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Full Length Research Paper

Evaluation of agromorphological variability of Argan tree under different environmental conditions in Morocco: Implication for selection

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In order to identify promising wild argan trees (*Argania spinisa* L. Skeels), with high oil content and facilitated of crushing seeds, as a part of domestication and breeding programs, seventy five candidate plus trees were chosen from different eco-geographical regions in the southwest of Morocco. Based on several biometric characters describing trees and their fruits, uni and multivariate analysis of eighteen quantitative traits were done. Results showed significant differences (P<0.01, GLM) between trees of the same provenances and among it for all morphological fruit traits, except the tree traits. Considerable variability was found in oil production ranged from 39.19% to 57.92%. Thus, Ao, Hd, La and Bi provenances exhibited high performance yield and appeared to be the best adapted to drought conditions, contrary to Al provenance. Based on the variance components method, high broad-sense heritability was recorded for oil content (93.28%), indicating the additive gene action. Correlation analysis revealed that fruit weight, seed weight, almond weight, seed length, seed width and AW-90S are highly and positively correlated with oil content. Hence, almond weight and the number of almond per seed are positively correlated to AW/SW ratio. However, there was no correlation between crushing seed trait and oil content. In addition, promising trees which have a clear superiority relating to the oil production and the facility of crushing seed, were identified and made a first pre-selected for the oil yield improvement for further studies.

Key words: *Argania spinosa* (L.) Skeels, provenance, oil content, crushing seed, pre-selection.

INTRODUCTION

Natural populations of Argan, only representative species of the tropical family Sapotaceae in Morocco is widely distributed in arid and semi-arid areas; it plays a great role in the biodiversity of the ecosystems forest (Msanda et al., 2005). This species include different fruit forms; round, ovoid to the spindle one, distinguished since 1953 by Chevalier (1953). The dried kernel (almond) of the fruit is 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. The polyunsaturated fatty acid varied from 80 to 90% with two principals fatty acids types; oleic acid type 46 to 55% with an approximate range of linoleic acid 35 to 38% (Charouf and Guillaume, 1999) and unsaponifiable fraction. The oil content depends on genotype and environmental conditions; it extends from 50 to 56 g/100 g of kernels (Huyghebaert and Hendricks, 1974; Nerd et al., 1994). Therefore, Argan tree (*Argania spinosa* (L.) Skeels) is an important multipurpose oleaginous plant; it plays an immense ecological, socio-economical role, and it is the principal incomes for local population in the arid regions (Benchakroun and Buttoud, 1989).

At the present time, several physical and anthropogenic factors reduce the density and surface of Argan eco-systems, so it decreases the biodiversity in natural areas. Due to the continuous intensify of genetic erosion, it is necessary to save situation of this species. The Argan

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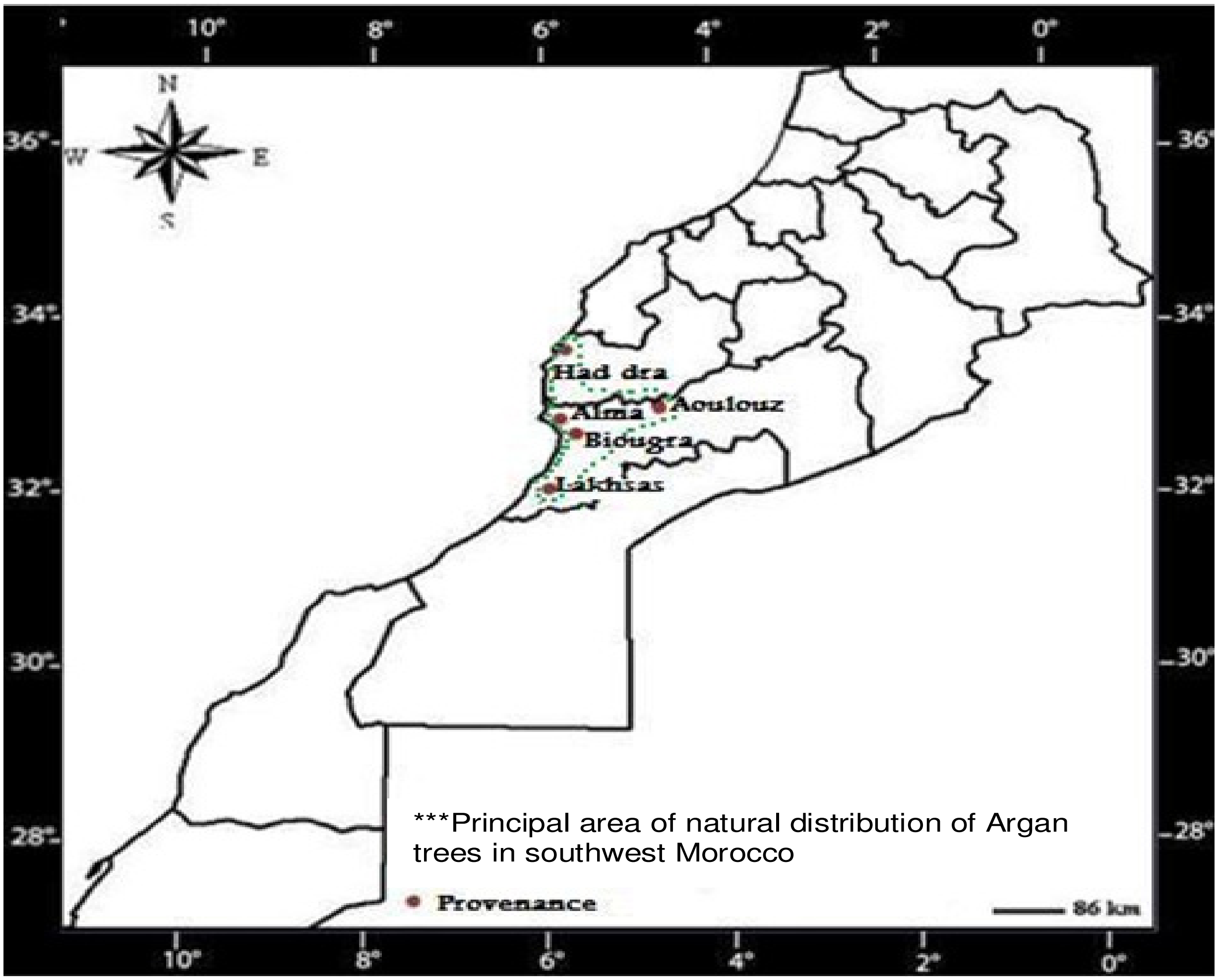


Figure 1. Map of Morocco showing location of different provenances included in the study.

tree harbour a high diversity, recorded at different levels (Petit et al., 1998).

So, a good understanding of the variation within a species is necessary for its domestica-tion, conservation and sustainable management (El Kassaby, 2000). Several searches have been conducted to provide information to the genetic diversity at different levels using molecular approach (Bani and Hilu, 1996; El Mousadik and Petit, 1996a, b; Majaurhat et al., 2008) and phenological studies (Ferradous, 1995; Zahidi, 1997; Bani and Ferradous, 2001; Benlahbil, 2003).

Evaluation of phenotypic diversity is a logical first step in the elaboration of a program to improve germplasm management and deployment of any crop. Facing the problem of the high demand of Argan oil, we must focus our conservation programs in the plantations of trees with high productivity on oil, in this sense comes our research to exploit the morphological diversity that mainly affect the oil yield of the seed. To do so, we chose five provenances representative of the Argan tree stands with high density and are subjected to different soil and climatic conditions.

MATERIALS AND METHODS

The study area

The trees evaluated were from the natural stand which represented five principal provenances of Argan in south-west of Morocco,it covers an area from the Had Dra in Essaouira, Alma in Agadir Ida Outanane, Biougra in Chtouka Ait baha, Aoulouze in Taroudante to Lakhsas in Tiznit (Figure 1).

Geographic data base (latitude, longitude, and altitude) were recorded for each accession of Argan tree using a global positioning system (Table 1). The altitudinal distribution ranges from 109 m in Biougra to 988 m in Lakhsas. Climate of this region is arid and semi arid Mediterranean type. Rainfall is scarce and very variable (100 to 300 mm in annual average), taking place mainly during the cold period, while summer season is dry. Still there are differences between the sites in mean annual rainfall and mean annual temperature (Table 1). Their soils are sandy-clay at Had Dra, poorly drained containing stones and gravels at Alma, sandy at Biougra, fertile clay at Aoulouze and brown calcic containing stones and gravels at Lakhsas.

Table 1. Geographic original of Argan tree.

Origin site	Code	Province	Rainfall (mm)	Temperature (°C)	Latitude (N)	Longitude (W)	Altitude (m)
Aoulouze	Ao	Taroudante	189	19.90	30° 42'-30° 43'	008° 06'-008° 09'	737-850
Had Dra	Hd	Essaouira	295	17.20	31° 33'-31° 35'	009° 33'-009° 35'	181-226
Alma	Al	Agadir	231	18.45	30° 28'-30° 30'	009° 33'-009° 35'	275-430
Biougra	Bi	Chtouka Ait Baha	200	19.00	30° 14'-30° 18'	009° 20'-009° 21'	109-137
Lakhsas	La	Tiznit	122	20.30	29° 22'	009° 43'-009° 44'	916-988

* Annual mean data in 2007-2008

Plant materials

A total of 75 Argan trees were marked in five provenances, for each provenance, 15 superior individual trees were chosen according to investigations with local populations and marked "1V to 15V" for each provenance. Random samples of 6750 mature fruits were collected from all provenances corresponding to 90 fruits for each tree. The diversity to each tree pre-selected was measured, using quantitative and qualitative characters, related to tree, fruits, seed and almond. as follows:

Tree height (HT) (m), tree circumference (CiT) (m), number of trunk (NT), tree crown (CrT) (m), leaf area (LA) (cm^2), fruit weight (FW) (g), seed weight (SW) (g), seed length (SL) (mm), seed width (SW) (mm), hull thickness (HT) (mm), carpel number (CN), number of almond per seed (AN), almond weight (AW) (g), almond length (AL) (mm), almond width (AWi) (mm), almond weight/ seed weight ratio (AW/SW), almond weight for 90 seed (AW-90S), oil content (OC) (%) and oil volume (OV) (ml). The oil content character was estimated with Soxhlet method using two repetitions for each tree.

Statistical analyses

The data were analysed using appropriate procedures of the Statistica V.6 software. An analysis of variance inter- and intra-provenance for each trait was performed using the GLM procedure to test the significance of differences among populations. Differences between means were compared according to the Duncan's multiple range test that uses multiple ranges for testing differences between the means.

For multivariate analysis, the matrix data was analyzed using the mean values of all descriptor correlate with oil content trait for each tree. Then, an exploratory analysis was elaborated with analysis discriminates.

Genetic parameter estimates

The statistical analysis was based on the following linear model:

$X_{ijk}=\mu+P_i+A/P_{ij}+e_{ijk}$,

where Xijk is the value of the studied variable which is the sum of four components defined as follows: μ = the overall mean, Pi = the effect of the ith provenance, A/Pij = effect of the jth tree within the ith provenance (random) and eijk = the residual term. Variance components σ^2_p (phenotypic variance) and σ^2_g (genotypic variance) were estimated from the mean squares in the analysis of variance (Panse and Sukhatme, 1976; Falconer and Mackay, 1996).
Phenotypic (PCV) and genotypic (GCV) coefficients of variation were calculated as:

$CV= (\sqrt{\sigma^2}/\mu)*100$,

where $\sqrt{\sigma^2}$ correspond to the phenotypic and genotypic standard deviations, and μ is the global mean.
Heritability in the broad sense (h^2) and genetic advance (GA) was estimated by Johnson et al. (1955), where $h^2= \sigma^2_g/\sigma^2_p$ and GA (as% of the mean) = $(GA/\mu)*100$ was calculated with the intensity of selection (i) assuming selection of the superior 20% of the genotypes using the formula $GA=i\sqrt{\sigma^2 ph^2}$. Phenotypic and genetic correlations coefficients among the characters studied were calculated from the analysis of covariance using the model corresponding to the analysis of variance following Kwon and Torrie (1964).

RESULTS

Variability analysis and performance means

Important morphological variation was found among provenances (Table 2.). In general, majority of morphological traits exhibited wide range of variation, expressed with a coefficient of variation ranging from 5.54 to 83.51%. The comparison of means (Table 2) reveals that provenance Bi showed the highest mean values for the crown diameter of tree (10.59 m), leaf area (64.94 cm^2), fruit weight (4.17g), seed weight (2.61g), seed length (22.68 mm), seed width (14.77 mm), hull thickness (2.39 mm), almond weight (0.28 g), almond length (17.23 mm), almond width (9.11 mm) and almonds weight of 90 seeds and mean value lowest for almond weight/seed weight ratio (0.11). Provenance La showed the highest mean value for the oil yield (53.76%) which corresponds to 6.06 ml/ 10 g of almond, this provenance shares the highest mean value of almond weight/seed weight ratio (0.13) with Ao and Hd provenances, which are classified in the same group. Also, three provenances: Ao, Hd and Bi showed the same value of the oil content and almond weight/seed weight ratio trait. However, a high difference between these provenances and provenance *Al* was found for all traits.

The analysis of variance shows a highly significant differences among population ($p < 0.001$) for all traits excepted plant height, circumference, number of trunk, crown tree and leaf area. Evaluation of this difference and inter- and intra- trees/provenance is illustrated in Table 3. An important genetic variation among the

Table 2. Comparison of the mean values and analysis of variance for the morphological traits over five provenances studied.

	Tree					fruit
Provenances	**HT**	**CiT**	**NT**	**CrT**	**LA**	**FW**
Ao	6.97	3.04	2.00	8.61	45.76	3.08[a]
Hd	6.77	1.96	1.53	10.21	56.22	2.94[a]
Al	6.33	2.54	2.93	9.49	32.91	2.25[c]
Bi	6.41	2.85	2.40	10.59	64.94	4.17[b]
La	6.83	2.90	1.73	10.21	36.42	4.09[b]
Mean	6.66	2.66	2.12	9.82	47.25	3.31
SD	1.56	1.29	1.77	3.24	2.87	1.17
CV(%)	23.48	48.71	83.51	33.00	6.08	35.51
Provenance(P)	ns	ns	ns	ns	ns	***
			Seed			
	SW	**SL**	**SW**	**HT**	**CN**	**AN**
Ao	1.71[ab]	18.86[a]	12.63[a]	1.91[a]	2.17[b]	1.07[a]
Hd	1.73[ab]	19.03[a]	12.68[a]	1.95[a]	2.27[a]	1.20[b]
Al	1.30[a]	15.70[b]	12.23[a]	1.97[a]	2.27[a]	1.16[ab]
Bi	2.61[c]	22.68[c]	14.77[b]	2.39[b]	2.20[a]	1.09[a]
La	2.15[b]	19.17[a]	13.97[b]	2.16[ab]	2.35[c]	1.10[a]
Mean	1.90	19.09	13.26	2.08	2.25	1.12
SD	0.74	3.65	1.68		0.37	0.27
CV(%)	38.77	19.13	12.71	17.72	11.90	10.83
Provenance(P)	***	***	***	***	***	***
				Almond		
	AW	**AL**	**AWi**	**AW/SW**	**AW-90S**	**OC**
Ao	0.21[a]	14.89[a]	8.09[a]	0.13[a]	19.63[b]	52.72[a]
Hd	0.23[a]	15.11[a]	8.01[a]	0.13[a]	20.72[ab]	52.05[ab]
Al	0.16[c]	11.43[b]	7.08[c]	0.12[ab]	14.45[c]	50.17[b]
Bi	0.28[b]	17.23[c]	9.11[b]	0.11[b]	24.85[a]	52.74[a]
La	0.26[ab]	14.87[a]	8.90[b]	0.13[a]	24.10[a]	53.76[a]
Mean	0.23	14.71	8.24	0.12	20.75	52.29
SD	0.12	0.07	3.05	1.20	0.02	2.90
CV(%)	32.41	20.72	14.62	18.79	31.21	5.54
Provenance(P)	***	***	***	***	***	***

*** Significant at p< 0.001; ns = not significant; SD: Stand deviation; CV: Coefficient of variation.

natural populations is often considered. High significant ($P<0.01$, GLM) variation was recorded within and between trees and provenance for all characters. Moreover, the factors of genotype, provenance and genotype in provenance indicate high significant difference for all the characters (Table 3).

Genetic parameters of traits

To compare the variation among various traits, estimates of variance components (σ^2_p, σ^2_g), phenotypic (PCV) and genotypic coefficient of variability (GCV), broad sense heritability (h^2) and genetic advance (GA) as a percentage of mean are given in Table 4.

Phenotypic coefficient of variability (PCV) was ranged from 1.95 (AW-90S) to 47.64% (AW). The genotypic coefficient of variation (GCV) showed similar trends as (PCV) and ranged from 0.90% for (AW-90S) to 31.57% for seed weight. Heritability estimates in broad sense were higher than 45% under study, which reflected the predominance of heritable variation for all the traits. The heritability in the broad sense for all characters is ranging between 8.02% for a number of almonds per seed to 93.28% for oil content. The highest heritability ($h^2 > 40\%$) as recorded for oil content closely followed by fruit weight, Seed weight, seed length, almond length, seed width and hull thickness. Among them, the heritability of number of the carpel, almond weight, almond width, almond weight/seed weight ratio and almonds weight of

Table 3. Mean square values from ANOVA analysis (GLM) for agromorphometrical data in five locations.

Traits	Provenance (df=4)	Genotype (df=74)	Genotype (Provenance) (df=70)
FW	865.96**	123.17**	80.72**
SW	304.45**	47.24**	32.54**
SL	7231.21**	1137.46**	789.25**
SW	1435.13**	251.76**	184.14**
HT	45.79**	11.77**	9.83**
CN	6.26**	6.51**	6.53**
AN	3.64**	1.33**	1.20**
AW	2.89**	0.48**	0.34**
AL	462.45**	810.27**	550.14**
AWi	885.80**	128.90**	85.65**
AW/SW	0.09**	0.05**	0.04**
AW-90S	1.22**	0.62**	0.59**
OC	26.30**	8.9**	7.9**

df = degrees of freedom; ** significant at $p \leq 0.01$.

Table 4. Estimation of genetic parameters for fruit, seed, almond and oil content traits.

Traits	σ^2_p	σ^2_g	h^2 (%)	PCV(%)	GCV(%)	GA	GA (%)
FW	1.39	0.89	64.15	35.66	28.56	0.24	7.32
SW	0.58	0.36	61.99	40.09	31.57	0.15	7.95
SL	11.33	8.74	77.13	17.64	15.49	0.83	4.35
SW	3.44	2.03	59.07	13.99	10.75	0.35	2.64
HT	0.24	0.11	45.20	23.52	15.82	0.07	3.40
CN	0.23	0.07	30.75	21.31	11.82	0.05	2.10
AN	0.15	0.01	8.02	34.22	9.69	0.01	0.88
AW	0.01	0.00	31.65	47.64	26.80	0.01	4.82
AL	11.02	6.06	54.98	22.57	16.74	0.58	3.97
AWi	2.74	0.93	34.00	20.10	11.72	0.18	2.19
AW/SW	0.00	0.00	25.93	35.15	17.90	0.00	2.92
AW-90S	0.16	0.04	21.39	1.95	0.90	0.03	0.13
OC	6.56	6.12	93.28	4.90	4.73	0.76	1.46

Phenotypic variances (σ^2p); genotypic variances (σ^2g); (h^2) broad-sense heritability;(PCV) phenotypic coefficient of variation, (GCV) genotypic coefficient of variation.(GA) genetic advance and GA as percentage (% of mean).

90 seeds, was relatively higher ($40\% > h^2 > 20\%$). Heritability estimates for number of almonds were lower ($h^2 < 20\%$) than all traits.

Genetic advance (GA) varied from 0.13% for almond weight of 90 seeds to 7.95% for seed weight (Table 4). Though, high heritability for the character coupled with high genetic advance was detected. AW/SW ratio trait presents the lowest genetic advance. The character, fruit weight, seed weight, seed length, seed width and oil content exhibited highest genetic advance.

Correlation coefficients of various agromorphometrics traits of Argan trees with oil contents

Genotypic and phenotypic correlation coefficients between various characters are shown in Table 5. The phenotypic and genetic correlations revealed that tree dimension, hull thickness, number of carpel, number of almond per seed, length and width almond are not correlated to the oil content. Fruit weight, seed weight, almond weight, seed length, seed width and AW-90S are positively correlated with oil content. Contrary, fruit weight, seed weight, length and width seed and hull thickness are negatively correlated and stronger with AW/SW ratio trait.

However, hull thickness character shows an unexpected result concerning its correlation with AW/SW ratio trait. Also, almond weight and the number of almond per seed are positively correlated to this trait. The magnitude of correlation coefficient at genotypic level was higher than their corresponding phenotypic coefficient of correlations.

Table 5. Genotypic (G) and Phenotypic (P) correlation coefficient between morphological traits and oil content in argan tree

Variable	Correlation	FW	SW	SL	SW	HT	CN	AN	AW	AL	AWi	AW/SW	AW-90S
AW/SW	G	-0.40*	-0.40*	-0.27*	-0.41*	-0.58*	-0.12	0.40***	0.20**	-0.02	0.07		
	P	-0.43*	-0.43*	-0.29*	-0.44*	-0.61*	-0.14	0.39***	0.17*	-0.03	0.03		
OC	G	0.21**	0.17**	0.21**	0.05**	0.43	-0.08	-0.02	0.26**	0.08	0.14	0.22	0.14*
	P	0.22***	0.18**	0.22**	0.05**	0.44	-0.08	-0.03	0.28***	0.09	0.14	0.21	0.27***

*** Significant at 0.1% level; ** significant at 1% level; * significant at 5% level.

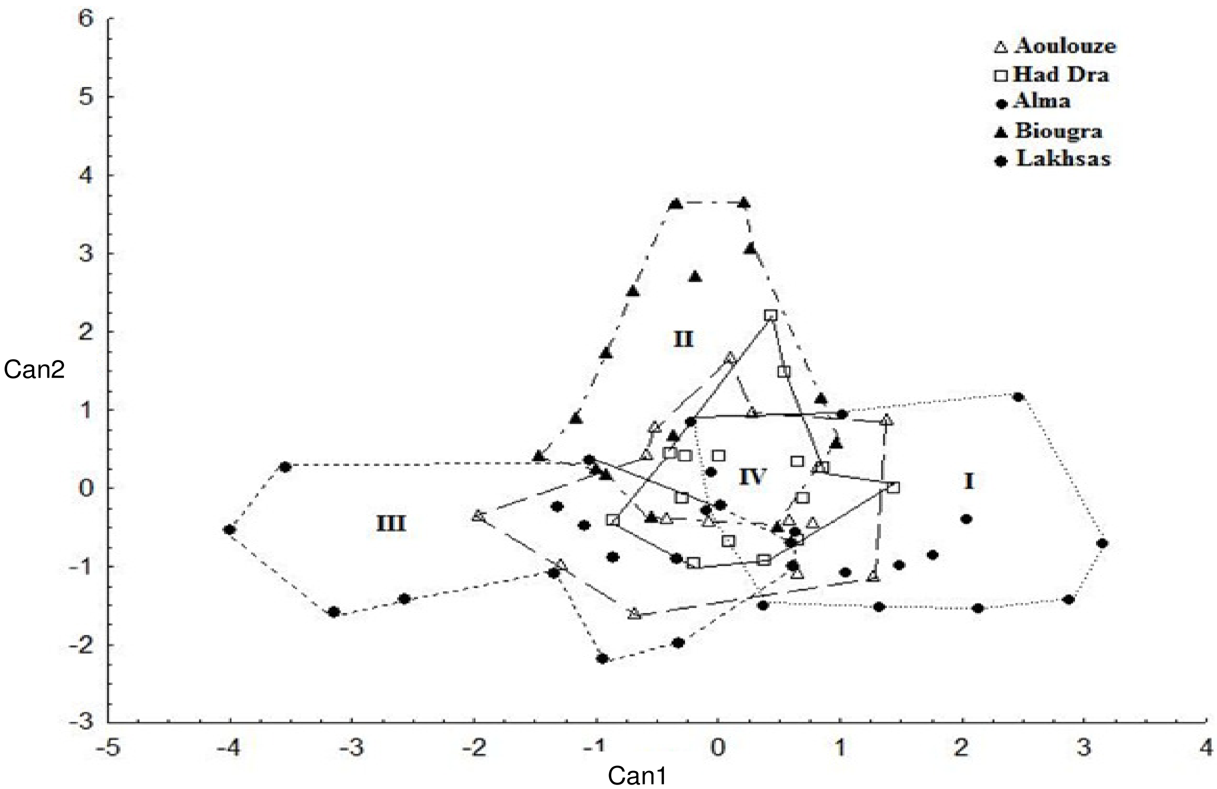


Figure 2. Analysis discriminates based on seven characteristics that correlate directly with oil content trait of seventy seven Argan tree.

Discriminate analysis

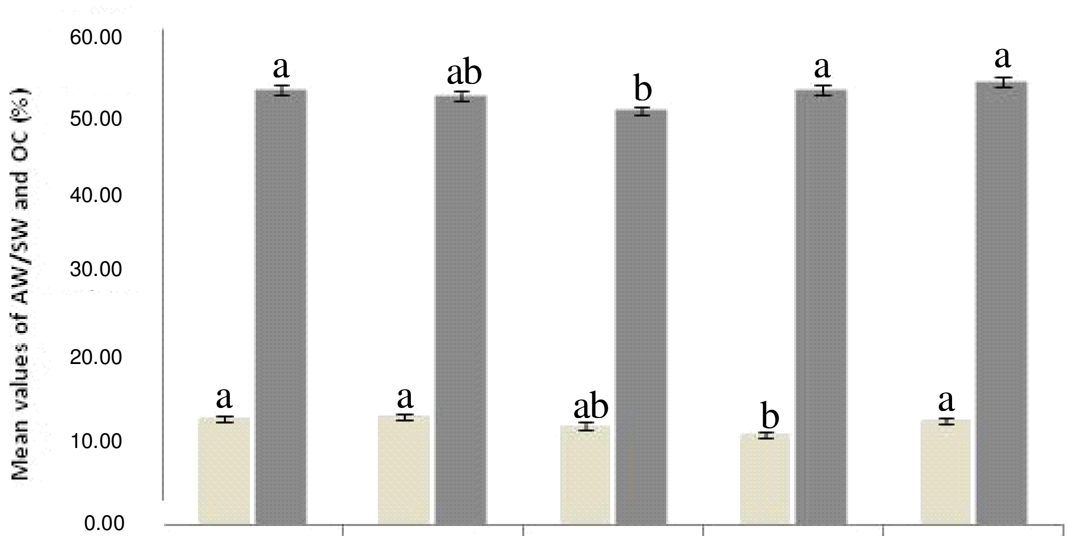
Based on the combination of the results from the correlation method for all characteristics with oil content, the traits that correlate directly with productivity were chosen and utilized in the discriminate analysis. The results (Figure 2) show that the populations, according to discriminate analysis, were separated into four large groups: I, II, III and IV.

For Groups I, II and III, despite the vast diversity of natural climatic conditions, the discriminate analysis showed a clear separation of these groups. This grouping pattern indicates that these provenances have same characteristics of genotypes distinct from the rest of the genotypes studied. For the Group IV, this cluster indicate that it constitute a homogeneous group with two provenance (*Ao* and *Hd*) with different origins.

This illustration offers some information of the natural distribution of cultivar groups, but it is difficult to determine the genotypes interesting for selection. When considering, two traits possible to obtain adequate separation and characterisation of elite genotypes in each provenance.

Identification/selection of canditate plus tree of argan tree

According to the users of the autochthons populations of Argan, and the resistance of the dryness which



	Ao	Hd	Al	Bi	La
AW/SW (%)	12.83	13.13	12.03	10.89	12.60
OC (%)	52.72	52.05	50.17	52.74	53.76

Figure 3. Distribution of the mean values of two selection criteria (AW/SW (%) and OC (%))

dominates since 1997 up to 2008, the trees which are the subject of this study are candidate plus trees. The breaking of the Argan seed constitutes a boring stage for oil production. For that, selection of the very productive trees with seed that is easy to break is a necessary point for such improve program of oil production. These characters were suggested as promising for selection of elite genotype suitable for this tree breeding programme.

The comparison of means (Figure 3) for these two traits between provenances selected reveals that provenances Hd, Ao, La and Bi showed the high mean values for oil content. However, provenance Al showed the lowest mean values for this trait. Three provenances Hd, Ao and La showed the highest mean values for AW/SW ratio contrary to Bi and AL provenance.

We have observed significant variation, between provenances and between genotypes for oil content and AW/SW ratio. Significant differences between mean values of each tree genotype were compared using the Duncan multiple range test (5%) and regrouping in homogenises groups. For all genotypes, oil content expressed in volume range from 4.85 to 6.59 ml/ 10 g of almond and AW/SW ratio range from 0.06 (very hard crack seed) to 0.18 (very easy crack seed). For this, the superior Argan trees selected within each provenance having better oil content and AW/SW ratio are showed in Figure 3.

Nine promising genotypes interesting for height oil content are selected in each provenances Al, Bi and La. These genotypes are shown in gray histogram (Table 6), namely;

AL-4V, AL-6V, AL-7V, AL-8V, AL-9V, AL-10V, AL-11V, AL-12V, AL-13V, BI-1V, BI-3V, BI-5V, BI-6V, BI-7V, BI-11V, BI-12V, BI-13V, BI-15V and LA-1V, LA-2V, LA-5V, LA-6V, LA-7V, LA-9V, LA-10V, LA-11V, LA-15V respectively.

Seven promising genotypes selected in provenance Ao and Hd namely;

Ao-4V, Ao-5V, Ao-8V, Ao-10V, Ao-11V, Ao-12V, Ao-14V, Hd-1V, Hd-2V, Hd-3V, Hd-4V, Hd-6V, Hd-10V, Hd-12V respectively.

Then, on the basis of easy to crack seed trait, all provenances had the same effective 6/15 of genotypes that were selected,

Ao-1V, Ao-3V, Ao-4V, Ao-6V, Ao-11V, Ao-13V, AL-3V, AL-5V, AL-6V, AL-9V, AL-11V, AL-12V, BI-1V, BI-3V, BI-5V, BI-6V, BI-8V, BI-9V and LA-1V, LA-2V, LA-5V, LA-6V, LA-7V, LA-9V.

Contrarily, for provenance Hd seven promising genotypes were selected namely

Hd-2V, Hd-3V, Hd-4V, Hd-5V, Hd-6V, Hd-12V, Hd-13V in all trees studied.

Though, if one associates these two traits, the selection becomes more severe to select the genotypes apt to our

Table 6. Classification of superior genotypes with high two selection criteria (oil content expressed in volume (ml) and WA/SW ratio traits) for all provenance studied, using Duncan at 5%, (grey columns indicate trees having exceeded significantly mean for provenance).

Hd		Ao		Al		Bi		La	
OV	AW/SW	OV	AW/SW	OV	AW/SW	OV	AW/SW	OV	AW/SW
Hd-14V^{a}	Hd-1V^{a}	Ao-13V^{ab}	Ao-8V^{a}	Al-2V^{a}	Al-15V^{a}	Bi-8V^{a}	Bi-2V^{a}	La-4V^{a}	La-3V^{a}
Hd-5V^{ab}	Hd-14V^{b}	Ao-15V^{ab}	Ao-7V^{ab}	Al-1V^{ab}	Al-14V^{b}	Bi-4V^{a}	Bi-7V^{a}	La-3V^{a}	La-12V^{b}
Hd-15V^{ab}	Hd-10V^{ab}	Ao-8V^{ab}	Ao-2V^{ab}	Al-15V^{abc}	Al-7V^{c}	Bi-10V^{ab}	Bi-11V^{b}	La-13V^{a}	La-9V^{b}
Hd-8V^{ab}	Hd-11V^{c}	Ao-2V^{a}	Ao-5V^{bc}	Al-14V^{abc}	Al-4V^{cd}	Bi-9V^{ab}	Bi-12V^{b}	La-12V^{a}	La-6V^{c}
Hd-11V^{ab}	Hd-9V^{c}	Ao-12V^{ab}	Ao-9V^{bc}	Al-5V^{abc}	Al-10V^{cde}	Bi-2V^{abc}	Bi-10V^{bc}	La-8V^{ab}	La-7V^{cd}
Hd-13V^{bc}	Hd-15V^{c}	Ao-6V^{ab}	Ao-12V^{bc}	Al-3V^{abc}	Al-2V^{cde}	Bi-14V^{abc}	Bi-13V^{cb}	La-14V^{ab}	La-1V^{de}
Hd-7V^{bc}	Hd-7V^{c}	Ao-14V^{ab}	Ao-15V^{bc}	Al-13V^{bc}	Al-8V^{def}	Bi-11V^{abc}	Bi-4V^{d}	La-15V^{ab}	La-14V^{ef}
Hd-9V^{bcd}	Hd-8V^{c}	Ao-1V^{ab}	Ao-14V^{c}	Al-6V^{bc}	Al-13V^{def}	Bi-7V^{bc}	Bi-14V^{d}	La-10V^{ab}	La-8V^{ef}
Hd-6V^{cdef}	Hd-2V^{d}	Ao-9V^{ab}	Ao-10V^{cd}	Al-4V^{bc}	Al-1V^{efg}	Bi-13V^{bc}	Bi-15V^{d}	La-9V^{ab}	La-10V^{ef}
Hd-10V^{cde}	Hd-3V^{d}	Ao-5V^{b}	Ao-13V^{de}	Al-10V^{bc}	Al-5V^{fg}	Bi-3V^{bc}	Bi-1V^{de}	La-5V^{ab}	La-15V^{efg}
Hd-2V^{cde}	Hd-13V^{de}	Ao-10V^{ab}	Ao-6V^{e}	Al-7V^{bc}	Al-11V^{gh}	Bi-1V^{bc}	Bi-6V^{ef}	La-1V^{ab}	La-13V^{fgh}
Hd-4V^{ef}	Hd-4V^{de}	Ao-3V^{ab}	Ao-1V^{ef}	Al-8V^{bc}	Al-3V^{h}	Bi-5V^{bc}	Bi-3V^{ef}	La-6V^{ab}	La-11V^{gh}
Hd-12V^{cdef}	Hd-6V^{de}	Ao-11V^{ab}	Ao-4V^{ef}	Al-11V^{bc}	Al-9V^{h}	Bi-6V^{c}	Bi-5V^{ef}	La-11V^{ab}	La-5V^{gh}
Hd-1V^{def}	Hd-5V^{de}	Ao-7V^{ab}	Ao-3V^{f}	Al-9V^{bc}	Al-12V^{i}	Bi-15V^{c}	Bi-9V^{fg}	La-7V^{ab}	La-4V^{h}
Hd-3V^{f}	Hd-12V^{e}	Ao-4V^{ab}	Ao-11V^{g}	Al-12V^{c}	Al-6V^{j}	Bi-12V^{c}	Bi-8V^{g}	La-2V^{ab}	La-2V^{h}

objective, which has a 2 genotypes for provenance Ao, namely Ao-4V, Ao-11V and four genotypes for Al, Bi, La provenances namely;

AL-6V, AL-9V, AL-11V, AL-12V, BI-1V, BI-3V, BI-5V, BI-6V and LA-2V, LA-5V, LA-11V, LA-15V

and five genotypes for Hd namely Hd-2V, Hd-3V, Hd-4V, Hd-6V, Hd-12V. These genotypes were found to be the best selected for our study on the basis of oil content and AW/SW ratio characters.

DISCUSSION

The analysis of variance according to general linear model (GLM) revealed high significant differences ($P<0.01$) among the Argan genotypes for all characters studied.

Results obtained for the qualitative and quantitative characters between Argan genotypes and between provenances indicate that an important genetic variation exists between individual accessions within each provenance. Similar studies based on the description of the provenances using morphological traits was effected in the shea tree, *Vitellaria paradoxa* (Sanou et al., 2006), very important Spotacaea species as *Argania spinosa* in Morocco. Thus, variance between populations is considered. The climatic and soil effects can be markedly different between locations and the variance between populations often strongly confound the environmental and the genetic variance (Sanou et al., 2006). High significant differences between provenances and genotypes for the majority of morphological traits ($P<0.01$), was observed, except for the trees traits. Fruit traits shows higher levels of coefficient of variance (CV), indicate high variation between trees, this can be explained with the result of two combined influences – climate conditions and eco-geographical distribution. In spite of the observed variation, the provenance Hd, Ao, La and Bi showed the best performance for all traits, contrary to the provenance Al, because this provenance showed the most sensitive to dryness factor dominated during our study. For that, arid climate dominate in four provenances (Al, Bi, Ao and La), and semi arid area for provenance Hd, apart from these environmental factors, there is two geographic situation varied to the arid rocky mountains for provenance La and Ao and plain region for provenance Bi, Al and Hd.

The variance related to the locality effect is generally lowest at the Argan, since it has a great adaptive plasticity to the geographical area (Bani and Ferradous, 2001). The study of seed morphological characters of the natural populations is often considered to be useful in the study of the genetic variability (Kaushik et al., 2007). Uni and multivariate procedures based on morphologic and agronomic traits have been used in the assessment of genetic diversity and the performances in other species such as *Acacia tortilis* and *Acacia raddiana* in Tunisia (El Ferchichi et al., 2009), *Pinus roxburghii* Sarg. (Mukherjee et al., 2004), *Pinus sylvestris* L. (Rweyongezaet et al., 2002), *Triticum turgidum* var. *Durum* (Maniee et al., 2009) and sunflower (*Helianthus annus* L.) (Ekin et al., 2005). This research manages to simulate the genotypic effect and environmental effect on the phenotypical values of an individual under various climates.

This variability in characters of tree, pod and seed can be exploited for the selection of desirable plant genotypes for breeding programme. The decomposition of variance recorded between Argan genotypes for all traits relationship of oil contents in five provenances studied can be exploited to evaluate the variance related to difference between genotypes (σ^2 inter-provenance) and the variance related to the geographic area (σ^2 geographic).

Little difference between phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) and high estimates of heritability (broad sense) for fruit and seed weight, seed and almond length, seed breadth and oil content characters under study revealed the heritable nature of variability present. High estimates of heritability (>54%) suggested that these traits play an important genetic markers in predicting the selection of best individual. A higher heritability (broad sense) estimate for oil content (93%) indicate the lowest environmental effect, a similar result has been observed in another species as *Pongamia pinnata* (L) in which h^2_{oc} = 100%, (Kaushik et al., 2007), *Jatropha curcas* L. h^2_{oc} = 99% (Kaushik et al., 2007) and sunflower, h^2_{oc} = 71% (Mudassar et al., 2009). Number of almond per seed showed minimum magnitude of broad sense heritability and moderate value of genetic advance, which advocated that this character might be influenced by pollination. Heritability estimated have an important place in tree improvement programme, it provides an index of the relative role of heredity and environment in the expression of various traits (Johnson et al., 1955; Dorman, 1976), it is also indicated that the importance of this estimation is useful when accompanied with estimate of genetic advance for future improvement through selection.

Fruit weight, seed weight, seed size, almond length and oil content showed maximum magnitude of broad sense heritability coupled with high genetic advance, this was an indication of the involvement of enough genetic and additive effects in the inheritance of these characters. Mudassar et al. (2009), advocate that this character might be improved through selection. Therefore, these characters are good indicators for such program of selection and improvement of the Argan tree. However, this study investigates two selection criteria in advance of good performing trees in relation to the oil contents, these two criteria are oil content and easy crushing seed, because these traits are useful to guarantee continuity and a sustainable development for this species. Impact of various quantitative and qualitative traits on oil contents and easy to crushing seed is made in the study of correlation. According to Falconer (1989), the study of this correlation is required to obtain the response of various traits to the characters interesting for selection. Genotypic and phenotypic correlation coefficients between various characters under study revealed that magnitude of correlation coefficient at genotypic level was higher than their corresponding phenotypic coefficient of correlations.

This clearly indicated the genotypic association among the characters (Kaushik et al., 2007). Oil content ranging from 39.19 to 57.92%, similar results has been observed in *Azadirachta indica* of five provenances in India (Kaura et al., 1998). This character showed significant positive correlation with fruit, seed and almond weight, seed and almond size and almond weight of 90 seeds (P<0.05). However, there was no correlation between facility to crushing seed traits and oil content. A highly significant and negative correlation was found between this traits and fruit weight, seed weight, seed size, almond size and hull thickness. Through, positive correlations with almond weight were detected. Facility or difficulty to crushing seed does not have any relation with the oil content, due to morphological aspect of tree (size, port, ramification...) (Nouaïm et al., 2007). The response to crushing studied showed that the trees with seed that was easy to break present a hull thickness and AW/SW ratio statistically very low, contrary to the trees with seed that was difficult to break; these results are similar to the results found by Nouaïm et al. (2007).

Selection of good performing trees (candidate tree plus) having more oil content was based on these characters: best oil yield contents and facility of breaking seeds. Number of the selected trees becomes more rigorous because absence of the interdependence between these two characters interesting for selection. However, the effect of this selection changes from provenance to another, where the frequency of the trees selected and repented to our objective was 7% in provenance Ao, 27% in the three provenances La, Bi and Al respectively and 33% at the Hd provenance. Hence, provenance Al is less classified to other provenance, but having the good genotypes to will be selected. This may be justified with the high mean value of these two traits of selection were explained by a great plasticity adapted to the aridity of this species.

Conclusion

Significant variations in characters studied were detected both at within and between provenance levels. Diversity analysis of the Argan genotypes studied using the agromorphometrical approach allowed for selection of genotypes adapted to two selection criteria. Furthermore, the higher amount of heritability in broad sense coupled with considerable genetic advance for oil contents, fruit and seed weight, seed size and almond length indicated the additive genetic effects in the heritage of these characters. High heritability (93%) of oil content can be considered as a good genetic marker for selection and to identify suitable seed sources with high oil content. Positive and significant correlation of oil contents with fruit weight, seed weight and seed size report that these traits could be useful criteria for selection of the oil yield under different environmental conditions. Moreover, this result has important practical implications for genetic management of resource and for future breeding activities of improvement programs of Argan tree.

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