and small/medium (41-45g): Oud Hmida and the two hybrids Ouardi and Raki. Some differences were noted between these results and those recorded for some cultivars in their zone of origin (Krichen, 2001). This may be due to the different pedoclimatic conditions and the known adaptation of apricot cultivars to very narrow zones. In addition, cultivation techniques (thining, pruning and fertirrigation) may affect the "potential quality" (Audergon et al., 1991b). Ledbetter et al. (1996) reported significant differences in fruit weight of apricot varieties in the same experimentation site. The fruit weight was a major inherited quantitative factor determining the yield, fruit quality and consumers acceptability (Dirlewanger et al., 1999).

Cultivars Bedri Ahmar and Bouk Ahmed had the lowest fruit dimensions (height and width) (Table 3). Whereas, the fruits of Ouardi were the longest (38.3 mm) and those of Raki were the largest (40.7mm) (Table 3). According to the standard size (Ctifl, AFNOR, 1995), only the new hybrid cultivar Raki produced fruits with "A" size and the other cultivars hybrids were characterized by "B" fruit size (Table 3). Mlika et al. (2002) studied the fruit size of the hybrids (Ouardi, Sayeb, Asli and Raki) under the same pedoclimatic conditions and classified Raki as "A-AA and more", Sayeb and Asli as "A-AA" and Ouardi as "B-A". Differences could be due to the trees age, soil status, rainfall variations and cultivation techniques.

Concerning fruit thickness, Bouthani Ben Friha grouped with Bedri Ahmar and Bouk Ahmed having the lowest values, 33.9mm, 33.9mm and 34.2mm, respectively. Whereas Oud Rhayem and Oueld El Oud showing the highest fruit thickness values (39.2mm) (Table 3). The lowest ratios fruit thickness/width and length/width were obtained for Adedi Ahmar. Whereas, Oud Rhayem had the highest thickness/width ratio. Bouthani Ben Friha, Hamidi and Bouk Ahmed showed the highest length/width ratio (Table 3). Krichen et al. (2006; 2010) also found a wide variability of several quantitative characters between local apricot cultivars of various areas and even of the same area.

The highest flesh firmness value was obtained in Oud Hmida whereas the least value was found in Bouk Ahmed. For the flesh percentage, the values ranged between 90.9 (Adedi Ahmar) and 96.1 (Oud Rhayem) (Table 3) and were closed to those obtained by Mratinic et al. (2011). Therefore, this trait can be considered in the selection of cultivars with high fruit quality. Stone fruit weight varied from 1.4g (Oud Rhayem) to 3.0g (Adedi Ahmar). The stone fruit weight, as well as flesh firmness and flesh percentage were the least uniform traits showing a high variation between cultivars. The results showed that the cultivar with a high stone percentage had a low flesh percentage (Table 3). Apricot stones were well used in genotype identification (Ozcan, 2000; Mandal et al., 2007). Many authors reported a high variability among apricot cultivars regarding this parameter (Ruiz and Egea 2008b; Hernandez et al., 2010; Milošević et al., 2010).

Our results showed no differences related to the fruit position for the most physical traits. Significant differences were noted only for the flesh firmness and the flesh percentage. South part of the tree gave the least flesh firmness fruit and also the least flesh percentage (Table 3). Audergon et al. (1991b) highlighted, on apricots collected individually, the existence of a very important variability of the fruit quality according to the fruit position on the tree (height, orientation, type of fructification and fruits association). Indeed, the fruits located at north have a size and weight average higher than those of the other sectors. Apricot exposure to the sun resulted in a substantial gain in size (Audergon et al., 1991b).

It's important to note that year effect was highly significant for all the fruit physical traits, except the stone weight. During 2009, we noted the highest values for the majority studied traits (Table 3). Belluau and Chanel (1989) showed an important effect of water supply on the average weight and the fruits size of 'Modesto' variety.

1.6. Chemical fruit traits

The juice content varied from 32.6% (Oud Hmida) to 49.8% (Sayeb) and 9 among 12 cultivars had more than 40%. The pH varied from 3.5 (Ouardi) to 4.1 (Oueld El Oud) (Table 4). Values of titratable acidity ranged between 17.9 meq/100g (Oueld El Oud) to 33.3 meq/100g (Oud Hmida) (Table 4). The levels can vary from less than 10 to over 40 meq/100g (Lichou et al. 1998). Akin et al. (2008) reported that malic acid was the predominant organic acid in apricots. It varied considerably according to the cultivars (Souty et al. 1976). Qualitative and quantitative determination of acids and sugars in apricot fruits could be a powerful tool in evaluating fruit maturity and quality (Dolenc-Šturm et al., 1999).

The total soluble solids percentage varied from 11.1 % (Sayeb) to 14.1% (Oueld El Oud) (Table 4). These values were close to those obtained by Ishag et al. (2009) and Mratinic et al. (2011). Some authors reported that apricot accessions with TSS content higher than 12 Brix were characterised by an excellent gustative quality (Egea et al.

1994; Guerriero et al. 2001). Ruiz and Egea (2008b) reported that this parameter is a very important quality attribute, influencing notably the fruit taste. Lichou et al. (2003) have shown that TSS values range from 9 to 18°Brix with a variation from 1 to 3°Brix according to the culture and climatology conditions and if the value is lower than 10.5°Brix, the apricot is likely to be perceived slightly sweet.

A highly significant "cultivar" effect was recorded for all the analyzed chemical variables (Table 4). Similar results were obtained by Mratinic et al. (2011) and Mehlenbacher et al. (1990). Our results also showed some differences with those reported for the same cultivars in their origin sites (Testour and Ras Jebel) (Krichen, 2001). These differences were related to the maturity stage which may influence differently and clearly the fruit technological traits (Audergon et al., 1991b). Also, the agroecological conditions at Mornag and the two sites of origin may be the cause.
No significant differences were related to fruit position for the four chemical fruit traits. However, these traits were significantly influenced by the year (Table 4). The apricots harvested in 2008 were the juiciest (49.2%), whereas, those harvested in 2007 and 2009 showed the highest values of pH, acidity and sugars (Table 4). Similar results were reported by Ruiz et al. (2010). Audergon et al. (1991b), studying during eight years the fruits of 'Red of Roussillon' under the same pedoclimatic and cultivation conditions, noted inter-annual variations for TSS, pH and titratable acidity. A regular decrease of titratable acidity was observed during the maturation of the fruit and depended on weather conditions, leading to different acidity levels from one year to another. The evolution of all organic acids is similar to that of total titratable acidity, but the malic acid seems to be metabolized faster than the citric acid, especially in the first stages of maturation. As a result, the malic/citric ratio differed by 10% from one year to another (Audergon et al., 1991b). The water supplies had an adverse effect on the TSS content whose values were inversely proportional to the size (Audergon et al., 1991b).

1.7. Correlation between the physical and chemical fruit traits

Significant positive and negative correlations were obtained between several fruit physical and chemical traits. Thus, fruit weight was highly correlated with fruit length (R=0.83**) and with fruit width (R=0.86**) (Table 5). Our results confirmed those obtained by Lichou et al. (1998) showing the existence of a good correlation between the weight and the size (width) for the same apricot variety. Moreover, fruit length was correlated positively with fruit width (R=0.65*).

Also, a positive correlation was obtained between fruit thickness and fruit weight (R=0.82**), fruit width (R=0.95**) and total soluble solids (R=0.61*), indicating the tendency of big fruits to have important total sugars content. In the same way, Leccese et al. (2010) found that cultivars with medium large fruits were the sweetest and having the lowest acidity, whereas Milošević et al. (2010) and Mratinic et al. (2011) reported that large fruits have a smaller capacity to accumulate sucrose.

The flesh firmness was positively correlated with fruit weight (R=0.61**), fruit thickness and fruit width (R=0.68*, respectively). While, it was negatively correlated with juice percentage (R=-0.59*) indicating that fruits with higher firmness values were less juicy. This result was similar to those obtained by Infante and Munoz (2010) studying the effect of growth regulators on postharvest apricot quality. Also, flesh percentage was negatively correlated with stone weight (R=-0.81**) in a way that the fruits with big stones, generally, had small edible portions. A positive correlation was found between pH and total soluble solids (R=0.76**) as reported by Ruiz and Egea (2008b).

1.8. Principal Components Analysis

The first three components (1, 2 and 3) explained 77.43% of total variability (Table 6). The first axis absorbed 40.18 % of total variability and it was positively correlated with fruit weight, thickness, length and width, flesh firmness and total soluble solids content. It was negatively correlated to the juice percentage (Table 6).This axis differentiated Oud Hmida which presented the highest fruit firmness and the least juicy fruits from those of Bouk Ahmed with the least firmness and from the juicy fruits of the hybrid Sayeb (Fig. 2). According to this axis Oud Hmida joined the two hybrids Ouardi and Raki characterized by small-medium fruits (41-45g) and opposed to Bedri Ahmar and Bouk Ahmed characterized by very small fruits (20-30g) (Fig. 2). Also, PC1 separated Ouardi and Raki having the highest fruit length values from Bedri Ahmar and differentiated the new hybrid Raki with the largest fruits from Bouthani Ben Friha, Bedri Ahmar and Bouk Ahmed (Fig. 2). This axis also permitted to distinguish the sweetest fruits of Oueld El Oud and the new hybrid Asli from those of Bedri Ahmar and Hamidi (Fig. 2).

The second axis explained 22.91 % and it was positively correlated with fruit thickness/fruit width ratio, flesh percentage and total soluble sugars percentage and negatively correlated with stone weight and titratable acidity (Table 6). This axis separated Oud Rhayem characterized by the highest values of fruit thickness/fruit width ratio and flesh percentage and the smallest stone in weight from Adedi Ahmar with the opposite characters (Fig. 2). It permitted the separation of Oueld El Oud and Asli from Hamidi based on total soluble solids content. According to this axis, Oud Hmida with the highest juice titrable acidity was opposed to Oueld El Oud having the lowest acidity

values (Fig. 2). The third axis accounted for 14.34% of the total variation and it showed a positive correlation with fruit length and flesh percentage and a negative correlation with pH (Table 6). Our results confirmed again the usefulness of Principal Component Analysis for the characterization of apricot germplasm. It has been already used previously to establish the relationships among sets of apricot genotypes (Badenes et al., 1998; Guerriero et al., 2001; Azodanlou et al., 2003; Ruiz and Egea 2008b).

1.9. Hierarchical classification Analysis

Three independent cultivar clusters were obtained by hierarchical classification. The level of square of the Euclidean distance varied from 1 to 25 (Fig. 3).

Although their geographic origin were different, Bouk Ahmed and Bedri Ahmar clustered together to form the first cluster. They were characterized by the smallest fruits (26.7 g and 27.8 g respectively) with the least values of fruit thickness and fruit width (Table 3). The single cultivar Oud Hmida was isolated at d=20 and represented the second cluster. Its fruits were small/medium (in weight), significantly firmer than the others cultivars, the least juicy and the most acid. The third cluster was separated at d=19 and it was subdivided in two groups. The first group was subdivided in two sub-groups: Oueld El Oud with the two hybrids cultivars Asli and Raki formed the first sub-group. Fruits of Oueld El Oud and Asli were similar in length, width, fruit thickness/fruit width, flesh firmness and solids soluble sugars content while Raki individualized by the biggest fruits in size (A) (Table 3). On the other hand, the association of the two hybrids Raki and Asli, confirmed their similarities for some fruit characteristics as juice percentage and pH (Table 3). The local cultivar Oud Rhayem originated from Testour joined the hybrid Sayeb at d= 06. Their main characteristic was the high juice content and the low juice pH value (Table 3). The second group was subdivided in two sub-groups. Adedi Ahmar isolated alone at d=14 was characterized by the fruits with big stones and small edible portions (Table 3). Hamidi and Bouthani Ben Friha formed together with Ouardi the second sub-group. This least one detached with d=09, was individualized by the biggest fruits with the lowest pH value (Table 3). Bouthani Ben Friha (from Testour) and Hamidi (from Ras Jebel) grouped at d= 01 with similar mean values of fruit thickness/fruit length and fruit length/fruit width ratios, juice content, pH, titratable acidity and TSS content.

Table 1Apricot physical and chemical fruit studied traits

Traits	Unity/Scale	Code
Physical		
Fruit		
Weight	g	FW
Thickness	mm	FTh
Length	mm	FL
Width	mm	FWi
Thickness/Width	-	FTh/FWi
Length/Width	-	FL/FWi
Flesh		
Firmness	Durofel index (DI)	FlFir
Percentage	%	Fl%
Stone	g	SW
Weight		
Chemical		
Jus percentage	%	J
pH	-	pH
Titrable acidity	meq/100g	TA
Total Soluble Solids	%	TSS

Table 2
Maturity dates (average of 7 years data) of Tunisian apricot cultivars at INRAT-Mornag Research Station (36°7' latitude and 10°2' longitude) as compared to Ouardi and Sayeb

Cultivar	Year	Maturity date	Maturity date/Ouardi	Maturity date/Sayeb
Oud Rhayem	**2003**	25 May	+3 days	+3 days
	2004	19 May	-1 day	-5 days
	2005	23 May	+ 5 days	-2 days
	2006	15 May	+0 days	-4 days
	2007	7 May	-14 days	-19 days
	2008	7 May	-5 days	-8 days
	2009	16 May	-7 days	-10 days
		Average	**-3 days**	**-6 days**
Oud Hmida	**2003**	8 June	+17 days	+17 days
	2004	2 June	+13 days	+9 days
	2005	4 June	+17 days	+10 days
	2006	27 May	+12 days	+8 days
	2007	1 June	+11 days	+6 days
	2008	22 May	+10 days	+7 days
	2009	29 May	+6 days	+3 days
		Average	**+12 days**	**+9 days**
Bouthani Ben Friha	**2003**	8 June	+17 days	+17 days
	2004	2 June	+13 days	+9 days
	2005	1 June	+14 days	+7 days
	2006	27 May	+12 days	+8 days
	2007	1 June	+11 days	+6 days
	2008	17 May	+5 days	+2 days
	2009	1 June	+9 days	+6 days
		Average	**+12 days**	**+8 days**
Bedri Ahmar	**2003**	27 May	+5 days	+5 days
	2004	27 May	+7 days	+3 days
	2005	-	-	-
	2006	-	-	-
	2007	17 May	-4 days	-9 days
	2008	12 May	+0 days	-3 days
	2009	18 May	-5 days	-8 days
		Average	**+1 day**	**-2 days**
Oueld El Oud	**2003**	10 June	+19 days	+19 days
	2004	9 June	+20 days	+16 days
	2005	8 June	+21 days	+14 days
	2006	-	-	-
	2007	4 June	+14 days	+9 days
	2008	22 May	+10 days	+7 days
	2009	29 May	+6 days	+3 days
		Average	**+15 days**	**+11 days**

Table 2 (Continued)

Cultivar	Year	Maturity date	Maturity date/Ouardi	Maturity date/Sayeb
Asli	**2003**	28 May	+6 days	+6 days
	2004	31 May	+11 days	+7 days
	2005	27 May	+9 days	+2 days
	2006	23 May	+8 days	+4 days
	2007	30 May	+9 days	+4 days
	2008	18 May	+6 days	+3 days
	2009	28 May	+5 days	+2 days
		Average	**+12 days**	**+4 days**
Raki	**2003**	2 June	+11 days	+11 days
	2004	2 June	+13 days	+9 days
	2005	2 June	+15 days	+8 days
	2006	27 May	+12 days	+8 days
	2007	1 June	+11 days	+6 days
	2008	26 May	+14 days	+11 days
	2009	2 June	+10 days	+7 days
		Average	**+8 days**	**+9 days**
Hamidi	**2003**	25 May	+3 days	+3 days
	2004	27 May	+7 days	+3 days
	2005	-	-	-
	2006	-	-	-
	2007	16 May	-5 days	-10 days
	2008	12 May	+0 days	-3 days
	2009	15 May	-8 days	-11 days
		Average	**-1 day**	**-4 days**
Bouk Ahmed	**2003**	28 May	+6 days	+6 days
	2004	2 June	+13 days	+9 days
	2005	-	-	-
	2006	-	-	-
	2007	19 May	-2 days	-7 days
	2008	18 May	+6 days	+3 days
	2009	25 May	+2 days	-1 day
		Average	**+5 days**	**+2 days**
Adedi Ahmar	**2003**	30 May	+8 days	+8 days
	2004	2 June	+13 days	+9 days
	2005	-	-	-
	2006	-	-	-
	2007	23 May	+2 days	-3 days
	2008	16 May	+4 days	+1 day
	2009	28 May	+5 days	+2 days
		Average	**+7 days**	**+3 days**
Ouardi	**2003**	**22 May**		
	2004	**20 May**		
	2005	**18 May**		
	2006	**15 May**		
	2007	**21 May**		
	2008	**12 May**		
	2009	**23 May**		
Sayeb	**2003**	**22 May**		
	2004	**24 May**		
	2005	**25 May**		
	2006	**19 May**		
	2007	**26 May**		
	2008	**15 May**		
	2009	**26 May**		

Table 3
Phyiscal fruit traits of tweleve Tunisian apricot cultivars (mean ± standard error)a

Cultivar	FW (g)	FTh (mm)	FL(mm)	FWi (mm)	FTh/FWi	FL/FWi	FlFir (DI)	Fl%	SW (g)
Oud Rhayem	38.4 ± 0.7 b	39.2 ± 0.2 a	35.7 ± 0.2 c	39.4 ± 0.3 b	**1.0** ± 0.0 a	0.9 ± 0.0 d	42,5 ± 1,0 e	**96,1** ± 0,1 a	**1.4** ± 0.0 j
Oud Hmida	40.3 ± 0.7 a	38.7 ± 0.3 ab	37.0 ± 0.2 b	39.8 ± 0.3 b	1. 0 ± 0.0 cd	0.9 ± 0.0 c	**61,5** ± 1,0 a	92,7 ± 0,1 f	2.8 ± 0.0 b
Bouthani Ben Friha	30.1 ± 0.4 e	33.9 ± 0.2 e	34.4 ± 0.2 e	35.0 ± 0.2 d	1.0 ± 0.0 d	1.0 ± 0.0 a	39,3 ± 0,9 f	91,6 ± 0,1 g	2.4 ± 0. 0 e
Bedri Ahmar	27.8 ± 0.6 f	**33.9** ± 0.3 e	**31.4** ± 0.2 f	**34.5** ± 0.3 d	1.0 ± 0.0 bc	0.9 ± 0.0 d	36,7 ± 0,8 g	93,3 ± 0,1 e	1.7 ± 0.0 h
Oueld El Oud	38.1 ± 0.4 b	**39.2** ± 0.2 a	34.7 ± 0.2 de	39.7 ± 0.2 b	1.0 ± 0.0 b	0.9 ± 0 .0 f	46,0 ± 0,8 d	93,4 ± 0,1 e	2.5 ± 0.0 e
Ouardi	**41.8** ± 0.7 a	37.5 ± 0.3 c	**38.3** ± 0.2 a	39.5 ± 0.2 b	0.9 ± 0.0 e	1.0 ± 0.0 b	38,3 ± 0,7 fg	93,3 ± 0,1 e	2.7 ± 0.0 c
Sayeb	32.4 ± 0.5 d	38.0 ± 0.2 bc	34.6 ± 0.2 de	39.4 ± 0.2 b	1.0 ± 0.0 d	0.9 ± 0.0 f	50,2 ± 1,0 c	93,6 ± 0,1 d	2.0 ± 0.0 g
Asli	35.2 ± 0.4 c	38.4 ± 0.2 bc	35.0 ± 0.2 d	39.2 ± 0.1 b	1.0 ± 0.0 bc	0.9 ± 0.0 e	48,0 ± 0,6 cd	95,4 ± 0,0 b	1.6 ± 0.0 i
Raki	40.4 ± 0.7 a	38.4 ± 0.3 b	37.9 ± 0.2 a	**40.7** ± 0.2 a	0.9 ± 0.0 e	0.9 ± 0.0 c	53,9 ± 0,5 b	94,4 ± 0,1 c	2.3 ± 0.0 f
Hamidi	35.1 ± 0.4 c	36.1 ± 0.2 d	36.6 ± 0.2 b	37.2 ± 0.2 c	1.0 ± 0.0 cd	1.0 ± 0.0 a	42,9 ± 1,0 e	92,5 ± 0,1 f	2.6 ± 0 .0 d
Bouk Ahmed	**26.7** ± 0.5 f	34.2 ± 0.2 e	34.2 ± 0.2 e	34.6 ± 0.3 d	1.0 ± 0 .0 ab	**1.0** ± 0.0 a	**32,2** ± 0,7 h	94,2 ± 0,1 c	1.5 ± 0.0 j
Adedi Ahmar	34.2 ± 0.4 c	37.4 ± 0.2 c	34.5 ± 0.1 de	39.6 ± 0.2 b	**0.9** ± 0.0 f	**0.9** ± 0.0 g	39,5 ± 0,8 f	**90,9** ± 0,1 h	**3.0** ± 0.0 a
Moyenne	35.0 ± 0.2	37.1 ± 0.1	35.3 ± 0.1	38.2 ± 0.1	1.0 ± 0.0	0. 9 ± 0.0	44,3 ± 0,3	93,5 ± 0,0	2.2 ± 0.0
Signification	**	**	**	**	**	**	**	**	**
Fruit position									
Est	34.9 ± 0.3 a	37.1 ± 0.2 a	35.2 ± 0.1 a	38.2 ± 0.1 a	1.0 ± 0.0 a	0.9 ± 0.0 a	43,9 ± 0,6 ab	93,5 ± 0,1 a	2.2 ± 0.0 a
Ouest	35.1 ± 0.3 a	37.2 ± 0.2 a	35.4 ± 0.1 a	38.3 ± 0.1 a	1.0 ± 0.0 a	0.9 ± 0.0 a	44,5 ± 0,6 ab	93,5 ± 0,1 a	2.2 ± 0.0 a
Nord	35.2 ± 0.4 a	37.1 ± 0.2 a	35.4 ± 0.1 a	38.3 ± 0.2 a	1.0 ± 0.0 a	0.9 ± 0.0 a	45,1 ± 0,6 a	93,5 ± 0,1 a	2.2 ± 0.0 a
Sud	34.9 ± 0.4 a	37.0 ± 0.2 a	35.3 ± 0.1 a	38.2 ± 0.2 a	1.0 ± 0.0 a	0.9 ± 0.0 a	43,8 ± 0,6 b	93,3 ± 0,1 b	2.2 ± 0.0 a
Signification	ns	ns	ns	ns	ns	ns	**	**	ns
Year									
2007	33,6 ± 0,3 b	36,1 ± 0,1 b	34,4 ± 0,1 c	37,3 ± 0,1 b	1,0 ± 0,0 a	0,9 ± 0,0 b	44,3 ± 0,5 b	93,2 ± 0,1 b	2,2 ± 0, 0 a
2008	31,7 ± 0,2 c	36,2 ± 0,1 b	34,8 ± 0,1 b	37,4 ± 0,1 b	1,0 ± 0,0 b	0,9 ± 0,0 a	43,0 ± 0,5 c	92,9 ± 0,1 c	2,2 ± 0, 0 a
2009	39,8 ± 0,3 a	39,0 ± 0,1 a	36,8 ± 0,1 a	40,0 ± 0,1 a	1,0 ± 0,0 a	0,9 ± 0,0 c	45,7 ± 0,5 a	94,2 ± 0,1 a	2,2 ± 0, 0 a
Signification	**	**	**	**	**	**	**	**	ns

[a]: Différent letters in columns for cultivar, fruit position or year represent differences at 0.05 probability level (Duncan test)
ns: none significant, * P<0.05 and ** P<0.01

Table 4
Chemical fruit traits of twelve Tunisian apricot cultivars (mean ± standard error)[a]

Cultivar	J%	pH	TA (meq/100 g)	TSS%
Oud Rhayem	46.7 ± 2.1 abc	3.7 ± 0.0 d	24.1 ± 0.5 d	11.9 ± 0.2 c
Oud Hmida	**32.6** ± 1.0 e	3.8 ± 0.0 bc	**33.3** ± 0.2 a	12.7 ± 0.1 b
Bouthani Ben Friha	45.0 ± 3.4 abcd	3.7 ± 0.0 d	25.1 ± 0.2 c	11.5 ± 0.2 cd
Bedri Ahmar	41.7 ± 1.8 bcd	3.7 ± 0.0 cd	19.6 ± 0.3 f	11.2 ± 0.2 d
Oueld El Oud	42.9 ± 2.0 abcd	**4.1** ± 0.1 a	**17.9** ± 0.2 g	**14.1** ± 0.2 a
Ouardi	44.3 ± 2.3 abcd	**3.5** ± 0.0 e	26.6 ± 0.2 b	11.9 ± 0.2 c
Sayeb	**49.8** ± 1.6 a	3.6 ± 0.0 de	25.5 ± 0.2 c	**11.1** ± 0.2 d
Asli	38.3 ± 1.9 de	3.9 ± 0.0 b	24.1 ± 0.6 d	13.8 ± 0.1 a
Raki	38.8 ± 1.9 cde	3.9 ± 0.0 b	20.2 ± 0.5 f	13.1 ± 0.2 b
Hamidi	40.7 ± 2.6 bcd	3.7 ± 0.0 d	25.4 ± 0.3 c	11.3 ± 0.2 d
Bouk Ahmed	48.6 ± 4.6 ab	3.7 ± 0.0 d	22.1 ± 0.3 e	11.6 ± 0.1 cd
Adedi Ahmar	40.9 ± 1.4 bcd	3.9 ± 0.1 b	26.0 ± 0.3 bc	11.5 ± 0.2 cd
Moyenne	42.5 ± 0.7	3.8 ± 0.0	24.2 ± 0.2	12.1 ± 0.1
Signification	**	**	**	**
Fruit position				
Est	40.3 ± 1.3 a	3.8 ± 0.0 a	24.2 ± 0.4 a	12.0 ± 0.1 a
Ouest	41.8 ± 1.4 a	3.9 ± 0.0 a	24.2 ± 0.4 a	12.1 ± 0.1 a
Nord	43.9 ± 1.4 a	3.9 ± 0.0 a	24.2 ± 0.4 a	12.1 ± 0.1 a
Sud	44.0 ± 1.6 a	3.9 ± 0.0 a	24.0 ± 0.4 a	12.3 ± 0.2 a
Signification	ns	ns	ns	ns
Year				
2007	44,2 ± 0,9 b	3,9 ± 0,0 a	24,4 ± 0,4 a	12,3 ± 0,1 a
2008	49,2 ± 1,5 a	3,7 ± 0,0 c	23,9 ± 0,4 b	11,7 ± 0,1 b
2009	33,7 ± 0,8 c	3,8 ± 0,0 b	24,2 ± 0,3 ab	12,4 ± 0,1 a
Signification	**	**	*	**

[a]: Different letters in columns for cultivar, fruit position or year represent differences at 0.05 probability level (Duncan test)
ns: none significant, * P<0.05 and ** P<0.01

Table 5
Correlation matrix among the physical and chemical fruit traits a,b

	FW	FTh	FL	FWi	FTh/FWi	FL/FWi	FlFir	Fl%	SW	J%	pH	TA	TSS%
FW	1.00	**0.82****	**0.83****	**0.86****	-0.27	-0.16	**0.61***	0.17	0.43	-0.44	0.18	0.29	0.52
FTh		1.00	0.54	**0.95****	-0.09	**-0.58***	**0.68***	0.36	0.17	-0.29	0.39	0.17	**0.61***
FL			1.00	**0.65***	-0.37	0.30	0.46	0.09	0.41	-0.28	-0.10	0.41	0.28
FWi				1.00	-0.38	-0.53	**0.68***	0.19	0.35	-0.34	0.33	0.22	0.52
FTh/FWi					1.00	0.08	-0.17	0.56	**-0.67***	0.30	0.04	-0.25	0.17
FL/FWi						1.00	-0.35	-0.12	0.01	0.15	-0.54	0.19	-0.37
FlFir							1.00	0.11	0.27	**-0.59***	0.35	0.39	0.51
Fl%								1.00	**-0.81****	0.24	0.00	-0.30	0.37
SW									1.00	-0.49	0.15	0.44	0.01
J%										1.00	-0.47	-0.37	-0.45
pH											1.00	-0.37	**0.76****
TA												1.00	-0.23
TSS%													1.00

a Pearson correlation coefficient
b Correlations significant at * P<0.05 and ** P<0.01

Table 6
Proportion of total variability among apricot Tunisian cultivars as explained by the 3 first principal and component loadings for quality fruit traits

Principals compounds (PC)	**CP1**	**CP2**	**CP3**
Percent of variance	40,18	22,91	14,34
Cumulative (%)	40,18	63,10	77,43
Fruit quality traits	**Component loading**		
FW	**0.89**	-0.06	0.32
FTh	**0.88**	0.30	0.18
FL	**0.67**	-0.32	**0.55**
FWi	**0.93**	0.09	0.13
FTh/FWi	-0.36	**0.66**	0.23
FL/FWi	-0.42	-0.46	0.47
FlFir	**0.81**	0.04	0.03
Fl%	0.06	**0.79**	**0.57**
SW	0.49	**-0.74**	-0.35
J%	**-0.63**	0.22	0.35
pH	0.47	0.46	**-0.66**
TA	0.31	**-0.63**	0.30
TSS%	**0.65**	**0.55**	-0.16

CONCLUSION

This study on local apricot cultivars completed other studies on local fruit germplasm (Mars et al., 1998; Mars and Marrakchi, 1999; Saddoud et al., 2008). Based on physical and chemical traits, it allowed an evaluation of genetic diversity and the assessment of the fruit quality of apricot cultivars in order to valorize their potentialities in breeding programs. This study showed a large variability between cultivars and years. Thus pedo-climatic and agro-ecological conditions should be considered for the assessment of the cultivar's behavior. Indeed, some differences were noted for some cultivars maintained in "*ex situ*" collection as compared to their "*in situ*" behavior. Multivariate analysis highlighted similarities and differences between studied cultivars. Some fruit traits were highly discriminant such as fruit weight, fruit size, stone weight, flesh firmness, flesh percentage, etc. Significant correlations were obtained between some fruit traits which could permit to reduce their number for further apricot germplasm studies as suggested by Mratinic et al. (2011). For further breeding program, and considering statements of Egea et al. (1994) and Guerriero et al. (2001) related to apricot gustative quality, it was possible to identify, among the set of studied cultivars, some with high fruit quality as the three early hybrid cultivars Ouardi (big fruits, important juice percentage (44%) and around 12% TSS) Sayeb (high juice percentage with 11% TSS) and Raki (high fruit size and 13% TSS). Also, some indigenous cultivars as the early ripening one Oud Rhayem (high flesh percentage (96%) with important juice percentage and around 12% TSS) and Oud Hmida (high firmness fruits with TSS content superior than 12%). In fact, the three hybrids were recently used (in 2012) as female parents and the local cultivar Oud Rhayem as male parent for a new apricot breeding program aiming the development of early ripening commercial varieties with high fruit quality.

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