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Genetic diversity analysis by the morphometric tool of some olive tree (*Olea europaea*) varieties in Western Algeria

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Abstract

The diversity of the olive trees in Algeria is to some extent ambiguous. Thus an inventory has been effected in western Algeriatocollect local and introduced varieties of the olive tree (*Olea europaea*) in view of their morphological characterization. In fact, a collection of 25 traditional and modern accessions of the olive tree was studied using eleven quantitative agro-morphological traits. Phenotypic diversity was determined by the diversity index of Shannon-Weaver (H") at several levels (Total sample, by typology and by variety name). The H' estimates showed a large phenotypic variability for the various traits with an average H' of 0.66. Hence the results of the analysis of the multiple correspondences and the hierarchical classification showed a clear distinction between the different accessions. The results of this work revealed the great phenotypic diversity of the olive varieties, which partly corresponds to the names of the varieties because of the existence of homonyms and synonyms in the names given by the farmers. The results show that these local accessions (whose genetic composition remains to be studied with more precision) are mainly cultivated by traditional farmers who conserve this genetic resource.

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Introduction

The olive tree (*Olea europea* L.) is the characteristic tree of the region of the Mediterranean basin. It is one of the major elements of the agricultural economy of some countries in this region. Otherwise Algeria is one of the countries of the Mediterranean basin where the olive tree finds its extension. Since 2002, it has benefited from an operation to set up 1,000,000 hectares of new olive groves under several programs spread until 2014: PPDRI (Rural Development Proximity Project) FNRDA (Regulation and agricultural development) PSD (Sectoral Development Program). Frah *et al.* (2015). Despite the efforts performed by the state, the production of olives and olive oil is still low. This situation is mainly due to the persistence of several constraints such as unfavorable climatic conditions (irregular rainfall and high temperatures), poor application of farming techniques and technical itineraries of farmers, as well as the adaptation of selected varieties to environmental conditions, etc. Rebour (2005).

In order to preserve, restore and enhance the diversity of available genetic material, it is necessary to study its genetic characteristics, which are materialized externally by the phenotypic characters that are represented by morphology, phenology and physiology within the knowledge that constitutes a prerequisite for Varietal improvement. Bonjean, (2001).

This work is a continuation to another one which was carried out in a later realized study during the 2009-2010 company on for the analysis of the specific diversity by the study of the phenotypic characteristics of some varieties of the olive tree (*Olea europaea*) as well as the extent of the influence of the pedological nature on the yield of the different varieties. Sidhoum M *et al.* (2011; 2017). This work is lunched because we need before starting a genetic improvement; know what we have like varieties in the field (especially in North-West of Algeria). This knowledge helps us to detect a real number of varieties existing in the area studied and facilitate like this our improvement approach.

Similar studies have already been carried out in Algeria on other wheat species Bellatreche A *et al.* (2012; 2016) barley Warda Taibi *et al.* (2016) and carob tree Mahdad Yassine *et al.* (2016).

Materials and methods

Vegetable material

Our study is mainly based on the characterization of the diversity of the olive tree (*Olea Europaea*). The characteristic plant material is obtained from a field survey during the year 2014-2016 in the Algerian western regions (Figure 1).

A total of one hundred and ten (110) olive trees belonging to twelve (12) introduced varieties and two (02) varieties of local types (Algerian). The latter were collected from fifteen (12) localities belonging to different sites in this study area, while the selected introduced varieties originated from the olive collections of the Technical Institute of Fruit and Mohammadia (Mascara). (I.T.A.F) and the Djidiouia region (Relizane) (Table 1).

The characterization of the varieties studied concerns the morphological description of the main organs of the tree (fruit, core and leaf) eleven (11) morphological characters that is currently used for the primary characterization of olive varieties Barranco and Rallo (1984) selected for this study.

Characterization Quantitative characterization of tree organs (Table 21) was done for 30 leaves, 30 fruits and 30 stones. Observations ranged from three (3) to five (5) trees per variety and per collection. Each individual was basically selected and identified on its phytosanitary status.

Statistical analyzes

After carrying out the data collected on a matrix several statistical tests were carried out by the R software.

The statistical analyzes were mainly carried out by the software R. (version R-2.15.3) and software GenStat (version3.0).

Fig. 1. Localization of the agricultures Fields of different sites of collection.

Shannon-Weaver Index

Before carrying out this test a transformation of the quantitative traits in the class was done this latter was realized with the "summary" function of the software R which divides the range of values into the desired number of classes (four), and determines the limits of each class.

The frequencies of the different phenotypic classes for each trait in each of the three collection areas as well as in the four classes were calculated for each line. On the basis of these frequencies, the Shannon-Weaver index (Shannon and Weaver, 1948) was calculated for each trait in order to estimate the phenotypic diversity that exists in these study areas and for each variety.

The Shannon-Weaver index is calculated using the following formula:

$$H' = -\sum_{i=1}^{n} Pi\ Ln\ Pi / Ln(n)$$

With:

H = Shannon and Weaver Diversity Index

Pi = Frequency of each phenotypic class i of a given character

N = Number of phenotypic classes of each character

The index (H) is converted to the relative phenotypic diversity index (H ') by dividing it by its maximum value H max (Ln (n)) in order to obtain values between 0 and 1.

$$H' = -\sum_{i=1}^{n} Pi\ Ln\ Pi / Ln(n)$$

The relative index of diversity (H ') reaches its minimum value which is equal to zero for the monomorphic characters.

Moreover, the value of this index increases with the degree of polymorphism and reaches a maximum value (1) when all the phenotypic classes present have equal frequencies.

Analysis of variance (ANOVA)

Analysis of variance was used to calculate variation among accessions, using the R software (version R-2.15.3).

Principal components analysis (PCA)

Principal components analysis was carried out on the correlation matrix. It uses the Facto MineR software (version R-2.15.3).

Hierarchical Ascending Classification (HAC)

Hierarchical Ascendant Classification or cluster analysis, using the Facto MineR software (version R-2.15.3) to better classify the 14 accessions of the olive tree.

Interaction genotypes- environments

The genotype-environment interaction was analyzed to get an idea of the effect of the regions studied on the measured characters using the GenStat software (Version3.0).

Results

Relative index of diversity of different quantitative characteristics

The relative index of diversity (means H) of all the studied characteristics studied over all the varieties is of the order of 0.66 (Table 3).

This index varies between 0.56 for the weight of fruit and 0.79 for the width of the leaf.

Table 1. Number and origin of accessions studied.

Region	Varieties	Cities	Longitudes	Latitudes	Altitudes
Tlemcen	Sigoise Chemlal	Tlemcen	1°18′53″ O	34°52′41″ N	811 m
Oran	Sigoise Chemlal	Oran	0°38′30″ O	35°41′27″ N	109 m
Sidi Belabes	Chemlal	Sidi Belabes	0°37′51″ O	35°11′23″ N	476 m
Ain-Temouchent	Chemlal	Ain-Temouchent	1°08′25″ O	35°17′50″ N	240 m
Sig	Sigoise	Sig	0°11′37″ O	35°31′41″ N	62 m
Relizaine	Sigoise	Relizaine	0°33′21″ E	35°44′14″ N	98 m
Mostaganem	Sigoise	Mostaganem	0°05′21″ E	35°55′52″ N	102 m
Saida	Sigoise	Saida	0°09′06″ E	34°49′49″ N	840 m
Tiaret	Sigoise	Tiaret	1°19′01″ E	35°22′15″N	1031 m
Djidiouia	Sigoise Verdale	Djidiouia	0°49'33" E	35°58'2" N	50 m
ITAF	Sigoise Nocellara Messinese Sant'agostino Pasola Di Andria Termite di Bitetto Pasola Picholine Nocellara Del Belice Sourani Terilia Zaiti Khodairi	Mohammadia	0° 4′ 12″ E	35° 35′ 25″ N	30 m

The highest average of diversity index (H'≥0.60) is obtained for eighteen accessions, the intermediates values (0.40≤ H'≥0.60) are obtained for five accessions and the lowest diversity values (0.10 ≤ H'≥ 0.40) are observed for two accessions.

Characteristics according to the regions

The Shannon and Weaver index has been calculated for the different traits in the prospected areas.

The Sigoise variety showed means diversity index of the order of 0.82, followed by Chemlal with mean H' = 0, 66, and that of the Italian varieties with mean H = 0.57 and finally for Syrian varieties with an average H'= 0.51.

After the calculation of the diversity index of S.W, we have effected an ANOVA for the different values of the characteristics studied thus the following table is obtained (Table 4).

Characterization of fruit: The average character of the fruit weight in the different accessions studied varies from 2.60g for Pasola to 7.41g for Khodairi.

Whereas the average character of the fruit length varies between 2.08 cm for Chemlal at 2.70 cm for Khodairi.

The average character of the width of the fruits, it will vary between 1.40cm for Chemlal to 2.15 cm for Khodairi.

the average character of the length/width ratio of the fruits varies between 1.10 for Sant 'Agostino to 1.49 for Chemlal.

Table 2. Quantitative characterization parameters and their codes.

Settings	Codes
Fruit weight	PF
Fruit length	LFr
Fruit width	lFr
Fruit length / width ratio	(L/l) Fr
Weight of the stone	PN
Length of the stone	LN
stone width	lN
Length / width ratio of the stone	(L/l) N
Length of the leaf	LFe
Length of the leaf	lFe
Length / width ratio of the leaf	(L/l) Fe

Characterization of the stone: The average character of the weight of the stone in the various accessions studied varies from 0.47g for Picholine to 0.96g for Nocellara Messinesse.

While the average length of the stone varies between 1.34 cm for Sourani and 1.82 cm for Picholine

As long as we take the average of the character of the width of the stone we find that it will change between 0.68cm for the Picholine to 0.97cm for Terilia.

The average length-to-width ratio of the stone ranges from 1.39 for Teriliato 2.64 for Picholine.
Characterization of leaves:

The average leaf length characteristic of the different accessions studied changes from 6.59cm for Khodairi and Zaiti to 9.34cm for Sant' Agostino.

While the average of the character of the width of the leaves varies between 1.30cm for the Picholine) and Zaiti to 1.83cm for Pasola.

If we take the average of the character of the ratio length / width of the leaves that varies between 3.90 for the Picholine I.T.A.F (Italian) to 6.14 for Nocellara Messinesse.

We will observe at the ACP of Fig. 2 that the characters studied in all the varieties approximate in their majorities of the circle (apart from the character the length of the stone) which translates a statistically important level of significance.

Nevertheless, we note that the ACP in question represents 59.66% of the information used for statistical processing which is really acceptable.

The dendrogram shows the relationship between the different accessions studied (Fig. 3) and divides the latter into three major groups.

Effect of regions on variety behavior
Effect of 9 regions on the phenotypic characters of the variety of Sigoise
After the calculations an ANOVA was performed for the different values of the characters studied in fact the following table (5) is obtained:

Effect of 4 regions on the phenotypic characteristics of Chemlal
After the realization of the ANOVA, we obtain the following Table 6:

Concerning the length of the leaves, the formation of two groups, one in Tlemcen, Oran and Ain-Temouchent regions and the other one constituted in Sidi Belabes and Oran regions that has been not

observed, whereas the length/width ratio of the leaf consists of two groups, and The fruit length/width ratio which is made up of three groups.

Table 3. Relative index of diversity of the different traits and accessions studied.

Variety	PF (g)	LFr (cm)	lFr (cm)	(L/l) Fr	PN (g)	LN (cm)	lN (cm)	(L/l) N	LFe (cm)	lFe (cm)	(L/l) Fe	Average
Sigoise Tlemcen	0,73	0,77	0,86	0,94	0,69	0,8	0,56	0,93	0,92	0,98	0,93	0,83
Sigoise Oran	0,72	0,82	0,84	0,95	0,69	0,8	0,56	0,93	0,91	0,9	0,91	0,82
Sigoise Sig	0,74	0,73	0,87	0,96	0,64	0,79	0,55	0,94	0,843	0,83	0,94	0,80
Sigoise Relizaine	0,77	0,72	0,85	0,94	0,68	0,75	0,58	0,92	0,99	0,94	0,98	0,83
Sigoise ITAF	0,75	0,81	0,9	0,97	0,55	0,7	0,62	0,96	0,95	0,93	0,98	0,83
Sigoise Mostaganem	0,78	0,79	0,8	0,89	0,63	0,67	0,53	0,83	0,98	0,97	0,98	0,80
Sigoise Saida	0,77	0,83	0,78	0,91	0,68	0,78	0,56	0,92	0,98	0,93	0,97	0,83
Sigoise Tiaret	0,70	0,77	0,81	0,98	0,62	0,69	0,59	0,88	0,96	0,92	0,98	0,81
Sigoise Djidiouia	0,72	0,80	0,85	0,92	0,63	0,86	0,52	0,96	0,98	0,95	0,96	0,83
Average of the variety sigoise	0,74	0,78	0,84	0,94	0,65	0,76	0,56	0,92	0,95	0,93	0,96	0 ,82
Chemlal.Oran	0,47	0,77	0,40	0,34	0,98	0,94	0,68	0,85	0,51	0,41	0,95	0,66
Chemlal.Sidi Belabes	0,47	0,77	0,22	0,44	0,97	0,93	0,67	0,85	0,59	0,66	0,83	0,67
Chemlal.Ain-Témouchent	0,48	0,78	0,29	0,37	0,99	0,97	0,66	0,83	0,47	0,57	0,87	0,66
Average of the chemlal variety	0,48	0,78	0,27	0,37	0,98	0,95	0,67	0,85	0,51	0,56	0,87	0,66
Verdale.Djidiouia	0,58	0,72	0,75	0,83	0,99	0,88	0,78	0,96	0,92	0,86	0,75	0,82
Nocellara Messinese.	0,23	0,41	0,22	0,69	0,00	0,57	0,04	0,66	0,87	0,97	0,44	0,46
Sant'agostino.	0,51	0,61	0,46	0,00	0,64	0,50	0,51	0,30	0,15	0,62	0,68	0,45
Pasola Di Andria.	0,54	0,72	0,73	0,94	0,88	0,48	0,27	0,86	0,69	0,83	0,72	0,70
Termite di Bitetto.	0,66	0,59	0,53	0,49	0,88	0,94	0,62	0,73	0,47	0,90	0,82	0,69
Pasola	0,43	0,49	0,75	0,73	0,82	0,57	0,71	0,71	0.68	0,25	0,15	0,56
Picholine	0,34	0,00	0,49	0,76	0,72	0,24	0,00	0,00	0,90	0,81	0,66	0,45
Nocellara Del Belice	0,69	0,58	0,63	0,81	0,73	0,65	0,59	0,88	0,66	0,57	0,96	0,70
Average of Italian variety	0,53	0,42	0,60	0,70	0,79	0,60	0,48	0,58	0,68	0,63	0,65	0,57
Sourani	0,05	0,49	0,00	0,22	0,43	0,40	0,29	0,09	0,92	0,92	0,25	0,37
Terilia.	0,53	0 ,56	0,28	0,00	0,21	0,36	0,12	0,00	0,49	0,95	0,24	0,32
Zaiti.	0,75	0,60	0,96	0,93	0,77	0,98	0,60	0,94	0,71	0,79	0,26	0,75
Khodairi	0,15	0,27	0,20	0,68	0,79	0,70	0,75	0,56	0,74	0,98	0.25	0,58
Average of Syrian varieties	0,37	0,45	0,36	0,46	0,55	0,61	0,44	0,40	0,72	0,91	0,25	0,51
Average	0,56	0,65	0,58	0,67	0,71	0,72	0,52	0,73	0,75	0,79	0,74	0,66

Effect of the Mohammadia region (I.T.A. F) on the phenotypic characteristics of Italian varieties

After the calculations, an ANOVA was performed and we have obtained the following Table 7.

After the calculations, an ANOVA was performed therefore we have got the table below 8.

Effect of the Mohammadia region (I.T.A. F) on the phenotypic characteristics of the Syrian varieties

Effect of the region (Djidiouia) on genotypes (Sigoise and Verdale)

After carrying out the ANOVA, the following Table 9 is obtained.

Discussion

In this work, we have obtained a highest value of the relative index of diversity of different quantitative characteristics that was around 0.66, This value reveals the great morphological diversity of the olive varieties of this sampling. The same trend was observed by Laaribi (2014) for a group of olive hybrids of the Tunisian variety Chemlali Sfax. index varies between 0.32 for the Terilia Terilia variety (sampled in the region of EL Mohammadia at the level of ITAF (Mohammadia) and 0.83 for the Sigoise variety in several regions (Tlemcen, Relizaine, ITA F, Saida, Djidiouia).

Several factors may explain the difference in Shanon and Weaver index values between localities, including natural factors such as adaptation to local conditions and human factors predominantly farmers' preference Belhadj *et al.* (2015).

Table 4. Averages and SD characters of different varieties of the olive tree.

Genotype	PFr*	LFr*	lFr*	(L/l)* Fr	PN*	LN*	lN*	(L/l)* N	LFe*	lFe*	(L/l)* Fe
Sigoise Tlemcen	4,24± 0.05	2.38± 0.01^{a}	1.76± 0.01^{b}	1.35± 0.01	0.65± 0.01^{b}	1.64± 0.01^{ab}	0.81± 0.005	2.03± 0.02	7.29± 0.09^{a}	1.38± 0.02^{a}	5,42± 0.05^{a}
Sigoise Oran	4,05± 0.05	2.33± 0.01^{b}	1.75± 0.01^{b}	1.33± 0.01	0.65± 0.01^{b}	1.64± 0.01^{ab}	0.81± 0.005	2.03± 0.02	6.93± 0.09^{e}	1.39± 0.01^{b}	5.00± 0.04^{de}
Sigoise Sig	4,21± 0.05	2.38± 0.01^{a}	1.76± 0.01^{b}	1.35 ± 0.01	0.66 ± 0.01^{ab}	1.65 ± 0.01^{ab}	0.81 ± 0.005	2.03 ± 0.02	6.61 ± 0.10^{f}	1.33± 0.01^{c}	4.96 ± 0.04^{e}
Sigoise Relizaine	4,27± 0.05	2.39± 0.01^{a}	1.81± 0.01^{a}	1.33 ± 0.01	0.66 ± 0.01^{ab}	1.65 ± 0.01^{a}	0.80 ± 0.005	2.05± 0.02	7.32 ± 0.10^{bc}	1.41 ± 0.02^{b}	5.16 ± 0.04^{c}
Sigoise ITAF	4,03± 0.07	2.35± 0.01^{ab}	1.75± 0.01^{b}	1.34 ± 0.01	0.68 ± 0.01^{a}	1.66 ± 0.01^{a}	0.81 ± 0.01	2.04 ± 0.02	7.02 ± 0.12^{cd}	1.38± 0.02^{b}	5.08 ± 0.05^{cde}
Sigoise Mostaganem	4.20± 0.04	2.37± 0.01^{a}	1.75± 0.01^{b}	1.35 ± 0.01	0.67 ± 0.01^{ab}	1.66 ± 0.01^{a}	0.81 ± 0.004	2.05± 0.01	7.18± 0.08^{cd}	1.39 ± 0.02^{b}	5.16 ± 0.04^{c}
Sigoise Saida	4.17± 0.05	2.36± 0.01^{ab}	1.75± 0.01^{b}	1.34 ± 0.01	0.65 ± 0.01^{ab}	1.64 ± 0.01^{ab}	0.81 ± 0.004	2.02 ± 0.01	7.23 ± 0.08^{bc}	1.39 ± 0.02^{b}	5.21 ± 0.04^{bc}
Sigoise Tiaret	4,23± 0.04	2.37± 0.01^{a}	1.77± 0.01^{b}	1.34 ± 0.01	0.68 ± 0.01^{a}	1.67 ± 0.01^{a}	0.81 ± 0.004	2.06± 0.01	7.11 ± 0.09^{cd}	1.39 ± 0.02^{b}	5.11 ± 0.04^{cd}
Sigoise Djidiouia	4,05± 0.04	2.36± 0.01^{ab}	1.78± 0.01^{ab}	1.33 ± 0.01	0.64 ± 0.01^{b}	1.62 ± 0.01^{b}	0.80 ± 0.003	2.02 ± 0.01	7.51 ± 0.07^{b}	1.42 ± 0.02^{b}	5.30 ± 0.03^{ab}
Chemlal Tlemcen	2.72± 0.03	2.09± 0.01	1.40± 0.01	1.49 ± 0.01^{a}	0.54 ± 0.01	1.55 ± 0.01	0.76± 0.01	2.06 ± 0.02	9.30 ± 0.10^{a}	1.74 ± 0.02^{a}	5.36 ± 0.03^{a}
ChemlalOran	2.69± 0.03	2.08± 0.01	1.42± 0.01	1.46 ± 0.005^{c}	0.54 ± 0.01	1.56 ± 0.01	0.76 ± 0.01	2.06 ± 0.02	9.08 ± 0.09^{ab}	1.75 ± 0.02^{a}	5.18 ± 0.04^{b}
Chemlal Sidi Belabes	2.69± 0.03	2.08± 0.01	1.40± 0.01	1.48 ± 0.004^{bc}	0.52 ± 0.01	1.54 ± 0.01	0.75 ± 0.01	2.06 ± 0.01	8.92 ± 0.08^{b}	1.67 ± 0.02^{b}	5.36 ± 0.02^{a}
Chemlal Ain-Témouchent	2.68± 0.03	2.09± 0.01	1.41± 0.01	1.48 ± 0.004^{ab}	0.54 ± 0.01	1.56 ± 0.01	0.76 ± 0.01	2.07 ± 0.01	9.24 ± 0.08^{a}	1.73 ± 0.01^{a}	5.35 ± 0.03^{a}
Verdale Djidiouia	3.01± 0.03	2.09± 0.01	1.63± 0.01	1.29 ± 0.01	0.54 ± 0.01	1.48 ± 0.01	0.78 ± 0.01	1.90 ± 0.01	6.87 ± 0.07	1.52 ± 0.01	4.54 ± 0.04
NocellaraMessinese	6.18± 0.13^{a}	2.54± 0.02^{a}	2.01± 0.01^{a}	1.26 ± 0.01^{c}	0.96 ± 0.02^{a}	1.71± 0.02^{a}	0.97 ± 0.01^{a}	1.76 ± 0.02^{b}	8.17± 0.13^{a}	1.35 ± 0.03^{d}	6.14 ± 0.08^{a}
Sant'agostino	4.84± 0.08^{b}	2.10± 0.01^{a}	1.88± 0.01^{b}	1.10 ± 0.01^{c}	0.64 ± 0.01^{b}	1.37 ± 0.01^{b}	0.88 ± 0.01^{a}	1.56 ± 0.02^{c}	9.34 ± 0.07^{a}	1.63 ± 0.02^{b}	5.83 ± 0.08^{b}
PasolaDiAndria	4.56± 0.05^{c}	2.15± 0.02^{a}	1.59± 0.01^{d}	1.35 ± 0.01^{b}	0.51 ± 0.01^{c}	1.48 ± 0.005^{a}	0.76± 0.01^{b}	1.95 ± 0.02^{a}	7.09 ± 0.06^{b}	1.57 ± 0.02^{bc}	4.55± 0.06^{d}
Termite DiBitetto	4.75± 0.07^{bc}	2.19± 0.01^{a}	1.93± 0.02^{a}	1.14 ± 0.01^{c}	0.60 ± 0.01^{c}	1.51 ± 0.01^{a}	0.83 ± 0.01^{a}	1.89 ± 0.01^{b}	7.33 ± 0.06^{a}	1.54 ± 0.02^{c}	4.79± 0.05^{c}
Pasola	2.60± 0.05^{d}	1.94± 0.01^{a}	1.58± 0.01^{d}	1.23 ± 0.01^{c}	0.55 ± 0.01^{c}	1.38 ± 0.01^{b}	0.77± 0.01^{b}	1.79± 0.02^{b}	7.06 ± 0.07^{b}	1.83 ± 0.03^{a}	3.90± 0.06^{d}
Picholine	5.20± 0.05^{a}	2.58± 0.01^{a}	1.88± 0.01^{b}	1.28 ± 0.01^{a}	0.47 ± 0.01^{c}	1.82 ± 0.01^{a}	0.68 ± 0.004^{c}	2.64 ± 0.02^{a}	7.91 ± 0.09^{a}	1.30 ± 0.02^{d}	4,55 ± 0.11^{a}
NocellaraDelBelice	4.22± 0.07^{d}	2.30± 0.02^{a}	1.71± 0.01^{c}	1.34 ± 0.01^{b}	0.66 ± 0.01^{b}	1.67± 0.01^{a}	0.81± 0.01^{a}	2.04 ± 0.02^{a}	8.47 ± 0.08^{a}	1.77 ± 0.03^{a}	4.88 ± 0.09^{c}
Sourani	6.13± 0.06^{a}	2.33± 0.01^{a}	2.11± 0.01^{a}	1.10 ± 0.01^{a}	0.73 ± 0.01^{b}	1.34 ± 0.01^{b}	0.91 ± 0.01^{a}	1.46 ± 0.01^{a}	7.61 ± 0.09^{a}	1.34 ± 0.02^{b}	5.77 ± 0.07^{a}
Terilia	3.93± 0.04^{a}	2.10± 0.01^{a}	1.81± 0.004^{a}	1.15 ± 0.04^{a}	0.85 ± 0.01^{a}	1.35 ± 0.01^{b}	0.97 ± 0.01^{a}	1.39 ± 0.01^{a}	6.41 ± 0.04^{c}	1.41 ± 0.01^{a}	4.60 ± 0.05^{b}
Zaiti	4.28± 0.07^{a}	2.29± 0.01^{a}	1.71± 0.01^{a}	1.26 ± 0.01^{a}	0.63 ± 0.01^{c}	1.57 ± 0.01^{a}	0.81 ± 0.01^{a}	1.93 ± 0.02^{a}	6.59 ± 0.05^{b}	1.30 ± 0.01^{b}	4,25 ± 0.06^{a}
Khodairi	7.41± 0.15^{a}	2.72± 0.02^{a}	2.15± 0.02^{a}	1.36 ± 0.01^{a}	0.74 ± 0.02^{b}	1.74 ± 0.02^{a}	0.81 ± 0.01^{a}	2.09 ± 0.01^{a}	6.59 ± 0.06^{b}	1.40 ± 0.02^{a}	4.74± 0.05^{b}

Note: *Significant statistical test *p-value*= 2e-16; *** (2e-16<0.05).

The high diversity of the studied collection is mainly due to the presence of several polymorphic characters (H '> 0.65). The value of this index is particularly high for character of the leaf (H '= 0.79), which is the highest value of this index, followed by the leaf length (H' = 0.75); The ratio LoLength/Widthof the sheet (H '= 0.73)); The length of the core (H '= 0.72)), and also the weight of the core (H' = 0.71) andthe length/width ratio Lo/La of the fruit with a value (H = 0.67). These results agree with those of Guellaoui I. *et al.* (2015).

Table 5. Effect of 9 regions on the phenotypic characters of the Sigoise variety.

Characters / Region	PF (g)	LFr (cm) ***	lFr (cm) **	(L/l) (Fr)	PN (g) *	LN (cm) *	lN (cm)	(L/l) (N)	LFe (cm) *	lFe (cm) ***	(L/l) (Fe) ***
Tlemcen	4.25± 0.05	2.38± 0.01^{a}	1.76± 0.01^{b}	1.35± 0.01	0.65± 0.01^{b}	1.64± 0.01^{ab}	0.81± 0.005	2.03± 0.02	7.92± 0.09^{a}	1.48± 0.02^{a}	5.42± 0.05^{a}
Oran	4.05± 0.05	2.33± 0.01^{b}	1.76± 0.01^{b}	1.32± 0.01	0.65± 0.01^{b}	1.64± 0.01^{ab}	0.81± 0.005	2.03± 0.02	6.93± 0.09^{e}	1.39± 0.01^{b}	5.00± 0.04^{de}
Sig	4.21± 0.05	2.38± 0.01^{a}	1.77± 0.01^{b}	1.35± 0.01	0.66± 0.01^{ab}	1.65± 0.01^{ab}	0.81± 0.005	2.04± 0.02	6.61± 0.10^{f}	1.33± 0.01^{c}	4.95± 0.04^{e}
Relizaine	4.28± 0.05	2.40± 0.01^{a}	1.81± 0.01^{a}	1.33± 0.01	0.66± 0.01^{ab}	1.66± 0.01^{a}	0.80± 0.005	2.06± 0.02	7.23± 0.10^{bc}	1.42± 0.02^{b}	5.16± 0.04^{c}
ITAF	4.03± 0.07	2.36± 0.01^{ab}	1.75± 0.01^{b}	1.35± 0.01	0.68± 0.01^{a}	1.66± 0.01^{a}	0.82± 0.01	2.04± 0.02	7.02± 0.12^{cd}	1.38± 0.02^{b}	5.08± 0.05^{cde}
Mostaganem	4.20± 0.04	2.37± 0.01^{a}	1.76± 0.01^{b}	1.35± 0.01	0.67± 0.01^{ab}	1.66± 0.01^{a}	0.81± 0.004	2.06± 0.01	7.18± 0.08^{cd}	1.39± 0.02^{b}	5.16± 0.04^{c}
Saida	4.17± 0.05	2.36± 0.01^{ab}	1.76± 0.01^{b}	1.34± 0.01	0.66± 0.01^{ab}	1.64± 0.01^{ab}	0.81± 0.004	2.02± 0.01	7.23± 0.08^{bc}	1.39± 0.02^{b}	5.21± 0.04^{bc}
Tiaret	4.24± 0.04	2.38± 0.01^{a}	1.77± 0.01^{b}	1.34± 0.01	0.68± 0.01^{a}	1.67± 0.01^{a}	0.81± 0.004	2.06± 0.01	7.12± 0.09^{cd}	1.39± 0.02^{b}	5.11± 0.04^{cd}
Djidiouia	4.06± 0.04	2.37± 0.01^{ab}	1.79± 0.01^{ab}	1.33± 0.01	0.65± 0.01^{b}	1.63± 0.01^{b}	0.81± 0.003	2.02± 0.01	7.51± 0.07^{b}	1.42± 0.02^{b}	5.30± 0.03^{ab}

Note : *Significant codes '***'< 0.001 '**' <0.01 '*' <0.05.

It is found that the length and weight of the fruit of the two characters' express values of H '(H' = 0.58); and (H '= 0.56) as a result these values are respectively closest to those that are reported by S. Ben Maachia *et al.*(2016).

Table 6. Effect of 4 regions on the phenotypic characteristics of Chemlal.

Characters / Region	PF (g)	LFr (cm)	lFr (cm)	(L/l) (Fr) ***	PN (g)	LN (cm)	lN (cm)	(L/l) (N)	LFe (cm) *	lFe (cm) *	(L/l) (Fe) ***
Tlemcen	2.72± 0.03	2.09± 0.01	1.40± 0.01	1.50± 0.01^{a}	0.55± 0.01	1.56± 0.01	0.76± 0.01	2.06± 0.02	9.30± 0.10^{a}	1.74 ± 0.02^{a}	5.36± 0.03^{a}
Oran	2.69± 0.03	2.08± 0.01	1.42± 0.01	1.46± 0.005^{c}	0.55± 0.01	1.56± 0.01	0.76± 0.01	2.06± 0.02	9.08± 0.09^{ab}	1.76± 0.02^{a}	5.18± 0.04^{b}
Sidi Belabes	2.69± 0.03	2.08± 0.01	1.41± 0.01	1.48± 0.005^{bc}	0.53± 0.01	1.54± 0.01	0.76± 0.01	2.06± 0.01	8.91± 0.08^{b}	1.67± 0.02^{b}	5.36± 0.02^{a}
Ain- Témouchent	2.68± 0.03	2.09± 0.01	1.41± 0.01	1.48± 0.004^{ab}	0.54± 0.01	1.56± 0.01	0.76± 0.01	2.07± 0.01	9.24± 0.08^{a}	1.73± 0.01^{a}	5.35± 0.03^{a}

Note : *Significant codes '***'< 0.001 '**' <0.01 '*' <0.05.

Taking all traits and varieties into account, the highest diversity index (H '= 0.99) across all varieties is based on several characteristics such as: leaf length for the Sigoise variety in the wilaya of Relizaine; Weight of the nucleus for the Chemlal variety in the wilaya of Ain-Témouchent and thus for the verdant variety in the region of Djidiouia. Therefore, these hypervariable characters cannot (or hardly) be taken into consideration as a possible criterion of varietal identification.

If we apply this index on the studied regions, and according to the ACP, the formation of three groups of characters is distinguished. This shows a positive correlation between the parameters within the same groups and a negative correlation between the

parameters at the level of the 1st group and the parameters of the 3rd group which makes it possible to envisage the use of the two characters “the width and the length of the leaf” as selection parameters for future trees with important fruit.

Table 7. Effect of the Mohammadia region (I.T.A. F) on phenotypic characters on Italian varieties.

Characters / Region	PF (g) ***	LFr (cm) ***	lFr (cm) ***	(L/l) (Fr) ***	PN (g) ***	LN (cm) ***	lN (cm) ***	(L/l) (N) ***	LFe (cm) ***	lFe (cm) ***	(L/l) (Fe) ***
Nocellara Messinese	6.19± 0.13 a	2.54± 0.02 a	2.01± 0.01a	1.26± 0.01 c	0.97± 0.02 a	1.71± 0.02 a	0.97± 0.01a	1.76± 0.02 b	8.17± 0.13 a	1.35± 0.03 d	6.14± 0.08 a
Sant'agostino	4.84± 0.08 b	2.10± 0.01 a	1.88± 0.01 b	1.11± 0.01 c	0.64± 0.01 b	1.38± 0.01 b	0.89± 0.01 a	1.56± 0.02 c	9.34± 0.07 a	1.63± 0.02 b	5.83± 0.08 b
Pasola Di Andria	4.56± 0.05 c	2.15± 0.02 a	1.59± 0.01 d	1.35± 0.01 b	0.51± 0.01 c	1.48± 0.005a	0.76± 0.01 b	1.95± 0.02 a	7.09± 0.06 b	1.57± 0.02 bc	4.55± 0.06 d
Termite di Bitetto	4.75± 0.07 bc	2.19± 0.01 a	1.93± 0.02 a	1.14± 0.01 c	0.60± 0.01 c	1.52± 0.01 a	0.84± 0.01 a	1.81± 0.01 b	7.33± 0.06 a	1.54± 0.02 c	4.79± 0.05 c
Pasola	2.60± 0.05 d	1.94± 0.01 a	1.58± 0.01 d	1.23± 0.01 c	0.55± 0.01 c	1.38± 0.01 b	0.77± 0.01 b	1.80± 0.02 b	7.07± 0.07 b	1.84± 0.03a	3.90± 0.06 d
Picholine	5.21± 0.05 a	2.59± 0.01 a	1.88± 0.01 b	1.39± 0.01 a	0.48± 0.01 c	1.82± 0.01 a	0.69± 0.004 c	2.65± 0.02 a	7.91± 0.09 a	1.29± 0.02 d	6.22± 0.11 a
Nocellara Del Belice	4.22± 0.07 d	2.30± 0.02 a	1.72± 0.01 c	1.34± 0.01 b	0.67± 0.01 b	1.67± 0.01 a	0.81± 0.01 a	2.04± 0.02 a	8.47± 0.08 a	1.77± 0.03 a	4.88± 0.09 c

Note: *Significant codes '***'< 0.001 '**' <0.01 '*' <0.05.

The correlation of these characteristics can either be explained by the influence of genes, that is to say that these characters are controlled by a certain number of genes in common.

Consequently, according to the dendogram we note that there is no geographical structuring of the varieties studied. Finding Italian varieties (with very high yields in Italy and low in Algeria) very close to the dendrogram with Algerian varieties is in fact a point in favor of improving the technical way to ameliorate the yield (this means that genetics are not involved in low yields).

Table 8. Effect of the Mohammadia region (I.T.A. F) on phenotypic characters on Syrian varieties.

Characters / Region	PF (g) ***	LFr (cm) ***	lFr (cm) ***	(L/l) ***	(Fr)	PN (g) ***	LN (cm) ***	lN (cm) ***	(L/l) (N) ***	LFe (cm) ***	lFe (cm) ***	(L/l) (Fe) ***
Sourani	6.14± 0.06a	2.34± 0.01a	2.1± 0.01a	1.11± 0.01a		0.74± 0.01 b	1.3± 0.01b	0.92± 0.01a	1.4± 0.01a	7.61± 0.09a	1.3± 0.02b	5.7± 0.07a
Terilia	3.94± 0.04a	2.10± 0.01a	1.8± 0.004a	1.15± 0.004a		0.85± 0.01a	1.3± 0.01b	0.97± 0.01a	1.3± 0.01a	6.41± 0.04c	1.4± 0.01a	4.6± 0.05b
Zaiti	4.29± 0.07a	2.30± 0.01a	1.7± 0.01a	1.36± 0.01a		0.63± 0.01c	1.5± 0.01a	0.81± 0.01 a	1.9± 0.02a	6.59± 0.05b	1.3± 0.01b	5.1± 0.06 a
Khodairi	7.42± 0.15 a	2.73± 0.02 a	2.1± 0.02a	1.27± 0.01a		0.74± 0.02b	1.7± 0.02a	0.83± 0.01a	2.0± 0.01a	6.60± 0.06 b	1.4± 0.02a	4.7± 0.05b

Note : *Significant codes '***'< 0.001 '**' <0.01 '*' <0.05.

In another way, we looked for the effect of the regions on the varieties behavior, so the first step was about the effect of the nine regions on the phenotypic characters of the segoise variety, It is noted that there are no varietal effects on the characters: fruit weight, fruit length/width ratio, stone width and stone length/width ratio when the existence of two groups of characters:

The length and width of the fruit, the weight and length of the stone, and three groups for the width of the leaf and quarter groups for the characters: the length and the length/width ratio of the leaf reflects the unparalleled influence of the character towards the environment.

The second step was about the effect of the four regions on the Chemlel variety. It has been found that the climate is not adequate for the width of the leaf in Sidi Belabes region by contribution to other regions. According to the results of the ACP this region is not suitable for good fruit production.

It is noted that there are no varietal effects on the characters: fruit weight, fruit length and width, stone weight, stone length and width, and stone length/width ratio.

Table 9. Effect of the region (Djidiouia) on genotypes (Sigoise and Verdale).

Characters / Region	PF (g)	LFr (cm)	lFr (cm)	(L/l) Fr	PN (g)	LN (cm)	lN (cm)	(L/l) (N)	LFe (cm)	lFe (cm)	(L/l) (Fe)
Sigoise	4.06± 0.04	2.37± 0.01	1.79± 0.01	1.33± 0.01	0.65± 0.01	1.63± 0.01	0.81± 0.003	2.02± 0.01	7.51± 0.07	1.42± 0.02	5.30± 0.03
Vardale	3.01± 0.03	2.10± 0.01	1.63± 0.01	1.30± 0.01	0.54± 0.01	1.48± 0.01	0.78± 0.01	1.90± 0.01	6.87± 0.07	1.52± 0.01	4.54± 0.04

Thun we searched about the effect of the Mohammadia region on the phenotypic characters of the Italian and the Syrian varieties: for the first one we noticed that there is no varietal effect on the character: Fruit length, whereas this effect exists for all remaining characters, and for the second one, it is important to mention that there is no varietal effect on the characters: Fruit weight, Fruit length, Fruit width, stone width, while this effect for characters: stone weight, stone length, Leaf length, Width of the leaf.

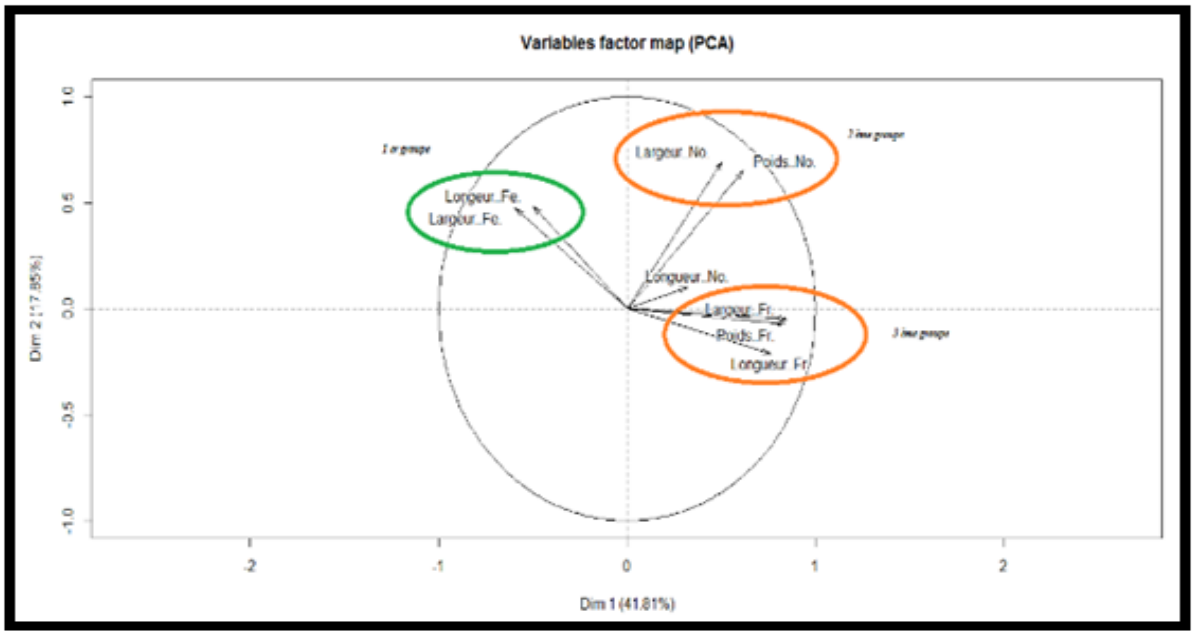

Fig. 2. ACP accessions of the olive tree according to the averages of various characters of all the individuals and the regions studied.

Finally, we took for consideration effect of the region (Djidiouia) on genotypes (Sigoise and Verdale): it is remarkable that the virial effect exists in the region of the differences observed between the two varieties which are probably due to an effect of the genome.

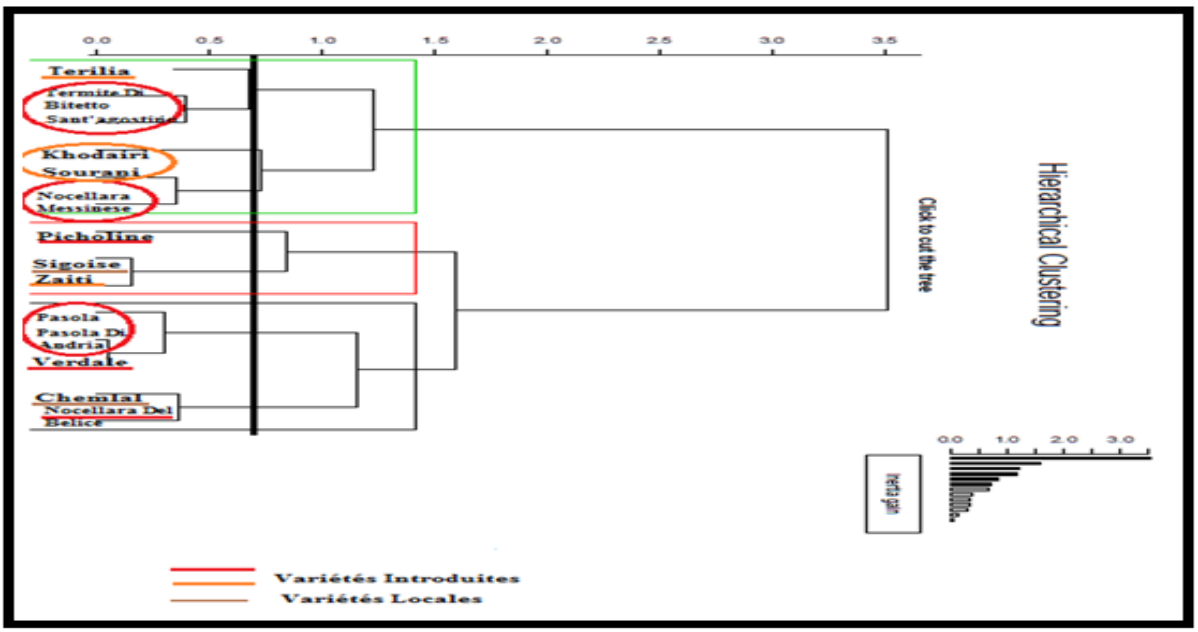

Fig. 3. Hierarchical ascendant classification (CAH) of accessions of the olive tree studied.

Conclusion

Our study that aimed to analyze the diversity on the basis of agro-morphological characteristics of accessions collected in western Algeria, showed that there is a significant diversity in the different accessions studied.

This breeding diversity is also due to the traditional typological nature which these various accessions characterized by low selective pressure are cultivated. The CAH has shown a varieties repartition in three groups. Each group contains an admixture of different varieties (we found in the same group varieties with a different geographic origin).

The logical continuation of this work would be the blocking of these varieties in order to know more about their phytotechnical and genetic potential (to have an idea on the characters most influenced by the environment and those depending more on the genetics).

Finally, a study by molecular markers will give us the opportunity to have a precise and concise idea of the genetic variability and the exact number of the variety, which is very important to take into account for the establishment of genetic management and the improvement plan of this important potential.

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