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Morphological Variability in Argan Seedlings (Argania Spinosa (L.) Skeels) and Its Implications for Selecting Superior Planting Material in Arid Environments

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Abstract The argan multi-purpose tree, is often described as an endangered species since several physical and anthropogenic factors reduced the density and surface of argan ecosystem. With the aim of helping to select superior planting material for implementation of conservation activities in arid environments, genetic variability for several morphological characters of stem and root was studied. 12 seedlings per family distributed in randomized complete block were grown for 12 months under nursery conditions. Several morphological characters of stem and root were observed at the end of the experiment. Intra-family variability was more important than inter-family variability for all characters. Higher heritabilities were observed (0.54 to 0.59) for length of the smallest root and stem length. We did not observe any differentiation between the three populations for stem and root characters. Seedlings from drier site appear to have taproots longer; root / stem ratio and ratio of fresh mass were also higher. Seedlings of some families invested more in their taproot, a key organ for Argan seedling survival. Argan is characterized by great variability between individuals of the same family 'half-brother' which gives possibility to select high quality planting material for regeneration and that can adapt to drought conditions especially after transplantation.

Keywords *Argania spinosa*, Arid environments, Diversity, Root seedling growth, Stem

1. Introduction

Indigenous fruit trees have the potential to contribute towards food security, nutrition health and income generation (Jamnadass et al., 2009) and mitigate environmental degradation in developing countries (Simbo et al., 2012; Cuni-Shanchez et al., 2011). The Argan tree (*Argania spinosa*) is one of these indigenous fruit, fodder and forest tree endemic to south west of Morocco and arid Mediterranean type area where rainfall occurs in the winter, highly adapted to aridity (Emberger, 1939; Prendergast and Walker, 1992). As is the case of many species, the domestication of this fruit and forest tree can play a prominent role both for the environment preservation, mostly because of encroaching desert threat (Nerd et al., 1994; Simbo et al., 2012; Zahidi, 1997; Zahidi et al., 2013b) and for the overall economy of the region since it is an important resource for wood, oil and fodder (Nouaim et al., 1991). This multi-purpose tree is therefore the foundation for a unique agro-forestry system (De Ponteves et al., 1990). The potential for growth and production capacity of branches and leaves in plants especially at seedling stage represents a necessary step in understanding biology of the species (Ehrenberg, 1989; Laâmouri and Sghaier, 1998). In addition, stem and root growth is specific to each species, reflecting the adaptation of plants to changes in bioclimatic environment (Becker et al., 1983; Gorenflot, 1986; Larsen et al., 1986). In forest species, production of plant able to grow after planting, is crucial for large-scale reforestation and for developing a conservation program of an appropriate level of genetic diversity (Behm et al., 1997; Zahidi and Bani-Aameur, 1998; Zahidi et al., 2013b). Genetic variation is fundamental component, which ensures survival and stability of the forest ecosystems. This variability determines the potential of population to adapt to changing in environmental conditions. Thus genetic characterization of natural forest resources is necessary for better understanding of genetic resources for implementation of conservation activities (Zhang et al., 2004; Zhang et al., 2005; Turna et al., 2006; Xiao et al., 2008). In fact, in three natural populations of argan in south west Morocco a great variation in growth

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and fruits productivity has already been reported for trees in the fields (Zahidi, 1997; Zahidi et al., 2014). We distinguish five morphological types of tree habit. In addition growth, branching and leaves production were higher in humid season than in dry season. In three natural populations of argan in south west Morocco a great variation in argan tree growth has already been reported (Zahidi, 1997; Zahidi et al., 2013a). We distinguish five morphological types of tree habit. In addition, growth, branching and leaves production were higher in humid season than in dry season. The relative contribution of genotype (tree / locality) and tree x environment interaction in the total variance was more pronounced (22.2% to 54.3%) for most traits. Individuals from the driest provenance were most affected by inter-annual climate changes; this site through its arid climate can create an environment for selection of resistant genotypes to drought. Argan in the fied is characterized as a slow-growing tree since shoot length even in humid season reached about 30 cm (Zahidi et al., 2013c). But V.A. mycorrhization increased total shoot length, stem growth and biomass of the plants, when cultivated in controlled conditions (Nouaim and Chaussod, 1994). At the present time, studies on variability of growth in argan seedlings are absent. This study aims to investigate the diversity in Argan seedling growth and estimating genetic parameters at nursery stage in order to select high quality planting material for implementation of conservation activities and artificial regeneration.

2. Materials and Methods

2.1. Plant Material

Kernels are from mature fruits harvested in summer from three geographical origins in south west Morocco, Ait Melloul (AM), Argana (AR) and Ait Baha (AB) (Zahidi, 1997; Bani-Aameur, 2004). Almond kernels from 29 families in each site, with a total of 87 families, are germinated and transplanted according to experimental protocol described previously (Zahidi and Bani-Aameur, 1998a). At the beginning of the experiment, each of 87 families was represented by four transplanted seedlings per block, 20 seedlings within 5 blocks. Due to losses of seedlings (Zahidi and Bani-Aameur, 1998b), we were content to ten families per provenance and only three blocks (12 seedlings per family per geographic origin).

2.2. Methodology

Seedlings from the three provenances were grown for 12 months. At the end of experiment, several characteristics were recorded from each seedling (Figure 1):

+ *Stem growth and branching*

LC: collar length; LT: main stem length (main axis); FS: number of simple leaves on the main stem; FG: number of grouped leaves on the main stem; NE: number of enter-nodes on the main stem; EP: number of spines on the main stem; RS: number of secondary shoots; RSE: number of secondary shoots spiny; RT: number of tertiary shoots; RTE: number of tertiary shoots spiny; LNS: length of the smallest secondary shoot; LYS: medium length of the secondary shoot; LXS: length of the greatest secondary shoot; LNT: length of the smallest tertiary shoot; LYT: medium length of the tertiary shoot; LXT: length of the greatest tertiary shoot; DS: distance to the first secondary shoot from the base of the main stem; DT: distance to the first tertiary shoot from the base of the main stem;

At harvest; the roots were surface-cleaned by quickly rinsing with water. We observed the following characters:

LTf: main stem length at the end of the experiment.

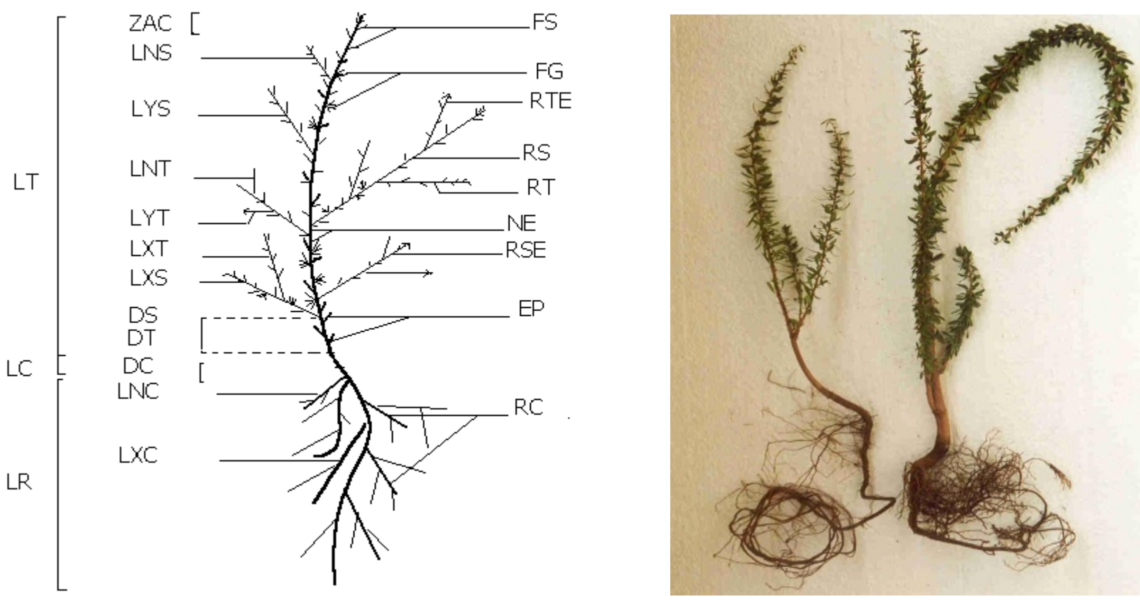


Figure 1. Morphological characters of the stem and root observed in Argan seedlings grown in nursery conditions for 12 months

+ *Root growth and branching*

LR: main root length; RCS: number of secondary roots; LNC: length of the smaller secondary root; LXC: length of the longest secondary root; DC: distance to the first secondary root from the base of the main root;

We deduced the root/shoot ratio (RL: LR/LTf: main root length / main stem length at the end of the experiment).

+ *Biomass production*

Fresh weight and dry weight of the above-ground and below-ground parts of each seedling of each family was recorded. The two parts were oven-dried at 60°C for 96 hours (Heitholt, 1989). Fresh and dry weights were determined using an electronic balance. We deduced fresh and dry weight ratios.

PFT: stem fresh weight; PST: stem dry weight; PFR: root fresh weight; PSR: root dry weight; RPF: fresh weight ratio (root fresh weight / stem fresh weight); RPS: dry weight ratio (root dry weight / stem dry weight).

2.3. Statistical Analyzes

Analysis of variances (ANOVA) with three factors in hierarchical model was adopted. Factor family (seedlings from the same tree) is hierarchical to provenance factor, given that families are not repeated between localities, and within each geographic origin. Factors block and geographic origin are crossed. Comparisons were made with recourse to LSD (method of least significant difference) using a significance level of 95% (Sokal and Rolf, 1995). Variance components were estimated from the appropriate linear functions of mean squares (Lentner and Bishop, 1993) (Table 1).

Table 1. Expectations of mean squares and estimated variance components of the stem and root growth traits of Argan seedlings

Source of variation	DF	Mean square	Expectations of mean squares
Block	2	CM_B	$\sigma^2_e + 4\,\sigma^2_{BFPr} + 40\,\sigma^2_{BPr} + 120\,\sigma^2_B$
Geographic origin	2	CM_{Pr}	$\sigma^2_e + 4\,\sigma^2_{BFPr} + 40\,\sigma^2_{BPr} + 120\,\sigma^2_{Pr}$
Block x geographic origin	4	$CM_{B\,x\,Pr}$	$\sigma^2_e + 4\,\sigma^2_{BFPr} + 40\,\sigma^2_{BPr}$
Family / geographic origin	27	$CM_{F/Pr}$	$\sigma^2_e + 4\,\sigma^2_{BFPr} + 12\,\sigma^2_{FPr}$
Block x family / geographic origin	54	$CM_{B\,x\,F/Pr}$	$\sigma^2_e + 4\,\sigma^2_{BFPr}$
Error (block x family / geographic origin x seedling)	270	CM_e	σ^2_e

DF: degree of freedom.

All factors are considered as random in variance calculation. Estimating the relative contribution of each factor is calculated relative to the total variance (σ^2 T) (Gale et al., 1988; Wheeler et al., 1995; Wu et al., 1997; LeBuhn and Mazer, 1999; Hodge et al., 2002).

$$\sigma^2_T = \sigma^2_B + \sigma^2_{PR} + \sigma^2_{B\,x\,PR} + \sigma^2_{F/PR} + \sigma^2_{B\,x\,F/PR} + \sigma^2_{B\,x\,PL\,x\,F/PR}$$

σ^2_T: total variance; σ^2_B: variance due to block; σ^2_{PR}: variance related to geographical origin; $\sigma^2_{B\,x\,PR}$: variance due to block x geographic origin interaction; $\sigma^2_{F/PR}$: variance due to family / geographic origin (inter-family variance); $\sigma^2_{B\,x\,F/PR}$: variance due to block x family / geographic origin interaction; $\sigma^2_{B\,x\,PL\,x\,F/PR}$: intra-family variance: genetic variance due to differences between seedlings of the same family (error).

In heritability estimate, the fact that seedlings of each family are from kernels collected separately in each of the three sites and families are not repeated between provenances and at the same geographical origin. Variance component associated to family factor is confounded with genetic variation between provenances. Narrow sense heritability is calculated using the following model (Gale et al., 1988; Corneluis et al., 1996; Wheeler et al., 1995; Ward, 2001):

$$h^2 = 4\,\sigma^2_{F/PR} / (\sigma^2_{F/PR} + \sigma^2_{B\,x\,F/PR} + \sigma^2_{B\,x\,PL\,x\,F/PR})$$

$\sigma^2_{F/PR}$: expresses inter-family variance (variance due to family / geographic origin), $\sigma^2_{B\,x\,F/PR}$: denotes variance related to block x family / geographic origin interaction, $\sigma^2_{B\,x\,PL\,x\,F/PR}$: means intra-family variance (variance due to differences among seedlings within the same family). Factorial discriminate Analysis (AFD) was performed on averages of each family in order to examine the simultaneous contribution of all parameters studied in discriminating families and provenances (Bernstein and al., 1988). Dendogram was built using clustering method UPGMA "pair-group method unweighetd arithmetic average". Statistical treatments were performed using Statitcf, Statistix software and Ntsys version 1.40 (Rolf, 1988).

3. Results

3.1. Variability Characterization

3.1.1. Block Effect

+ *Stem, root growth and branching*

Block factor was significant for most characters of the root and stem growth and branching (Table 2).

+ *Biomass production*

Block effect was highly significant for stem (PST) and root (PSR) dry weight, ratio of fresh (RPF) and dry weight (RPS). It was not significant for stem (PFT) and root (PFR) fresh weight.

3.1.2. Geographic Origin Effect

+ *Stem growth and branching*

Geographic origin was not significant for all traits (Table 2). Block x geographic origin interaction was not significant for all characters except length of the greatest secondary branch (LXS).

+ *Root growth and branching*

Block x geographic origin interaction was significant for LR and LNC, but not significant for the other traits (Table 2). Geographic origin factor was highly significant for LR and RL, but not significant for the remaining characters. Ait Baha population showed longest roots and higher ratio of lengths than Argana and Ait Melloul populations. Thus, main root lengths were between 10.7 to 138.4 cm in Ait Baha, 20.5 to 114.4 cm in Argana and between 20.2 and 132.4 cm in Ait Melloul. Ratio of length (RL) also varied in the same way in the three geographical origins. There were between (6.13 to 0.7) in Ait Baha, (3.25 to 0.48) in Argana and (6.35 to 0.45) in Ait Melloul (Table 3).

+ *Biomass production*

Block x geographic origin interaction was significant only for root fresh weight. Geographic origin factor was not significant for all traits except fresh weight ratio (RPF) (Table 2). Seedlings in Ait Baha had the highest fresh weight ratio (0.51 and 1.91) whereas they had the lowest fresh weight ratio in Ait Melloul (1.23 to 0.51) and Argana (1.18 to 0.45) (Table 3).

3.1.3. Family / Geographic Origin

+ *Stem growth and branching*

Block x family / geographic origin interaction was significant for all traits except number of tertiary shoots. Factor family / geographic origin was significant for most characters of the stem (Table 2). Highest variability was observed among families according to variation intervals of maximum, minimum, average and coefficient of variation (Table 3). Thus, there were two classes of genotypes First class consisting genotypes such as, family (1) of Ait Melloul, families (3 and 7) from Argana, and family (7) of Ait Baha whose stems are longer, with a high number of simple, grouped leaves (Table 4a). In this first class, for the branched seedlings, most shoots are second order. Tertiary branching is very low. In addition, secondary shoots length was important as was the case of families (1) from Ait Melloul, (3) of Argana and family (5) of Ait Baha. Lengths of the greatest shoots were respectively 32.5, 44.3 and 42.1 centimeters. These lengths constitute 48%, 69.4% and 58.1% (LXS x 100 / LTF) of the main stem. Second class includes genotypes from mother-trees such as family (4) from Ait Melloul, family (8) from Argana and family (8) from Ait Baha whose stems are relatively short, with a smaller number of simple and grouped leaves. Branching is very low, when it exists, it is mainly second order. The lateral shoots length was also low.

+ *Root growth and branching*

Block x family / geographic origin interaction was highly significant for all traits of the below-ground part. Family / geographic origin was significant for LR, RL, RCS and LRCS (Table 2). It was not significant for the remaining characters. Large variability was also found between families (Table 3). Root length was between 10.7 and 138.4 cm, root / shoot length ratio was between 0.45 and 6.35, number of secondary roots varied from 4 to 56. For these characters, two categories of genotypes are also distinguished (Table 4b). The first category consists mother-tree genotypes such as families (6) from Ait Melloul, (6) from Argana, and (2) of Ait Baha whose main root was longer, with considerable number of secondary roots, and whose ratio lengths are higher. If the family (1) of Ait Melloul, and family (7) Argana had relatively shorter roots (average about 45.9 and 52.14 cm), they instead exhibit high number of secondary roots about (18.6 and 24.3 units). Second group of genotypes contains family (3) from Ait Melloul, family (8) from Argana, and family (8) of Ait Baha whose main roots remained shorter, with small number of secondary roots and whose ratio lengths are among the lowest except for family (8) of Ait Baha.

+ *Biomass production*

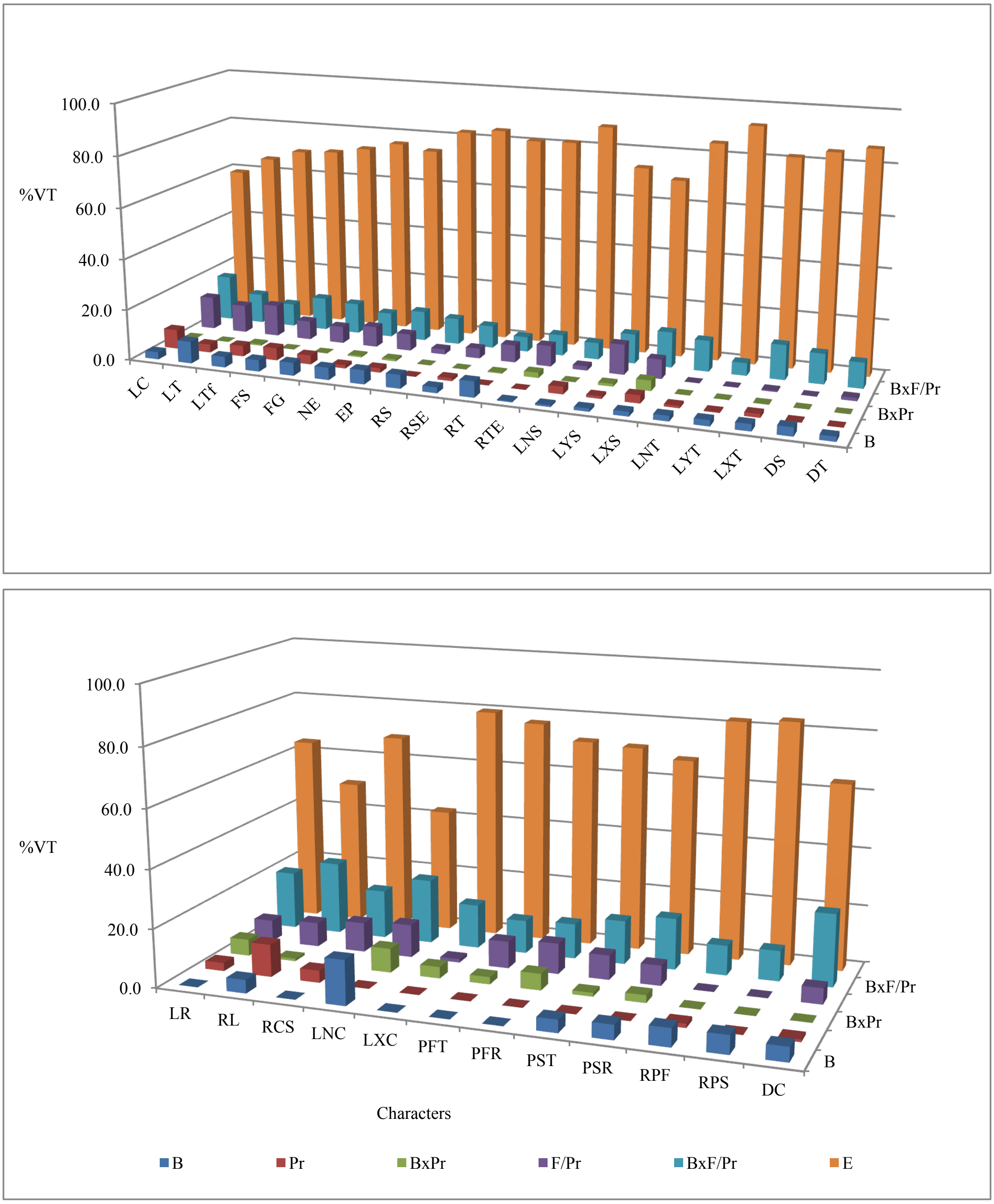
Block x family / geographic origin interaction was significant for fresh and dry weight of the stem and the root and their ratio. Family / geographic origin was significant for PFT, PFR, PST and PSR (Table 2). It was not significant for RPF and RPS. For these traits, there was high level of variation between families (Table 3). We distinguish first class of genotypes consisting families such as (1) from Ait Melloul, family (7) from Argana, and family (7) of Ait Baha, whose fresh and dry weights of the stem and the root are most important. Second class of genotypes consisting families such as (3 and 6) from Ait Melloul, (8) from Argana, and (8) of Ait Baha, whose fresh and dry weights of the stem and the root are lower (Table 4b).

3.2. Variance Components

Relative contribution related to block, geographic origin and block x geographic origin interaction in the total variance was low (0% and 16.2%) for all stem and root traits (Figure 2). The percentage of variance related to block x family / geographic origin interaction in total variance was low and between 5.1% and 6.6% for the tertiary shoot length and number of tertiary shoot. It was relatively high (8.9% and 25.5%) for the other characters. Great intra-family variability was observed for all traits, since the contribution of variance related to block x seedling x family / geographic origin interaction (intra-family variance related to differences between seedlings of the same family) in the total variance was higher (45.1% and 93.5%). The percentage of variance associated with family / geographic origin (mother-tree genotype which means the inter-family variance) in the total variance was variable and ranged between 0% and 13.1% for all characters. Heritabilities varied in large proportions. The lowest values (0.0 to 0.08) were recorded for RS, LNS, LNT, LYT, LXT, DS, DT, LXC, fresh and dry weight ratios (Table 5). For the other characters, heritabilities in narrow sense were between 0.16 for number of secondary shoot and 0.59 for length of the smallest secondary root.

3.3. Diversity Analysis

Correlation for the stem and the root growth and branching was very marked (Table 6). Stem growth traits such as LT, FS, FG, NE and EP are highly correlated (0.91 and 0.99). For the remaining characters of the stem, correlation was ranged from 0.51 to 0.85. Root characters are not correlated. Fresh and dry weights of the stem and the root are highly correlated (0.84 to 0.96).



B: block; Pr: geographic origin, B x Pr: geographic origin x block interaction, F / Pr: family / geographic origin (mother-tree genotype: inter-family variance); BXF / Pr: block x family / geographic origin interaction, E (block x family / geographic origin x seedling interaction: intra-family variance).

Figure 2. Percentages of variance components in the total variance (VT) for the stem and root characters in Argan seedlings grown in nursery conditions

Table 2. Analysis of variance of the stem and root growth and branching traits of Argan seedlings grown for 12 months

Source of variation	DF	Mean square																		
		LC	LT	LTf	FS	FG	NE	EP	RS	RSE	RT	RTE	LNS	LYS	LXS	LNT	LYT	LXT	DS	DT
Block	2	3,7 *	1794,9**	1176,2 **	5273,7 **	5146,4 **	4635,2 **	5763,6 **	76,5**	11,7 *	7,5 **	1,5 ns	24,6 ns	98,4 ns	499,3 **	2,6 ns	5,5 *	22,1 *	381,8 *	70,9 ns
Geographic origin	2	8,5 ns	750,9 ns	1175,9 ns	5638,1 ns	3774,4 ns	1897,2 ns	2530,2 ns	8,3 ns	7,2 ns	0,01 ns	0,8 ns	66,8 ns	90,2 ns	663,6 ns	1,4 ns	1,9 ns	14,9 ns	92,9 ns	13,4 ns
Block x geographic origin	4	0,8 ns	139,4 ns	238,4 ns	754,1 ns	594,8 ns	890,9 ns	1069,7 ns	11,3 ns	2,4 ns	1,01 ns	1,2 ns	10,9 ns	51,8 ns	287,3 *	0,5 ns	1,3 ns	6,7 ns	69,8 ns	11,5 ns
Family / geographic origin	27	2,4 **	388,1 **	471 **	1758,5 *	1481,1*	1367,1 *	1417,4 *	14,8 ns	5,7 ns	1,6 *	1,3 *	21,7 ns	83,7 **	216,8 *	0,9 ns	1,6 ns	6,8 ns	69,1 ns	37,7 ns
Block x family / geographic origin	54	1,1 **	179,1 **	195,8 **	1022,6 **	897,8 **	741,9 **	857,8 **	12,4**	4,1 **	0,9 ns	0,7 **	18,5 *	38,3 **	125,6 **	1,1 **	1,7 *	6,5 **	102,1 **	33,8 **
Block x seedling / Family / geographic origin	270	0,5	104,8	129,2	592,5	541,9	494,3	526,7	8,3	2,9	0,7	0,5	14,3	23,5	69,8	0,7	1,4	3,9	65,4	23,1

Source of variation	DF	Mean square											
		LR	RL	RCS	LNC	LXC	PFT	PFR	PST	PSR	RPF	RPS	DC
Block	2	61,8 ns	4,4 * *	71,7 ns	59,3 * *	27,5 ns	3,1 ns	17,4 ns	32,9 * *	27,3 * *	0,2 * *	0,2 * *	214,2 * *
Geographic origin	2	2511,5 * *	9,1 * *	384,2 ns	0,6 ns	220,2 ns	0,4 ns	3,2 ns	0,2 ns	0,8 ns	0,06 *	0,02 ns	62,5 ns
Block x geographic origin	4	1319,6 *	1,1 ns	93,7 ns	11,9 * *	269,7 ns	21,3 ns	22,2 *	8,5 ns	7,9 ns	0,02 ns	0,02 ns	30,4 ns
Family / geographic origin	27	829,4 *	1,5 *	149,4 * *	6,9 * *	140,4 ns	22,5 * *	15,8 * *	10,8 *	7,2 *	0,02 ns	0,03 ns	71,4 ns
Block x family / geographic origin	54	513,3 * *	0,9 * *	78,5 * *	3,4 * *	127,4 **	11,8 * *	7,7 * *	6,1 * *	4,5 * *	0,03 * *	0,03 * *	50,9 * *
Block x seedling x Family / geographic origin	270	228,9	0,3	39,6	1,1	72,3	7,4	4,6	3,3	2,2	0,02	0,02	19,9

DF: degree of freedom, ns: Not significant, *: Significant at 5%, **: Significant at 1%.

Table 3. Variation interval of the absolute maximum, absolute minimum, average and coefficients of variation of the stem and the root characters in argan seedlings grown for 12 months in nursery conditions

Characters	LC		LT		LTf		FS		FG		NE		EP		RS		LYS		LXS		RT		RTE	
	Interval	CV	Interval	CV	Interval	CV	Interval	CV	Interval	CV	Interval	CV	Interval	CV	Interval	CV	Interval	CV	Interval	CV	Interval	CV	Interval	CV
Average	3,58-1,72	17,62	44,31-18,6	14,64	47,5-20,0	15,1	84,94-31,98	16,61	74,4-27,5	17,3	84,0-39,3	13,44	78,5-34,7	14,85	4,63-0,93	33,91	9,0-0,0	65,1	21,5-3,3	37,11	1,2-0,0	118,0	1,17 - 0	144,7
Absolute maximum	**6,50**-2,70	21,4	**69,3**-34,5	16,45	**72,3**-41,8	13,1	**162,0**-76,0	16,97	**152,0**-68	17,8	**160,0**-72	18,58	**158,0**-70	18,88	**20,0**-2,0	39,21	**22,6**-1,8	44,8	**44,3**-11,2	27,9	**9,0** -0,14	102,3	**9 -** 0	144,9
Absolute minimum	2,00-**0,50**	29,09	25,2-**6,50**	35,67	33,5-**6,5**	37,9	56,00-**4,00**	60,44	50,0-**0,0**	86,8	53,0-**14,0**	39,04	50,0-**4,0**	59,98	0,0-**0,0**	-	0	-	0	-	0	-	0	-
CV	51,3-20,9	21,8	46,3-16,1	26,45	49,3-19,2	25,9	71,71-1795	33,1	70,7-19,8	30,3	54,1-16,9	27,5	64,2-17,1	29,5	149,1-64,7	23,32	280,9-0,0	40,1	155,6-54	29,57	426,8-0,0	56,6	452 - 0,0	97,4

Characters	LR		RL		RCS		LNC		PFT		PFR		PST		PSR	
	Interval	CV	Interval	CV	Interval	CV	Interval	CV	Interval	CV	Interval	CV	Interval	CV	Interval	CV
Average	72,68 - 41,77	14.23	2,47 - 1,10	22.44	25,1 - 11,9	17.4	5,61 - 2,3	17.4	8,72 - 3,4	17.9	7,25 - 2,76	18.7	4,9 - 1,91	20.18	4,5 - 1,63	20.51
Absolute maximum	**138,4** - 62,8	22.97	**6,35** - 1,71	42.97	**56** - 23	22.5	**12,3** - 3,2	22.5	**19,7** - 6,2	27.7	**16,3** - 4,92	29.8	**13,87** - 3,38	28.34	**14,3** - 2,82	32.5
Absolute minimum	37,30 - **10,70**	19.57	1,21 - **0,45**	24.58	17,0 - **4,00**	31.2	2,4 - **1,17**	31.2	4,83 - **0,7**	45.6	3,83 - **0,84**	39.2	2,68 - **0,45**	47.53	2,47 - **0,32**	47.1
CV	41,81 - 20,89	20.87	81,67 - 17,7	41.1	75,3 - 21,8	29.2	69,6 - 22,8	29.2	59,2 - 24,1	29.2	61,1 - 19,4	26.3	70,62 - 31,29	23.52	72,28 - 26,54	27.3

Discriminate factor analysis shows that 100% of the total variance could be explained using the two canonical components (Table 7). First CP1, explaining about 62.2% of variation, was linked to variables related to tertiary branching (RT, LNT, LYT, LXT, DT), biomass production (PFT) and growth in length of the lateral roots (LNC, LXC and DC). Second CP2 that was responsible for 37.8% of variation was linked to the stem growth characters (LT, LTf, FS, FG, NE, NP, LNS, LXS) secondary branching (RS and RSE), to biomass production (PFR, RPF, RPS and PSR) and to root growth (LR, RL). The ordering of families revealed that genotypes are not grouped according to their population since respectively 50% from Ait Melloul, 60% from Argana and 30% of families from Ait Baha were among individuals with developed and branched seedlings, with more simple and grouped leaves and with longer main and lateral roots (Figure 3). If we do not consider the geographical origin, polygon of Ait Melloul covers about 60% (18/30), Argana 70% (21/30), Ait Baha 56.7% (17/30) of the total families. So there was no clear separation between families on the basis of growth and branching characters of the stem and the root of seedlings grown in nursery for 12 months. In addition, Mahalanobis distances are very low especially between Argana and Ait Melloul, and between Ait Melloul and Ait Baha (Table 8). No clear separation between individuals for morphological characters but there is instead a considerable heterogeneity between seedlings within each family. This heterogeneity is more pronounced especially in Argana and Ait Baha characterized by strong inter-annual climate variability.

The dendrogram generated based on all morphological traits, showed a similar pattern. Two groups are distinguished in a Euclidean distance of 1.35. The first group consists of three families (8, 4 and 1) all originate from Ait Baha (Figure 4). These families are characterized by dwarf seedlings, with a low number of single and grouped leaves, branching is mostly third degree, with longer principal roots but with a low number of secondary roots and with higher length ratio (RL). In these families, there has been development of the root instead of the stem. Second group containing remaining families, is divided into two classes in a Euclidean distance of 0.78. The first class contains 18/30 (60%) of families with 4/18 (22.2%) originate from Ait Melloul, 8/18 (44.4%) from Argana and 6/18 (33.3%) are originated of Ait Baha. The second group containing 9 families with 6/9 (66.7%) are from Ait Melloul, 2/9 (22.2%) from Argana and 1/9 (11.1%) from Ait Baha. So, families were not grouped according to belonging to the geographical origin, since the two major groups include both families from Ait Melloul, Argana and Ait Baha. Differentiation between the three populations is not established. Sites classification shows two groups at a Euclidean distance about 2.05 (Figure 5). A first group consists Ait Baha and a second group containing Ait Meloul and Argana. This classification is not the result of geographical isolation. Argana characterized by cold winter, and Ait Melloul with mild temperatures are generally not differentiated from Ait Baha known for its drought summer.

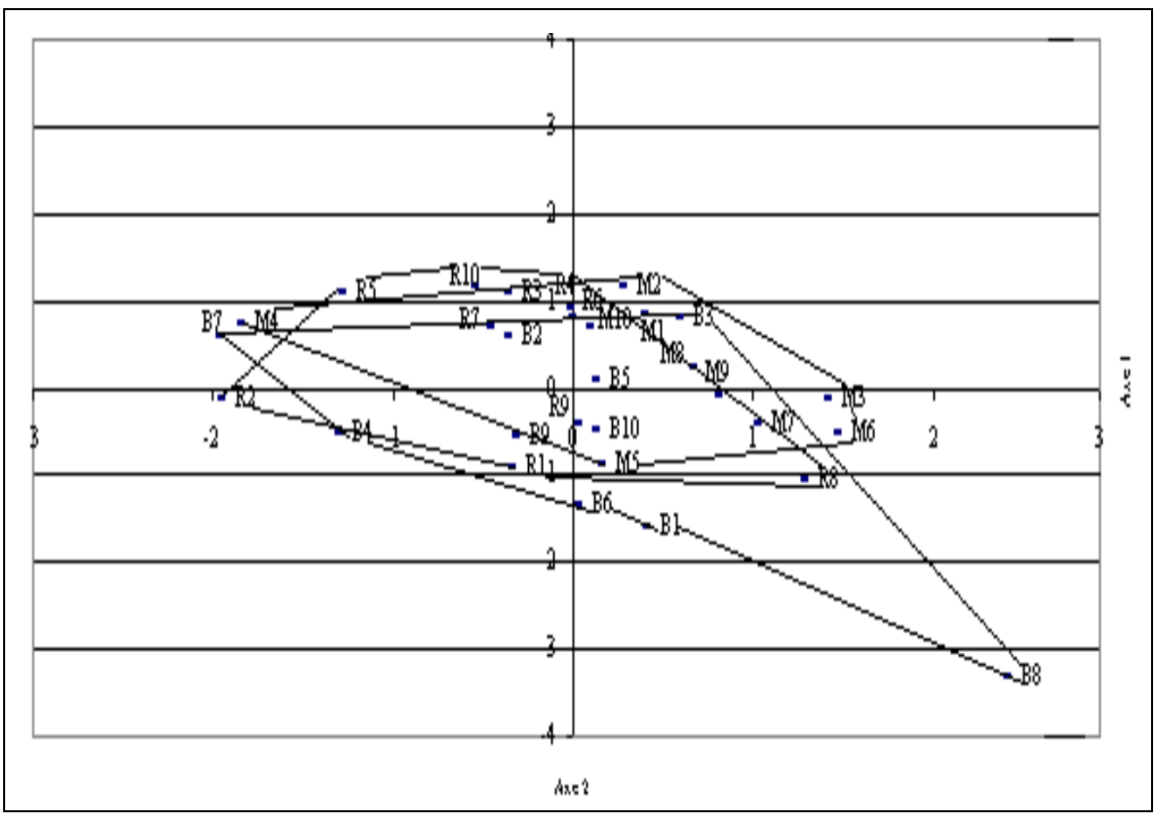


Figure 3. Representation of families from Ait Melloul (M), Argana (R) and Ait Baha (B) in the plane defined by the first two canonical components

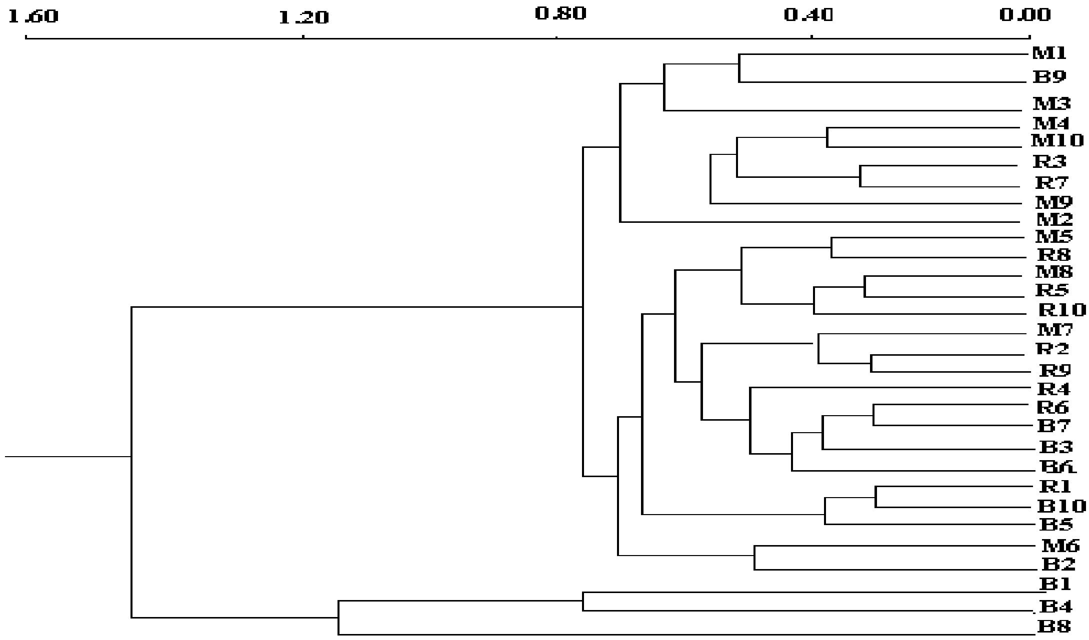


Figure 4. Cluster analysis classification of families based on growth and branching characters of the stem and root in Argan seedlings at nursery stage

Table 4a. Range of variation compared to average of three geographic origins, family number for the stem traits in Argan seedlings

characters	Range of variation	Ait Melloul	Argana	Ait Baha	average of three geographic origins
	> 2,37	1,2,3*,5,6,7,9 , 10	3,6,7 , 9*	1*,4 , 5	
LC	< 2,37	4 , 8*	1,2,4,5,8* , 10	2,3,6,7,8*,9 , 10	2,37 cm
	> 34,7	1,2*,3,8,9 , 10	3*,4,5,6,7 , 10	2,3,5,7 , 9*	
LT	< 34,7	4,5*,6,, 7	1,2,8* , 9	1,4,6,8*,10	34,7 cm
	> 37,7	1,2*,3,8,9 , 10	2,3*,4,5,6,7 , 10	2,3,7* , 9	
LTf	< 37,7	4*,5,6 , 7	1,8* , 9	1,4,5,6,8* , 10	37,7 cm
FS	< 67,8	4*,5,6 , 7	1 , 8*	1,4,5,6,8* , 10	67,8
FG	< 58,6	4,5*,6 , 7	1 , 8*	1,4,5,6,8* , 10	58,6
	> 69,7	1*,2,3,4,8,9 , 10	2,3,4,5,6,7* , 10	2,3,5,7 , 9*	
NE	< 69,7	5*,6 , 7	1,8* , 9	1,4,6,8* , 10	69,7
	> 2,8	1,2,5,7,8*,9 , 10	1*,2,3,7,9 , 10	1*	
RS	< 2,8	3,4 , 6	4,5,6 , 8*	2,3,4,5,6,7*,8,9 , 10	2,8
	> 3,52	1*,7 , 9	1,2,3*,9 , 10	1*,2,4,5,6 , 10	
LYS	< 3,52	2,3,4,5*,6,8 , 10	4,5,6,7 , 8*	3,7,8 , 9*	3,52 cm
	> 10,6	1*,6,7 , 9	1,2,3*,7,9 , 10	1,2,4*,5,9 , 10	
LXS	< 10,6	2*,3,4,5,8 , 10	4,5,6 , 8*	3,6*,7 , 8	10,6 cm
	> 0,26	4 , 5*	1,2,7 , 10	1*,5,7 , 8	
RT	< 0,26	1*,2,3,6,7,8,9 , 10	3*,4,5,6,8 , 9	2,3,4,6,9 , 10	0,26
	> 0,19	4,5*	1,2,3,5* , 10	4*,7 , 8	
RTE	< 0,19	1,2*,3,6,7,8,9 , 10	4*,6,7,8 , 9	1,2*,3,5,6,9 , 10	0,19

*: family number with greatest or smallest value.

Table 4b. Range of variation compared to average of three geographic origins, family number for the root characters in Argan seedlings

Character	Range of variation	Ait Melloul	Argana	Ait Baha	average of three geographic origins
	> 54,01	6* , 8	2,3,4,5,6 , 10*	1,2*,3,4,6 , 7	
LR	< 54,01	1,2,3,4*,5,7,9 , 10	1,7,8* , 9	5,8*,9 , 10	54,01 cm
	> 1,57	5 , 6*	1*,5 , 6	1,2,4,5,6,7,8* , 10	
RL	< 1,57	1*,2,3,4,7,8,9 , 10	2,3,4,7*,8,9 , 10	3 , 9*	1,57
	> 18,5	1,2,4,5,6,7,9* , 10	2,3,5,6,7* , 10	2*,7 , 9	
RCS	< 18,5	3* , 8	1,4,8* , 9	1,3,4,5,6,8* , 10	18,5
	> 3,1	4,5,6* , 9	2*,3,4,5,6,7 , 10	2*,7 , 10	
LNC	< 3,1	1,2,3*,7,8 , 10	1,8* , 9	1,3,4,5,6*,8 , 10	3,1 cm
	> 6,4	1*,2,4,8,9 , 10	1,2,3,5,7* , 10	1,2,3,4,7 , 9*	
PFT	< 6,4	3,5,6* , 7	4,6,8* , 9	5,6,8* , 10	6,4 gramme
	> 5,2	1*,8,9 , 10	2,3,4,7* , 10	1,2,3,4,7 , 9*	
PFR	< 5,2	2,3,4,5,6* , 7	1,5,6,8* , 9	5,6,8* , 10	5,2 gramme
	> 3,9	1*,2,4,8 , 9	2,3,4,5,7*,9 , 10	1,2*,3,4,7 , 9	
PST	< 3,9	3,5,6*,7 , 10	1,6 , 8*	5,6,8* , 10	3,9 gramme
	> 3,18	1*,2,8 , 9	2,3,4,7*,9 , 10	1,2*,3,4,7 , 9	
PSR	< 3,18	3,4,5,6*,7 , 10	1,5,6 , 8*	5,6,8* , 10	3,18 gramme

*: family number with greatest or smallest value.

4. Discussion

The analysis of variance revealed a strong morphological variation in argan seedlings for the stem, root characters and biomass production. A wide range of variation was observed between geographical origins in root length, root / stem ratio and fresh weight ratio characteristics. In general, seedlings from drier site, seems to have characteristics often related to drought tolerance than those from wetter provenances. Thus, from drier site Ait Baha 30% and over 60% of families have respectively main roots 2.5 times and 1.5 times longer than the main stems. Seedlings from Ait Melloul, only 10% of families have main roots 2.5 times longer and 30% of them with roots 1.5 times longer than the main stems but with high number of lateral roots. While seedlings from wetter site Argana, 0% and 60% of families have roots respectively 2.5 times and 1.5 times longer than the stem. In addition, seedlings have relatively more water stored in their roots, since its content represents more than 60% of the total root weight in 7/10 families of Ait Baha and Ait Melloul and 6/10 families from Argana. This root system growth will be useful when transplanted to the field, plants achieved rapid deep rooting and root avoided excessive surface ramification. This might help seedlings from drier environments to survive periods of drought stress, which are likely to be more common in drier sites where rainfall is lacking more than 6 months (Ferradous et al., 1996; Zahidi, 1997). Similar findings were observed in other plants (Kundu and Tigerstedt, 1997; Cuni-Sanchez et al., 2011). In these species, seedlings from drier provenances have longer roots and root length / stem length higher. Whereas, seedlings from wetter sites showed shorter roots and smaller ratio lengths, but with a high number of lateral roots. In *Eucalyptus microtheca* (Li, 1998), seedlings from locality with low rainfall have ratio length (root length / stem length) (0.49) higher than seedlings from watered locality (0.41). Root dry weights varied in opposite direction between the two geographical origins.

Natural populations of Argan, was the only representative species of the tropical family Sapotaceae in south west Morocco. Hamrick et al., (1992), reported that woody perennial species maintain generally most of their variation within populations, which holds true for tropical trees in particular. This variation was associated with the life history and ecological characteristics of the woody species. Our result is congruent with such as description, sine the contribution of inter-family and intra-family variance in the total variance was higher than variance related to geographical origin. These two components explain between 58.8% and 93.5% of total variability. Intra-family is much higher than variability between families. It has been reported that percentage of intra-family variance in *Jungus hindsii* was between 59.5% and 83.1% for the four traits studied (Gale et al., 1988), for height, diameter, fresh weight of stem and root in *Tsuga mertensiana* (Benowicz and Kassaby, 1999), and in *Eucalyptus grandis* and *E. globulus* in which, there is wide difference between families within geographic origins and between families for height and fresh weight of the stem (Marcar et al., 2001)._ Similar differences were also observed among and within progenies for different growth parameters at the age of 8 years in fifty-four progenies of *Melia azedarach* selected from 11 geographical locations in India (Meena et al., 2014).

Table 5. Variance components and heritabilities in norrow sense of the stem and root characters of argan seedlings grown in nursery conditions

Sources of variation	Variances																		
	LC	LT	LTf	FS	FG	NE	EP	RS	RSE	RT	RTE	LNS	LYS	LXS	LNT	LYT	LXT	DS	DT
Block σ^2_B	0,024	13,796	7,815	37,663	37,930	31,203	39,116	0,543	0,078	0,054	0,003	0,114	0,388	1,767	0,018	0,035	0,128	2,600	0,495
Geographic origin σ^2_{Pr}	0,064	5,096	7,813	40,700	26,497	8,386	12,171	0,000	0,040	0,000	0,000	0,466	0,320	3,136	0,008	0,005	0,068	0,193	0,016
Family / geographic origin $\sigma^2_{F/Pr}$	0,108	17,417	22,933	61,325	48,608	52,100	46,633	0,200	0,133	0,058	0,050	0,267	3,783	7,600	0,000	0,000	0,025	0,000	0,325
Block x geographic origin $\sigma^2_{B \times Pr}$	0,000	0,000	1,065	0,000	0,000	3,725	5,298	0,000	0,000	0,003	0,013	0,000	0,338	4,043	0,000	0,000	0,005	0,000	0,000
Block x family / geographic origin $\sigma^2_{B \times F/Pr}$	0,150	18,575	16,650	107,525	88,975	61,900	82,775	1,025	0,300	0,050	0,050	1,050	3,700	13,950	0,100	0,075	0,650	9,175	2,675
Block x family / geographic origin x seedlings $\sigma^2_{B \times Pl \times F/Pr}$ (error)	0,50	104,80	129,20	592,50	541,90	494,30	526,70	8,30	2,90	0,70	0,50	14,300	23,50	69,800	0,700	1,400	3,900	65,400	23,100
$h^2 = 4\sigma^2_{F/Pr} / \sigma^2_{F/Pr} + \sigma^2_{BFPr} + \sigma^2_E$	**0,57**	**0,49**	**0,54**	**0,32**	**0,29**	**0,34**	**0,28**	0,08	**0,16**	**0,29**	**0,33**	0,07	**0,49**	**0,33**	0,00	0,00	0,02	0,00	0,05

Sources of variation	Variances											
	LR	RCS	LNC	LXC	DC	PFT	PFR	PST	PSR	RL	RPF	RPS
Block σ^2_B	0,000	0,000	0,395	0,000	1,532	0,000	0,000	0,203	0,162	0,028	0,002	0,002
Geographic origin σ^2_{Pr}	9,933	2,421	0,000	0,000	0,268	0,000	0,000	0,000	0,000	0,067	0,000	0,000
Family / geographic origin $\sigma^2_{F/Pr}$	26,342	5,908	0,292	1,083	1,708	0,892	0,675	0,392	0,225	0,050	0,000	0,000
Block x geographic origin $\sigma^2_{B \times Pr}$	20,158	0,380	0,213	3,558	0,000	0,238	0,363	0,060	0,085	0,005	0,000	0,000
Block x family / geographic origin $\sigma^2_{B \times F/Pr}$	71,100	9,725	0,575	13,775	7,750	1,100	0,775	0,700	0,575	0,150	0,003	0,003
Block x family / geographic origin x seedlings $\sigma^2_{B \times Pl \times F/Pr}$ (error)	228,90	39,600	1,100	72,300	19,900	7,400	4,600	3,300	2,200	0,300	0,020	0,020
$h^2 = 4\sigma^2_{F/Pr} / \sigma^2_{F/Pr} + \sigma^2_{BFPr} + \sigma^2_E$	**0,32**	**0,43**	**0,59**	0,05	**0,23**	**0,38**	**0,45**	**0,36**	**0,30**	**0,40**	0,00	0,00

Table 6. Correlation coefficients among stem and root characters of Argan seedlings grown in nursery for 12 months

Variables	LC	LT	LTf	FS	NE	FG	EP	RS	RSE	RT	RTE	LNS	LYS	LXS	LNT	LYT	LXT	DS	DT	LR	RCS	LNC	LXC	DC	RL	PFT	PFR	RPF	PST	PSR	RPS
LC	1,00																														
LT	0,29	1,00																													
LTf	0,23	**0,98**	1,00																												
FS	0,09	**0,91**	**0,92**	1,00																											
NE	0,03	**0,91**	**0,91**	**0,96**	1,00																										
FG	0,11	**0,91**	**0,92**	**0,99**	**0,97**	1,00																									
EP	-0,01	**0,91**	**0,91**	**0,96**	**0,99**	**0,96**	1,00																								
RS	0,30	0,25	0,23	0,17	0,18	0,16	0,23	1,00																							
RSE	0,23	0,03	0,04	-0,04	-0,04	-0,04	-0,01	**0,66**	1,00																						
RT	0,03	-0,29	-0,34	-0,28	-0,25	-0,28	-0,27	0,43	**0,62**	1,00																					
RTE	-0,16	-0,16	-0,16	-0,07	-0,06	-0,05	-0,05	0,28	0,48	**0,72**	1,00																				
LNS	0,03	-0,16	-0,19	-0,23	-0,18	-0,25	-0,16	0,18	-0,21	-0,12	-0,20	1,00																			
LYS	0,17	0,09	0,08	0,04	0,01	0,03	0,07	**0,62**	0,15	0,08	-0,14	0,47	1,00																		
LXS	0,11	-0,04	-0,09	-0,09	0,01	-0,05	0,03	0,36	0,05	0,13	-0,10	**0,67**	**0,59**	1,00																	
LNT	-0,07	-0,36	-0,35	-0,36	-0,33	-0,34	-0,33	0,20	0,35	**0,59**	**0,50**	0,06	0,16	0,38	1,00																
LYT	0,05	-0,41	-0,42	-0,43	-0,40	-0,40	-0,36	0,28	0,37	**0,55**	**0,57**	0,03	0,21	0,42	**0,80**	1,00															
LXT	-0,05	-0,24	-0,26	-0,24	-0,24	-0,22	-0,23	0,22	0,34	**0,53**	**0,63**	0,02	0,16	0,43	**0,85**	**0,85**	1,00														
DS	0,04	0,34	0,29	0,28	0,31	0,25	0,32	0,44	0,32	0,07	0,21	-0,19	0,13	-0,15	-0,06	0,09	0,10	1,00													
DT	0,12	-0,04	-0,06	-0,08	-0,06	-0,08	-0,10	0,16	0,42	0,39	0,37	-0,29	-0,13	-0,01	**0,69**	**0,51**	**0,62**	0,18	1,00												
LR	-0,20	0,21	0,19	0,21	0,18	0,17	0,20	0,08	-0,09	-0,02	-0,04	0,28	0,38	0,25	0,07	0,02	0,08	-0,16	-0,11	1,00											
RCS	0,04	**0,64**	**0,66**	**0,68**	**0,63**	**0,67**	**0,68**	0,32	0,15	-0,09	-0,16	-0,07	0,14	0,12	-0,02	-0,17	-0,13	0,08	-0,16	0,19	1,00										
LNC	-0,31	0,14	0,17	0,28	0,24	0,29	0,28	-0,08	0,05	0,11	0,15	-0,29	0,11	-0,02	-0,17	-0,08	-0,05	-0,22	-0,20	0,43	0,48	1,00									
LXC	-0,22	0,01	0,01	0,07	0,01	0,07	0,08	0,24	0,36	0,32	0,36	0,01	-0,01	0,02	-0,10	0,17	0,32	-0,03	0,03	0,42	0,29	0,36	1,00								
DC	0,30	0,21	0,21	0,13	0,11	0,13	0,12	-0,01	0,09	-0,07	-0,15	0,13	-0,06	0,09	-0,08	-0,32	-0,14	-0,27	-0,13	0,13	0,13	-0,03	0,10	1,00							
RL	-0,18	**-0,68**	**-0,73**	**-0,72**	**-0,68**	**-0,70**	**-0,67**	-0,13	-0,13	0,18	0,05	0,47	0,20	0,37	0,34	0,45	0,31	-0,42	-0,02	0,43	-0,40	0,09	0,22	-0,09	1,00						
PFT	0,08	**0,72**	**0,70**	**0,72**	**0,78**	**0,74**	**0,77**	0,48	0,15	0,03	-0,05	0,06	0,35	0,38	-0,03	-0,12	-0,02	0,22	-0,04	0,23	**0,59**	0,14	0,02	0,06	-0,46	1,00					
PFR	0,11	**0,63**	**0,61**	**0,61**	**0,70**	**0,64**	**0,67**	0,47	0,11	-0,01	-0,10	0,11	0,41	0,43	-0,07	-0,01	-0,07	0,14	-0,10	0,33	0,49	0,20	-0,01	0,07	-0,32	**0,96**	1,00				
RPF	0,18	-0,19	-0,25	-0,32	-0,19	-0,28	-0,24	0,13	-0,05	0,18	0,15	0,31	0,30	0,34	-0,09	0,02	-0,14	-0,16	-0,16	0,33	-0,31	0,09	-0,11	0,07	0,46	-0,04	0,22	1,00			
PST	0,21	**0,72**	**0,67**	**0,64**	**0,71**	**0,68**	**0,71**	0,45	0,19	0,02	-0,06	-0,04	0,35	0,39	0,01	-0,05	0,01	0,10	0,01	0,39	**0,53**	0,23	0,09	0,21	-0,34	**0,90**	**0,92**	0,16	1,00		
PSR	0,17	**0,61**	**0,58**	**0,57**	**0,63**	**0,60**	**0,63**	0,47	0,17	-0,03	-0,14	0,03	0,44	0,36	-0,07	-0,13	-0,09	0,06	-0,04	0,46	0,46	0,28	0,09	0,11	-0,22	**0,85**	**0,92**	0,29	**0,96**	1,00	
RPS	-0,11	-0,29	-0,28	-0,23	-0,24	-0,25	-0,26	0,04	-0,16	-0,02	-0,27	0,22	0,34	-0,10	-0,20	-0,13	-0,26	0,01	-0,12	0,18	-0,35	-0,05	0,03	-0,37	0,34	-0,24	-0,12	0,39	-0,29	-0,03	1,00

Table 7. Canonical correlation between the components and characteristics of the stem and root in Argan seedlings grown in nursery for 12 months

Variables	LC	LT	LTf	FS	NE	FG	EP	RS	RSE	RT	RTE	LNS	LYS	LXS	LNT	LYT	LXT	DS	DT	LR	RCS	LNC	LXC	DC	RL	PFT	PFR	RPF	PST	PSR	RPS	Eigen values	Percentages explained (%)	Cumulative percentages (%)
CP1	0,07	-0,07	0,02	0,18	0,06	0,12	0,25	-0,11	0,02	**0,79**	**0,67**	0,23	**0,68**	0,39	**0,53**	**0,76**	**0,86**	**0,60**	**-0,83**	0,46	0,01	**0,94**	**0,96**	**-0,94**	0,01	**0,93**	0,03	-0,32	**0,57**	0,09	0,15	1,05	**62,2**	**62,2**
CP2	0,48	**0,64**	**0,64**	**0,63**	**0,64**	**0,63**	**0,62**	**0,64**	**0,64**	-0,36	0,46	**-0,62**	-0,45	**-0,59**	**-0,52**	-0,39	-0,29	0,50	0,32	**-0,56**	**0,64**	0,14	0,04	0,13	**-0,64**	0,17	**-0,64**	**-0,60**	-0,51	**-0,64**	**-0,63**	0,64	**37,8**	**100**

CP 1: First canonical component, PC 2: Second canonical component

Table 8. Mahalanobis distance between the three geographic origins for the stem and root growth characters in argan seedlings

Geographic origin	Ait Melloul	Argana	Ait Baha
Ait Melloul	0,00		
Argana	0,84	0,00	
Ait Baha	0,88	1,04	0,00

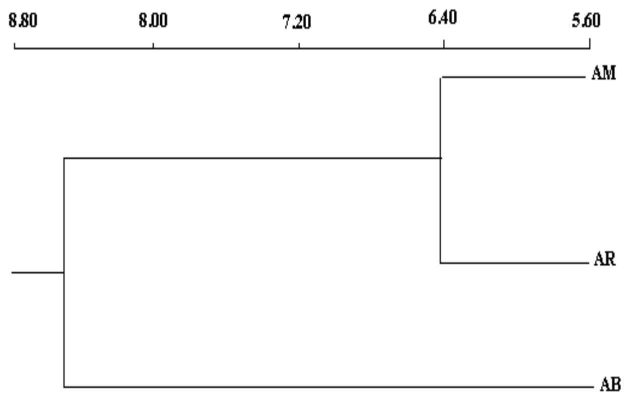


Figure 5. Cluster analysis classification of geographical origins based on growth and branching characters of the stem and root in Argan seedlings at nursery stage

In areas where environmental constraints were hard, the creation of adapted varieties and then superior planting material goes through evaluation of genetic diversity level of local landraces. In this study, seedlings from different maternal trees such as family (1) from Ait Melloul, (3 and 7) from Argana, and (7) from Ait Baha have developed the above-ground manifested by long stems, with high number of simple and grouped leaves and able to branch. In the same time, they have developed a below-ground part, with a relatively long main root, a high number of secondary roots sometimes accompanied by strong lateral root development. This case is not always present because growth of the stem and formation of simple and grouped leaves was not always accompanied by root growth, but correlated to ratio of lengths, biomass production (root fresh and dry weight). As reported by Rodríguez et al., (2012) for Mediterranean oaks that mother identity presented stronger effect on seedling performance. *In situ*, mother-trees genotypes of families (1, 7 and 7) are characterized by longer main branches, longest shoots and important branching since secondary, tertiary and even quaternary branches are present (Zahidi, 1997). These families can be used as germoplasm in breeding program of growth and branching character. Further information on the nature and the degree of genetic diversity present in argan could help to identify elite trees for genetic improvement through hybridization. High heritabilities in narrow sense (0.26 and 0.59) for most characters of the stem and the root can be considered as good genetic markers for selection and identify suitable plants adapted to environmental conditions in arid areas. These values are relatively lower than those observed in *Eucalyptus grandis* and *E. globulus* (0.35 and 0.92) for height and fresh weight of the stem (Marcar et al., 2001) and in white spruce seedlings aged 18 weeks for growth in stem length (0.92) (Rweyongeza et al., 2003), and of *Pangamia pinnata* (Divakara et al., 2010) for seeds traits, heritability is ranged from 0.82 (for seed length) to 0.98 (for 100pod weight); or in seedlings in two provenance–progeny tests of sweet chestnut (Castanea sativa Miller) (heritability is ranged from 0.12 to 0.43) (Miguez-Soto and Fernandez-Lopez, 2014) .

Distribution of diversity is not done in relation with belonging of the families to their geographical origin. Mahalanobis distances were smaller between Argana and Ait Melloul, between Ait Baha and Ait Melloul, compared with distances observed for fruiting branch characters (Zahidi, 1997; Zahidi et al., 2013), for fruit and stone characters in the field (Bani-Aameur and Ferradous, 2001). Main groups obtained by UPGMA, include individuals from Ait Melloul, Argana and families of Ait Baha. Thus, differentiation for growth and branching traits in argan seedlings is not established especially among populations geographically close Argana, Ait Baha and Admine as reported by El Mousadik and Petit, (1996a) on the basis of nine isozyme loci in ten populations of Argan area. This distribution pattern was observed also in *Taxus brevifolia* on basis of morphological characters (Wheeler et al., 1995), and in *J. californica* and *J. hindsii* on basis of biometric traits (Gale et al., 1988) and in fourteen accessions of pearl millet (*Pennisetum glaucum* (L.) R. Br) from Tunisia and West Africa (Skates et al., 2003). In *Pinus silvestris*, analysis showed that significant differences were observed within populations for morphological characters of seeds and for seedlings one year old (Sevik et al., 2010). In our Case, the grouping obtained based on morphological characteristics were influenced by genome in contrast to results reported by Dinis et al., (2011) in Chestnut tree (Judia variety). Morphological characters studied were not influenced by genome but essentially by the different climatic conditions and potentially differences in the expression of genes associated with the adaptation strategies.

At the present time, several physical and anthropogenic factors reduce the density and surface of argan ecosystems, so it decreases the biodiversity in natural area. Due to the continuous intensify of genetic erosion, it is necessary to save this species. Our study identify mother-tree genotypes with superior traits, so a common garden with superior trees in specific traits from several geographical origins could be established to determine if they will be reproduce the trait of interest in different environment as it proposed for the African baobab (Simbo et al., 2012)._

5. Conclusions

Results from this study indicate that there is a great morphological variability in Argan seedlings at nursery stage for growth and branching characters of the stem and root. 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. Our analysis provides information on the nature and the degree of genetic diversity present in argan which could help to identify elite trees for genetic improvement through hybridization. In fact, seedlings from drier provenances allocated more resources to their main roots expressed by strong growth in length, but a few number of lateral roots. This ability to develop long roots even if they are grown under nursery conditions seems to be drought adaptation criteria. This drier provenance is an environment selective of resistant genotypes to drought. Further research is thus needed to address the relationship between seedling establishment and field magangement pratices in order to select drought tolerant planting material for conservation and regeneration in future breeding programs.

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REFERENCES

[1] Bani-Aameur F, Ferrradous A (2001) Fruit and stone variability in three Argan (*Argania spinosa* (L.) Skeels) populations. Forest Genetics 8: 39-45.

[2] Bani-Aameur F (2004) Morphological diversity of argan (Argania spinosa (L.) Skeels) populations in Morocco. Forest Genetics 11: 311-316.

[3] Becker B, Picard JF, Timbal J (1983) Les arbres. Masson. Paris New York Barcelone Milan Mexico Sao Polo. 141p.

[4] Behm A, Becker A, Dörflinger H, Franke A, Kleinshmit J, Melchior GH, Muhs HJ, Schmitt HP, Stephan BR, Tabel U, Weisgerber H, Widmaier T (1997) Concept for the conservation of forest genetic ressources in Federal Republic of Germany. Silvae Genetica 46: 24-35.

[5] Benowicz A, El-Kassaby YA (1999) Genetic variation in mountain hemlock (*Tsuga mertensiana* Bong.): quantitative and adaptative attributes. Forest Ecology and Management 123: 205-215.

[6] Bernstein IH, Teng GK, Garbin CP (1988) Applied Multivariate Analysis. Springer-Verlag New York Berlin Heidelberg London Paris Tokyo. 508p.

[7] Corneluis J, Apedaile L, Mesen F (1996) Geographic origin and family variation in height and diameter growth of *Cupressus lusitanica* Mill. at 28 months in Costa Rica. Silvae Genetica 45: 82-85.

[8] Cuni-Shanchez A, De Smedt S, Haq N, Samson R (2011) Variation in baobab seedling morphology and its implications for selecting superior planting material. Scientia Horticulturae 130: 109-117.

[9] De Ponteves E, Bourbouze A, Narjisse H (1990) Occupation de l'espace, droit coutumier et législation forestière dans l'arganeraie marocaine. Cahiers de la Recherche et Développement 26:28-43.

[10] Dinis LT, Peixoto F, Pinto T, Costa R, Bennett RN, Gomes-Laranjo J (2011) Study of morphological and phenological diversity in chestnut trees ('Judia' variety) as a function of temperature sum. Environmental and Experimental Botany 70: 110-120.

[11] Divakara BN, Alur AS, Tripati S (2010) Genetic variability and relationship of pod and seed traits in *Pongomia pinnata* (L.) Pierre, a potential agroforestry tree. International Journal of Plant Production 4: 129-141.

[12] Ehrenberg C (1989) Breeding for stem quality. American Journal of Botany 123-127.

[13] Emberger L (1939) Aperçu general sur la végétation du Maroc, Bull. Soc. Sci. Nat. Maroc, 40-157.

[14] El Mousadik A, Petit RJ (1996a) High level of genetic differentiation for allelic richness among populations of the argan tree (*Argania spinosa* (L.) Skeels) endemic to Morocco. Theoretical and Applied Genetics 92: 832-839.

[15] Ferradous A, Bani-Aameur F, Dupuis P (1996) Climat stationnel, phénologie et fructification de l'arganier (*Argania spinosa* L. Skeels). Actes Institut Agronomique et Vétérinaire (Maroc) 17: 51-60.

[16] Gale HM, Hansen J, Shaw DV (1988) Inter and intraspecific variation in California Black Walnuts. Amer. Soc. Hort. Sci. 113: 760-765.

[17] Gorenflot R (1986) Biologie Végétale. Plantes Supérieures. 1. Appareil Végétatif, Ed. Masson Paris New York Barcelone Milan Sao Polo 238p.

[18] Hamrick JL, Godt MJW, Sherman-Broyles SL (1992) Factors influencing levels of genetic diversity in woody plant species. New Forests 6: 95-124.

[19] Heitholt JJ (1989) Water use efficiency and dry matter distribution in nitrogen and water stressed winter wheat. Agronomy Journal 81: 464-469.

[20] Hodge GR, Dvorak WS, Uruena H, Rosales L (2002) Growth, provenance effects and genetic variation of *Bombacopsis quinata* in field in Venezuela and Colombia. Forest Ecology and Management 158: 273-289.

[21] Jamnadass R, Lowe AJ, Dawson I (2009) Molecular markers and the management of tropical trees: the case of indigenous fruits. Trop. Plant Biol. 2:1-12.

[22] Kundu SK, Tigerstedt PMA (1997) Geographical variation in seed and seedling traits of Neem (*Azadirachta indica* A. Juss.) among ten populations studied in growth chamber. Silvae Genetica 46:129-137.

[23] Laâmouri A, Sghaier T (1998) Performances en croissance et biomasse de trois légumineuses arbustives fourragères en milieu semi-aride de la Tunisie. Ann. Rech. For. Maroc, 31:40-50.

[24] Larsen HS, South DB, Boyer JM (1986) Root growth potentiel, seedling morphology and bud dormancy correlate with survival of loblolly pine seedlings planted in December in Alabama. Tree Physiology 1:253-263.

[25] Lentner M, Bishop T (1993) Experimental Design and Analysis. 2Ed. Valley Book Company, 585p.

[26] Li C (1998) Variation of seedling traits of *Eucalyptus microtheca* origins in different watering regimes. Silvae Genetica 47: 132 - 135.

[27] Marcar NE, Cawford DF, Saunders A, Matheson AC, Arnold RA (2001) Genetic variation among and within provenances and families of *Eucalyptus grandis* W. Hill and *E. globulus* Labill. subsp. *globulus* seedlings in response to salinity and waterlogging. Forest Ecology and Management 162: 231-249.

[28] Mazer S, LeBuhn G (1999) Genetic Variation in Life History Traits In: Vuorisalo, T.O. and Mutikainen, P.K. Life History Evolution in Plants. Kluwer, Boston, MA.

[29] Meena H, Kumar A, Sharma R, Chauhan SK, Bhargava KM (2014) Genetic variation for growth and yield parameters in half-sib progenies of *Melia azedarach* (Linn.). Turk. J. Agric. For., 38: 531-539.

[30] Miguez-Soto B, Fernandez-Lopez J 2014 Variation in adaptive traits among and within Spanish and European populations of Castanea sativa: selection of trees for timber production. New Forests DOI 10.1007/s11056-01 4-9445-5.

[31] Nerd A, Eteshola E, Borowy N, Mizrahi Y (1994) Growth and oil production of argan in the Negev Desert of Israel. Industrial Crops and Products 2: 89-95.

[32] Nouaim R, Chaussod R, El Aboudi A, Schnabel C, Peltier JP (1991) L'arganier, essai de synthèse des connaissances sur cet arbre. In: Groupe d'Etude de l'Arbre (eds) Physiologie des arbres et arbustes en zones arides et semi-arides. John Libbey Eurotext, Paris 373-388.

[33] Nouaim R, Chaussod R (1994) Mycorrhizal dependency of micropropagated argan tree *(Argania spinosa):* I. Growth and biomass production. Agroforestry Systems 27: 53-65.

[34] Prendergast HDV, Walker CC (1992) The argan: multipurpose tree of morocco. The Kew Magazine 9:76-85.

[35] Raies A, Ibrahima O, Oran SA (2003) Evaluation morphologique de cultivars de mil (*Pennisetum glaucum* (L.) R. Br.) collectés en Tunisie et en Afrique de l'Ouest. Bulletin des Ressources Phytogénétique FAO, IPGRI, n° 133.

[36] Rohlf FJ (1988) Numerical Taxonomy and Multivariate Analysis System. Applied Biostatistics Inc., New York. 170p.

[37] Rodríguez VG, Barrio IC, Villar R (2012) Within-population variability influences early seedling establishement in four Mediterranean oaks. Acta Oecologica 41: 82-89.

[38] Rweyongeza DM, Yeh FC, Dhir NK (2003) Genetic parameters for seasonal height and height growth curves of white spruce seedlings and their implications to early selection. Forest Ecology and Management 187: 159-172.

[39] Sevik H, Sezgin A, Turna I, Yahyaglu Z (2010) Genetic diversity among populations in Scotch pine (*Pinus Silvestris* L.) seed stands of western black sea region in Turkey. African Journal of Biotechnology 9: 7266-7272.

[40] Simbo DJ, De Smedt S, Den Bilcke NV, De Meullenaer B, Camp JV, Uytterhoeven V, Tack F, Samson R (2012) Opportinities for domesticating yhe African baobab (*Adonsonia digitata* L.): multi-trait fruit selection. Agrofor. System DOI, 10.1007/s10457-012-9568-7.

[41] Sokal RR, Rolf FJ (1995) Biometry, the Principales and Practice of Statistics in Biological Research. 3 Ed. W.H. Freeman and Company New York, 887p.

[42] Turna I, Yahyaoglu Z, Yuksek F, Ayaz FA, Guney D (2006) Morphometric and electrophoretic analysis of 13 populations of Anatolian black pine in Turkey. J. Environ. Biol. 27: 491-497.

[43] Ward SM (2001) Response to selection for reduced grain saponin content in quinoa (*Chenopodium quinoa* Willd.) Field Crops Research 68:157-163.

[44] Wheeler NC, Jech KS, Masters CA, O'Brien CJ, Timmons DW, Stonecypher RW, Lupkes A (1995) Genetic variation and parameter estimates in *Taxus brevifolia* (Pacific yew). Can. J. For. Res. 25: 1913-1927.

[45] Wu HX, Yeh FC, Dhir NK, Pharis RP, Dancik BP (1997) Genotype by environment interaction and genetic correlation of greenhouse and field performance in *Pinus contorta ssp. latifolia*. Silvae Genetica 46: 170-175.

[46] Xiao X, Xu X, Yang F (2008) Adaptive responses to Progressive drought stress in Two *Populus cathayana* populations. Silva Fennica 42: 705-719.

[47] Zahidi A (1997) Phenology, typology and genetic variability of branching and foliation characters in *Argania spinosa* (L.) Skeels. Thesis of the 3rd cycle, Faculty of Sciences, Ibn Zohr University Agadir. 177p.

[48] Zahidi A, Bani-Aameur F (1998a) Germination et survie des amandes de l'arganier (*Argania spinosa* (L.) Skeels) : effet de la durée de stockage, de la date de semis et du génotype. Ann. Rech. For. Maroc 30: 2-16.

[49] Zahidi A, Bani-Aameur F (1998b) Argan seedling damping-off under nursery conditions: effects of mother-tree genotype, kernel origin and seedling age. *Ecologia mediterranea* 24: 27-32.

[50] Zahidi A, Bani-Aameur F, El Mousadik A (2013a) Morphological variability of the fruiting branches in *Argania spinosa*: Effects of seasonal variations, locality and genotype. Journal of Horticulture and Forestry. 5: 168-182.

[51] Zahidi A, Bani-Aameur F, EL Mousadik A (2013b) Growth variability in *Argania spinosa* seedlings subjected to different levels of drought stress. Journal of Horticulture and Forestry 5: 204-217.

[52] Zahidi A, Bani-Aameur F, El Mousadik A (2013c) Seasonal change effects on phenology of *Argania spinosa* (L.) in the fields. Journal of Ecology and the Natural Environment 5: 189-205.

[53] Zahidi A, Bani-Aameur F, EL Mousadik A (2014) Variability in the productivity of fruits and oil in three natural populations of *Argania spinosa* L. Skeels: combined effects of environment and genotype. *Int. J. Pure App. Biosci.* 2: 86-105.

[54] Zhang XL, Zang RG, Li CY (2004) Population differences in physiological and morphological adaptations of Populus davidiana seedlings in response to progressive drought stress. Plant Science 166: 791-797.

[55] Zhang XL, Wu N, Li CY (2005) Physiological and growth responses of Populus davidiana ecotypes to different soil water contents. Journal of Arid Environments 60: 567-579.