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MORPHOLOGICAL DIVERSITY OF ARGAN (*ARGANIA SPINOSA* (L.) SKEELS) POPULATIONS IN MOROCCO [1]

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ABSTRACT

Argan (*Argania spinosa* (L.) Skeels) populations, a Sapotaceae tree endemic to Morocco, were surveyed for variation of four morphological characters with three to six phenotypic classes. Twenty-five sampling sites were dispersed within four major ecosystems of argan main distribution area south-west of Morocco (5: Haha + Ida Ou Tanane, 6: Souss plain, 13: Center and west High Atlas mountain and 17: Anti Atlas mountain). Variation was monitored using the Shannon-Weaver diversity index (H'). Ecosystem 5 (sub humid to semiarid) was highly significantly less diverse than the three ecosystems 6 (semiarid), 13 (semiarid) or 17 (semiarid to arid). Characters showed a similar level of diversity except within ecosystem 5 where fruit and stone shapes had lower diversity indices than leaf shape or branching angle. Although populations were highly polymorphic for all characters, polymorphism was low in some populations for fruit and stone shapes, whereas it was high for leaf shape and branching angle in most populations. Indeed, differences between site populations means within the four ecosystems were not significant, their mean diversity index interval being located between 0.76 and 0.48 as compared to global Morocco index (0.64). As it is, this study suggests that, although there is no difference between sites, future conservation plans may have to privilege large numbers of sampling sites within all ecosystems as a precaution not to miss the character diversity.

Key words: *Argania spinosa*, conservation, diversity index, qualitative characters, Shannon-Weaver index

INTRODUCTION

Argan (*Argania spinosa* (L.) Skeels) tree area of distribution south west of Morocco is now a UNESCO MAB (Man And the Biosphere) Reserve, asubject to increased national and international focus. There, the argan tree is endemic to a 830,000 hectares although isolated limited populations still exist as far to the North East as Bni-Snassen or to the south east as Oued Noun river (EMBERGER 1925; BOUDY 1950; BOUDY 1952, METRO 1970; EHRIG 1974). Argan tree has an undisputed ecological value because of its phenomenal resistance to arid conditions (FERRADOUS, BANI-AAMEUR & DUPUIS 1996, BANI-AAMEUR 2002). Its major traditional uses are a highly prized oil for human consumption and leaves, fruit flesh and cake for forage (BOUDY 1952; EHRIG 1974; MAURIN 1992).

Rcent research on argan genetics and diversity concerned morphological variability analysis of fruit and stone (BANI-AAMEUR & FERRADOUS 2001), branching and foliation (ZAHIDI 1997) of three populations within three geographically different sites and also dealt with progeny molecular diversity in populations (MSANDA *et al.* 1994, EL MOUSADIK & PETIT 1996). It appears that levels of diversity in the main argan area were higher within than among-populations. Therefore, argan is not formed of differentiated populations in adapted ecotypes to local environments. In the present study, our objective is to contribute to increase argan diversity database investigating qualitative characters of the fruit, stone, leaf and the branch pattern in populations in argan main area of distribution. We aimed to describe diversity within- and between ecosystems applying Shannon-Weaver diversity index to four qualitative characters with at least two phenotypic classes.

MATERIALS AND METHODS

Methodology

Twenty six populations dispersed within the five major argan ecosystems (5: Haha + Ida Ou Tanane, sub humid to semiarid; 6: Souss plain, semiarid; 13:

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Table 1. Characterisation of the sampled sites.

Abbr.	Site	Geographical location	Altitude	Distance to the sea (km)	Ecosystem
KT	Khniss Takat	Plateau of Haha	280	17	5
AI	Arba Ida ou gourd	Dunes of Haha	123	12	5
TZ	Tnine Ida ou Zemzem	Northern slopes of High Atlas	810	40	5
TT	Tnine Imin Tilt	Northern slopes of High Atlas	930	25	5
SD	Sebt Aid Daout	Northern slopes of High Atlas	1120	41	5
KH	Khmiss Aziar	Plateu of Haha	916	37	5
TM	Tamanar	Dunes of Haha	360	13	5
IR	Ida Ou Trouma	Dunes of Haha	420	12	5
IT	Imozzer Ida Ou Tanane	Axis of High Atlas	1161	26	5
TR	Tamri	Dunes of Haha	35	5	5
AM	Ait Melloul	Souss plain	32	12.5	6
AZ	Anezi	Southern slopes of Anti Atlas	450	45	6
GN	Ida ou Gnidif	Western slopes of Anti Atlas	1388	70	6
YT	Barrage youssef Ben Tachfine	Sout West Sous Plain	150	20	6
TO	Tnine Oulad Taima	Souss Plain	123	32	6
AA	Admine/Aeroport	Souss Plain	40	5	6
SM	Parc National Souss Massa	Souss Plain	131	5	6
OG	Oued Grou Arganate	Central Plateau	500	30	8
AB	Ait baha	Northern slopes of Anti Atlas	550	50	13
AK	Ait Khattab	Western slopes of High Atlas	2045	85	13
TG	Timinsgadiouine	Western slopes of High Atlas	905	73	13
AS	Ameskroud		281	30	13
HD	Had Mnizla	Southern slopes of High Atlas	250	55	13
AR	Argana	Southern slopes of High Atlas	620	60	17
LK	Tleta Lakhsas	Centre Anti Atlas	1051	37	17
AL	Taliouine	Centre Anti Atlas	1020	160	17
LZ	Aoulouz	High Atlas / Anti Atlas intersection	700	142	17
FG	Tafengoult	Southern slopes of High Atlas	790	126	17
ZI	Zaouite Imim Adrar	Southern slopes of High Atlas	900	87	17
UT	Tiout	Central Anti Atlas	250	87	17
OU	Oulkadi	Central Anti Atlas	1330	110	17
BS	Beni Snassen	Bni Snassen Mountains	200	60	20

Center and west High Atlas mountain, semiarid; and 17: Anti Atlas mountain, semiarid to arid.) were sampled during the summer 1996 to cover argan area of distribution in Morocco (Table 1) (EMBERGER 1955; BENABID 1997). Rainfall is often scarce and variable (0 to 300 mm in average), taking place mainly during the cold period while summer season is dry. Thirty sampled trees at each site were scored individually and distinct phenotypic classes of fruit (6 classes), stone (3 classes) and leaf (4 classes) shapes and for shoot angle (3 classes) were determined as described by BANI-AAMEUR,, FERRRADOUS & DUPUIS (1999) and ZAHIDI (1997) (table 2).

Shannon-Weaver index *H'* has been used to analyse morphological diversity of some species and polymorphism was determined between and among characters, sites, countries or regions (JAIN *et al.* 1975, TOLBERT *et al.* 1979; RAMADE 1984; JARADAT 1989; TESFAYE, GETACHEW & WOREDE 1991; POLIGNANO *et al.* 1999). Shannon -Weaver diversity index (*H*) was computed using the formula

$$H = \sum_{i=1}^{n} p_i \log_e p_i$$

where: p_i – proportion of the ith. phenotypic class of the character; n – the number of phenotypic classes for a character.

The estimates of diversity index values for each character (*H*) was divided by $\log_e n$ for standardisation of values of *H'* within 0 to 1 interval.

Table 2. Distribution of phenotype classes per ecosystems and sites.

Sites	Ecosystem	Fruit shape					Stone shape				Leaf shape				Shoot angle		
		E	HS	NE	O	EP	S	NE	E	HS	OO	SO	LA	LM	30°	60°	90°
Ida Ou Trouma	5	80.0	0.0	3.3	0.0	13.3	0.0	3.3	93.3	3.3	70.0	16.7	13.3	0.0	6.7	56.7	56.7
Imouzzer Ida ou Tanane	5	63.3	6.7	0.0	3.3	26.7	0.0	6.7	90.0	3.3	70.0	13.3	13.3	3.3	6.7	53.3	76.7
Khmiss Aziar	5	66.7	0.0	0.0	10.0	16.7	0.0	3.3	96.7	0.0	53.3	20.0	23.3	3.3	0.0	73.3	60.0
Khmiss Takat	5	66.7	0.0	0.0	20.0	10.0	0.0	10.0	83.3	6.7	46.7	13.3	10.0	30.0	0.0	30.0	53.3
Sebt Ait Daoud	5	66.7	0.0	0.0	6.7	10.0	0.0	16.7	73.3	10.0	83.3	6.7	6.7	3.3	3.3	60.0	43.3
Tamanar	5	53.3	0.0	0.0	0.0	20.0	3.3	6.7	86.7	6.7	43.3	33.3	16.7	6.7	0.0	60.0	23.3
Tamri	5	53.3	3.3	6.7	0.0	33.3	3.3	13.3	83.3	3.3	70.0	10.0	13.3	6.7	0.0	46.7	36.7
Tnine Imin Tilt	5	70.0	0.0	3.3	3.3	16. 7	0.0	13.3	86.7	0.0	46.7	40.0	13.3	0.0	3.3	70.0	36.7
Total ecosystem 5		65.0	1.3	1.7	5.4	18.3	0.8	9.2	86.7	4.2	60.4	19.2	13.8	6.7	2.5	56.3	26.7
Admine-Airport	6	50.0	0.0	10.0	16.7	23.3	0.0	13.3	83.3	3.3	73.3	10.0	10.0	6.7	0.0	60.0	40.0
Ait Melloul	6	41.1	20.0	14.7	2.1	14.7	7.4	14.0	58.1	27.9	70.0	13.3	10.0	6.7	0.0	43.3	16.7
Anezi	6	50.0	13.3	0.0	23.3	10.0	3.3	10.0	80.0	10.0	56.7	3.3	23.3	16.7	23.3	60.0	40.0
Ida ou Gnidif	6	66.7	6.7	0.0	13.3	10.0	3.3	6.7	80.0	13.3	46.7	10.0	20.0	23.3	0.0	73.3	70.0
Parc national Souss Massa	6	66.7	6.7	0.0	23.3	3.3	0.0	23.3	76.7	0.0	43.3	33.3	20.0	3.3	0.0	63.3	26.7
Total ecosystem		54.9	9.3	4.9	15.8	12.3	2.8	13.5	75.6	10.9	58.0	14.0	16.7	11.3	4.7	60.0	36.7
Ait Baha	13	46.6	8.0	19.3	3.4	11.4	11.4	10.8	56.8	32.4	80.0	13.3	3.3	3.3	0.0	40.0	40.0
Ait Khattab	13	40.0	23.3	6.7	3.3	16.7	10.0	3.3	90.0	6.7	40.0	30.0	23.3	6.7	6.7	73.3	26.7
Ameskroud	13	56.7	23.3	10.0	0.0	10.0	0.0	20.0	60.0	20.0	56.7	30.0	13.3	0.0	0.0	66.7	36.7
Had Mnizla	13	46.7	13.3	6.7	6.7	23.3	3.3	13.3	86.7	0.0	50.0	23.3	16.7	10.0	0.0	56.7	53.3
Timinsgadiouine	13	46.7	16.7	0.0	13.3	16.7	6.7	13.3	80.0	6.7	43.3	33.3	16.7	6.7	6.7	53.3	37.3
Total ecosystem		47.3	16.9	8.5	5.3	15.6	6.3	12.2	74.7	13.2	54.0	26.0	14.7	5.3	2.7	58.0	40.0
Aoulouz	17	70.0	6.7	3.3	10.0	10.0	0.0	13.3	70.0	16.7	43.3	23.3	30.0	3.3	0.0	56.7	20.0
Argana	17	37.4	13.2	17.6	2.2	13.2	16.5	25.3	43.4	31.3	86.7	13.3	0.0	0.0	0.0	23.3	43.3
Oulkadi	17	70.0	3.3	0.0	13.3	10.0	3.3	3.3	83.3	13.3	56.7	26.7	10.0	6.7	6.7	56.7	33.3
Tafengoult	17	66.7	0.0	0.0	10.0	20.0	3.3	6.7	83.3	10.0	56.7	16.7	13.3	13.3	3.3	73.3	36.7
Taliouine	17	50.0	6.7	13.3	13.3	13.3	3.3	20.0	73.3	6.7	60.0	13.3	20.0	6.7	0.0	46.7	52.6
Tiout	17	66.7	0.0	10.0	0.0	23.3	0.0	20.0	80.0	0.0	50.0	30.0	13.3	6.7	6.7	56.7	36.7
Tketa Lakhsass	17	70.0	16.7	3.3	6.7	3.3	0.0	10.0	76.7	13.3	56.7	3.3	10.0	30.0	0.0	60.0	40.0
Total ecosystem		61.5	6.6	6.8	7.9	13.3	3.8	14.1	72.9	13.0	58.6	18.1	13.8	9.5	2.4	53.3	37.5
Total Morocco		58.5	7.5	8.2	8.2	15.2	3.1	12.0	78.2	9.8	58.0	18.0	14.5	9.5	3.1	54.7	52.6

Note: E – ellipsoid, HS – high spheroid, NE – narrowly elipsoid, O – obovate, EP – ellipsoid pointed, S – spheroid, OO – obovate obtuse, LA – lanceolate acute, LM – lanceolate mucronate.

Statistical analysis

Analysis of variance was performed on *H'* on a three factors design of four characters, five to eight sites per ecosystem (unequal number) and four ecosystems. The factor site was hierarchical to the factor ecosystem because sites were not repeated between ecosystems (SOKAL & ROHLF 1995). The Least Significant Difference test (LSD) ($\alpha = 5\%$) of equality of means was used to compare differences between factors.

RESULTS

Distribution of phenotypic classes.

Oval fruits and stones, OT leaves and shoots at 60° angle were the most frequent phenotypic classes (Table 2). But the four characters showed polymorphism (using 95 % criterion), i.e. frequencies of phenotypic classes varied depending on the character and the site within the ecosystem. Some phenotypic classes had intermediate frequencies, others were uniformly rare in all sites.High spheroid, narrowly ellipsoid and spheroid fruit shapes were missing or rare in most sites of ecosystem 5 and in few sites of ecosystem 6, 13 and 17. Lanceolate leaf shape with mucronate apex was missing in few sites in all ecosystems but lanceolate ones with acute apex was missing only at Argana. Shoot angle at 30° was missing in most sites. Indeed some phenotypic classes such as fruit shape high spheroid (0 to 23.3 %) or stone shape high spheroid (0 to 332.5 %) or leaf shape lanceolate with mucronate apex (0 to 30.0 %), were missing to rare in some sites whereas they had intermediate frequencies in other sites.

Diversity analysis

Ecosystem was a highly significant factor for *H'* (table 3), probably because ecosystem 5 was less diverse than the rest of ecosystems (table 4). As it is, ecosystems 6, 13 and 17 had higher numbers of phenotypic classes for most observed characters (table 2). Character or site within ecosystem (site / ecosystem) diversity index differences were not significant whereas the interaction character × ecosystem was significant. That is, in ecosystem 5, leaf shape and shoot angle showed higher mean diversity indices than fruit or stone shapes whereas character diversity indices in the remaining ecosystems were similar (Table 3).

Table 3. Analysis of variance of *H*.

Source of variance	Df	Mean square
Ecosystem	3	0.1130**
Character	3	0.1530ns
Site/ecosystem	21	0.0088ns
Ecosystem × character	12	0.0605**
Error	96	0.0111

DISCUSSION AND CONCLUSION

In this study, variation of four morphological characters with three to six phenotypic classes in 25 populations of argan (*Argania spinosa* (L.) Skeels) of four ecosystems, covering a large surface within its area of distribution south west of Morocco was surveyed. Using the Shannon-Weaver index, the study revealed that argan populations were quasi equally polymorphic with regard to geographical and ecological disparity between sampled sites. There were no significant differences for diversity index between sites or even between ecosystems, except for ecosystem 5, suggesting that among population diversity in argan is not important and enforce previous reports that diversity was higher within than among-populations (ZAHIDI 1997, BANI-AAMEUR & FERRADOUS 2001).

Indeed, ecosystem 5 (Haha + Ida Ou Tanane, sub humid to semiarid) is an exception with a pattern different from the three other ecosystems (6: Souss plain, semiarid 13: Centre and west High Atlas mountain semiarid and 17: Anti Atlas mountain, semiarid to arid). It had less diversity because some phenotypic classes were either rare to missing or had higher frequencies as compared to the remaining ecosystems.

Argan is endangered due to clearing for urban land, fuel, and animal feed (MELLADO 1989; EL YOUSFI & BENCHKROUN 1992). For germplasm conservationist, this study suggests to be cautious when deciding for a future conservation plans to maintain argan variability and/or to reintroduce the specie through reforestation or orchard establishment. Decision may have to privilege a reasonable number of sampling sites within every ecosystems as a precaution not to miss character diversity.

In this survey we covered large areas within different ecosystems with different bio-climates (EMBERGER 1955). Environmentally induced changes on observed phenotypes are therefore expected. The lack of striking population differences observed in this case may be explained by either insignificant biological impact of the differences between the observed sites or by a remarkable degree of plasticity of argan species. Because of the dimensions of the area covered in this study, we tend to favour plasticity hypothesis.

Table 4. Distribution of Shannon-Weaver index per character, site and ecosystem *H*.

Sites	Ecosystem	Character				Mean
		Fruit	Stone	Leaf	Angle	
Ida Ou Trouma	5	0.31	0.22	0.59	0.79	0.48
Imouzzer Ida Ou Tanane	5	0.52	0.34	0.65	0.65	0.54
Khmiss Aziar	5	0.45	0.16	0.80	0.53	0.48
Khmiss Takat	5	0.46	0.49	0.88	0.56	0.59
Sebt Ait Daoud	5	0.38	0.69	0.45	0.72	0.56
Tamanar	5	0.43	0.39	0.87	0.61	0.58
Tamri	5	0.62	0.52	0.67	0.63	0.61
Tnine Imin Tilt	5	0.43	0.47	0.71	0.65	0.57
Total ecosystem 5		**0.45b**	**0.41b**	**0.70a**	**0.64a**	**0.55b**
Admine-Airport	6	0.68	0.52	0.63	0.61	0.61
Ait Melloul	6	0.85	0.82	0.67	0.62	0.74
Anezi	6	0.72	0.53	0.77	0.86	0.72
Ida ou Gnidif	6	0.59	0.49	0.90	0.53	0.63
Parc National Souss	6	0.50	0.68	0.84	0.60	0.66
Total ecosystem 6		**0.67**	**0.61**	**0.76**	**0.64**	**0.67a**
Ait Baha	13	0.83	0.80	0.48	0.61	0.68
Ait Khattab	13	0.85	0.28	0.90	0.66	0.67
Ameskroud	13	0.63	0.85	0.69	0.58	0.69
Had Mnizla	13	0.80	0.47	0.88	0.62	0.69
Timinsgadiouine	13	0.78	0.57	0.87	0.80	0.76
Total ecosystem 13		**0.78**	**0.59**	**0.76**	**0.66**	**0.70a**
Aoulouz	17	0.56	0.70	0.85	0.62	0.68
Argana	17	0.89	0.98	0.28	0.49	0.66
Oulkadi	17	0.54	0.38	0.78	0.79	0.62
Tafengoult	17	0.52	0.44	0.84	0.62	0.60
Taliouine	17	0.81	0.71	0.78	0.63	0.73
Tiout	17	0.47	0.62	0.83	0.79	0.68
Tleta Lakhsass	17	0.53	0.58	0.74	0.61	0.62
Total ecosystem 17		**0.62**	**0.63**	**0.73**	**0.65**	**0.66a**
Total Morocco		**0.63**	**0.56**	**0.74**	**0.65**	**0.64**

Argan tree is also contributing to the local economy making it a potential candidate for domestication and a useful source of drought resistance or tolerance genes. Survey of the genetic material available for the determination of a pool of variable germplasm is the first step in this prospect. Characters showed a similar level of diversity except within ecosystem 5 where fruit and stone shapes had lower diversity indices than leaf shape or branching angle. till, a quickly available character such as leaf shape or shoot angle may be adopted for practical instant surveys.

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