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GROWTH AND BRANCHING VARIABILITY OF *ARGANIA SPINOSA* (L.) SKEELS IN ARID ENVIRONMENTS AND IMPLICATION FOR SELECTION

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ABSTRACT

With the aim to select plus trees with superior desirable characteristics for domestication, morphological variability for growth and branching was studied in three natural populations of argan in south west Morocco. Growth, branching and leaves production were higher in humid season than in dry season. The relative contribution of season, locality and season x locality interaction in the total variance was low for most traits. Tree x environment interaction explains from 22.2% to 33.7% of total phenotypic variability for most traits. Individuals from Ait Baha were most affected by inter-annual climate changes; this site through its arid climate will constitute an environment for selection of resistant genotypes to drought. The contribution of genotype (tree / locality) was very important for all characters (20.4% and 54.3%). Repeatabilities were higher (22.9% to 54.7%) for most traits. Differentiation among the three populations is not established. The observed diversity was mainly due to differences between trees within the same population. Some trees have strong potential for growth in length, branching and leaf production even in dry season. This adaptive response in morphology may be a primary mechanism by which the argan can cope with the environmental characteristics. Thus, identification and selection of resistant genotypes to drought in their area of distribution may be an effective method for genetic improvement of argan trees, and a first step for further breeding studies.

Keywords: *Argania spinosa*; Diversity; Repeatability; Branching; Multivariate Analysis; Arid Environments

INTRODUCTION

Argan tree is endemic species to south west Morocco in arid and semi-arid areas characterized by great fluctuation in rainfall. The summer is dry and hot **[1]**. One of the essential features for selecting mother-trees for domestication is the identification of elite plus trees with superior desirable characteristics. To achieve this, a quantitative study to describe the genetic diversity for stem morphological traits was undertaken, in order to protect the natural population and at the same time meet the demands of the local communities in fruit, oil, forage and wood, the argan tree should be domesticated **[2]**. Variability has sometimes been studied by comparing the relative proportions of variance components as was the case of *Juglans Regia* **[3]**, *Abies amabilis* (Dougl.) Forbes) **[4]** and for *Festuca ruba* (L.) **[5]**. The broad-sense heritabilities were ranged between 0.0 and 0.76 in *Populus balsamifera* (L.) for wood traits **[6]**. The distribution of variability within and between populations is used to measure the degree of population differentiation. This distribution is the product of the interaction of several factors, such as natural selection, the population size, and ability of the species to disseminate pollen and seeds **[7, 8]**. Indeed, **[9]** found in six populations of *Cupressus bakeri* a high degree of differentiation between different populations, even geographically very nearer. Variation among populations of the southern slope very close, in similar ecological conditions, was very important. The authors suggest that the differentiation has a genetic origin. While the morphological differences observed between populations of the north side are rather due to environmental conditions. Research on genetic diversity of argan is recent. Thus, **[10]**, have approached study of genetic variability of four enzymatic systems GOT, MDH, ACP and EST in thirty trees in three populations of the Anti-Atlas. They found that intra-population variability was higher than inter-population variability. **[11]**, have studied the variability of the chemical composition of oil from fruits with different shapes and sizes collected in three different sites. The authors propose four varieties chemotaxonomic quite different. **[12]** studied the genetic diversity of nine isozyme loci in ten populations of argan area. A high level of diversity (3.6 alleles / locus), and a strong differentiation (FST = 0.25) were observed. The grouping of populations in relation to their geographical proximity was sometimes found. RAPD markers were used for the first time in argan by **[13]**. These authors found a remarkable polymorphism among genetic markers. The hierarchical classification method yielded groups more or less concordant with the grouping based on metric characters of fruit and stone.

Morphological diversity in argan was conducted on fruit and stone characters **[14, 15]**. Genetic variance was very important for weight and fruit length, for weight, length, width and kernel ratio (width / length). The broad-sense heritabilities (repeatabilities) were ranged from 0.08 for fruit width and 0.52 for kernel ratio. Variability for the studied traits were dispersed in the prospected area, the grouping of genotypes was not related to their geographical origins. Similar results was observed for fruit traits in five populations, since repeatabilities was ranging between 8.02% for number of almonds and 93.28% for oil content **[16, 17]**. Variability of fourteen qualitative traits of tree branching, fruit, stone and leaves showed that Ait Melloul and Ait Baha had variability levels (0.60 and 0.56) significantly higher than Argana (0.41) **[18, 19]**. Tree branching, fruit and stone shape showed the diversity indices of Shannon and Weaver (H') the highest (0.9-0.75), while fruit color had the lowest diversity level (0.15). In twenty-five sampling sites dispersed within four major ecosystems of argan, 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 but it was higher for leaf shape and branching angle in most populations **[2]**. The leaf characters and fruiting branches traits also showed remarkable levels of variability **[20]**. One of the essential features for selecting mother-trees for domestication is the identification of elite plus trees with superior desirable characteristics. To achieve this, a quantitative study to describe the genetic diversity for stem morphological traits was undertaken. Morphological variability of argan remains incomplete; this work is a contribution in this direction. Our objective is to study the genetic diversity and its distribution pattern in three populations in south west Morocco for branching, growth in length and foliation characters.

MATERIALS AND METHODS

Description of Variability

The study was carried out during three consecutive seasons (season 1; season 2; season 3) in three populations: Ait Melloul (latitude: 30° 20' N, longitude: 9° 29' W, altitude: 32 m), Argana (latitude: 30° 78' N, longitude: -9° 11' W, altitude: 620) and

Ait Baha (latitude: 34° 21' N, longitude: 5° 33' E, altitude: 550) located in South west Morocco. Rainfall is often scarce and variable (0 to 300 mm in average), taking place mainly during the cold period while summer season is dry **[2]**.

Year	AM	AR	AB
1	103.7	158.8	115.3
2	612.6	1041.5	468.2
3	381.9	547.1	351
Average of 14 years	245.29	415.4	226.82

Thirty trees were selected randomly in each site. Among the principal branches facing south at breast height, two were labeled and we recorded at the end of May the following characters **(Figure 1)**.

RV: number of green branches; 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 **[21, 22]**. 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.

We measured in centimeters:

DV: distance to the first green shoot from the insertion point of the main branch; DI: distance to the first branch 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; 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;

All these observations have been reported at 100 centimeters by dividing by main branch length and multiplying by 100 to homogenize the results.

Variance Components

The variance components were estimated from linear functions of the appropriate means square **[23, 24] (Table 1).** All factors were considered as random in variance calculations. To compare the relative contribution of variance related to different factors, the percentage of each component was calculated relative to the total variance (σ^2_T):

$$\sigma^2_T = \sigma^2 A + \sigma^2 l + \sigma^2 A \times l + \sigma^2 a/l + \sigma^2 A \times a/l + \sigma^2 e$$

$\sigma^2 A$: variance due to season, $\sigma^2 l$: variance due to locality, $\sigma^2 A \times l$: variance due to season x locality interaction, $\sigma^2 a/l$: genotypic variance due to tree / locality, $\sigma^2 A \times a/l$: variance due to genotype x environment interaction (season x tree / locality) and $\sigma^2 e$: variance due to error). The relative percentage of each factor in the total variance for one site (σ^2_{Ts}) was expressed as:

$$\sigma^2_{Ts} = \sigma^2 A + \sigma^2 a + \sigma^2 A \times a + \sigma^2 e$$

$\sigma^2 A$: variance due to season, $\sigma^2 a$: variance due to tree, $\sigma^2 A \times a$: variance due to season x tree interaction and $\sigma^2 e$: variance by site due to error.

Trees were not repeated between sites and at the locality itself. We calculated repeatabilities (broad sense heritability estimated by the ratio of variance tree / locality tothe total phenotypic variance): global repeatability ($r^2 g$) calculated on the three stations and repeatability ($r^2 s$) in all three stations individually using the formula below by assimilating season of observation at a repetition in time **[15, 25]**:

$$r^2 g = 100 \times (\sigma^2_{a/l} / \sigma^2_{a/l} + \sigma^2_{Axa/l} + \sigma^2 e)$$

The sum ($\sigma^2_{a/l} + \sigma^2_{Axa/l} + \sigma^2 e$) was the total phenotypic variance in the three stations and ($\sigma^2 a/l$) was the genetic variance in a broad sense (variance of Association tree and locality). The variance due to tree / locality in our case overestimates the genetic variance due to the combination of tree to locality, and the lack of repetition of the trees in localities.

Repeatability per station was calculated using the following formula:

$$r^2 s = 100 \times (\sigma^2_a / \sigma^2_a + \sigma^2_{Axa} + \sigma^2 e)$$

The sum **($\sigma^2_a + \sigma^2_{Axa} + \sigma^2 e$)** is considered to be the total phenotypic variance per site and **($\sigma^2 a$)** the variance due to the tree.

Distribution of Genetic Diversity

Ten characters, for which tree component (genetic) was very important, are kept to study dispersion of variability: RII, RIII, RIV, NFG, LB, LPL, LD, DV, DPL and DD.

Statistical Analyzes

An analysis of variance (ANOVA) in hierarchical model and calculation was conducted using Statistix software. Tree factor is hierarchical to locality because trees were not duplicated between sites. Factors season and locality were crossed. Mean separation was done with Fisher's protected least significant difference test (LSD) **[23, 26, 27]**.

Principal component analysis (PCA) was performed on the reduced centered data matrix **[28, 29]**. We used the annual averages since tree response with respect to inter-annual seasonal changes was not homogeneous according to the characters **[20].** Trees and localities classifications were performed on annual averages by 'unweighted pair-group method arithmetic average' or (UPGMA). All statistical parameters: mean, standard error, variance and coefficient of variation were analysed statistically using the software Statistix, Statitcf and Ntsys version 1.40 **[30]**.

RESULTS

Description of Variability

Season Factor

Season factor was significant for RV, RIE, FRE, RII, RIV, DV, DI, RVE, LV, LI, FSV, FSI and NFG **(Table 2)**. It was not significant for the other characters. The formation of RV, RVE, RIE and frequency of spiny shoots (FRE) were greater during the very humid season, than in dry and humid seasons **(Table 3a)**. More the annual water balance was higher; formation of green branches and spiny shoots was considerable. High variability was found for the four characters explained by coefficients of variation (113.3% to 518.4%). More secondary (RII), and tertiary shoots (RIII) were formed in the second season (36.5 and 7.3) than in third (39.5 and 7.9) and first season (26.4 and 4.3) **(Table 3a)**. Thus secondary and tertiary branching was particularly important that the season was wet. The elongation of green and to indefinite growth shoots and simple and grouped leaves production were higher during the very humid season than during humid and dry seasons **(Table 3b; 3c)**.

Locality

Locality was significant for RI, DD, DPL, DI, RV, LV, LI, LPL, FSI and FSV, but not significant for the remaining characters **(Table 2)**. Season x locality interaction was significant for RVE, RI, LI, LPL and FSI. It was not significant for the remaining **(Table 2)**. The formation of green shoots, shoots to indefinite growth was higher in Ait Baha than in Ait Melloul and Argana **(Table 3a)**. Shoot elongation and production of simple leaves were greater in Ait Melloul and Ait Baha than in Argana **(Table 3b; 3c)**. The last and longest shoots on the main branch were further away from the apex in Ait Melloul (12.7 cm and 24.8 cm) than in Ait Baha (5.3 cm and 11.6 cm) and Argana (4.8 and 13.7 cm) **(Table 3b)**. Shoots to indefinite growth were very near from the insertion point of the main branch in Argana, than Ait Baha and Ait Melloul. Argana showed more variability for several traits than Ait Baha and Ait Melloul.

Genotype

Genotype factor (tree / locality) has significantly influenced all traits except RIE, demonstrating the potential of diversity available for selection during the breeding programs for branching characters **(Table 2)**. Genotype x environment interaction expressed by the association (season x tree / locality) was highly significant for RV, RVE, RI, RIE, FRE, LV, LI, NFG, FSV and FSI. It was not significant for other traits of branching and growth. Tree response with respect to inter-annual climate change was different in the three localities. This reaction results in frequency of trees that produced RV, RVE, RI, RIE, NFG, FSV and FSI **(Table 4)**. These frequencies varied in wide proportions and ranged from 100% for grouped leaves and 0% for number of shoots to indefinite growth.

Variance Components

The relative contribution of variance associated to climatic season in the total variance was low (0% to 9.9%) for all characters except for RV (13.5%), LV (22.8%) and FRE (20.6%) (Figure 2a, b). It was similar for locality effect and locality x season interaction (0% to 14%), except for distances (16.2% and 26.9%). The percentage of variance due to genotype x environment interaction (season x tree / locality) in the total variance was greater (22.2% to 33.7%) for RV, RVE, RI, RIE, FRE, LV, LI, FSV and FSI (**Figure 2a, b)**. Considering each site, the population of Ait Baha showed more variation to inter-annual climate change than Ait Melloul and Argana populations. The contribution of variance related to season x tree interaction taken at Ait Baha, driest site, was higher. Values varied from 21.9% for FRE and 56.7% for FSV. At Argana, humid site, less inter-annual variations was found for the same characters. Season x tree interaction percentages was low (0% and 9.5%) except for FRE (27.5%). At Ait Melloul, season x tree interaction percentages were ranged from 2.9% for RVE and 42.2% for FRE. Therefore, Argana will be the most stable site, while Ait Baha is the most selective provenance, which creates the contrast. Ait Baha station would be candidate for selection of resistant genotypes to inter-annual climate variations.

The contribution of variance related to genotype (tree / locality) factor in the total phenotypic variance was greater (20.4% and 54.3%) for RII, RIII, RIV, LB, LPL, LD, DD, DPL, DV, DI and NFG (Figure 2a, b). In each locality, percentage related to tree factor in total variance was ranged from 17.5% for DV and 63.9% for LB in Ait Melloul, between 25.2% for DD and 48.8% for RIII at Argana. While at Ait Baha, these percentages were between 12.9% for DV and 55.2% for LB.

Repeatabilities for all characters varied in large proportions and ranged from 54.7% for LB and 0.44% for RIE. The calculation of repeatability in each site can provide an estimate of heritability although trees are not repeated in localities. Characters such as LB, LPL and RII, repeatabilities in Ait Melloul were higher than in Ait Baha and Argana **(Table 5)**. But, for DPL and NFG, repeatabilities were higher in Ait Baha than in Argana and Ait Melloul. For RV, LV, LI and FSV which repeatabilities are low, in population of Ait Melloul, values were higher than those observed in Argana and Ait Baha. While for FSI, RVE repeatabilities were higher in Ait Baha than in Ait Melloul and Argana.

Distribution of Genetic Diversity

Correlation between the ten characters varied in large proportions in the three seasons. The annual values of DD, DPL, LD, LB, LPL, NFG, RII, RIII and RIV were highly correlated **(Table 6)**. The direction of trees response in the dry season (1) was so similar to reactions in humid seasons (2, 3) even though the levels are variable. DV values obtained in the dry season are not correlated with the values of the humid seasons. But, values of humid seasons are correlated. The traits DD and DPL, LPL and LB are always correlated whatever the climatic season. The correlation coefficients of LB and DD, DPL and LPL, LB and LPL, LPL and NFG, RII and RIII, RIII and RIV have varied in large proportions by climate season.

PCA shows that 59.2% of the total variance could be explained using three first principal components (PC) **(Table 7)**. The first axis explains 29.8% of total variation, is highly correlated to LB, DD, DPL, but with a lesser degree to LPL. Second PC that was responsible for 16.8% of variation was linked to RII, RIII and RIV. Third PC, explained 12.6% of total variability was attributed to LD. The ordering of individuals revealed that genotypes are not grouped according to their geographical origin due to the high variability of morphological traits both within and between the three populations. There is no clear separation between genotypes since trees of Ait Melloul, Argana and Ait Baha are not grouped according to their originating site but a remarkable mixture of genotypes was observed (**Figure 3**). The dendrogram generated based on all morphological data, showed a similar pattern. Two major clusters of genotypes were distinguished in a Euclidean distance of 5.93 **(Figure 4 and Table 8)**. The first group was formed by only one individual from Ait Melloul (tree 3), with shorter main branches (28.5 cm), with more RIII (42.6). The second group contains 89 trees, is divided in two classes. One class contains tree 1 from Ait Baha. The second class is divided at a distance of 4.82 in: a first sub-group which includes sixty three individuals. Thirteen trees from Ait Melloul (20.6%), twenty-eight trees from Argana (44.4%), and twenty-two trees originate of Ait Baha (34.9%). The second sub-group consists of 25 individuals. Sixteen trees were from Ait Melloul (64%), seven from Ait Baha (28%) and two from Argana (8%). The classification of three populations on the basis of average of thirty trees in each site can distinguish two groups at Euclidean distance of about 2.11 **(Figure 5)**. A first group contains Ait Melloul site, second group formed by Argana and Ait Baha localities. Differentiation for branching characters was not established for argan in the field. Diversity was mainly due to differences between genotypes. However, there is significant heterogeneity between genotypes of Ait Melloul and Argana populations compared to Ait Baha population.

DISCUSSION

Factors season, locality and tree / locality influenced differently branching, shoot growth production of leaves. Seasonal climate change effect reflects the influence of temperature but especially precipitation. The second campaign was very humid and cold; the first season was dry and warm, but the third season was wet **[20]**. Thus, more the annual water balance was greater; formation of green and spiny shoots; secondary and tertiary branching, shoot growth and leaf production were particularly important. Reducing of those characters observed in dry and humid seasons are related to irregular rainfall observed during the two campaigns. Therefore, a better production of branches, leaves and shoot elongation require distributed rainfall in autumn and winter. Precipitation in autumn and winter associated with sweet ambient temperatures were crucial for the annual production of shoots and leaves in argan tree. Indeed, March and April of the third season was wettest in Ait Baha (78 mm) than in Argana (44.6 mm) and Ait Melloul (37.1 mm). These rainfalls during this period were probably favorable to the formation of large number of green and to indefinite growth shoots observed in Ait Baha. This increase which occurred during the third season that made the difference between Ait Baha, Ait Melloul and Argana. Generally, the number of green and to indefinite growth shoots was higher in Ait Melloul and Ait Baha compared to Argana although it was the wettest site. This reduction at the site of the High Atlas characterized by a cold autumn and winter

[1] was probably related to the low temperatures that can induce a slowdown in physiological processes of budding and branches growth **[31]**. Similar finding in green oaks (*Q. suber* and *Q. ilex*), reported that tree water stress during the dry season restricted shoot elongation **[32]**. In *Picea crassifolia* from four sites in the arid and semi-arid region of north western China, the significant limiting factor on tree growth was spring precipitation **[33].** In *M. spinosum* annual shoot extension occurs mainly in spring when upper soil layers are yet hydrated, or during autumn before the lower winter temperatures appear and when rainfall begins to increase **[22]**. In the three localities, this variation of morphological traits in argan reflect the influence of temperature and rainfall as it was observed in other species such as peach and apple **[34]**, cedar of Atlas **[35],** and cypress **[36]**, in which the effects of environmental factors such as temperature and precipitation are manifested by a reduction or increase of branching and growth in length. High variability was found for all traits. This variability was mainly due to the differential trees response to inter-annual climate change. Changes in frequency of trees that produced shoots and leaves show that sensitivity to inter-annual changes in temperature and precipitation for these characters depends on the tree genotype. Thus, even under best conditions such in second season, tree response was very heterogeneous. Some trees from Ait Baha, Argana and Ait Melloul have produced shoots and leaves even in very dry season (1st season), but a more or less important number of trees depending on locality have not produced branches and leaves in the same season. We find therefore in argan the existence of two genotypes, sensitive and resistant genotypes to considerable variation in temperature and precipitation during the first and third season. This resistance was more pronounced in Ait Baha, characterized by its aridity. Therefore, this station can be a medium for selection of resistant genotypes for fruit and stone traits as it was reported by **[14]**, and for leaf characters **[19].**

The relative contribution of variance associated to climatic season in the total variance was low for all characters. Low percentages of variance associated with this were also noted for eleven characters of fruit and stone (0.6 to 11.2%) **[14]**, for eight traits of simple and grouped leaves (0% to 17.1%) **[19]**. The relative contribution of the variance associated to season x locality interaction in the total variance was also low for all branching characters. These percentages were generally smaller compared to those obtained for fruit and stone characters exception of number of lodges **[14, 15]**, and for leaf traits **[19]**. The contribution of variance related to locality was also lower for fruit and stone characters (0.7 to 4.2%) with the exception of color (64.8%) and for leaf traits. This variance can be decomposed into variance due to differences between trees in localities (inter-population σ^2) and a component related to geographic origin (geographical σ^2). In argan, these two components are low despite the important ecological differences between the three communities. The inter-population component is very small compared to the intra-population component. Argan show therefore a high adaptive plasticity towards the middle. **[37]** showed a steep clinal reduction in leaf size from south to north in relation to precipitation and annual aridity. It suggested that the morphological cline is the result of plastic and/or adaptative responses to environmental conditions, and indicative of further ecophysiological latitudinal differences among *Q. rugosa* populations. In addition, in *Castanea sativa* Mill. var. 'Judia', the current results suggest that the morphological and phenological differences among ecotypes are not related to the small genetic differences, but are simply phenotypic adaptations to different climatic conditions **[38]**. The percentage of variance due to genotype x environment interaction (season x tree / locality) in the total variance was greater for several branching traits. Thus contribution of variance associated with season x tree interaction taken in each locality has revealed more variation in Ait Baha, the driest site, than Argana and Ait Melloul. Therefore, Argana is the medium most stable, while Ait Baha is the medium more selective, and creating contrast. Ait Baha station would be a candidate for the selection of genotypes resistant to inter-annual climate variations. Branching traits were also more sensitive to inter-annual changes in temperature and precipitation compared to fruit and stone characters **[14]**. Indeed, the percentage of variance related to genotype x environment interaction has ranged from 14.7% for stone width and 4.4% for fruit width. Greater values were also observed for all traits in both two types of leaves except for dry weight in simple leaves (0%). This percentage has varied from 14.9% for leaf length and 40.5% for number of secondary ribs and for the five characters of the fruiting branch. It explained a percentage between a maximum of 42.8% for number of branches to four or more fruits and a minimum of 18.5% for the total number of fruiting shoots **[18, 19]**. The contribution of variance related to genotype (tree / locatity) in the total variance was greater for several characters. Repeatabilities (broad sense heritability) were varied in large proportions for all characters. For DV, DI, LPL, LB, LD, NFG, DD, DPL, RII, RIII and RIV with high repeatability, most of variability was explained by variance associated with tree / locality, while the contribution of the climatic season was very low. By against for RV, FRE, LI, LV with low repeatability, most of variability was related to season and tree x season interaction, while contribution of tree factor was small. These results reflect diversity level for these branching traits. They add to the criteria of fruit and stone with a high repeatability such as fruit and kernel weight, fruit and kernel length, fruit width and kernel ratio observed in the same three populations **[14]** and for leaf traits for which repeatabilities were ranged from 21.7% for leaf width and 57.9% for leaf length **[19]**. For fruit traits observed in five other populations, repeatabilities was ranging between 8.02% for number of almonds and 93.28% for oil content **[16]**. The first three axes of the PCA, absorbing 59.2% of total variability. This percentage is lower compared to that obtained for fruit and stone characters (74.1%) **[14]**, for leaf traits (62.1%) of argan and for morphological characters in four natural populations of *Paramichelia baillonii* (Pierre) Hu in China, about 77.6% of variability **[39]**. At Inter-population level, individuals classification was not performed according to their belonging to origin sites, since the two major groups contain both trees of Ait Melloul, Argana and Ait Baha. Distances obtained were less than those observed in argan for fruit and stone traits **[14]**, for leaf traits and fruiting branch **[18, 19]** and leaf characteristics (4.6) and fruit traits (6.4) in *Julans regia* (L.), **[3]**. Argana and Ait Baha populations are not differentiated but are relatively remote from Ait Melloul population. This grouping does not appear to be the result of geographical and ecological isolation of three populations in adaptations to local environmental conditions since the two mountain sites, Argana and Ait Baha are climatically very different **[1]**. Argana locality of the south side of the western high Atlas, is more humid and characterized by a cold autumn and winter. Ait Baha, site north side of the western Anti Atlas is most dry, spring and summer are warmer. Even though Ait Melloul is generally with mild temperatures, the annual average rainfall was relatively identical to those enregistred in Ait Baha. The two populations (Argana and Ait

Baha) with morphological similarities are not differentiated of the plain population (Ait Melloul). These results are consistent with those of **[15]** for fruit and stone traits, for leaf traits and fruiting branches **[18, 19]** and by **[12]** based on molecular markers, which reported relatively high levels of similarity between populations especially geographically close (Argana, Ait Baha and Admine). But using discriminate analysis, results in five populations observed for one year on the basis of fruit characters shows a distinction into four groups. For I, II and III despite the vast diversity of natural climatic conditions, it appear a clear separation of these groups. This grouping pattern indicates that provenances have some genotypes with several characteristics distinct from the rest of genotype studied **[16]**. Characters that vary depending on localities are the longest branch length, distance to the last branch, and distance to longer branch. The percentage of variance due to locality factor (inter-populations σ^2 + geographical σ^2) in the total variance was lower for the three characters compared to contribution genotype (tree / locality). Morphological type, more spineless and little branched (V) and less spiny little branched type (IV) are more abundant in Ait Melloul (70%) than in Ait Baha (53.3%) and Argana (13.3%). But type very spiny highly branched (I) and spiny branched type (II) are more frequent in Argana (66.7%) than in Ait Baha (20%) and Ait Melloul (20%) **[20]**. If types IV and V are characterized by high distances to last branches and to longest shoots, longest greatest shoots. But, types I and II are distinguished by low distances to last shoots, to longest branches and longest branches shorter. Frequencies differences of morphological types therefore affect the average of branching traits and therefore will remote Ait Melloul from Argana and Ait Baha populations. Thus differentiation between the three populations based on morphological branching characters was not established. But some genotypes were able for producing shoots, leaves and have better growth in length in dry season than wet seasons. Thus, to maintain an appropriate level of genetic diversity, development of a conservation strategy must take into account major problems of argan. Indeed, the quantitative and qualitative regression consequent destruction of trees without possibility of replacement; the arid conditions in the south west are not conducive to spontaneous regeneration can significantly reduce level of genetic diversity in argan. This diversity level currently available for all breeding programs; may attenuate if precautions of conservation and propagation of the species by planting kernels are not considered.

CONCLUSION

Morphological variability for branching characters in the three populations was remarkable. The relative contribution of variance related to climatic season, locality and locality x season interaction in total variance was relatively low compared to the genetic variance. By against the contribution of variance related to genotype x environment interaction was significant for characters in relation to formation of green and to indefinite growth shoots, shoots growth and simple leaves. In addition, argan showed a potential resistance to aridity of environment estimated by frequency of trees that produced simple and grouped leaves, green and shoots to indefinite growth. This frequency depending on characters and site was ranged between 7% and 76.7% of total trees during dry season. Overall, Ait Baha was the most influenced site by inter-annual changes in temperature and rainfall than Ait Melloul and Argana. Ait Baha, may be a selective medium for the selection of resistant genotypes to aridity. Repeatabilities varied in large proportions. This knowledge about the potential diversity of argan, implements in addition to fruit and kernel characters, other morphological criteria likely to map forest of argan. In this way, it might be possible to select the genotypes that show the most interesting characteristics for future strategies for the conservation of this species, to capture genetic diversity existing in argan population and to assure high performance under different environments.

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Table 1: Expectations of Mean Squares and Estimated of Variance Components for the Observed Traits in the Three Localities

Global

Source of variation	DF	Mean square	Expectations of mean squares
Season	2	CM A	$\sigma^2 e + 2\sigma^2 Aal + 60\sigma^2 Al + 180\sigma^2 A$
Locality	2	CM l	$\sigma^2 e + 2\sigma^2 Aal + 60\sigma^2 Al + 6\sigma^2 al + 180\sigma^2 l$
tree / locality	87	CM al	$\sigma^2 e + 2\sigma^2 Aal + 6\sigma^2 al$
Season x locality	4	CM Al	$\sigma^2 e + 2\sigma^2 Aal + 60\sigma^2 Al$
Season x tree / locality	174	CM Aal	$\sigma^2 e + 2\sigma^2 Aal$
Error	270	CM e	$\sigma^2 e$

By Locality

Source of variation	DF	Mean square	Expectations of mean squares
Season	2	CM A	$\sigma^2 e + 2\sigma^2 Aa + 60\sigma^2 A$
Tree	29	CM a	$\sigma^2 e + 2\sigma^2 Aa + 6\sigma^2 a$
Season x tree	58	CM Aa	$\sigma^2 e + 2\sigma^2 Aa$
Error	90	CM e	$\sigma^2 e$

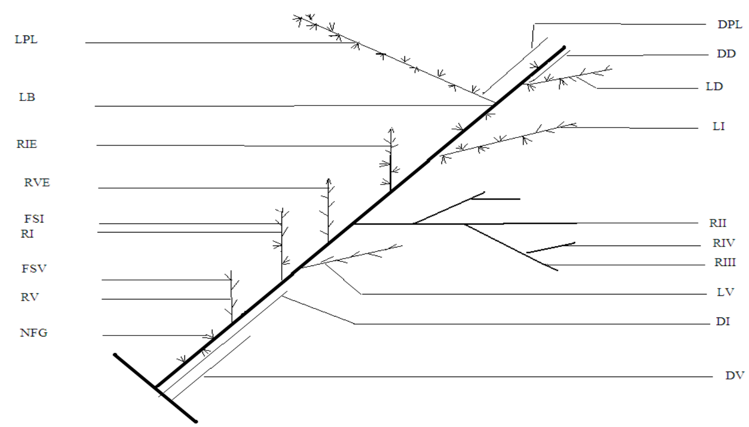


Figure 1: Characters of Branching, Growth in Length and Foliation Observed in the Three Localities

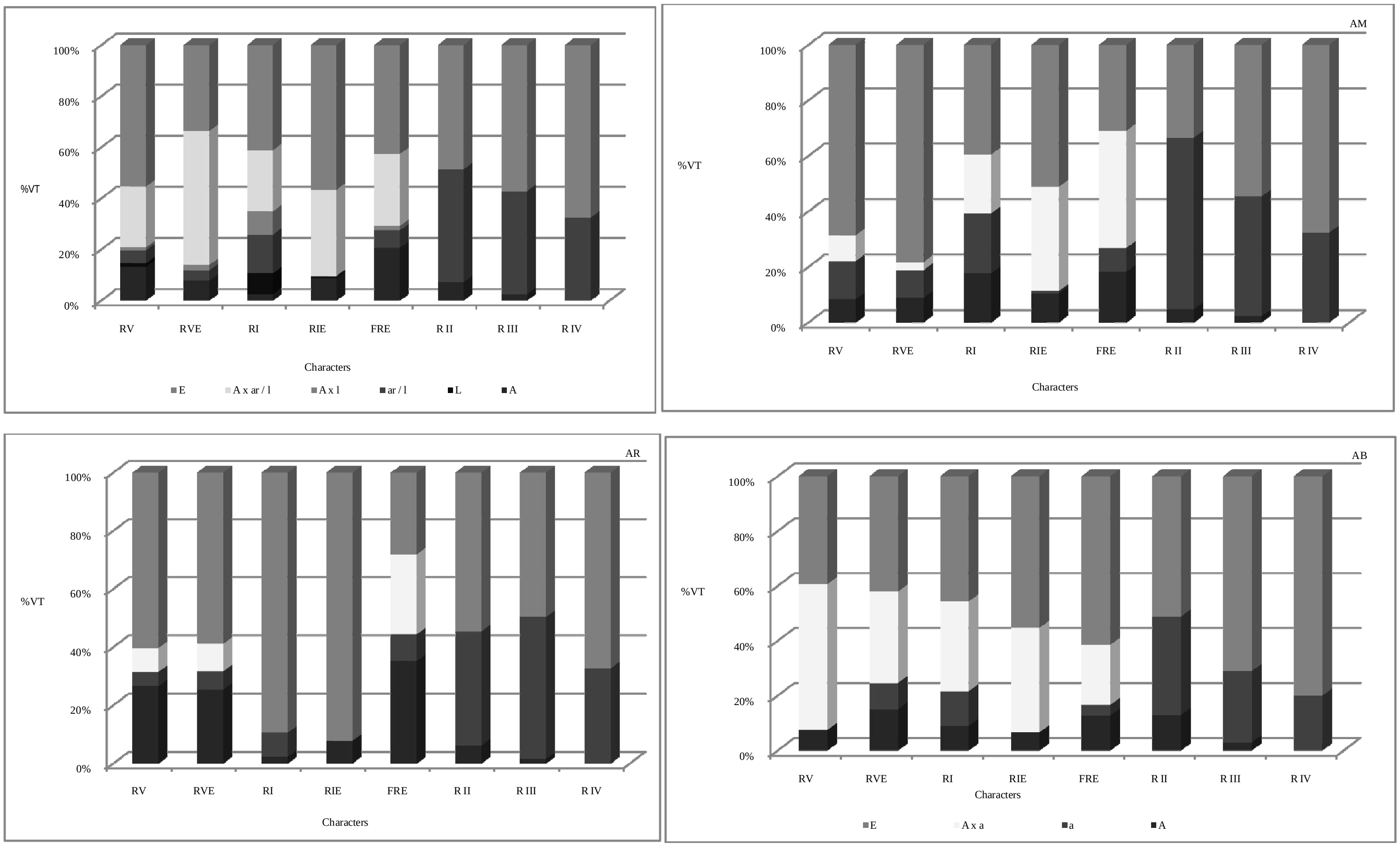


Figure 2a: Percentages of Total Variance for Branching Characters Observed in Ait Melloul, Argana and Ait Baha. A: Season, l: Locality, ar: Tree, E: Error, A xl: Season x Locality Interaction, A x ar / l: Season x Tree / Locality Interaction

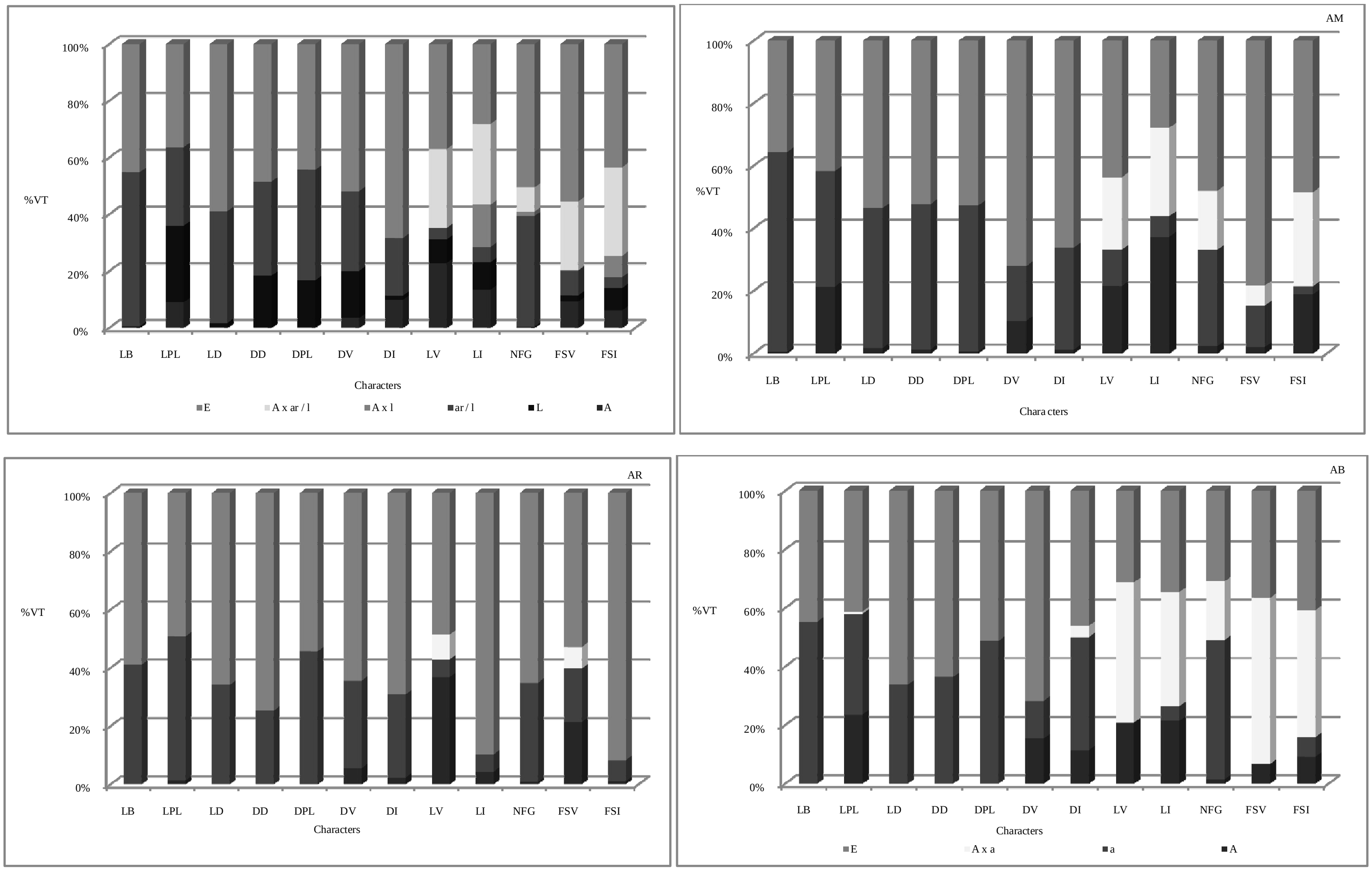
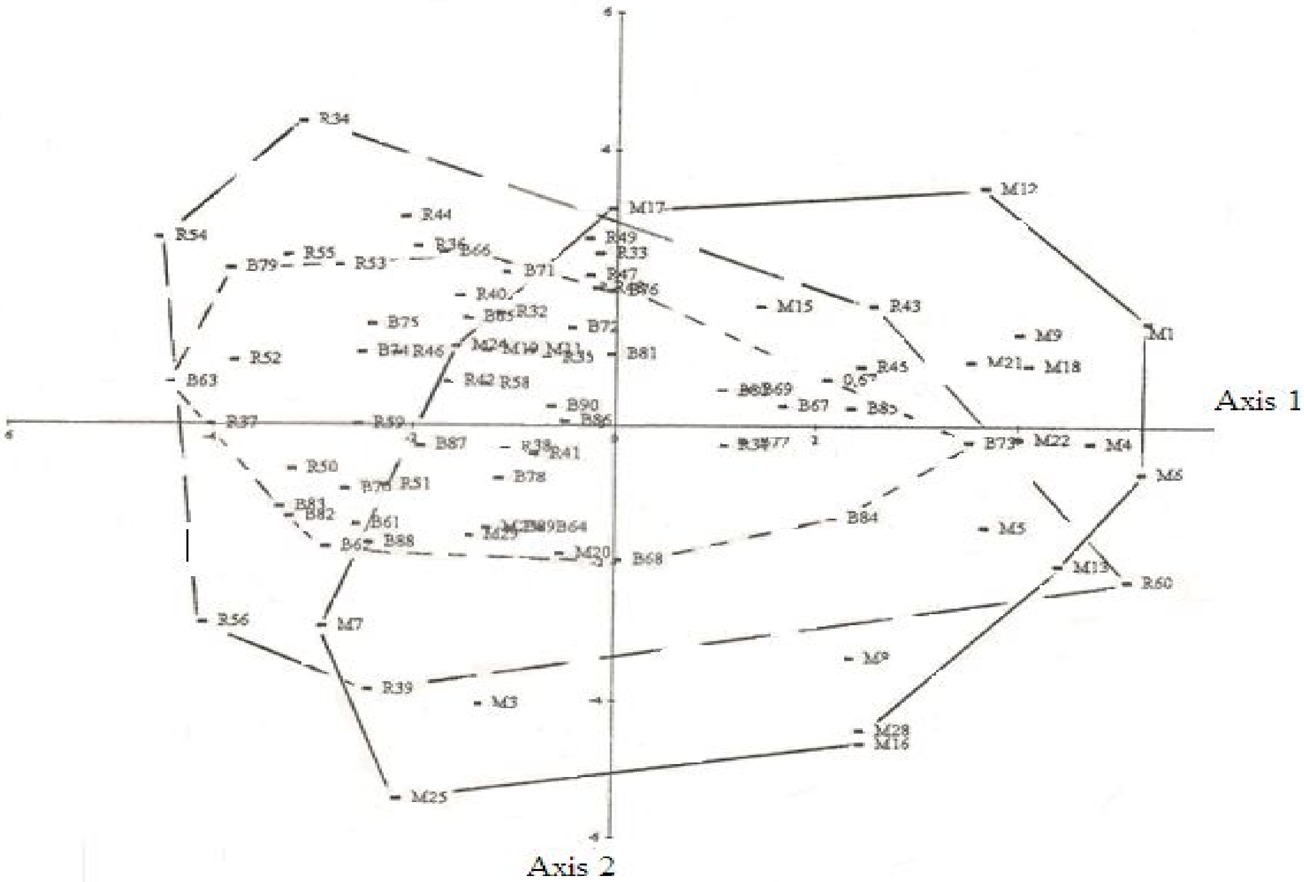


Figure 2b: Percentages of Total Variance for Growth in Length and Foliation Characters Observed in Ait Melloul, Argana and Ait Baha. A: Season, l: Locality, ar: Tree, E: Error, A xl: Season x Locality Interaction, A x ar / l: Season x Tree / Locality Interaction


Axis 1
Axis 2

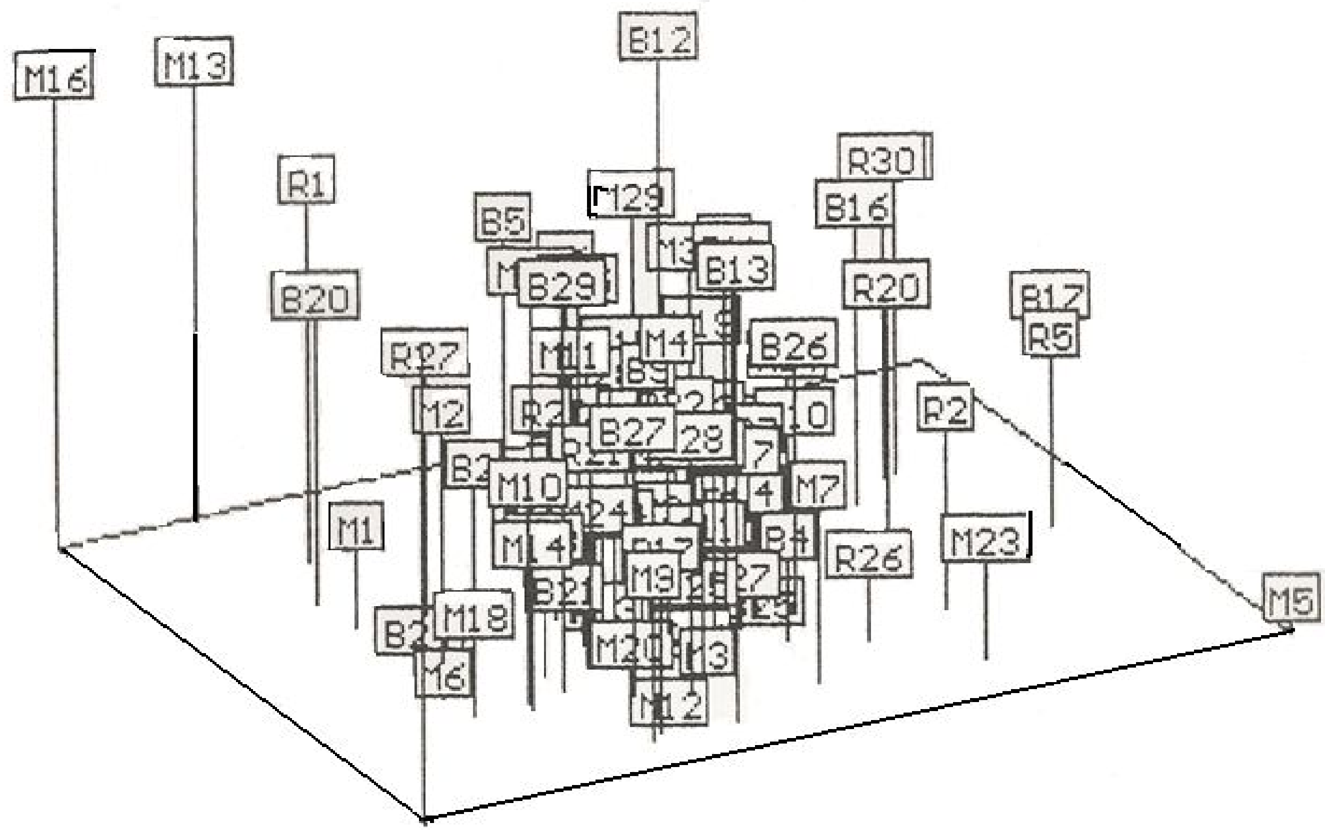


Figure 3: Projection of Individuals in the Plane and the Space Defined by the First Two and Three Principal Components

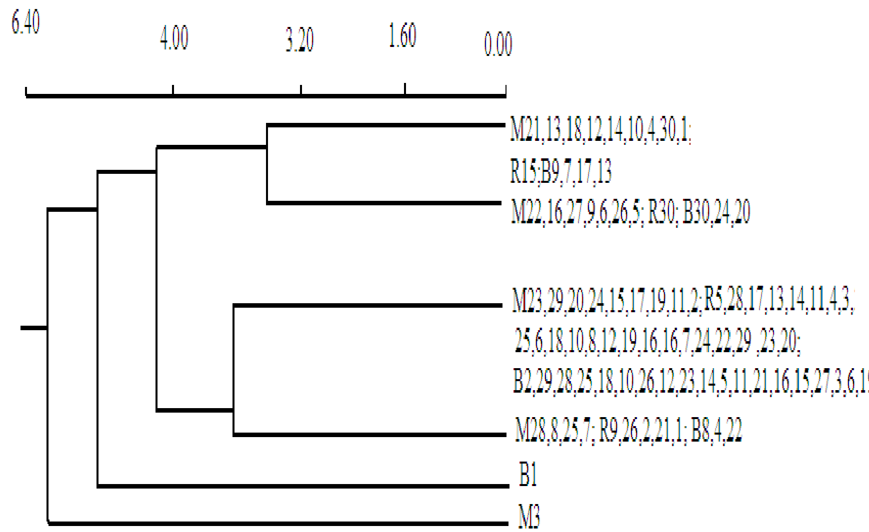


Figure 4: Classification of Individuals From Ait Melloul (AM), Argana (AR) and Ait Baha (AB) Based on Characters of the Branching Growth in Length and Foliation

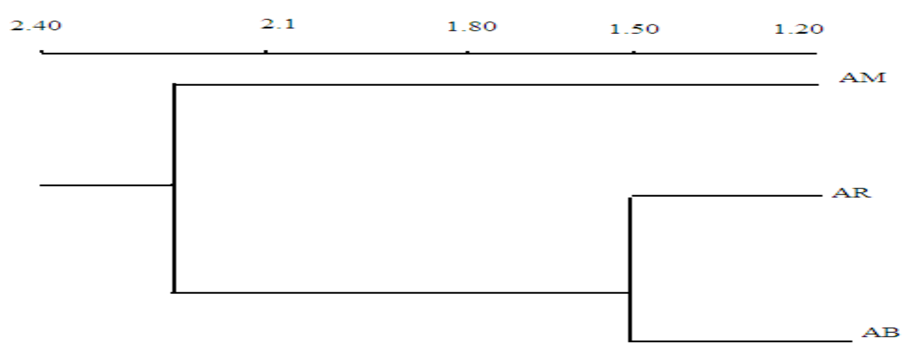


Figure 5: Classification of the Three Sites Ait Melloul (AM) Argana (AR) and Ait Baha Based on Branching, Growth in Length and Foliation Characters

Table 2: ANOVA for Branching, Growth in Length and Foliation Characters Observed in the Three Localities

Source	DF					Mean square					
		RV	RVE	RI	RIE	FRE	R II	R III	R IV	DD	DPL
Season	2	3667.4 **	2230 *	261.4 ns	99.13 **	71.35 **	8389.7 **	663.1 **	0.09 ns	18.01 ns	139.9 ns
Locality	2	651.4 *	291.3 ns	543.1 **	11.24 ns	3.8 ns	535.8 ns	109.2 ns	11.5 ns	3496.1 **	9027.6 **
Tree / locality	87	193.6 *	99.9 **	44.2 **	7.45 ns	2.57 **	1776.6 **	385.5 **	11.5 **	205.5 **	672.7 **
Season x locality	4	248.3 ns	244.7 **	156.02 **	6.77 ns	3.68 ns	231.3 ns	14.34 ns	0.03 ns	54.9 ns	29.05 ns
Season x tree / locality	174	149.2 **	63.8 **	21.9 **	7.31 **	1.81 **	92.92 ns	24.44 ns	0.05 ns	10.3 ns	16.3 ns
Error	270	80.3	48.8	10.12	3.34	0.78	306.8	85.6	3.98	46.9	124.1
Source	DF					Mean square					
		DV	DI	LB	LPL	LD	LV	LI	NFG	FSV	FSI
Season	2	737.9 **	2040.8 **	43.9 ns	2597.2 ns	50.1 ns	1542.3 **	1434.6 **	1956 **	746.3 **	541.1 **
Locality	2	3546.6 ns	456.2 **	1366.3 ns	7112.2 **	285.9 ns	585.9 **	1157.6 **	7296.7 ns	229.5 *	649.7 **
Tree / locality	87	228.1 **	195.8 **	1008.1 **	255.1 **	128.8 **	43.2 *	49.56 **	4671.7 **	65.5 **	41.9 *
Season x locality	4	57.7 ns	36.7 ns	51.5 ns	445.4 **	28.5 ns	19.3 ns	412.2 **	2494.2 *	47.15 ns	181.8 **
Season x tree / locality	174	42.15 ns	58.54 ns	6.6 ns	34.01 ns	7.1 ns	34.3 **	35.79 **	1048 **	43.5 **	34.4 **
Error	270	57.03	76.7	138.2	41.5	29.9	13.7	11.85	782.9	23.2	14.13

NOTE: ns: Not Significant, *: Significant at 5%, **: Significant at 1%

Table 3c: Absolute Maximum (Max), Absolute Minimum (Min), Average (Avg) and Coefficient of Variation (CV) of Foliation Traits Observed in the Three Localities

Character	Season		Ait Melloul				Argana				Ait Baha				Average		
		Max	Min	Avg	CV	Max	Min	Avg	CV	Max	Min	Avg	CV	Max	Min	Moy	CV
	1	180.0	0	61.5	55.7	273.5	3.33	98.6	49.8	169.7	0	61.0	71.1	207.7	1.11	73.7	68.9
NFG	2	142.2	0	52.2	57.6	244.9	10.57	94.5	45.5	193.9	6.45	62.6	67.8	193.7	5.8	69.8	57.0
	3	148.2	15.7	63.9	48.4	200	30.3	87.3	42.2	180	4.9	50.3	69.6	176.1	16.9	67.2	53.4
	Avg	156.8	5.2	59.2	53.9	239.5	14.7	93.5	45.8	181.2	3.8	57.9	69.5	192.5	7.9	70.2	56.4
	1	14.0	0	2.9 b	169.5	0	0	0.01	-	15	0	1.0 c	339.0	9.7	0	1.3	-
FSI	2	32.0	0	7.8 a	127.3	12	0	0.5	448.9	27	0	4.8 a	147.7	23.6	0	4.3	241.3
	3	15.0	0	1.2 b	284.5	10	0	0.3	551.7	16	0	2.5 b	197.9	13.7	0	1.3	344.7
	Avg	20.3	0	4.0 a	193.8	7.3	0	0.3 c	500.3	19.3	0	2.8 b	228.2	16.7	0	2.3	-
	1	23.0	0	3.9	158.5	19	0	1 b	359.4	21	0	4.1 b	160.5	21	0	2.9 b	226.1
FSV	2	33.0	0	5.8	137.8	28	0	6.0 a	104.2	25	0	6.9 a	106.0	28.7	0	6.2 a	127.9
	3	13.0	0	3.55	137.2	12	0	0.8 b	297.4	13	0	3.1 b	149.4	12.7	0	2.5 b	194.6
	Avg	23.0	0	4.4 a	144.4	19.7	0	2.6 b	265.7	19.7	0	4.7 a	138.6	20.8	0	3.9	182.9

NOTE: Means Followed by Letters are Significantly Different at 5%

Table 3a: Absolute Maximum (Max), Absolute Minimum (Min), Average (Avg) and Coefficient of Variation (CV) of Branching Traits Observed in the Three Localities

Character	Season			Ait Melloul				Argana				Ait Baha				Average		
		Max	Min	Avg	CV	Max	Min	Avg	CV	Max	Min	Avg	CV	Max	Min	Avg	CV
	1	71.1	0	7.2 b	185.8	31.3	0	2.1 b	237.8	38.0	0	7.1 b	139.4	46.8	0	5.5 b	187.7
RV	2	53.9	0	10.9 a	110.3	92.1	0	13.1 a	126.5	63.4	0	13.9 a	103.3	69.8	0	12.6 a	113.3
	3	42.5	0	3.7 c	175.2	34.9	0	1.8 b	295.5	50.0	0	7.4 b	129.7	42.5	0	4.3 b	200.2
	Avg	55.8	0	7.3 b	157.1	52.7	0	5.7 b	219.9	50.5	0	9.5 a	124.1	53.0	0	7.5	167.1
	1	63.6	0	2.5 b	363.3	12.5	0	0.4 b	479.1	15.8	0	0.5 b	473.7	30.6	0	1.1 b	438.7
RVE	2	53.8	0	6.5 a	171.4	85.7	0	10.6 a	148.0	30.8	0	3.9 a	191.8	56.8	0	7.0 a	170.4
	3	30.0	0	0.9 b	462.7	34.9	0	1.0 b	465.5	9.6	0	0.2 b	627.1	24.8	0	0.7 b	518.4
	Avg	49.2	0	3.3	332.5	44.4	0	4.0	364.2	18.7	0	1.5	430.9	34.7	0	2.9	375.8
	1	26.7	0	3.5 b	138.4	7.3	0	0.2	539.3	33.5	0	1.1 b	404.3	22.5	0	1.6	360.6
RI	2	31.1	0	5.7 a	116.2	8.9	0	0.7	288.9	33.5	0	4.9 a	128.7	24.5	0	3.8	117.9
	3	9.7	0	1.0 c	206.3	6.1	0	0.2	464.2	21.7	0	4.0 a	150.0	12.5	0	1.8	273.5
	Avg	22.5	0	3.4 a	153.6	7.4	0	0.4 b	430.8	29.6	0	3.3 a	227.6	19.8	0	2.4	270.7
	1	4.6	0	0.3 b	359.8	0.0	0	0 b	-	0.0	0	0 b	-	1.5	0	0.1 b	-
RIE	2	31.1	0	1.9 a	245.6	8.9	0	0.7 a	306.2	28.7	0	1.4 a	325.4	22.9	0	1.3 a	292.4
	3	0.0	0	0 b	-	0.0	0	0 b	-	0.0	0	0 b	-	0.0	0	0 b	-
	Avg	11.9	0	0.7	302.7	3.0	0	0.2	-	9.6	0	0.5	-	8.1	0	0.5	-
	1	4.6	0	0.4 b	224.4	2.8	0	0.1 b	467.2	2.6	0	0.1 b	477.2	3.3	0	0.2 b	389.6
FRE	2	4.6	0	1.0 a	132.0	6.3	0	1.7 a	99.7	15.0	0	1.1 a	215.2	8.6	0	1.3 a	148.9
	3	1.8	0	0.1 b	359.2	4.1	0	0.3 b	312.1	4.8	0	0.1 b	718.2	3.5	0	0.2 b	463.4
	Avg	3.6	0	0.5	238.5	4.4	0	0.7	293.0	7.4	0	0.4	470.4	5.1	0	0.5	334.0
	1	81.8	4	26.6 b	65.3	100.0	0	26.1 b	70.2	63.4	0	26.6 b	61.9	81.7	1.5	26.4 b	65.8
RII	2	100.0	5	33.8 a	61.1	133.3	0	38.8 a	72.6	80.0	3.1	36.8 a	49.3	104.4	2.6	36.5 a	61.0
	3	109.1	5	36 a	61.1	168.3	0	40.2 a	76.2	93.3	2.1	42.3 a	48.5	123.6	2.6	39.5 a	61.9
	Avg	97.0	5	32.1	62.5	133.9	0	35.0	73.0	78.9	2.0	35.2	53.2	103.2	2.2	34.1	62.9
	1	38.1	0	4.7	167.5	54.1	0	4.1	213.8	36.7	0	4.1	176.3	43.0	0	4.3 b	185.9
RIII	2	69.2	0	8.7	173.9	56.8	0	6.6	156.6	40.8	0	7.2	129.5	55.6	0	7.3 a	153.3
	3	74.4	0	9.2	170.9	56.8	0	6.6	156.7	40.8	0	7.9	123.3	57.3	0	7.9 a	150.3
	Avg	60.6	0	7.3	170.8	55.9	0	5.8	175.7	39.5	0	6.4	143.0	52.0	0	6.5	163.2
	1	8.7	0	0.2	511.9	21.6	0	0.5	572.2	0.0	0	0.0	-	10.1	0	0.2	-
RIV	2	8.7	0	0.2	511.9	24.3	0	0.6	584.7	4.4	0	0.1	774.6	12.5	0	0.3	623.7
	3	8.7	0	0.2	511.9	24.3	0	0.6	584.7	4.4	0	0.1	774.6	12.5	0	0.3	623.7
	Avg	8.7	0	0.2	511.9	23.4	0	0.5	580.5	3.0	0	0.1	-	11.7	0	0.3	-

NOTE: Means Followed by Letters are Significantly Different at 5%

Table 3b: Absolute Maximum (Max), Absolute Minimum (Min), Average (Avg) and Coefficient of Variation (CV) of Growth in Length Traits Observed in the Three Localities

Character	Season		Ait Melloul				Argana				Ait Baha				Average		
		Max	Min	Avg	CV	Max	Min	Avg	CV	Max	Min	Avg	CV	Max	Min	Avg	CV
	1	29.2	0.5	6.9	76.7	20.5	1.0	5.9	71.1	23.5	0.8	6.4	72.9	24.4	0.8	6.4	73.8
LD	2	41.2	0.5	9.1	102.1	21.3	0.4	5.9	69.1	25.6	0.8	6.9	81.9	29.7	0.6	7.3	84.4
	3	46.5	0.5	9.2	105.9	21.3	0.4	5.9	69.1	25.6	0.8	6.9	81.9	31.1	0.6	7.3	85.7
	Avg	38.9	0.5	8.4	94.5	21.0	0.6	5.9	70.1	24.9	0.8	6.7	78.9	28.3	0.6	7.0	81.3
	1	38.7	0.2	11.0	86.4	47.0	0	5.2	143.4	31.7	0	5.45	109.9	39.2	0.1	7.2	113.3
DDR	2	49.2	0.2	13.4	86.1	21.0	0	4.6	111.9	24.6	0	5.2	95.5	31.6	0.1	7.7	97.8
	3	49.2	0.2	13.6	84.2	21.0	0	4.6	111.9	24.6	0	5.2	95.5	31.6	0.1	7.8	97.2
	Avg	45.7	0.2	12.7 a	85.6	29.7	0	4.8 b	122.4	26.9	0	5.3 b	100.3	34.1	0.1	7.6	102.8
	1	78.5	1.2	22.9	68.8	44.6	0	12.7	90.6	41.0	0	11.4	94.5	54.7	0.4	15.7	84.6
DPL	2	78.5	1.2	25.6	65.3	54.0	0	14.2	92.9	41.0	0	11.6	86.1	57.8	0.4	17.1	81.4
	3	78.5	1.2	25.8	65.2	54.0	0	14.2	92.9	41.0	0	11.6	85.7	57.8	0.4	17.2	81.2
	Avg	78.5	1.2	24.8 a	66.4	50.9	0	13.7 b	92.1	41.0	0	11.6 b	88.8	56.7	0.4	16.7	82.4
	1	41.5	2.5	9.8	115.6	55.5	17.3	1.2	615.6	33.4	4.0	2.3 b	296.5	43.4	7.9	4.5 b	342.6
DI	2	42.5	4.5	12.2	78.1	34.6	8.5	3.1	248.4	33.4	3.2	7.4 a	120.5	36.8	5.4	7.6 a	149.0
	3	42.5	4.5	12.7	79.6	34.6	10.5	4.1	207.7	33.8	2.8	8.0 a	114.3	36.9	5.9	8.3 a	133.9
	Avg	42.2	3.8	11.6 a	91.1	41.6	12.1	2.8 c	357.2	33.5	3.3	5.9 b	177.1	39.0	6.4	6.7	208.5
	1	37.0	0.8	6.8 b	139.1	50.2	0.5	5.6 b	190.3	27.0	0.5	5.0 b	148.0	38.0	0.6	5.8 b	159.1
DV	2	47.7	1.8	13.2 a	87.8	38.5	1.5	9.7 a	92.0	27.0	2.7	9.7 a	79.6	37.7	2.0	10.9 a	86.5
	3	54.5	4.2	14.3 a	82.1	38.5	1.5	10.5 a	87.5	30.5	2.5	11.6 a	67.3	41.1	2.7	12.1 a	79.0
	Avg	46.4	2.3	11.4	102.9	42.4	1.2	8.6	123.3	28.2	1.9	8.8	98.3	38.9	1.8	9.6	108.2
	1	16.6	1.2	3.2 b	129.5	8.0	0.5	0.9 b	199.3	14.2	1.2	2.7 c	280.1	12.9	0.9	2.3 c	203.0
LV	2	28.0	1.2	9.3 a	78.0	23.0	1.0	5.4 a	101.3	28.2	0.8	8.5 a	114.3	26.4	1.0	7.7 a	97.9
	3	24.2	2.7	4.4 b	134.7	5.7	1.8	0.7 b	205.6	16.5	1.5	4.5 b	148.6	15.4	2.0	3.2 b	163.0
	Avg	22.9	1.7	5.6 a	114.1	12.2	1.1	2.3 b	168.7	19.6	1.2	5.2 a	181.0	18.3	1.3	4.3	154.6
	1	7.5	1.1	2.3 b	108.0	3.0	1.5	0.1 b	455.6	11.3	1.7	0.9 c	140.7	7.3	1.4	1.1 c	234.8
LI	2	29.2	1.8	11.4 a	89.4	7.4	2.5	0.6 a	275.6	28.7	1.5	6.9 a	85.3	21.7	1.9	6.3 a	150.1
	3	26.5	2.8	2.1 b	248.9	4.5	1.2	0.2 b	484.3	16.5	2.5	3.3 b	101.9	15.8	2.2	1.8 b	278.4
	Avg	21.1	1.9	5.3 a	148.7	5.0	1.7	0.3 c	405.2	18.8	1.9	3.7 b	109.3	14.9	1.8	3.1	221.1
	1	100.0	22.0	46.7	37.7	76.0	16	35.3	41.8	68.2	15.0	32.1	36.7	81.4	17.7	38.0	38.7
LB	2	100.0	22.0	49.2	39.5	76.0	16	35.3	41.5	68.2	15.0	32.1	36.7	81.4	17.7	38.8	39.2
	3	100.0	22.0	49.5	39.5	76.0	16	35.3	42.2	68.2	15.0	32.1	36.7	81.4	17.7	38.9	39.5
	Avg	100.0	22.0	48.5	38.9	76.0	16	35.3	41.8	68.2	15.0	32.1	36.7	81.4	17.7	38.5	39.1
	1	36.0	5.0	15.2 b	45.4	27.6	0	8.5	58.2	26.5	0.8	9.9 c	50.9	30.1	1.9	11.2	51.5
LPL	2	46.5	5.0	24.5 a	46.8	28.0	0	9.8	58.9	41.9	0.8	16.7 b	55.6	38.8	1.9	17.0	53.8
	3	64.6	5.0	26.1 a	51.9	28.0	0	9.8	58.9	50.7	0.8	19.0 a	53.0	47.8	1.9	18.3	54.6
	Avg	49.0	5.0	21.9 a	48.0	27.9	0	9.4 c	58.9	39.7	0.8	15.2 b	53.2	38.8	1.9	15.5	53.3

NOTE: Means Followed by Letters are Significantly Different at 5%

Table 4: Frequency of Trees that Produced Green (RV), Green Spiny Branches (RVE), Branches to Indefinite Growth (RI), to Indefinite Growth Acquiring a Spine Shoots (RIE), Branches Spiny (FRE), Grouped Leaves (NFG) and Simple Leaves on the Green and on the Branch to Indefinite Growth in the three Localities

Character	season		Ait Melloul		Argana	Ait Baha			Average
		Number	Frequency	Number	Frequency	Number	Frequency	Number	Frequency
	1	19	63.3%	14	47%	17	57%	16.7	56%
RV	2	28	93.3%	24	80%	27	90%	26.3	88%
	3	21	70%	9	30%	22	73%	17.3	58%
	1	8	26.6%	3	10%	2	7%	4.3	14%
RVE	2	20	66.7%	20	66.7	14	47%	18	60%
	3	3	10%	4	13%	2	7%	3	10%
	1	23	76.7%	3	10%	7	23%	11	37%
RI	2	24	80%	8	27%	23	77%	18.3	61%
	3	9	30%	3	10%	13	43%	8.3	28%
	1	4	13.3%	0	0%	0	0%	1.3	4%
RIE	2	15	50%	7	23%	7	23%	9.7	32%
	3	0	0%	0	0%	0	0%	0	0%
	1	10	33.3%	3	10%	2	7%	5	17%
FRE	2	22	73.3%	21	70%	16	53%	19.7	66%
	3	3	10%	4	13%	2	7%	3	10%
	1	30	100%	30	100%	30	100%	30	100%
NFG	2	30	100%	30	100%	30	100%	30	100%
	3	30	100%	30	100%	30	100%	30	100%
	1	12	40%	1	0.03%	4	13%	5.7	19%
FSI	2	18	60%	3	10%	15	30%	12	40%
	3	6	20%	2	7%	7	23%	5	17%
	1	13	43.3%	5	17%	12	40%	10	33%
FSV	2	19	63.3%	19	63%	21	70%	19.7	66%
	3	15	50%	6	20%	13	43%	11.3	38%

Table 5: Repeatabilities in Percentages of Branching, Growth and Foliation Characters Observed in the Three Localities

Character	RV	RVE	RI	RIE	FRE	R II	R III	R IV	DD	DPL
Global	6.06	9.7	18.8	0.44	8.9	47.8	41.3	32.4	40.9	46.9
Ait Melloul	14.9	10.9	26.2	0.93	10.5	64.8	44.1	32.3	47.1	46.9
Argana	6.7	8.3	8.5	0.0	14.2	41.7	49.6	32.7	25.2	45.7
Ait Baha	0.0	11.3	13.9	0.0	4.4	41.2	26.6	20.0	36.4	48.7
Character	DV	DI	LB	LPL	LD	LV	LI	NFG	FSV	FSI
Global	35.2	22.9	54.7	47.1	40.4	5.8	8.8	39.6	9.9	4.9
Ait Melloul	19.5	33.1	64.2	46.9	45.6	14.8	10.5	31.5	13.5	3.2
Argana	31.8	29.2	41.1	50.1	34.1	9.5	6.2	34.3	23.4	7.3
Ait Baha	15.2	42.5	55.2	45.0	33.6	0.0	6.3	48.2	0.0	7.4

Table 6: Correlation Matrix of Branching, Growth in Length and Foliation Characters Observed for Three Seasons in the Three Localities

Character	DV1	DV2	DV3	DD1	DD2	DD3	DPL1	DPL2	DPL3	LD1	LD2	LD3	LB1	LB2	LB3	LPL1	LPL2	LPL3	NFG1	NFG2	NFG3	RII1	RII2	RII3	RIII1	RIII2	RIII3	RIV1	RIV2	RIV3
DV1	-																													
DV2	0.28	-																												
DV3	0.3	0.77	-																											
DD1	-0.02	0.08	0.06	-																										
DD2	-0.02	0.15	0.12	0.83	-																									
DD3	-0.02	0.16	0.13	0.83	0.99	-																								
DPL1	0.21	0.25	0.19	0.57	0.52	0.52	-																							
DPL2	0.17	0.28	0.22	0.56	0.64	0.64	0.92	-																						
DPL3	0.17	0.28	0.23	0.56	0.64	0.64	0.92	0.99	-																					
LD1	-0.14	0.22	0.32	0.08	0.02	0.02	-0.22	-0.2	-0.2	-																				
LD2	-0.06	0.24	0.29	0.03	0.08	0.07	-0.17	-0.16	-0.16	0.82	-																			
LD3	-0.07	0.25	0.3	0.03	0.08	0.08	-0.17	-0.15	-0.15	0.82	0.99	-																		
LB1	0.26	0.39	0.35	0.47	0.53	0.54	0.76	0.79	0.79	-0.11	-0.05	-0.05	-																	
LB2	0.24	0.39	0.36	0.46	0.61	0.62	0.73	0.79	0.8	-0.1	-0.02	-0.01	0.98	-																
LB3	0.24	0.4	0.36	0.46	0.61	0.62	0.72	0.79	0.79	-0.1	-0.01	0.01	0.98	0.99	-															
LPL1	0.14	0.36	0.37	0.38	0.47	0.49	0.55	0.57	0.58	0.39	0.41	0.45	0.54	0.56	0.56	-														
LPL2	0.16	0.36	0.4	0.33	0.41	0.42	0.36	0.41	0.42	0.28	0.42	0.41	0.39	0.42	0.43	0.76	-													
LPL3	0.16	0.32	0.39	0.31	0.38	0.41	0.32	0.36	0.37	0.21	0.35	0.35	0.39	0.42	0.44	0.71	0.95	-												
NFG1	-0.19	-0.08	-0.12	-0.03	-0.09	-0.09	-0.27	-0.25	-0.25	0.2	0.02	0.02	-0.24	0.27	-0.25	-0.29	-0.35	-0.37	-											
NFG2	-0.27	-0.017	-0.21	-0.2	-0.23	-0.23	-0.39	-0.34	-0.34	0.11	-0.06	-0.06	-0.34	-0.36	-0.35	-0.42	-0.51	-0.52	0.69	-										
NFG3	-0.11	-0.11	-0.17	-0.21	-0.24	-0.25	-0.3	-0.29	-0.29	0.07	-0.03	-0.04	-0.42	-0.41	-0.41	-0.32	-0.38	-0.43	0.53	0.63	-									
RII1	0.22	0.02	-0.02	-0.35	-0.34	-0.35	-0.04	-0.08	-0.09	-0.11	-0.13	-0.13	-0.1	-0.09	-0.1	0.01	-0.11	-0.03	-0.26	-0.18	0.11	-								
RII2	0.14	0.06	0.01	-0.37	-0.43	-0.44	-0.045	-0.11	-0.12	-0.05	-0.13	-0.14	-0.12	-0.15	-0.16	-0.09	-0.01	-0.12	-0.05	-0.01	0.09	0.83	-							
RII3	0.13	0.04	0.03	-0.35	-0.43	-0.44	-0.05	-0.14	-0.14	-0.07	-0.15	-0.15	-0.12	-0.15	-0.16	-0.11	-0.08	-0.09	-0.1	-0.06	0.03	0.81	0.97	-						
RIII1	-0.04	-0.05	-0.03	-0.38	-0.32	-0.32	-0.13	-0.18	-0.18	0.06	0.1	0.08	-0.11	-0.11	-0.11	0.01	0.01	-0.04	-0.19	-0.05	0.06	0.46	0.36	0.36	-					
RIII2	-0.03	-0.08	-0.05	-0.37	-0.37	-0.37	-0.2	-0.21	-0.21	0.06	0.15	0.14	-0.13	-0.13	-0.13	-0.01	0.03	-0.02	-0.2	-0.16	-0.02	0.5	0.51	0.51	0.83	-				
RIII3	-0.01	-0.03	-0.01	-0.37	-0.36	-0.37	-0.07	-0.14	-0.14	0.04	0.12	0.11	-0.06	-0.07	-0.07	0.04	0.08	0.02	-0.2	-0.2	-0.05	0.51	0.51	*0.52*	0.81	0.97	-			
RIV1	-0.05	0.23	0.24	-0.17	-0.06	-0.06	-0.11	-0.04	-0.04	0.01	0.04	0.04	0.1	0.1	0.1	-0.1	-0.03	-0.05	0.03	0.05	-0.08	0.05	0.03	0.01	0.47	0.29	0.28	-		
RIV2	-0.07	0.21	0.21	-0.17	-0.08	-0.08	-0.12	-0.06	-0.06	0.02	0.04	0.04	0.1	0.07	0.07	-0.1	-0.03	-0.05	0.03	0.08	-0.08	0.05	0.04	0.01	0.9	0.31	0.29	0.99	-	
RIV3	-0.07	0.21	0.21	-0.18	-0.07	-0.08	-0.12	-0.06	-0.06	0.02	0.04	0.04	0.1	0.07	0.06	-0.1	-0.03	-0.05	0.03	0.08	-0.08	0.06	0.04	0.01	0.49	0.31	0.29	0.99	1.00	-

NOTE: 1: First Season, 2: Second Season, 3: Third Season

Table 7: Correlations Between Principal Components and the Ten Characters of Branching, Growth in Length and foliation Observed for Three Seasons in the Three Localities

Variables	PC1	PC2	PC3
DV1	0.21	-0.2	0.2
DV2	0.4	-0.34	-0.23
DV3	0.39	-0.36	-0.32
DD1	0.71	0.32	-0.03
DD2	0.8	0.25	-0.07
DD3	0.81	0.25	-0.08
DPL1	0.79	-0.07	0.38
DPL2	0.86	-0.05	0.33
DPL3	0.86	-0.05	0.33
LD1	0.02	-0.13	-0.83
LD2	0.1	-0.21	-0.86
LD3	0.11	-0.22	-0.87
LB1	0.84	-0.19	0.23
LB2	0.86	-0.19	0.19
LB3	0.86	-0.19	0.17
LPL1	0.72	-0.29	-0.28
LPL2	0.64	-0.33	-0.34
LPL3	0.63	-0.29	-0.3
NFG1	-0.32	0.38	-0.2
NFG2	-0.48	0.37	-0.12
NFG3	-0.47	0.25	-0.06
RII1	-0.27	-0.61	0.38
RII2	-0.35	-0.58	0.38
RII3	-0.34	-0.57	0.39
RIII1	-0.31	-0.74	0.01
RIII2	-0.33	-0.77	0.04
RIII3	-0.27	-0.79	0.08
RIV1	-0.07	-0.53	-0.15
RIV2	-0.09	-0.54	-0.15
RIV3	-0.09	-0.54	-0.15
Eigenvalues	8.95	5.05	3.78
Explained percentages (%)	29.8	16.8	12.6
Cumulative percentages (%)	29.8	46.6	59.2

PC1: First Principal Component, PC2: Second Principal Component, PC3: Third Principal Component