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Shapes of argan (Argania spinosa (L.) Skeels) in field classified on the basis of branching and growth charaters

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ABSTRACT

The visual characterization of argan trees (Argania spinosa L. Skeels) in their domain has always distinguished the presence of two forms. However, there are five morphological types on the basis of twenty-one characteristics of branching and growth observed in three natural populations in south west Morocco e.i. Ait Melloul, Argana and Ait Baha. The morphological type spinely, less branched with long branches is most abundant (31.1%). However, both morphological types, very little spiny, little branched with very long shoots, and spiny, branched with short branches are less frequent. The other two forms, very thorny and highly branched, with very short branches, and very spiny, very branched, with shoots moderately long, have intermediate percentages. The length of the main branch, number of green shoots, spiny green shoots, tertiary shoots, and green shoot angle were the discriminating characters between the five morphological types. Variability of shapes and frequencies in the three populations reflects potential diversity in physiognomy of trees, indicating differential behavior of main branches of trees within the same population. Type V is not represented in the mountainous site characterized by cold autumn and winter was probably due to low temperatures, which can induce a slowdown in physiological budding process and growth of branches.

Keywords*: multivariate analysis; Argania spinosa; model of branching; growth, branching; tree shape.*

INTRODUCTION

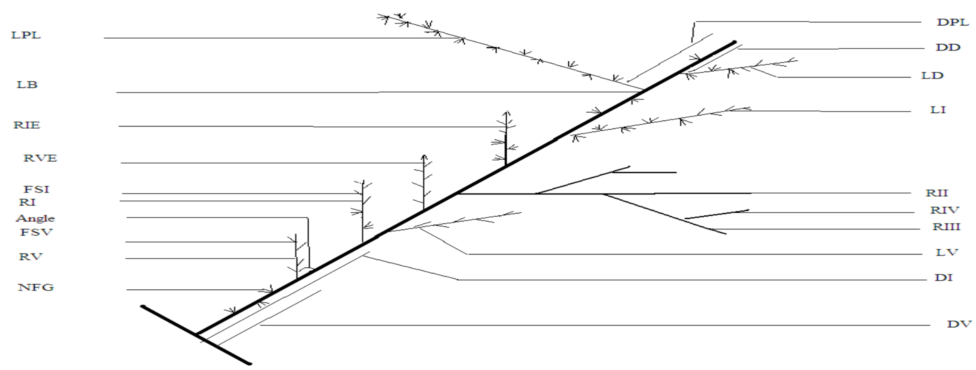
Wearing a tree is a specific characteristic, which reflects plant adaptation to changes in their environment bioclimatic[1,2]. This physiognomic notion is certainly very useful for the recognition of trees, but does in no way, understand how it works[3]. Adult form is actually based on the structure developed over the years, and reflects specific internal organization of plant. Thus, with the aim to understand better architecture, growth habit and vigour, which are important characters in botany and in various agronomic contexts for orchard management and production, several studies have been conducted in fruit and forest species. These studies have involved young plants or trees at the adult stage and are based on morphological characters such as the primary branch, number of secondary shoots, the angle of insertion of newly formed branches, length of shoots, the length of internodes, foliage and the growth direction (α) of the buds[4,5,6,7,8,9]. Different tree shapes can coexist in the same species (fastigiate, in a ball, weeper, Funnel, pyramidal)[10,11,12,13,14]. Shape description of plant taken as a whole is based on the mode of growth, branching pattern, and morphological differentiation of axis[15]. The study of morphological characteristics in fruit trees and in forest trees (apple, peach, walnut, poplar, spruce, cedar, cypress, pine) has identified several architectural models[3,16,14,17,18,19,20]. In argan, the tree habit was described visually in weeping type having flexible and drooping branches, and almost spineless[21,22,23] and erected highly spiny type[24]. More recently Dupuis[25] observed in Ait Melloul the erected forms and weeping trees which was visually characterized as such. For this author, the erected form is recognizable by branches of order N, with low growth and generally stabilized by a spine. The weeping habit is characterized by apical dominance of the terminal bud on the main branch; branches are rarely stabilized by spines. During late observations on six trees in Ait Melloul, Argana and Ait Baha where the author followed five branches per tree, Dupuis[26] noted that three trees selected as type spiny have 84% of their shoots stabilized by a spine, and their branching is important and branches of the fifth order are frequent on the main branches. The three trees identified by their weeping habit, showed 22% of spiny shoots, the remaining 78%, have a multi-year growth. The branching is low and shoots are essentially of the second order, the apical dominance is marked in this case. These findings obtained from faster surveys among small samples without detailed study of the branching of argan tree.

In a preliminary study, we identified five morphological types of argan based on eight branching characters of the main branch, in three populations in south west Morocco[27]. Both extreme types, very spiny, very branched; and little branched and spineless were less abundant than the three intermediate forms, branched spiny; spiny little branched and little branched, less spiny. Recently, the morphological diversity was studied in twenty six populations dispersed within the five major argan ecosystems based on fruit characters, kernels, branching and foliation[28]. Shoots at 60° angle were the most abundant phenotypic classes. Shoot angle at 30° was missing in some sites. But shoots at 90° angle had intermediate frequencies in other sites. We contribute by this work to characterize the five morphological types and distribution of their frequencies, in three natural populations, based on visual classification combined with the principal component analysis of twenty one characters of branching and growth in length.

MATERIALS AND METHODS

We observed thirty trees selected at random from each of three stations in south west Morocco: Ait Melloul (AM), Argana (AR) and Ait Baha (AB) described by (Ferradous *et al.*[29]. Each tree was individually photographed, then classified visually into one of five morphological types described by Zahidi *et al.*[27]. This visual classification reflects appearance and general shape of branches. Different forms of trees were numbered from I to V according to their belonging class. On two branches exposed to south, located at 1.5 m above ground, we observed the following characters in late May during three consecutive seasons. We opted for the mean of the three seasons for each character, while the effect of the climatic year was discussed in (Zahidi *et al.*,[35] (Figure 1)

Figure 1: Characters of branching, growth in length and foliation observed in Ait Melloul, Ait Baha and Argana



RV: number of green shoots; RVE: number of spiny green shoots; when shoot extension in successive growing periods was carried out by the same shoot apical meristem, growth was designated as indefinite. Thus, RI: number of shoots to indefinite growth. When the apical meristem of shoot was transformed into spine, its growth was considered definite. RIE: number of shoots to indefinite growth acquiring spine; FRE: number of green and to indefinite growth shoots spiny /total (green shoots + shoots to indefinite growth); RII: number of secondary shoots; RIII: number of tertiary shoots; RIV: number of quaternary shoots; NFG: number of grouped leaves on the main branch; FSV: number of simple leaves on the first green shoot; FSI: number of simple leaves on the first shoot to indefinite growth. All these observations except FSV and FSI have been reported at 100 centimeters by dividing by main branch length and multiplying by 100 to homogenize the results.

We measured in centimeters, LB: main branch length; LV: length of the greatest green shoot; LI: length of the longest shoot to indefinite growth; LPL: length of the longest shoot on main branch; LD: length of the last shoot; DV: distance to the first green shoot from the insertion point of the main branch; DI: distance to the first shoot to indefinite growth from the insertion point of the main branch; DPL: the distance to the longest shoot from the apex of the main branch; DD: distance to the last shoot from the apex of the main branch; Angle: angle formed by the green shoots with the main branch.

A principal component analysis (PCA) was performed using the average of twenty-one characters of each tree on the data reduced centered matrix[30,31,32]. Computer processing were performed using Statistix software, Statitcf and Ntsys-pc version 1.40 [33].

RESULTS

Frequencies of the morphological types

Frequencies of the five morphological types vary in large proportions (Figure 2a). Spinely, less branched with long shoots (IV) was most abundant (31.1%) (Figure 2b). Very little spiny, little branched with very long branches (V) and spiny, branched with short branches (II) are less frequent (14.4%). Very spiny and highly branched at very short branches (I), and very spiny, much branched with shoots moderately long (III) have an intermediate frequency. Type I was abundant in Argana (43.3%) than in Ait Melloul (13.3%) and Ait Baha (6.7%). Shape V, is more frequent in Ait Melloul (33.3%) than in Ait Baha (10%), but not represented at Argana. Form II represents only (6.7%) in Ait Melloul, but about 23.3% in Argana. The morphological type III is more frequent in Ait Baha and Argana than in Ait Melloul.

Characterization of morphological types

Figure 2 a: Five morphological type of argan tree

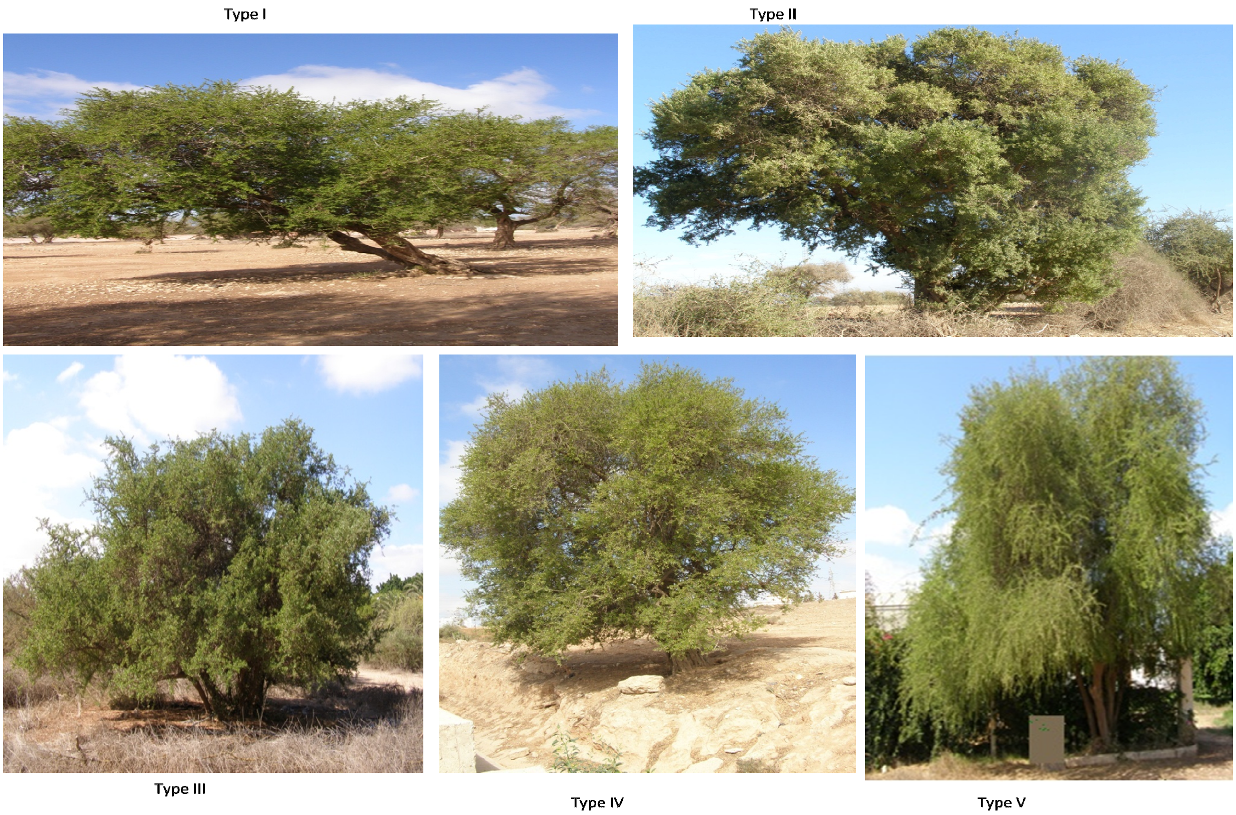
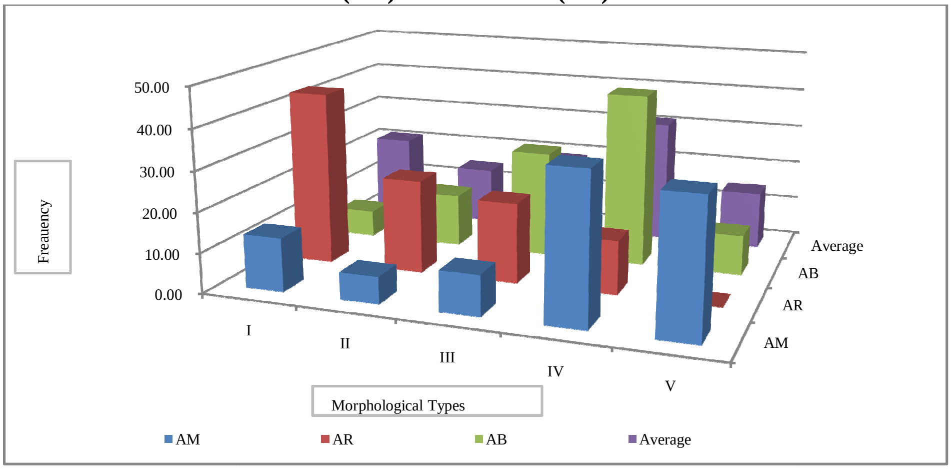


Figure 2b: Frequencies of the five morphological types of argan tree observed in Ait Melloul (AM), Argana (AR) and Ait Baha (AB)



+ Very spiny and** highly **branched at very short branches (I)

Characterized by short main branches, shorter shoots with high frequency of spiny shoots, with high number of green branches, but low number of shoots to indefinite growth (Table 1).

Table 1 : Average (Avg) and coefficient of variation (CV) of branching, growth in length and foliation traits observed in the three populations.

Character	Morphological types	I	II	III	IV	V
DI	Avg	3.21	5.5	6.9	10.2	11.3
	CV	142.7	115.6	104.3	86.4	70.5
DV	Avg	10.3	9.3	12.1	9.6	14.5
	CV	56.3	60.1	58.2	86.6	55.4
DD	Avg	5.9	5.5	4.10	8.3	16.1
	CV	79.2	78.2	73.5	93.4	61.9
DPL	Avg	16.1	15.1	13.6	16.5	26.8
	CV	76.7	50.7	80.6	76.8	53.2
FRE	Avg	1.77	1.42	1.74	0.85	0.63
	CV	76.1	100.7	139.9	134.6	176.8
LD	Avg	5.7	6.7	7.3	7.02	10.8
	CV	46.6	53.5	57.8	76.9	84.6
LB	Avg	33.6	35.8	36.3	40.7	48.7
	CV	30.3	26.7	41.1	43.03	34.9
LPL	Avg	11.2	16.1	16.72	17.2	26.4
	CV	46.5	61.8	55.7	59.5	31.5
LXI	Avg	1.07	4.61	5.01	8.39	12.9
	CV	246.04	163.2	127.3	106.9	50.1
LXV	Avg	6.47	6.01	11.0	6.83	8.92
	CV	70.7	72.1	59.4	92.8	68.49
RI	Avg	0.86	3.7	3.1	4.37	7.66
	CV	170.4	160.9	111.12	107.73	83.47
RIE	Avg	0.86	1.9	1.11	1.12	2.17
	CV	170.4	275.5	245.91	176.98	252.34
RV	Avg	14.1	10.59	21.60	8.54	9.73
	CV	92.5	100.46	70.53	92.3	80.3
RVE	Avg	11.1	7.6	9.15	4.42	3.12
	CV	115.1	142.6	108.77	147.2	187.67
ANG	Avg	60.2	62.37	67.1	88.9	90.0
	CV	14.9	13.35	19.6	6.37	0.0
R II	Avg	41.6	41.6	45.85	28.4	28.68
	CV	51.6	56.5	22.1	48.1	62.8
R III	Avg	5.1	6.34	11.28	8.18	4.36
	CV	137.4	105.14	107.9	123.8	105.66
R IV	Avg	0.2	0.05	0.84	0.21	0.08
	CV	435.9	360.6	350.48	398.26	360.5
NFG	Avg	87.4	73.7	64.5	63.9	59.7
	CV	45.1	53.5	59.45	58.56	39.57
FSI	Avg	1.2	4.85	2.67	3.91	11.5
	CV	223.1	155.24	232.48	152.23	61.58
FSV	Avg	7.2	6.81	8.58	4.53	4.73
	CV	100.6	81.76	75.24	128.51	124.73

Most of these shoots acquired spines in the year of their formation. The branching is important where shoots of 4th order are present. High variability was observed for most characters.

+ Spiny, branched with short shoots (II)

This type was distinguished by main branches relatively short, shorter shoots, with high frequency of spiny shoots. Majority of green shoots acquired spines in the same year of their formation. The branching is less important than type (I).

***+ Very spiny, much branched with branches moderately long (III)*:**

It is characterized by main branches moderately long, with high frequency of spiny shoots. Only a part of the newly formed shoots acquired spines in the same year of their formation. The branching is important where shoots of 4th order are present. In type (III), more variability than previous two types was found for the several characters.

***+ Spinely, less branched with long branches (IV)*:**

It differs from the three other types by the main branches relatively long, with low frequency of spiny shoots. Only a part of the newly formed green shoots acquired spines. The branching is essentially of second and third order.

***+ Very little spiny, little branched with very long branches (V)*:**

It is characterized by long main branches, with low number of spiny shoots. Only part of green shoots and shoots to indefinite growth had spines and is transformed to the spiny shoots. Others have retained the capacity to elongation during the next year, following their formation. Great variability for all characters, coefficients of variation ranged from 0% to 360.6%.

Principal component analysis (PCA)

Correlation between characters

Relation between characters is illustrated by observed differences in magnitudes and signs of correlation coefficients (Table 2). Some characters were highly correlated than others. The shoots angle is not significantly correlated with any characters. Measurements on the main branch do not determine the angle of branching.

Projection on principal axes

The first three axes of principal component analysis (PCA), absorbing 53.2% of total variability observed between morphological types. Approximately 42.5% was explained by the first two axes (Table 3). The first axis explained 25% of the total variation. This axis was highly correlated in negative sense to length of longest shoot, length of greatest shoot to indefinite growth, main branch length, distance to the last shoot from the apex of the main branch, to the distance to the first shoot to indefinite growth from the base of main branch, distance of longest branch from the apex, number of simple leaves on first shoot to indefinite growth and to green shoot angle. The same axis was correlated in positive direction to number of spiny green branches and number of grouped leaves. Types IV and V are projected on the negative side of first axis. Shape I and II are projected on positive side of first axis. The second axis explained 17.5% of total variation; is correlated in the negative direction to RV, RVE, RII, RIII, FRE, and LXV. Tree shapes more spiny, more branched with longer green shoots are projected on the negative side of this axis. The third axis explained only 10.7% of total variability; is correlated in negative direction to number of shoots to indefinite growth and those acquiring spine. This axis is also correlated in positive direction to main branch length and distance to longest shoot.

Projection of individuals in plane defined by the first two principal axes shows dispersion of type V limited mainly to the negative side of first axis, while type I was distributed on positive side of first axis (Figure 3). These two types are distinguished along the first axis. V and I are two distinct forms visually. From negative to positive side, we distinguish type IV, III and II. Type II overlaps significantly with type III, intersection between polygons corresponds to 53.3% of II and 70.6% of III. Intersection of the polygon that contains type IV and those of types II and III corresponded respectively to about 35.7% and

Table 2: Correlation matrix for branching, growth in length and foliation characters observed in the three localities.

Characters	DI	DV	DD	DPL	FRE	FSI	FSV	LD	LB	LPL	LXI	LXV	NFG	RII	RIII	RIV	RI	RIE	RV	RVE	Angle
DI	1.00																				
DV	0.28	1.00																			
DD	0.33	0.15	1.00																		
DPL	0.32	0.28	**0.64**	1.00																	
FRE	-0.21	-0.06	-0.31	-0.2	1.00																
FSI	0.14	0.27	0.28	0.3	-0.09	1.00															
FSV	-0.09	-0.19	0.14	0.06	0.18	-0.06	1.00														
LD	0.2	0.24	0.08	-0.16	0.09	0.11	-0.01	1.00													
LB	0.44	0.4	**0.61**	**0.79**	-0.38	0.23	0.01	-0.02	1.00												
LPL	**0.5**	0.36	0.41	0.41	-0.13	**0.67**	0.11	0.42	0.42	1.00											
LXI	**0.5**	0.31	0.27	0.2	-0.09	**0.72**	-0.01	0.3	0.25	**0.86**	1.00										
LXV	0.12	0.22	0.11	0.21	0.19	0.14	**0.6**	0.15	0.23	0.38	0.26	1.00									
NFG	-0.29	-0.17	-0.23	-0.34	0.05	-0.35	-0.05	-0.06	-0.35	**-0.51**	-0.45	-0.31	1.00								
RII	-0.24	0.06	-0.44	-0.12	0.42	-0.03	0.19	-0.13	-0.15	-0.1	-0.13	0.27	-0.01	1.00							
RIII	-0.13	-0.09	-0.37	-0.21	0.37	-0.08	0.06	0.15	-0.13	0.03	-0.02	0.25	-0.16	**0.51**	1.00						
RIV	0.02	0.21	-0.08	-0.06	0.04	-0.09	-0.12	0.04	0.07	-0.03	-0.02	0.02	0.08	0.05	0.31	1.00					
RI	0.35	0.1	0.11	0.11	0.02	**0.5**	-0.09	0.17	0.1	0.48	**0.53**	0.04	-0.34	0.02	0.04	-0.03	1.00				
RIE	0.14	-0.05	-0.12	-0.02	0.46	0.24	-0.09	0.15	-0.14	0.17	0.2	-0.03	-0.07	0.12	0.19	0.01	**0.58**	1.00			
RV	-0.2	0.04	-0.32	-0.11	**0.5**	-0.13	0.35	0.02	-0.15	-0.05	-0.1	**0.56**	0.01	**0.68**	**0.53**	0.03	-0.07	0.06	1.00		
RVE	-0.3	0.00	-0.31	-0.06	**0.64**	-0.18	0.26	-0.02	-0.13	-0.14	-0.18	0.26	0.1	**0.65**	**0.52**	0.03	-0.14	0.14	**0.78**	1.00	
Angle	0.31	0.11	0.34	0.19	-0.29	0.23	-0.22	0.1	0.3	0.3	0.41	0.04	-0.25	-0.38	-0.02	0.1	0.27	0.00	-0.26	-0.3	1.00

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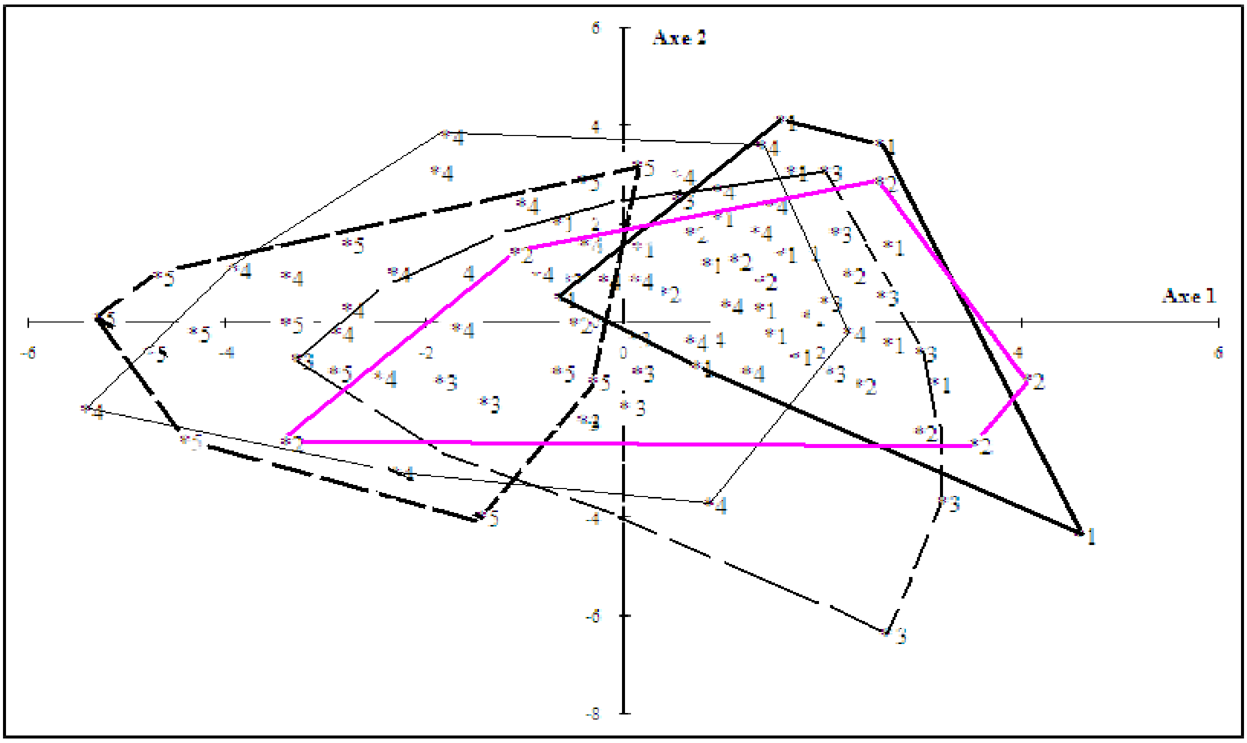
Table 3: Correlations between principal components and characters of branching, growth in length and foliation observed in the three localities

Variables	CP1	CP2	CP3
DI	**-0.64**	-0.1	-0.06
DV	-0.4	-0.23	0.12
DD	**-0.68**	0.13	0.4
DPL	**-0.6**	-0.1	**0.53**
FRE	0.47	**-0.56**	-0.2
FSI	**-0.61**	-0.31	-0.25
FSV	0.12	-0.38	0.48
LD	-0.22	-0.26	-0.3
LB	**-0.66**	-0.07	**0.53**
LPL	**-0.77**	-0.48	-0.08
LXI	**-0.73**	-0.4	-0.3
LXV	-0.13	**-0.67**	0.44
NFG	**0.51**	0.37	-0.05
RII	0.47	**-0.63**	0.1
RIII	0.33	**-0.6**	-0.12
RIV	0.05	-0.08	-0.06
RI	-0.47	-0.35	**-0.54**
RIE	-0.05	-0.39	**-0.61**
RV	0.47	**-0.73**	0.25
RVE	**0.54**	**-0.64**	0.19
Angle	**-0.56**	0.08	-0.13
Eigenvalues	5.25	3.68	2.24
Explained percentages (%)	**25**	**17.5**	**10.7**
Cumulative percentages (%)	**25**	**42.5**	**53.2**

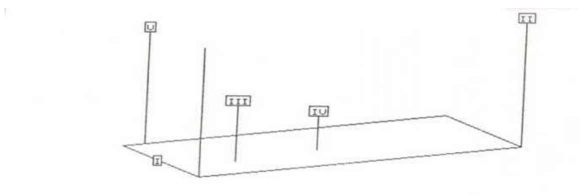
PC1: First principal component, PC2: Second principal component, PC3: Third principal component.

Figure 3: Projection of the five morphological types on plane defined by the first and second principal component (1:I, 2:II, 3:III, 4:IV, 5:V)



42.8%. The overlap observed is only apparent since we considered only the first two axes. Projection of the five morphological types on space defined by the three main components, allows clear distinction of the three intermediate types. Type II was distant from the positive side of the first principal component (Figure 4).

Figure 4: Projection of the five morphological types in space defined by the three principal components



Shape III is located in negative side to the center of first principal component, while type IV occupies an intermediate position. Canonical discriminated analysis allowed better classification of the five morphological types. The percentage of correctly classified trees was 63.3% (Table 4).

DV, DD, LPL, RI, RV, RII, FSI and green shoot angle were discriminating characters between the five morphological types (table 5).

Table 4: Classification of five morphological types by discriminant analysis based on branching, growth in length and foliation traits observed in the three localities

Group	I	II	III	IV	V	Total	% Of the membership class
I	11	6	1	1	0	19	57.9
II	5	7	0	1	0	13	53.8
III	4	2	10	1	0	17	58.8
IV	1	1	2	20	5	29	68.9
V	0	0	1	2	9	12	75
Total	21	16	14	25	14	90	63.3

Online: group membership, In column: group assignment

Table 5 : Characters discriminating between the five morphological types observed in Ait Melloul, Ait Baha and Argana obtained by discriminant factorial analysis

Variables	Residual variances	F (4 / 87)	Probability
DV	53.6	3.7	**0.01 ****
DI	53.1	0.7	57.0 ns
DD	41.7	7.8	**0 ****
DPL	149.9	1.5	21.0 ns
FRE	2.4	1.9	11.0 ns
FSI	37.4	4.8	**0 ****
FSV	39.1	1.5	21.0 ns
LD	27.7	2.1	9.0 ns
LB	220.3	1.9	12.0 ns
LPL	80.8	5.1	**0 ****
LXI	48.9	6.4	**0 ****
LXV	33.7	1.9	12.0 ns
NFG	1349.9	1.6	18.0 ns
RII	300.4	4.1	**0 ****
RIII	79.9	1.7	15.0 ns
RIV	2.1	0.9	49.0 ns
RI	20.5	4.6	**0 ****
RIE	11.1	0.5	75.0 ns
RV	124.1	4.1	**0 ****
RVE	88.2	2.3	7.0 ns
Angle	71.3	49.6	**0 ****

**: Significant at 1%, ns: not significant.

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DISCUSSION AND CONCLUSION

Visual classification of the five morphological types combined with principal component analysis of twenty-one traits observed on main branches can distinguish physiognomical differences that characterize five shapes in argan tree. Generally, types V and IV are characterized by visually drooping branches. Both types approach the weeping form for appearance of drooping branches as reported by Dupuis[25,26]. All times, shape V is distinguished by its clear appearance, and its relatively long drooping branches almost spineless. Branching was low, and shoots are essentially second order and rarely stabilized by spines. All green shoots newly emerged, have an angle of 90 ° with the main branch. Forms I, II and III compared to the two previous are characterized by their appearance erected, with shorter shoots and the majority of which were stabilized by terminal spines. These forms remind the erect type described by Dupuis[25,26]. Type I is distinguished from shape II by the erected branches, low growth since generally, all shoots are stabilized by spines. The tree is very dense with important branching where shoots of third and fourth order are frequent on the main branches. All green shoots newly emerged, have an angle of 60 ° with the main branch. Shape III is characterized by mixture of drooping and erected shoots that were predominant, the branching is more important; shoots to indefinite growth are relatively long compared to I and II.Most newly appeared branches form an angle of 60 ° with the main branch. Shoot angle was among characters to describe morphological variability of argan in large-scale and may be adopted for practical instant surveys[28]. Maximum bending of branch is limited to 90° from the vertical straight line was found in *Pinus sylvestris* (L.) [5]. Lengths of greatest shoot, main branch, greatest green branch, greatest shoot growing indefinitely, numbers of green, green spiny and tertiary shoots, number of simple leaves on shoot to indefinite growth and shoot angle were the discriminating characters of the canopy in argan. Shape variability estimated by the extent of polygons, reflects differences observed in their biometric characteristics. Among the twenty-one characters observed, distances, lengths and branching of the year contribute differently in principal components. Different contribution in principal components of 12 variables observed in field in order to characterize tree morphology was found in *Pinus monophylla* that dominates montane plant communities over large areas of the arid and semi-arid Intermountain West, USA[34]. These variations reflect differential behavior of the main branches of trees within the same population. These differences in branching and length growth are dependent on interannual variations in climate and tree genotype[35]. The age of branches may be also the cause of these differences in arid zones as was the case of *Prosopis flexuosa* in which multi-stemmed individuals rapidly decreased their growth rates after 60 years, one-stemmed trees maintained steady growth rates during the first 100 years[36]. Stem diameter, height, diameter of lowest branch, crown area, and index of bark texture varied also with tree age in *Pinus monophylla*[34]. Tree stature is an important ecological and silvicultural characteristic. In finding the balance between production and protection forest which seems difficult in arid areas because of their low potential for wood production as reported by (Alvarez *et al.*, [36]. The intense use of argan products would lead to degraded state of the forest, in addition growth and branching are weak and dependent on climatic conditions, appropriate silvicultural practices in sites being defended can contribute to the sustainable management of the forest of argan.

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