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TYPOLOGY OF FRUITS AND STONES OF *ARGANIA SPINOSA* (SAPOTACEAE)

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ABSTRACT

Establishing phenotypic descriptors is a useful first step in assessing variability for plant species conservation and exchange. In that prospect, fruit and stone typology of argan (*Argania spinosa* (L.) Skeels), based on visual determination and morphometric characters analyses (length; width; and length to width ratio), was described at three sites in southwest Morocco from 1990 to 1992. Six fruit shapes (narrowly ellipsoid, ellipsoid pointed, ellipsoid, obovate, high-spheroid and spheroid) and three stone shapes (narrowly ellipsoid, ellipsoid and high spheroid) were identified. Even tough aridity had a negative effect on fruit and stone lengths and widths, we did not observe shape changes. We propose fruit and stone shapes as characterization descriptors of argan.

Key words: *Argania spinosa*, argan, descriptors, fruit, shape, stone, typology.

INTRODUCTION

Argania spinosa L. Skeels, commonly called argan, is the unique living species of the genus *Argania* of the family Sapotaceae (BAEHNI 1948; EHRIG 1974). Its closest relatives are *Argania marmulano* in the Canary Islands, and *Arganioxylum sardum* in Sardinia, Italy which are both fossil woods (BIONDI 1981). This tree is believed to be a relic from the tertiary era (EMBERGER 1925; EHRIG 1974; BIONDI 1981). It is endemic to 830,000 hectares in Morocco, where it is a cultural and ethnic symbol contributing to the local economy through multiple uses such as edible oil extracted from nuts, wood for fuel and leaves for forage (M'HIRIT 1989). It is also a defense against the encroaching desert. Even though it has attracted the attention of travellers and explorers since the beginning of the 19th century because of its high adaptation to extreme aridity (JACCARD 1926; FAIRCHILD 1930; EHRIG 1974), information on its biology is scattered. Except for a few ecological studies, existing reports are mostly concerned about it as a forest tree facing extinction consequent to abusive exploitation, extensive urbanization and the increasing demand for land to put into more profitable agriculture (MELLADO 1989; EL YOUSFI & BECHEKROUN 1992).

The fruit of *Argania spinosa* was first described as a berry (BOUDY 1952; SANDRET 1957; RIEUF 1962). However a berry is defined as a fleshy indehiscent fruit with no stone (METRO & SAUVAGE 1955). Similar to other members of the Sapotaceae (AYENSU 1972), argan fruit is fleshy, indehiscent containing a single stone with one or more nuts (CRONQUIST 1981). METRO and SAUVAGE (1955) later classified it as a drupe. However, the hard shell protecting the nut of a drupe is formed from the lignified endocarp (ROLAND & ROLAND 1983). Whereas for the argan stone, the ligneous shell, or "pseudo-endocarp", does not originate from the inner epidermis of the carpel, but rather from the testa which forms the hard smooth shell which houses a nut in each unit (CORNU 1897; PERROT 1907). These units are joined in a single stone. Hence, the stone of argan fruit is a composite of two, three, four or five hard chambers (CORNU 1897; PERROT 1907; RIEUF 1962; AUBERVILLE 1964). Because stone chambers of ovular origin with no nut were observed, the outer integument may have continued to develop even after the embryo aborted (CORNU 1897; PERROT 1907).

Argan fruit shape and size have been arbitrarily compared to a large yellow/green olive (CORNU 1897; PERROT 1907; BOUDY 1952; SANDRET 1957), a plum (JACCARD 1926; SANDRET 1957), or a walnut (BOUDY 1952). Its shape was also described as ovoid terminating with an obtuse end (CORNU 1897); ellipsoid, obtuse or acute (PERROT 1907); ellipsoid, high spheroid, ellipsoid pointed, or short spindle (RIEUF 1962). HOOKER (1854) drew six different fruit shapes and SANDRET (1957) published a photo showing different fruit shapes. METRO (1952) offered the first detailed study of argan fruits. He described four shapes based on fruit length, width and width to length ratio. Elongate oblong fruit was longer and larger and has a lower ratio of width to length. Elongate mamelliform differed from elongate oblong fruits by a small point at their

apex. Globular fruit was rather round. Finally, pointed fruits were similar to elongate mamelliform fruits except that they were shorter.

Few studies have focused on the description of the argan stone. It was described as ovoid and shiny with a glossy leather color (CORNU 1897), ellipsoid , very smooth and light brown (PERROT 1907), oblong (JACCARD 1926). Hooker (1854) drew three different shapes and SANDRET (1957) photographed various stone shapes.

Typology is a step toward setting descriptors through characterization of phenotypic traits of argan to assess variability. This type of data is commonly used by International Plant Genetic Resources Institute (IPGRI) which is internationally recognized for establishing databases of plant genetic resources. Argan fruit and stone typology in literature is incomplete. The objective of this study was to construct typology of argan fruit and stone shapes. For the purpose of establishing characterization descriptors as defined by IPGRI (IPGRI, 1995), visual distinction of shapes was combined with morphometric criteria.

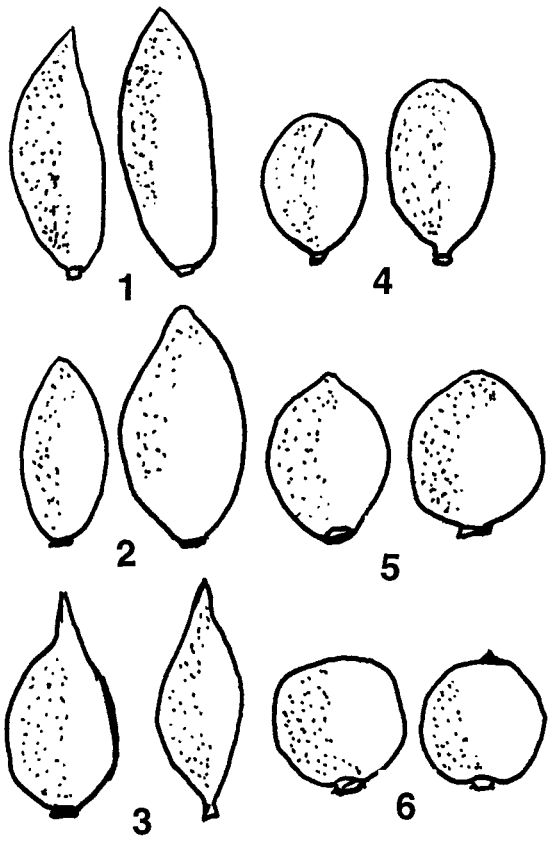

Fig. 1. Description of fruit shapes of *Argania spinosa* : narrowly ellipsoid (1), ellipsoid (2), ellipsoid pointed (3), obovate (4), high spheroid (5) and spheroid (6). The two fruit shapes shown in the drawing are meant to set the limits of each discrete classe of shape.

MATERIALS AND METHODS

Observation sites were Ait Melloul (AM) located 12.5 km from the Atlantic ocean at 35 m altitude in the Souss plain; Argana (AR) 60 km from the Atlantic ocean at 620 m altitude on southern slopes of High Atlas mountains and Ait Baha (AB) located farther south at 50 km from the Atlantic ocean at 550 m altitude on the northern slopes of Anti Atlas mountains in southwest of Morocco (FERRADOUS, BANI-AAMEUR & DUPUIS 1996). Climate of this region is of arid Mediterranean type. Rainfall is scarce and very variable (0 to 300 mm in average). It happens mainly during the cold period, while summer season is dry. Aridity increases from Argana to Ait Baha, Ait Melloul being under oceanic influence.

A preliminary investigation of fruit and stone shapes concerned 100 random trees per site. Taking example on IPGRI (IPGRI, 1995), the shapes encountered were described through visual examination of 30 fruits per tree. Discrete classes of shapes were set as shown in figures 1 and 2. An array of four ripe fruit colors (FC) was established and coded 1 to 4 from the lightest to the darkest: 1= light yellow, 2= yellow, 3 = red and 4 = dark red.

Then, for three seasons (1990–1992), 30 random trees were observed at each site. Every season, different

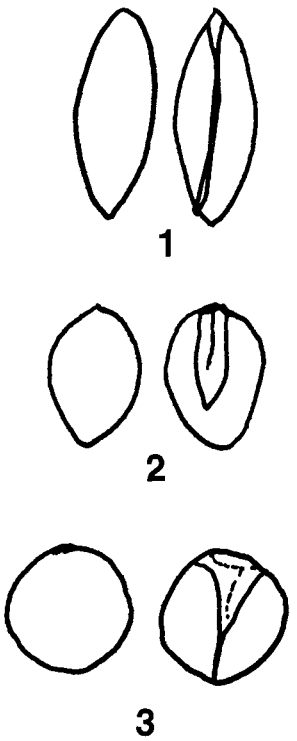

Fig. 2. Description *Argania spinosa* stone shape from back (left) and front (right) views : narrowly ellipsoid (1), ellipsoid (2) and high spheroid (3).

Table 1. Mean, minimum, maximum, and coeficient of variation (CV%) of length (FL), width (FW) in mm and ratio FW / FL (FR) of *Argania spinosa* fruit shapes.

Size (mm)	Fruit shape					
	ellipsoid	ellipsoid	ellipsoid	obovate	high spheroid	spheroid
	N = 12	N = 44	N = 7	N = 3	N = 10	N = 14
FL						
Mean	34.1	29.2	32.2	29.6	27.0	23.3
Minimum	27.9	25.0	28.3	28.0	23.4	21.6
Maximum	40.2	36.9	35.2	30.3	33.0	25.8
CV %	9.9	9.9	7.6	3.0	10.4	6.4
FW						
Mean	18.0	19.1	19.6	18.1	19.1	18.8
Minimum	14.7	16.6	17.6	17.7	17.1	16.6
Maximum	21.6	22.1	23.9	18.7	20.6	20.5
CV %	9.4	7.8	10.7	4.4	6.3	5.6
FR						
Mean	0.5	0.7	0.6	0.6	0.7	0.8
Minimum	0.5	0.5	0.5	0.6	0.6	0.8
Maximum	0.6	0.8	0.7	0.6	0.8	0.9
CV %	9.3	8.6	10.0	0.00	8.6	3.8

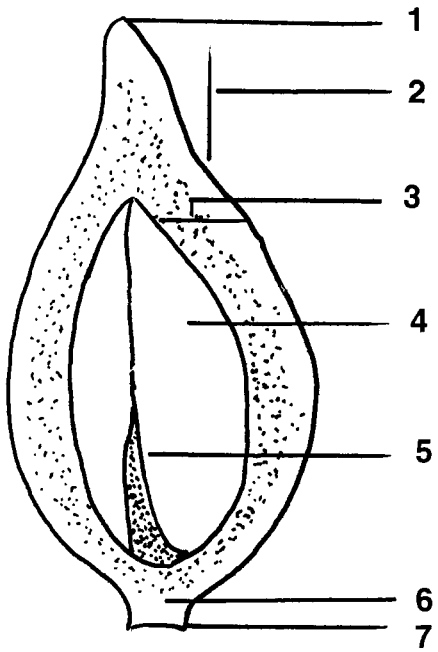

Fig. 3. Argan (*Argania spinosa*) fruit structure showing summit (1), apex point (2), pulp (mesocarp including laticifers) (3), stone (4), placental cords limiting stone chambers (5), basis (6) and peduncle (7) (x 2.5).

fruit and stone shapes were distinguished through visual examination of 30 fruits for any single tree. Length and width of the fruit (FL, FW) and the stone (SL, SW) were measured. The width / length ratio was calculated for the fruit (FR), and the stone (SR). To show the degree of association between shapes and morphometric traits, correlations were calculated between shape codes and values (SNEDECOR & COCHRAN 1973). Counts of stone chambers (CN) were made (Fig. 3).

Analysis of variance was performed on the variables FL, FW, FR, SL, SW, SR, CN and FC, using a three factors mixed model design using a sample of 30 fruits per tree, 30 random trees per site repeated over three seasons. Season and site were orthogonal factors. The factor tree was hierarchical to the factor site because the trees were not repeated between sites (STEEL & TORRIE, 1960; DAGNELIE, 1986). The Least Significant Difference test (LSD)(a = 5%) of equality of means was used to compare differences between FL, FW, FR, SL, SW, and SR means of seasons and sites.

RESULTS AND DISCUSSION

Characteristics of argan fruits at maturity. Immature argan fruit was light green and became yellow or red at maturity depending on individual trees. At Ait Melloul (AM), 93 % were dark red and 7 % were red, at Argana (AR) 100 % were dark yellow, at Ait Baha (AB) 93 % were dark yellow and 7 % were red.

We observed six distinct argan fruit shapes: narrowly ellipsoid (1), ellipsoid (2), ellipsoid pointed (3),

obovate (4), high spheroid (5) and spheroid (6) (Fig. 1 & 4).

Mean lengths of narrowly ellipsoid fruits (1) were the highest (34 mm), and FR ratio (0.5) the lowest as compared to alternative fruit shapes (Table 1). A transverse section revealed a thinner pulp at the level of placental line portion of the fruit (the section located between the basis and the median portion of the fruit). Mean length of ellipsoid fruit (2) was still high (29 mm), but FR ratio was intermediate to high (0.7). This shape had a thicker pulp around the placental line portion of the fruit.

Mean length of ellipsoid pointed fruits (3) was very high (32 mm), but FR was intermediate to low (0.6). A terminal point of varying length elongated the fruit leading to as high FL as ellipsoid fruits

Mean length of obovate fruits (4) were was intermediate to high (29 mm) and FR ratio was intermediate to low (0.6). Contrasting with the five previous fruit shapes in which case FL, FW and RF minimums-maximums intervals were relatively wide, they were short for obovate shape. The fruits were very round at their apex, but the base was shrunk resulting in a pyriform shape.

Mean length of high spheroid fruits (5) was intermediate to low (27 mm), but FR ratio was high (0.7). Fruit apex was clearly truncated.

Mean length of spheroid fruits (6) was the lowest (23 mm) and FR ratio was the highest (0.8). Spherical aspect of these fruits was very pronounced but the apex and the base were slightly flattened.

Narrowly ellipsoid as well as ellipsoid pointed shapes were previously individually observed (METRO 1952 ; RIEUF 1962). Metro (1952) grouped high spheroid and spheroid shapes as globular. The obovate fruit shape was described for the first time in this study.

Characteristics of argan stones. The stone of the fruit of argan was light brown, glossy, formed of one to five chambers with easily distinguished placental limits (Fig. 5). The number of chambers of a stone could vary from one to five (table 2). Two-chamber stones were the most frequent (78 %), followed by three-chamber stones (20 %). One, four- or five-chamber stones were very rarely observed.

Three stone shapes were observed: narrowly ellipsoid (1), ellipsoid (2) and high spheroid (3) (Fig. 2 & 5). For six fruit shapes, we observed three stone shapes. There for fruits of different shapes contained similar stones.

Considering dimensions mean, minimum or maximum values, we noted a steady decrease of SL and increase of SR trend from narrowly ellipsoid stones to high spheroid stones (Table 3). Narrowly ellipsoid stones (1) were the longest (26 mm) with the lowest ratios (0.5). Ellipsoid stones (2) had intermediate mean length (24 mm) and ratio (0.6), even though we observed large variability as it shows in the minimum-maximum interval. High spheroid stones (3) were short (20 mm). Their length and width values were similar and SR was close to one.

Frequencies of argan fruit and stone shapes. Ellipsoid fruit shape was the most abundant (41 % at AM, 37 % at AR and 46 % at AB), whereas obovate shape was the least frequent (2 % at AM, 2 % at AR and 3 % at AB) (Fig. 6A). Frequencies of remaining shapes were intermediate.

Ellipsoid stone shape was more abundant (58 % at AM, 43% at AR and 56 % at AB) than high spheroid

Table 2. Frequency of argan trees of different classes of chamber number at three sites for three seasons.

	Year	Chamber number (Frequency % *)				
		1	2	3	4	5
Ait Melloul	1990	0.3	83.1	16.1	0.4	0.1
	1991	0.3	87.3	12.2	0.2	0.0
	1992	0.3	82.3	17.4	0.0	0.0
Argana	1990	0.2	74.0	25.0	0.6	0.2
	1991	0.6	77.0	22.1	0.3	0.0
	1992	0.1	68.0	30.0	1.8	0.1
Ait Baha	1990	1.6	75.4	21.2	1.6	0.2
	1991	1.8	78.0	18.3	1.7	0.2
	1992	0.8	76.0	22.0	1.2	0
	Mean	0.6	77.9	20.5	0.9	0.1

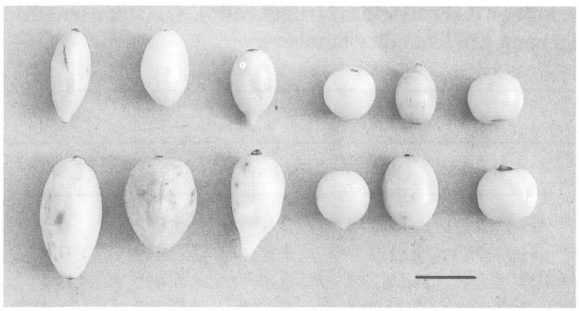

Fig. 4. Fruit shapes of *Argania spinosa,* from left to right : narrowly ellipsoid , ellipsoid, ellipsoid pointed, high spheroid, obovate, and spheroid (scale = 1cm).

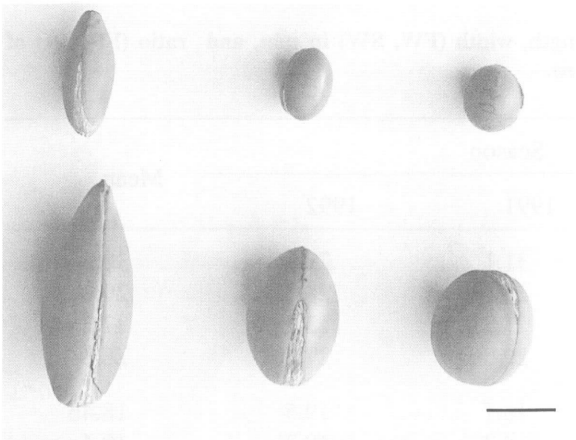

Fig. 5. Stone shapes of *Argania spinosa*. From left to right: narrowly ellipsoid, ellipsoid and high spheroid (scale = 1cm).

(28 % at AM, 31 % at AR and 32 % at AB) or narrowly ellipsoid stones which were the least abundant (14 % at AM, 25 % at AR and 11 % at AB. (Fig. 6B).

Season effect on variability of argan fruit and stone sizes. It was relatively hot and humid during 1990, while 1991 was cool and humid, and 1992 was very dry with a hot winter and spring and a cool summer and autumn (FERRADOUS, BANI-AAMEUR & DUPUIS 1996). For any individual tree fruit and stone shapes, no change was observed over the three seasons.

Site, individual tree effects and their interactions were significant on morphometric traits of argan fruit and stone (Table 4). These effects were discussed in previous papers (FERRADOUS, BANI-AAMEUR & DUPUIS 1996; FERRADOUS, BANI-AAMEUR & DUPUIS 1997) Season, and its interactions were significant effects on morphometric traits of argan fruit and stone (Table 4). Fruits and stones collected during the summer of 1990 were longer than those from 1991 or 1992 (Table 5). There for, under drought and high temperature conditions fruit and stone were shorter and narrower because

Table 3. Mean, minimum and maximum, and variation coefficient (CV%) of stone length (SL), width (SW) in mm and ratio (SR) of *Argania spinosa* stone shapes.

Size	Stone shape		
	narrowly ellipsoid	ellipsoid	spheroid
	$N = 15$	$N = 36$	$N = 39$
SL			
Mean	26.0	23.6	20.2
Minimum	23.4	19.8	17.3
Maximum	29.6	28.6	24.3
CV %	8.1	8.5	8.9
SW			
Mean	13.8	15.1	15.2
Minimum	10.2	13.2	12.6
Maximum	15.4	17.8	17.1
CV %	10.9	7.3	7.9
SR			
Mean	0.5	0.6	0.8
Minimum	0.4	0.6	0.7
Maximum	0.6	0.7	0.9
CV %	0.05	0.04	0.04

N: number of observations

arid conditions effects were more severe on length. But these changes were proportional because they did not affect the shapes.

Correlation of fruit or stone shape to length or to width/length were high, but the correlation to width was low (Table 6). Therefore length was determinant for argan fruit or stone shape, fusiform shape being the longest and spheroid the shortest. Because repeatability (an indicator of transmission of a character) of fruit and stone length was important (around 0.40) (FERRADOUS, BANI-AAMEUR & DUPUIS 1997), both shape and length are candidate as characterization descriptors of argan . This study has increased the knowledge data base on argan, a promising unexplored arid land species. Six fruit shapes and three stone shapes have been identified. Their determination fits IPGRI definition of a characterization descriptor (IPGRI, 1995). There for this study was a first step in fulfilling the criteria enabling characterization and assessment of variability, which will facilitate argan germplasm recognition and exchange.

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Table 4. Analyses of variance for FL (Fruit length), FW (Fruit width), FR (Fruit width / length ratio), SL (stone length), SW (stone width), SR (stone width / length ratio), FC (fruit color) and CN (chamber number).

Source of variance	DF	Mean squares							
		FL	FW	FR	SL	SW	SR	FC	CN
Season	2	7738.3**	567.7**	4.1**	6735.5**	532.5**	2.8**	5.0**	4.3**
Site	2	3875.2	798.7*	4.4**	3192.7**	221.9	1.9	127.8**	9.2
Season × site	4	4181.6**	1398.5*	1.3**	2975.2**	434.2**	0.8**	6.4**	0.4
Tree / site	87	1468.6**	242.0**	0.8**	658.5**	149.7**	0.6**	0.2**	4.5**
Season × tree / site	174	164.0**	68.4**	0.1**	76.0**	18.3**	0.1**	0.1**	0.6**
Season × fruit × tree/site	7830	30.0	82.4	72.8	27.6	25.8	29.2	17.5	68.7

Table 5. Mean *Argania spinosa* fruit (FL) and stone (SL) length, width (FW, SW) in mm, and ratio (FR, SR) of populations of *Argania spinosa* from three sites for three seasons.

Dimensions	Sites	Season			Mean
		1990	1991	1992	
FL	Ait Melloul	29.9	31.1	29.9	30.2
	Argana	30.2	28.4	28.3	29.0
	Ait Baha	30.8	27.5	23.3	27.2
	Mean	30.3a	29.0a	27.2b	28.8
FW	Ait Melloul	17.2	18.7	19.5	18.4b
	Argana	19.6	19.3	19.3	19.4a
	Ait Baha	18.5	20.2	17.7	18.8b
	Mean	18.4b	19.4a	18.8b	18.9
FR	Ait Melloul	0.6	0.6	0.7	0.6b
	Argana	0.6	0.7	0.7	0.7a
	Ait Baha	0.6	0.7	0.8	0.7a
	Mean	0.6b	0.7a	0.7a	0.7
SL	Ait Melloul	23.7	24.5	23.0	23.7a
	Argana	23.6	22.5	22.4	22.ab
	Ait Baha	24.4	22.9	17.6	21.6b
	Mean	23.9a	23.3a	21b	22.7
SW	Ait Melloul	14.6	15.3	15.0	15.0
	Argana	15.1	15.2	15.0	15.1
	Ait Baha	15.3	15.2	13.1	14.5
	Mean	15.0ab	15.2a	14.4b	14.9
SR	Ait Melloul	0.6	0.6	0.7	0.6
	Argana	0.6	0.7	0.7	0.7
	Ait Baha	0.6	0.7	0.7	0.7
	Mean	0.6b	0.7a	0.7a	0.7

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Table 6 . Correlation between fruit shape codes and fruit and stone length, fruit and stone width in mm, and fruit and stone width/length ratio of populations of *Argania spinosa* from three sites and three seasons toghether.

	Length	Width	Width/length
Fruit	0.65**	0.06	0.70**
Stone	0.74**	0.31*	0.88**

** Significant at 1 % level

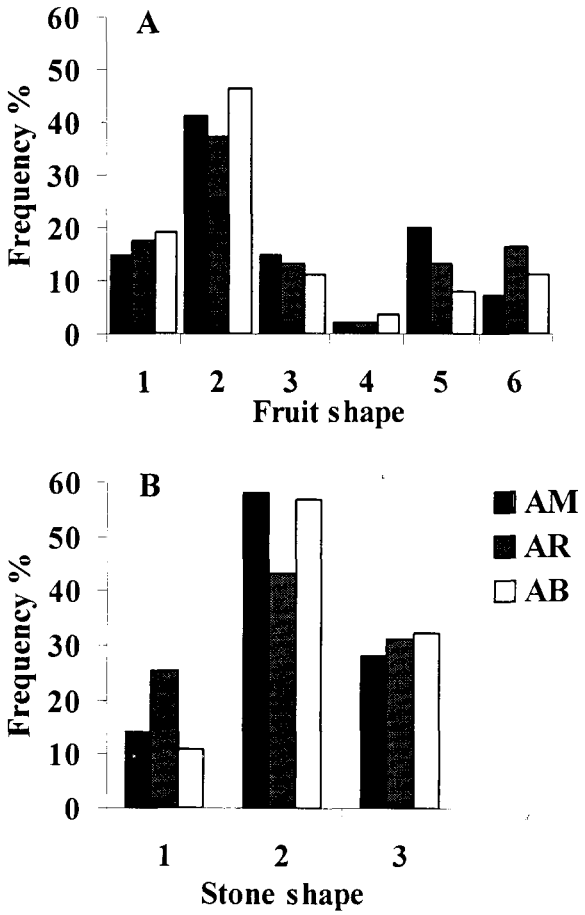

Fig. 6. Frequency distribution of fruit shapes (A) : narrowly ellipsoid (1), ellipsoid (2), ellipsoid pointed (3), obovate(4), high spheroid (5), spheroid (6), and stone shapes (B): narrowly ellipsoid (1), ellipsoid (2), high spheroid (3) within *Argania spinosa* tree populations at Ait Melloul (AM), Argana (AR), and Ait Baha (AB).

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