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Evaluation of variability in argan oil content through different environments and preselection of elite genotypes

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Abstract This investigation was carried out to determine the variability in oil content with the aim to identify genotypes of argan tree expressing high oil yield. The 150 argan trees were collected from five provenances in south west of Morocco over 3 years (2008–2010) and were screened from their oil content using Soxhlet method based on the 840 samples. Univariate and multivariate analysis were used to study the genetic variation between and within provenances. According to the results on the mean of the 3 years, the oil content was ranged from 38.45 to 62.54 %. The genotypes from Aoulouz and Had Dra expressing high oil yield. Variance components for fruit, seed, kernel traits and oil content showed significant differences ($P < 0.01$) among years, provenances, genotypes and their interaction. Principal component analysis proved that fruit, seed, kernel, weight traits are correlated with oil content and are discriminate characters between the genotypes. The results of the cluster analysis support the results of the principal component analysis, showing no correlation between oil content with geographical localization parameters. For all the promising genotypes, at least 25 % were found to be better and exceed the oil mean of the provenance for 3 years. So, 31 promising elite genotypes were preselected, and open new ways for future comparative test of them in diverse environments.

Keywords *Argania spinosa* L. · Provenance · Oil yield · Variability · Preselection

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Introduction

Argania spinosa L. is one of the endemic oldest forest trees with multiple values and uses. It is widely distributed along southern west of Morocco and it covered about 950,000 ha in 2010 (Lefhaili 2010). It tolerates heat and drought well and continues to grow and flower during the dry season, it can survive in arid environments by maintaining its water content without any wilting of the leaves or desiccation, even under severe stress conditions. Various parts of this tree are globally used from traditional medicine for common human and animal aliments. The traditional healthcare was scientifically validated (Charrouf and Guillaume 2010). The wood is a fuel source (Mhirit et al. 1998), remarkably, stable and used as firewood for cooking and for furniture manufacturing. The dried kernel (almond) of the fruit is commonly used to produce oil. Argan oil is thought to be one of the highest quality vegetable oils, has a high nutritional and dietetic value due to its chemical composition (Charrouf and Guillaume 1999; Cherki et al. 2005; Drissi et al. 2006; Gharby et al. 2011; Khallouki et al. 2003). The oil lowers cholesterol levels and hypertension in humans and reduces the indices of certain cancers (Drissi et al. 2006; El Babili et al. 2010). It can also help to variability farming systems and mitigate environmental degradation in the south west of Morocco. So, it plays a great role in the biodiversity of the forest ecosystems (Msanda et al. 2005). However, current situation of this tree due to degradation, overexploitation and overgrazing (Mhirit et al. 1998; Nouaim 2005; Waroux and Lambin 2012) called the implications for domestication, conservation in their natural habitats and maintenance of its genetic variation at different levels. Genetic variability and characteristic associations were previously studied by various works (Ait aabd et al. 2011, 2012; Bani Aameur and Ferradous 2001; El Mousadik and Petit 1996; Zunzunegui et al. 2010). So, knowledge on variability is important to design a suitable plant improvement programs. So, in the aim to meet the requirement of massive exploitation of oil argan, evaluation of good yielding argan tree is directly needed to select the elite genotypes highly productive. The analysis of adaptability and stability are important to identify elite genotypes under different environments, because the yield of any plant is the result of interaction of genetics and environment conditions.

The aim of the present investigation was to evaluate genetic variability in argan oil tree and to preselect the elite argan genotypes under different environmental conditions for better oil content.

Materials and methods

Study site

Field studies were carried out during the summer season for three years (2008–2010) at five principal provenances of argan tree in south-west of Morocco; it covers an area from the Had Dra in Essaouira, Alma in Agadir Ida Outanan, Biougra in Chtouka Ait Baha, and Aoulouz in Taroudante to Lakhsas in Tiznit. The details of each provenance are listed in Table 1 and presented in Fig. 1.

Plant materials and experimental design

The fruits of the 150 argan trees were sampled from five provenances (Table 1 and Fig. 1). For each provenance, thirty individual trees were geographically located using a global position system device. 90 fruits were randomly collected from each tree during the summer season 2008–2009, 2009–2010 and 2010–2011. A total of 37800 samples were subject to evaluate the variability, using quantitative and qualitative traits (Table 2). For each tree, 10 g of the dried kernel powder (with two repetitions) was extracted using a chemical method of Soxhlet according to the AOAC (1990). The oil content was calculated as a ratio of weight of the oil to its respective sample expressed in percentage.

Statistical analysis

All statistical analysis was performed with Statistica V.12 software. Analysis of variance was performed using general linear model procedure at different levels (year, provenance, genotype or mother tree and their interactions). Differences between mean values were compared using the post hoc test by Duncan Multiple Range Test (DMRT). The values are presented as mean ± standard deviation (SD). Variation assessment was also performed using univariate and multivariate analysis. To better understand the correlation between all characters studied with oil content, principal component analysis (PCA) was performed using a matrix generated from the mean morphological data, followed by cluster analysis by K-means method and the Euclidean distance.

Results and discussion

Variability analysis

Data collected during three successive years at five provenances were analyzed. The ranges, means and coefficient of variation for oil content are presented in Table 3. In spite of the variation, means of the provenances generally displayed considered differences between the minimum and maximum values of the oil content evaluated. The mean values over three years of this oil, expressed in percentage, varied between 49.54 and 52.90 % with the min values were

Table 1 Topographic and climatic characteristics of the five provenances

Characteristics	Provenance/seed source														
	Aoulouz			Had Dra			Alma			Biougra			Lakhsas		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Topographic															
Slope	Smooth slope			Flat terrain			Smooth slope			Flat terrain			Smooth slope		
Altitude (m)	802	737	850	207	181	226	332	275	430	123	109	137	954	916	988
Longitude (W)	30.71	30.70	30.73	31.57	31.56	31.59	30.48	30.00	30.51	30.27	30.25	30.31	29.38	29.38	29.38
Latitude (N)	8.14	8.11	8.15	9.58	9.58	9.59	9.58	9.57	9.59	9.35	9.34	9.36	9.74	9.73	9.75
Climatic															
Bioclimatic	Warm temperate, arid			Cool temperate, semi-arid			Warm temperate, arid			Warm temperate, arid			Warm temperate, arid		
Average temperature[a] (°C)	22	15	29	17	15	23	19	23	30	18	25	30	20	15	29
Rainfall[a] (mm)	192	55	331	313	173	568	211	23	200	200	12	231	134	23	203

[a] 1996–2011 for temperature and 1999–2011 for rainfall data (ORMVA/SM)

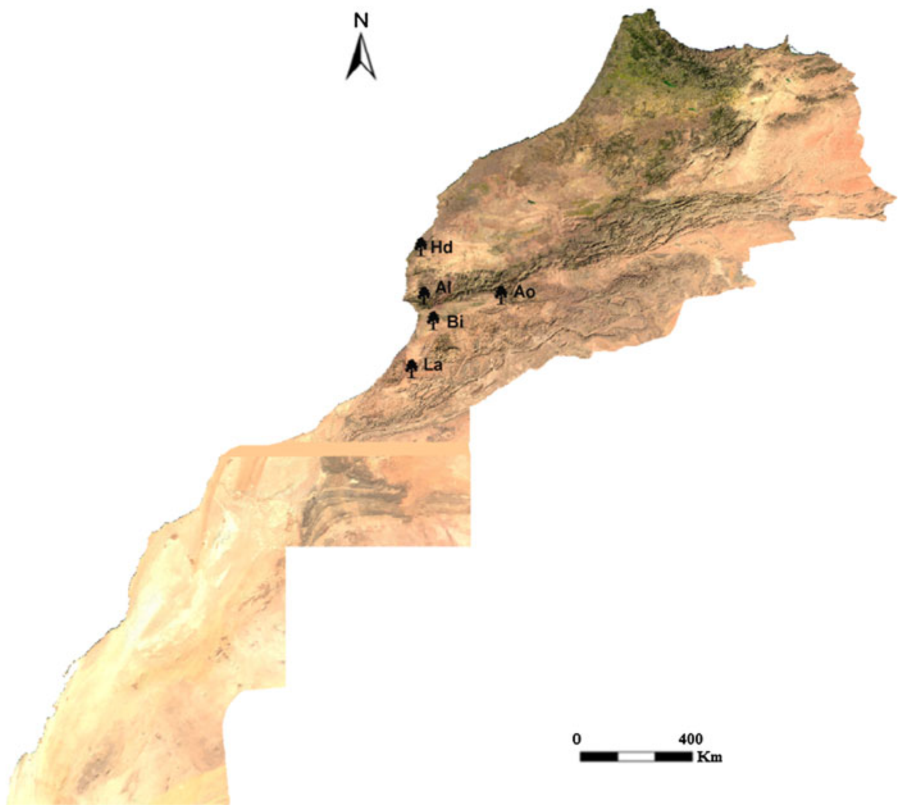


Fig. 1 Map showing locations of the site argan collections in 2008–2010. *Ao* (Aoulouz), *Hd* (Had Dra), *Al* (Alma), *Bi* (Biougra), *La* (Lakhsas)

38.45 % and the max values was 62.54 %. The highest coefficient of variation was recorded for Alma provenance followed by Lakhsas provenance, could be due to the heterogeneity existing among the genotypes because these provenances are affected by the drought dominated in these two natural habitats. The Duncan

Table 2 Morphological descriptors used in the variability analysis of *A. spinosa*

Fruit	Seed	Kernel
• Fruit weight (FW) (g)	• Seed weight (SW) (g)	• Kernel weight (KW) (g)
	• Seed length (SL) (mm)	• Kernel length (KL) (mm)
	• Seed width (SWi) (mm)	• Kernel width (KWi) (mm)
	• Hull thickness (HT) (mm)	• Number of kernel per seed (KN): (1) (1A); (2) (2A); (3) (3A); (4) (4A)
	• Carpel number (CN): (1) (1C); (2) (2C); (3) (3C); (4) (4C); (5) (5C);	• Kernel weight/seed weight ratio (KW/SW)
		• Oil content (OC) (%)
		• Oil volume (OV) (ml)

test was applied for comparison of mean performance. So, from separation of mean values of oil content indicated that Aoulouz and Had Dra are two homogenate groups, followed by Biougra provenance and Lakhsas provenance. Alma is the moderate group classed because the genotypes of this group are affected by drought and are not sampled in second year of study.

The univariate analysis of variance (ANOVA) for agro-morphological traits (fruit, seed, kernel weights, and dimensions) and oil content at different levels is detailed in Fig. 2. Data show significant differences ($P < 0.01$) between years, provenances, genotypes and their interaction. The great variation in oil yield due to interaction year × provenance. The interaction between year × provenance and genotypes show similar tendencies. With this analysis, we observe a high variability in oil yield among and within the provenances analyzed. Yield is a complex character associated with many interrelated components, and genotypic-environmental are main components that determine yield in plants. So, knowledge on the components of the genotype environment (G × E) interaction is a great importance for genetic improvement, but provides no detailed information on the performance of each cultivar under varying environmental conditions (Cruz et al. 2004). The significant interactions suggested that test of the selected genotypes under these environments were important and assisted in the partitioning of the magnitude sources of phenotypic variations.

Principal component analysis (PCA) is a multivariate technique was used in several studies to assess the interrelationships between various characters analyzed with interesting characters (i.e., oil content, fatty acid…) (Belaj et al. 2011; Klepo et al. 2013) and to clustering the genotypes. Hence, in the present study, principal component analysis was used to illustrate the correlation between the morphological traits, geographical localization parameters and the oil content. So, a matrix of mean value for three years was used for analysis. Correlation between the characters studied and the first three principal components is shown in Table 4. PC1, PC2 and PC3, respectively, explained 45.56, 13.27 and 11.03 % of total variability. The illustrations of the PC1 and PC2 axes are showed in Fig. 3. The first three PCA axes described 45.56 % of the total variance, indicating that this axe represent the majority of the variation for the characters studied. It was mainly determined by seven traits related to fruit seed and kernel weights, and seed, kernel dimensions. The second PC was associated with number of kernel per seed, seed weight/kernel weight ration, hull thickness, number of carpel per seed and longitude parameter. Hence it is correlated negatively to the altitude, longitude, fruit, seed weight, and size. However, positive correlations were found between oil content with two PCA axes. PCA showed also a strong association among fruit and seed dimensions. Consequently, PC analysis reveled that fruit, seed, kernel weight and dimensions are the most discriminate characters between the genotypes, and showed a strong association among these characters. Furthermore, to identifying the most important traits associated with argan oil content, in this illustration performed, the oil content apparent that correlated positively with the fruit, seed, kernel weight and dimensions. Significant correlation between fruit dimensions and oil content

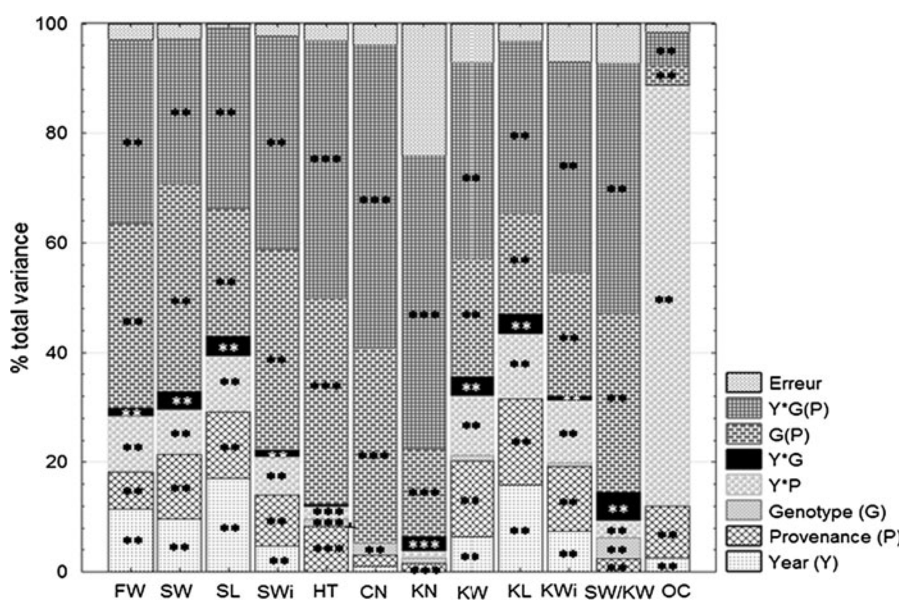
Table 3 Descriptive statistic parameters of oil content

Provenance	Years	Sample size	Mean ± SD	Min–Max	CV (%)
Aoulouz	Y_1	60	52.98 ± 1.87	48.79–57.79	3.54
	Y_2	60	52.09 ± 0.33	46.76 ± 56.77	3.38
	Y_3	60	53.64 ± 2.62	39.56 ± 57.64	4.88
	Total	180	52.90^a ± 2.20	39.56 ± 57.79	4.16
Had Dra	Y_1	60	52.82 ± 3.12	47.12 ± 59.97	5.91
	Y_2	60	53.24 ± 2.29	44.15 ± 58.56	4.31
	Y_3	60	52.35 ± 3.45	44.12 ± 59.70	6.60
	Total	180	52.80^a ± 3.00	44.12 ± 59.97	5.68
Alma	Y_1	60	49.78 ± 9.68	43.79 ± 55.11	19.44
	Y_2*	0	–	–	–
	Y_3	60	49.30 ± 10.44	38.45 ± 56.60	21.17
	Total	120	49.54^d ± 24.80	38.45 ± 56.60	75.10
Biougra	Y_1	60	52.30 ± 2.16	47.93 ± 56.70	4.12
	Y_2	60	49.74 ± 2.18	45.35 ± 54.95	4.37
	Y_3	60	52.62 ± 2.98	45.98 ± 57.81	5.67
	Total	180	51.55^b ± 2.77	45.35 ± 57.81	5.38
Lakhsas	Y_1	60	52.69 ± 2.74	46.06 ± 58.58	5.20
	Y_2	60	51.03 ± 2.70	46.73 ± 56.97	5.30
	Y_3	60	49.17 ± 8.82	45.32 ± 62.54	17.94
	Total	180	50.96^c ± 5.60	45.32 ± 62.54	10.99

SD standard deviation, *CV* coefficient of variation, *Y* year

* Missing values in second year

Fig. 2 Variance components for each character (See Table 2 for abbreviation details). Correlation analysis



was observed in other oleaginous studied; as olive oil (Belaj et al. 2011; Klepo et al. 2013) palm oil (Abdullah et al. 2011). In spite of wide variations in oil content across the geographical parameters (altitude and longitude), no significant relationships was found with altitudinal range.

A thorough, clustering of genotypes using principal component analysis was not very visible with PC axes, so using cluster k means, based on the interesting traits; oil content traits and geographical localization parameters, improved the clarity of illustrating the homogenous groups.

Structure of the groupings

In order to assess the patterns of variation and to identify discrete groups, multivariate analysis was done by considering geographical parameters (latitude, longitude and altitude) and oil yield for each provenances, according to cluster mean values obtained by K-means non-hierarchical clustering (Table 5). Based on the cluster means, the 150 genotypes grouped into four clusters. Maximum numbers of genotypes (60) were grouped into cluster IV. The important cluster was II for oil content, the lower mean values was noticed in cluster I.

As results, classification of the genotypes for their productivity associated with the original geographical data showed that high oil yields is not related to geographical distribution. Further, from the observation it was apparent that each cluster corresponds to each provenance except cluster IV, regrouped two provenances with same eco-geographical conditions. In addition, we can presume that the productivity is not following an environmental gradient, since we can observe high oil production among genotypes with high altitude (mountain) or inverse (plain). So, our findings for grouping the genotypes for geographical localization with their oil production show that each altitudinal origin is good scope for height production and for genetic improvement of oil yield. Similar findings were observed by several previous workers (Ginwal et al. 2005; Kaushik et al. 2003; Lal 2013; Shimelis et al. 2011a, b; Srivastava et al. 2011) concluded large variability in yield traits and oil content growing in large agro-climatic conditions. However, identifying promising genotypes based on performance mean is useful in various ecotypes/provenances/seed sources.

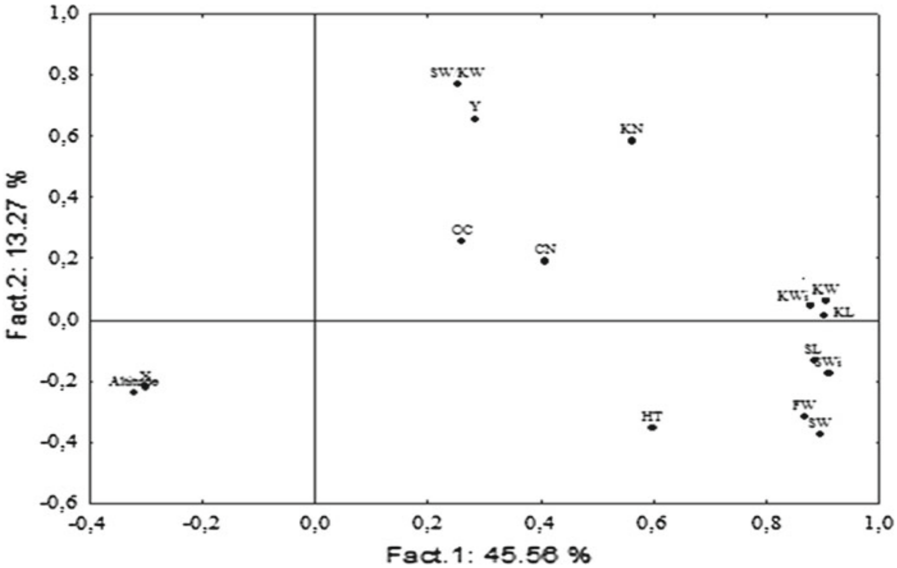
Table 4 Eigen values, percent and cumulative variance of the correlation matrix for each character of the 150 genotypes

Variable/PCA axes	PCA.1	PCA.2	PCA.3
Eigen value	6.83	1.99	1.65
Total variance explained (%)	45.56	13.27	11.03
Cumulative variance	45.56	58.83	69.86
Latitude	0.28	0.66	0.32
Longitude	−0.30	−0.22	0.61
Altitude	−0.32	−0.24	−0.89
Fruit weight	0.87	−0.32	−0.16
Seed weight	0.89	−0.37	0.00
Seed lenght	0.88	−0.13	−0.01
Seed width	0.91	−0.17	0.07
Hull thickness	0.60	−0.35	0.47
Number of carpel per seed	0.41	0.19	0.00
Number of kernel per seed	0.56	0.58	0.06
Kernel weight	0.90	0.05	−0.16
Kernel lenght	0.90	0.01	−0.10
Kernel width	0.90	0.04	−0.10
Seed weight/kernel weight ratio	0.25	0.77	−0.17
Oil content	0.26	0.26	−0.21

PCA Principal component analysis

Preselection of elite genotypes

Preselection of elite genotypes based on the best oil yield mean performance is given in Table 6. Considerable variation was observed among the preselected genotypes. According to the means, the productivity year to year and provenance to provenance is not stable. So, the effects of years, provenance and genotypes were more evidence on oil yield content. The comparison of means for oil yield within and between provenances reveals that the genotypes showed the differences in mean performance in the different years/environments indicated the presence of G × E interactions (Table 6). Argan oil yield is a complex trait influenced by many genetic as well as environment factor (Ait Aabd et al. 2011, 2012). Preselection has an important role in genetic improvement of oil yield, many researches in oleaginous have reported (Aghdaei et al. 2007; Chigeza et al. 2012; Iqbal et al. 2008; Lal 2013; Shimelis et al. 2011a, b; Srivastava et al. 2011; Shabanimofrad et al. 2013; Wang et al. 2011; Yadav et al. 2011; Zaher et al. 2011) and the considerable variation was observed among the selected genotypes. Because, genetic variation in oil yield is controlled by large genotype × year × location interactions. In this context, selection for yield and stability, genotype × environment interaction continuous to be a challenging issue among plant breeders, geneticists, and related agronomists



X: Longitude **Y:** Latitude **FW:** Fruit weight **SW:** Seed weight
SL: Seed length **SWi:** Seed width **HT:** Hull thickness **CN:** Carpel number
KW: Kernel weight **KL:** Kernel length **KWi:** Kernel width **OC:** Oil content
KW/SW: Kernel weight/ seed weight ratio **KN:** Number of kernel per seed .

Fig. 3 Principal component analysis illustrating correlation matrix between PCA axes with agro-morphological characters, geographical parameters (*X*, *Y altitude*) and oil content

Table 5 Grouping of the 150 genotypes of argan tree into clusters analysis based on oil yield and geographical localization

Cluster	Number of genotypes	Genotypes names	Oil yields (%)	Altitude (m)	Latitude (N)	Longitude (W)
I	30	Al-1V, Al-2V, Al-3V, Al-4V, Al-5V, Al-6V, Al-7V, Al-8V, Al-9V, Al-10V, Al-11V, Al-12V, Al-13V, Al-14V, Al-15V, Al-1R, Al-2R, Al-3R, Al-4R, Al-5R, Al-6R, Al-7R, Al-8R, Al-9R, Al-10R, Al-11R, Al-12R, Al-13R, Al-14R, Al-15R	49.54	331.60	30.48	−9.58
II	30	Ao-1V, Ao-2V, Ao-3V, Ao-4V, Ao-5V, Ao-6V, Ao-7V, Ao-8V, Ao-9V, Ao-10V, Ao-11V, Ao-12V, Ao-13V, Ao-14V, Ao-15V, Ao-1R, Ao-2R, Ao-3R, Ao-4R, Ao-5R, Ao-6R, Ao-7R, Ao-8R, Ao-9R, Ao-10R, Ao-11R, Ao-12R, Ao-13R, Ao-14R, Ao-15R	52.90	801.83	30.71	−8.14
III	30	La-1V, La-2V, La-3V, La-4V, La-5V, La-6V, La-7V, La-8V, La-9V, La-10V, La-11V, La-12V, La-13V, La-14V, La-15V, La-1R, La-2R, La-3R, La-4R, La-5R, La-6R, La-7R, La-8R, La-9R, La-10R, La-11R, La-12R, La-13R, La-14R, La-15R	50.96	954.00	29.38	−9.74
IV	60	Hd-1V, Hd-2V, Hd-3V, Hd-4V, Hd-5V, Hd-6V, Hd-7V, Hd-8V, Hd-9V, Hd-10V, Hd-11V, Hd-12V, Hd-13V, Hd-14V, Hd-15V, Hd-1R, Hd-2R, Hd-3R, Hd-4R, Hd-5R, Hd-6R, Hd-7R, Hd-8R, Hd-9R, Hd-10R, Hd-11R, Hd-12R, Hd-13R, Hd-14R, Hd-15R, Bi-1V, Bi-2V, Bi-3V, Bi-4V, Bi-5V, Bi-6V, Bi-7V, Bi-8V, Bi-9V, Bi-10V, Bi-11V, Bi-12V, Bi-13V, Bi-14V, Bi-15V, Bi-1R, Bi-2R, Bi-3R, Bi-4R, Bi-5R, Bi-6R, Bi-7R, Bi-8R, Bi-9R, Bi-10R, Bi-11R, Bi-12R, Bi-13R, Bi-14R, Bi-15R	52.18	164.77	30.92	−9.47

Al Alma, *Ao* Aoulouz, *La* Lakhsas, *Hd* Had Dra, *Bi* Biougra

Table 6 Preselection perspectives for genetic improvement of argan trees

Aoulouz		Had Dra			Alma		Biougra		Lakhsas
Trees	OC*	Trees	OC	Trees	OC	Trees	OC	Trees	OC
Genotypes preselected in first year (2008)									
Ao-3V	54.64	Hd-1V	55.09	Al-1V	54.20	Bi-3V	53.40	La-1V	57.11
Ao-4V	55.13	Hd-2V	53.86	Al-3V	52.76	Bi-5V	54.21	La-2V	55.18
Ao-5V	53.94	Hd-3V	57.92	Al-5V	53.12	Bi-6V	52.92	La-3V	56.08
Ao-7V	53.57	Hd-4V	53.87	Al-6V	51.44	Bi-7V	53.50	La-4V	53.80
Ao-9V	53.76	Hd-12V	54.29	Al-7V	52.04	Bi-8V	53.58	La-5V	53.94
Ao-10V	54.36	Hd-3R	56.95	Al-8V	50.69	Bi-10V	53.16	La-6V	57.29
Ao-11V	53.97	Hd-4R	53.91	Al-9V	54.61	Bi-11V	52.65	La-8V	52.76
Ao-4R	53.86	Hd-7R	57.68	Al-11V	55.11	Bi-12V	56.56	La-9V	54.83
Ao-7R	54.56	Hd-8R	59.97	Al-12V	52.17	Bi-14V	53.98	La-10V	52.74
Ao-10R	54.55	Hd-9R	57.66	Al-2R	52.77	Bi-15V	54.50	La-11V	54.55
Ao-11R	54.22	Hd-13R	56.67	Al-3R	51.33	Bi-4R	55.90	La-2R	54.28
Ao-12R	57.69	Hd-15R	53.62	Al-4R	51.56	Bi-7R	53.36	La-5R	58.58
Ao-13R	53.29			Al-5R	53.69	Bi-8R	55.19	La-7R	53.82
				Al-6R	53.52	Bi-10R	56.70	La-9R	54.89
				Al-7R	50.50	Bi-13R	54.46		
				Al-8R	53.42				
				Al-9R	54.07				
				Al-10R	51.31				
				Al-13R	54.15				
				Al-14R	50.78				
				Al-15R	52.42				
Genotypes preselected in second year (2009)									
Ao-4V	54.17	Hd-1V	54.76	–	–	Bi-1V	50.43	La-1V	55.76
Ao-7V	53.86	Hd-2V	54.37	–	–	Bi-3V	51.32	La-2V	56.97
Ao-8V	55.89	Hd-3V	56.12	–	–	Bi-5V	52.26	La-3V	55.89
Ao-9V	54.53	Hd-4V	54.64	–	–	Bi-7V	51.38	La-6V	54.06
Ao-10V	53.25	Hd-13V	55.58	–	–	Bi-8V	51.19	La-9V	52.59
Ao-11V	52.60	Hd-3R	55.53	–	–	Bi-10V	50.72	La-11V	53.88
Ao-13V	52.49	Hd-7R	55.00	–	–	Bi-12V	52.83	La-7R	53.31
Ao-1R	53.25	Hd-8R	58.56	–	–	Bi-15V	51.82	La-9R	55.09
Ao-4R	53.95	Hd-9R	56.35	–	–	Bi-3R	50.62		
Ao-7R	55.45	Hd-11R	54.71	–	–	Bi-4R	51.59		
Ao-11R	54.43	Hd-13R	54.79	–	–	Bi-5R	52.69		
Ao-12R	56.77			–	–	Bi-8R	51.68		
				–	–	Bi-10R	54.95		
				–	–	Bi-13R	51.77		
Genotypes preselected in third year (2010)									
Ao-1V	54.06	Hd-1V	54.29	Al-1V	56.66	Bi-2V	53.55	La-1V	56.11
Ao-3V	54.52	Hd-2V	54.07	Al-4V	52.08	Bi-6V	52.89	La-2V	54.59
Ao-4V	55.78	Hd-3V	57.00	Al-5V	53.11	Bi-8V	57.81	La-3V	62.54
Ao-5V	54.06	Hd-4V	54.07	Al-7V	52.33	Bi-10V	52.99	La-4V	52.45
Ao-7V	54.32	Hd-6V	52.93	Al-8V	53.17	Bi-11V	53.61	La-5V	52.44

Table 6 continued

Aoulouz		Had Dra			Alma		Biougra		Lakhsas
Trees	OC*	Trees	OC	Trees	OC	Trees	OC	Trees	OC
Ao-8V	55.83	Hd-8V	52.95	Al-9V	52.59	Bi-12V	57.27	La-6V	54.32
Ao-9V	54.29	Hd-9V	55.27	Al-11V	56.60	Bi-13V	54.25	La-9V	53.72
Ao-11V	53.70	Hd-11V	53.97	Al-14V	56.60	Bi-15sV	53.00	La-11V	54.87
Ao-12V	53.73	Hd-12V	55.12	Al-15V	51.52	Bi-2R	53.70	La-14V	52.60
Ao-4R	53.90	Hd-1R	52.51	Al-1R	53.86	Bi-3R	52.89	La-2R	53.75
Ao-6R	54.98	Hd-3R	56.11	Al-2R	49.79	Bi-4R	57.38	La-7R	56.44
Ao-7R	55.20	Hd-4R	52.89	Al-3R	52.41	Bi-7R	52.96	La-9R	55.20
Ao-11R	54.35	Hd-6R	53.70	Al-4R	56.97	Bi-8R	53.74	La-12R	52.48
Ao-12R	57.64	Hd-7R	55.89	Al-6R	50.28	Bi-9R	57.38	La-13R	53.03
		Hd-8R	56.68	Al-7R	52.71	Bi-10R	54.30		
		Hd-9R	59.60	Al-8R	53.46	Bi-11R	54.31		
		Hd-13R	56.08	Al-9R	50.70	Bi-12R	52.99		
		Hd-14R	52.78	Al-10R	52.44	Bi-13R	53.70		
				Al-11R	52.41	Bi-15R	52.86		
				Al-13R	51.02				
				Al-15R	50.58				

* OC oil content (%)

who conduct varietal performance field evaluation trials over years or across diverse environments (Lal 2012). This work represents the first step to identify promising elite genotypes that give reproducible performance. So, preselection experiment in different environment has been performed. There is little information to guide argan improvement, thus, it is necessary to investigate further the effects of agronomic practice and regional variation on argan oil yield of the main domesticates. From the above discussion the promising elite genotypes perfect over three year from different agroclimatic zones are summarized in Table 7. The results for comparative performance of the genotypes preselected each year show that the accession labeled : Ao-4V, Ao-7V, Ao-11V, Ao-4R, Ao-7R, Ao-11R, Ao-12R, Hd-1V, Hd-2V, Hd-3V, Hd-4V, Hd-3R, Hd-7R, Hd-8R, Hd-9R, Hd-13R, Bi-8V, Bi-10V, Bi-12V, Bi-15V, Bi-4R, Bi-8R, Bi-10R, Bi-13R, La-1V, La-2V, La-3V, La-6V, La-11V, La-7R, La-9R, Al-1V, Al-5V, Al-7V, Al-8V, Al-9V, Al-11V, Al-2R, Al-3R, Al-6R, Al-7R, Al-8R, Al-9R, Al-10R, Al-13R, Al-15R with higher oil content could be recommended for future comparative test in varying ecological conditions. Moreover, the great variability in oil inter-annual showed their potential for utilization in improvement programs at intra- and inter-specific level could also be utilized. To identify such genotypes, stability analysis is a good technique, which measures the adaptability of different yield genotypes to varying environments (Morales et al. 1991).

Conclusion and perspectives

The analysis of oil content of the 150 genotypes from different environmental sites has conducted to report the diversity in oil contents. Therefore, it is a good opportunity to identify elite genotypes that give reproducible performance among origin site. Genotypes, provenances and year factors were highly significant ($P < 0.01$) for oil content. The results of this study suggest that the structure of oil content variations in *A. spinosa* in their origin site is influenced by genetic and environmental factors. Hence, considering the interrelationships studied of various component characters with oil content, mentioned that the oil yield trait is a good parameters to select the best genotypes. Principal component analysis proved that fruit, seed, kernel, weight traits are correlated with oil

Table 7 Elite genotypes preselected of oil yield from five provenances over 3 years

Aoulouz		Had Dra		Alma*		Biougra		Lakhsas	
Trees	OC	Trees	OC	Trees	OC	Trees	OC	Trees	OC
Genotypes preselected over three years (2008–2010)									
Ao-4V	55.03	Hd-1V	54.71	Al-1V	55.43	Bi-8V	54.20	La-1V	56.33
Ao-7V	53.92	Hd-2V	54.10	Al-5V	53.11	Bi-10V	52.29	La-2V	55.58
Ao-11V	53.42	Hd-3V	57.01	Al-7V	52.18	Bi-12V	55.55	La-3V	58.17
Ao-4R	53.90	Hd-4V	54.19	Al-8V	51.93	Bi-15V	53.11	La-6V	55.23
Ao-7R	55.07	Hd-3R	56.20	Al-9V	53.6	Bi-4R	54.95	La-11V	54.43
Ao-11R	54.33	Hd-7R	56.19	Al-11V	55.86	Bi-8R	53.54	La-7R	54.52
Ao-12R	56.22	Hd-8R	58.40	Al-2R	51.28	Bi-10R	55.32	La-9R	55.06
		Hd-9R	57.87	Al-3R	51.87	Bi-13R	53.31		
		Hd-13R	55.85	Al-6R	51.90				
				Al-7R	51.61				
				Al-8R	53.44				
				Al-9R	52.38				
				Al-10R	51.87				
				Al-13R	52.58				
				Al-15R	51.50				

* Except for Alma provenance, the preselection evaluated over two years

content. The results of the cluster analysis indicate that genetic variability observed between provenances of oil yield was not related to geographical origin. A total of 31 promising elite genotypes were preselected and can be tested in the comparative study of provenance and progeny. The imperative for the future, it will be more great to study the stability and adaptability patterns for oil yield in different sites and we also hope to be able to widen the broad strategies for collection management through repeated among other agroclimatic sites applied for further exploited in the improvement programs and conservation their biodiversity for establishing base provenance.

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