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Seasonal change effects on phenology of *Argania spinosa* (L.) in the fields

Zahidi A*, Bani-Aameur F and EL Mousadik A

Laboratory of Biotechnologies and Valorization of Naturals Resources, Faculty of Sciences, Ibn Zohr University, BP 8106 Agadir 80000, Morocco.

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We investigated the relationship between shoot branching, shoot growth, leaf phenology and seasonal changes during three consecutive seasons in three natural populations of *Argania spinosa* ((L.) Skeels) in south west Morocco. Rainfall showed two peaks in autumn and winter but summer was dry. Locality, climatic season, genotype (tree/locality) and observation date influence differently all traits. Shoot branching, shoot elongation and leaf emergence were mainly dependant on cumulative rainfall recorded in autumn and winter. When water stress is high, trees were stressed and leaf fall was more intense since 75.4% and 78.9% of leaves were lost in late summer in dry seasons. But after lower or moderate water deficit, leaf drop was less important since only 57.7% of leaves were lost in humid seasons. If dry conditions were spread over a longer period, trees are completely defoliated. Thus, among the 90 trees in the three stations, 45.6% were completely defoliated in autumn in dry season, while only 2.2% were completely defoliated in autumn in humid season. This result suggests that some genotypes are resistant to dry conditions and will be useful for selecting plus trees which are essential for management and conservation practices of genetic resources in argan forest.

Key words: *Argania spinosa*, defoliation, budburst, shoot growth, leaf drop.

INTRODUCTION

The study of phenological aspects of plants subject to different seasonal changes involves observation, recording and interpretation of the timing of their life history events. The phenology of leafing, flowering and fruit production in a range of species and communities were observed. The selective forces that influence the timing of these events are discussed as phenological patterns of each phase (timing, frequency, duration, degree of synchrony, etc). They are probably the result of compromise between a variety of selective pressures, such as seasonal changes, resource availability, and the presence of pollinators, predators and seed dispersers (Fenner, 1998; Medeiros et al., 2007; Sekhwela and Yates, 2007; Milla et al., 2010; Soudani et al., 2012). A clear understanding of plant phenology was essential to clarify the function of community and diversity. In that order, to investigate the relationships between leaf phenology and environmental variables, soil water availability and several climatic variables were monitored for *Acacia tortilis ssp. raddiana*, in North Senegal. It appears that inter-annual variation of canopy phenology (peaks of leaf flush and leaf fall) is mainly tuned to atmospheric conditions as annual rainfall, temperatures or maximum value of vapor pressure deficit (Do et al., 2005). In evergreen species with continual leaf drop as well as brevi-deciduous species demonstrated peaks of leaf fall and leaf budding during the dry period (Miranda et al., 2011). But in Nineteen woody species growing in

*Corresponding author. E-mail: Dr.abdelaziz.zahidi@gmail.com. Tel: 212667265028.

semi-arid region of northeastern Brazil, leaf fall in these species occurred during the transition period between the rainy and the dry season. Species with high wood densities were strongly dependent on rainfall for leaf flush, flowering, and fruiting, as they are able to store only limited quantities of water in their trunks; leaf fall in these species occurred during the dry season (Lima and Rodal, 2010). Shoot elongation was mainly dependent on nutrient availability in top soil, as suggested by the strong and positive relationships between annual shoot growth and long-term cumulative rainfall (2-4 months) and short-term average temperature (1 month) prior to budburst (Pinto et al., 2011). In addition, In *Picea crassifolia* significant limiting factor on tree growth was spring precipitation (Gou et al., 2005).

The Argan tree is endemic to south west of Morocco in arid and semi-arid Mediterranean climate (Maire, 1939; Boudy, 1952; Emberger, 1925b, 1955; Prendergast and Walker, 1992) with a marked water deficit during late spring and summer (Peltier, 1982; Ferradous et al., 1996). The arid zone covers more than 520 000 ha (M' Hirit, 1989). We denote its existence in north east, in the upper basin of Oued Grou and in south east of Oued Noun (Emberger, 1925a; 1925b; Chevalier, 1953; Ehrig, 1974). Argan is a multipurpose tree which is remarkably adapted to aridity, surviving extended drought periods and high temperature. Argan wood is used for fuel and its leaves are used for forage, the fruits collected from the wild, are its most important non-timber product and a major source of income for local populations because of the valuable oil, extracted from the nuts. However, argan phenology is in early stages. Some observations for one season in Oued Cherrate showed that foliation begins in October, after the first rains (Metro, 1952). In January, it was complete and the young shoots begin to grow. Shoot growth continues and stops in June. Defoliation begins in August. Montoya Olivier (1984) reported that growth of small shoots stops in June. Complete defoliation was especially during dry seasons. Leaves of three trees in Admine appear in September, while defoliation begins in August and becomes more important after hot winds (Chergui) (El Aboudi, 1990). Shoot growth began in September or October depending on the trees. Stopping the shoot growth occurs between late April and early May, after an elongation phase, which lasted from 52 to 147 days resulting in a gain of 1.2 to 2.8 cm. In 90 trees from three populations, leaf drop was more intense in dry site (Ait Baha) than in humid locality (Argana), but no tree was completely defoliated At Ait Melloul (Ferradous et al., 1996). In autumn after the dry season, complete defoliation affects 15% of trees at Ait Baha, but 10% of trees have begun to lose their foliage at Argana. These studies are not complete since they have concerned a small number of trees or are limited in time. In this work, we analyzed the leaf phenology, shoot growth and shoot branching for three natural populations of Argan in south west Morocco and their relation to rainfall and temperature during three growing season.

MATERIALS AND METHODS

Study area and climate

The study was carried out during three consecutive seasons from September to August (2004-2005=season 1; 2005-2006=season 2; 2006-2007=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 (Figure 1). Mean monthly values of precipitation during autumn-summer (September-August) calculated from the daily precipitations recorded at the three sites. They were compared to means recorded in 14 seasons. Temperatures recorded in Ait Melloul have been analyzed and compared to temperatures during 14 seasons.

Plant material and measurements

Thirty selected trees from each site described by Ferradous et al. (1996) and Bani-Aameur and Ferradous (2001) were observed. Among the principal branches facing south at breast height, two were labelled. Measurements were carried out at intervals of 30 days during the three growing season from September to August (Figure 2). RV: Number of green shoots (annual 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 (Halle´ et al., 1978; Damascos et al., 2008). Thus, RVE: number of green shoots spiny; RIE: number of shoots to indefinite growth spiny; 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 shoots to indefinite growth. LB: the initial length of the labeled main branch; length of the greatest (LXV), the smallest (LMV) green shoot; length of the greatest (LXI), the smallest (LMI) shoot to indefinite growth were also measured at intervals of 30 days. We deduce period of foliation as number of days when the tree bears the grouped leaves. The season was divided into a first period from September to December (120 days), and a second period of January through August (220 days).

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, locality and observation date were crossed. Mean separation was done with Fisher's protected least significant difference test (LSD) (Steel and Torrie, 1960; Montgomery, 1984; Sokal and Rolf, 1995).

RESULTS

Precipitations and temperatures

Rainfall in the three sites showed two peaks in autumn and winter but summer was dry (Figure 3). The first peak from December to January, the second one was recorded

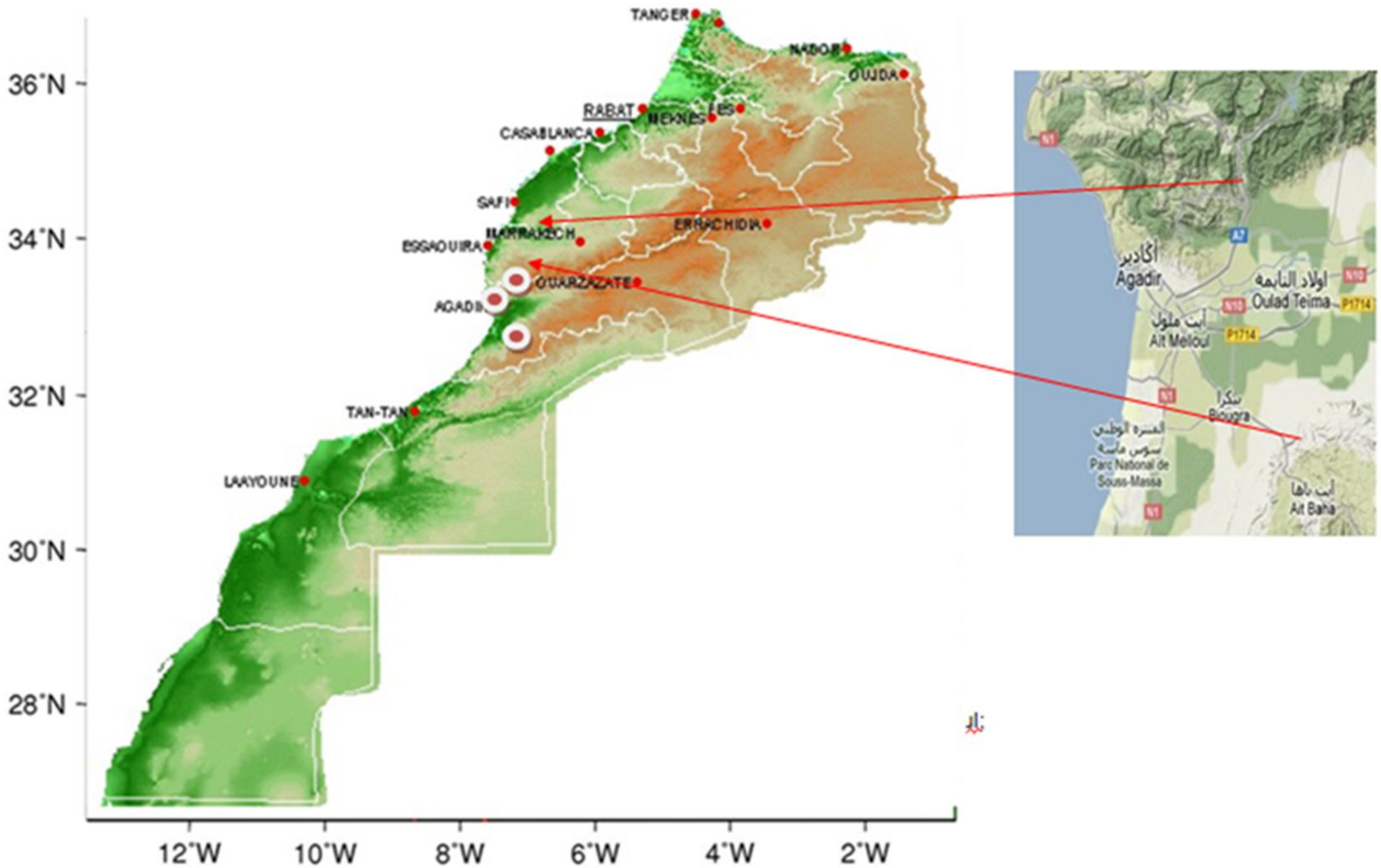


Figure 1. Geographical localization of Argania spinosa provenances under study AM: Ait Melloul; AR: Argana; AB: Ait Baha. (localities).

from March to April. Rainfalls were generally spread over six to nine months, and were distributed on a limited number of days. The first season (1) was especially dry and warm, rains were concentrated in February, March and April; autumn and beginning of winter were almost dry. Temperatures varied from 9.3°C in January and 30.6°C in August (Figure 3). The second season (2) was very wet with a relatively warm autumn, but winter and spring were relatively cold. Autumn and winter were very humid; rainfall distribution was spread over almost the entire period (September-June) especially in Argana and in Ait Melloul. The third season was so wet and hot; the rainfalls were concentrated from November to

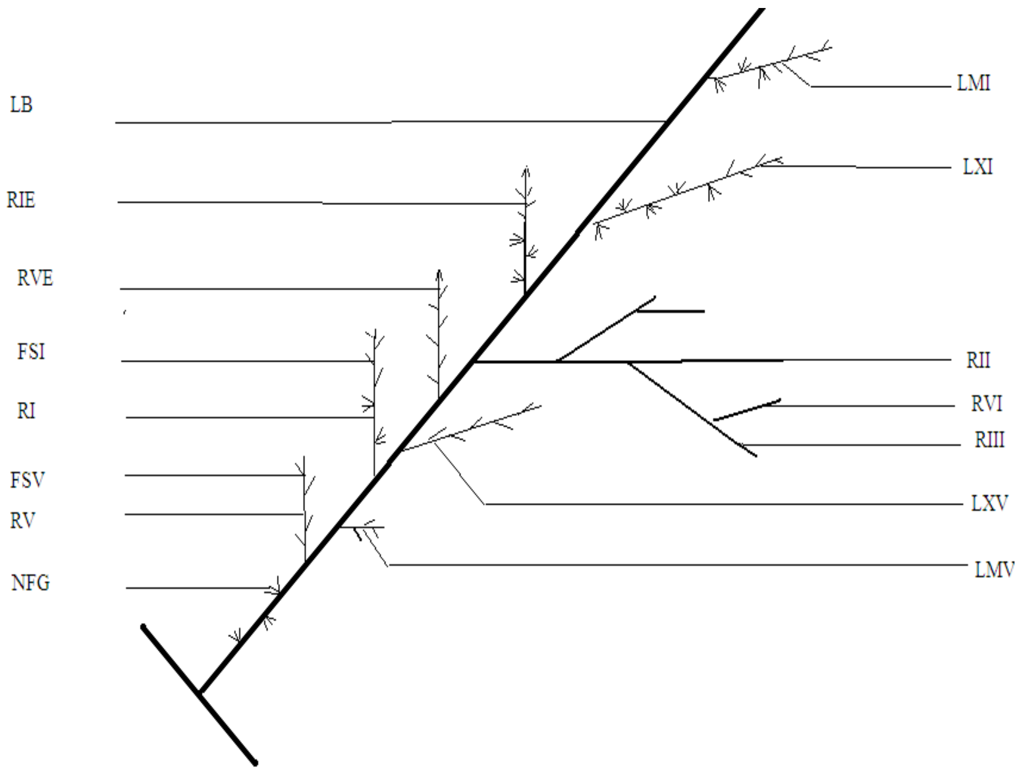


Figure 2. Phenological characters of shoot branching, shoot elongation and leaf phenology observed in Ait Melloul, Ait Baha and Argana.

January, February and March were almost dry.

Phenology

Locality

Locality effect was significant for shoot growth characters RI, LB, LMV, LXV, LXI and production of grouped leaves (NFG) and green branches (RV) (Table 1). But, it was not significant for branching characters as RVE, RIE, RII, RIII, RIV, and production of simple leaves (FSV and FSI). Locality x season interaction was highly significant for RV, RVE, RI, RIE, LMV, LXV, LMI, LXI, LB, and FSI. It was not significant for RII, RIII, RIV, NFG and FSV.

Tree effect

Tree / locality (genotype) was significant for all characters except LMV, LMI and NFG (Table 1). Tree x environment (season x tree / locality) interaction was highly significant for all characters except RIV and LB.

Season and observation date

Shoot branching: Climatic season was significant for RV, RVE, RI and RIE (Table 1). It was significant for RIII and not significant for RII and RIV. Production of RV, RVE, RI, RIE and RIII was greater during the very wet season (2) than in dry season (1) and wet season (3) (Table 2). Annual averages of RV, RVE, RI and RIE in the three stations were higher in second season than in first and third season. Tree response to form RV, RI and RVE was very heterogeneous especially in dry and wet seasons. Observation date was significant for RV, RI, RII, RIII and RVE (Table 1). It was not significant for RIE and RVI. Season x date interaction was highly significant for RV, RVE, RI, RII and RIE. It was not significant for RIII and RIV. Locality x date interaction was highly significant for RV, RI and RVE. It was not significant for RIE, RII, RIII and RIV. Season x date x locality interaction was highly significant for RV but not significant for the other characters. Tree / locality x observation date interaction was significant for RV, RVE, RI, RIE, LXV, LMI and NFG. It was not significant for RII, RIII, RIV, LB, LMV, LXI, FSV and FSI. Season x tree x observation date / locality interaction was highly significant for RI, LXV, LMI, LXI, NFG, FSV and significant for FSI and RIE. It was not significant for RV, RVE, RII, RIII, RIV, LB and LMV.

+ Green shoots: The trees had two distinct budburst dates of annual shoots each year: one in autumn after first rains of September and October and one in spring after cumulative rainfall (from December to April). This budburst occurs in the third week of September in the first season (1), the first week of November in second season (2) and the third week of November in the third season (3) and was less important. All times it was earlier

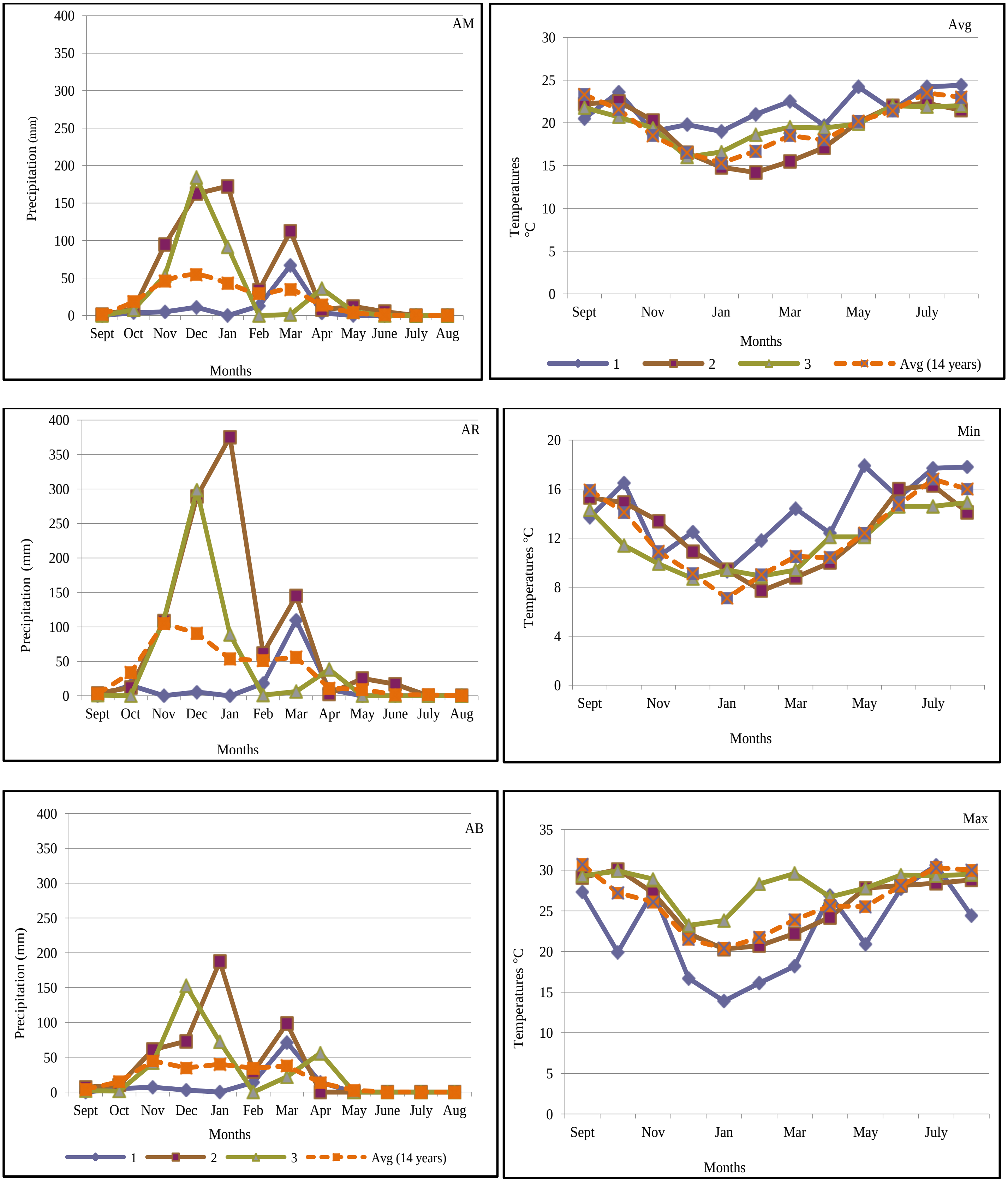


Figure 3. Climatic data from meteorological stations: mean monthly precipitation (mm), maximum, minimum and mean temperatures recorded at Ait Melloul (AM), Argana (AR) and Ait Baha. (2004-2005=season 1; 2005-2006=season 2; 2006-2007=season 3).

Table 1. Analysis of variance for shoot branching, shoot elongation and leaf phenology observed for three consecutive seasons in Ait Melloul, Argana and Ait Baha.

Source	DF	Mean square														
		Shoot branching				Shoot elongation						Leaf phenology				
		RV	RVE	RI	RIE	R II	R III	RIV	LB	LMV	LXV	LMI	LXI	NFG	FSV	FSI
Season	2	2703.9**	1166.2**	2303.1 **	475.4 **	14964 ns	1130.1 *	1.2 ns	796.9 ns	780.6 **	9310.8 **	1868.2 ns	8742.4 **	8639.2 ns	7674.2 **	4358.4 **
Locality	2	2920.2*	823.9 ns	2809 **	53.4 ns	7425.1 ns	976.7 ns	197.4 ns	22124 **	443.4 **	2955.2 **	1139.4 ns	5928.8 **	117360 **	1753.7 ns	478.7 ns
Date	16	5932.2**	1102.4 *	629.1 **	25.2 ns	3422.5 **	237.4 **	0.02 ns	15.9 ns	228.3 **	2121.5 **	202.2 **	1075.6 **	13043 **	420 ns	95.5 ns
Tree / locality	87	912.8**	532.1 **	229.4 **	34.9 **	2478 **	5443.2 **	190.1 **	1674.5 **	34.6 ns	211.4 **	98.2 ns	270.9 **	4429.9 ns	601.4 **	684.6 **
Season x locality	4	1077.2**	716.2 **	911.9 **	36.3 **	1943.8 ns	278.8 ns	0.4 ns	596.9 **	21.9 **	172.2 **	514.7 **	2530.9 **	3271.9 ns	43.9 ns	139.4 **
Season x date	32	1014.6 **	525.3 **	91.4 **	21.3 **	611.9 **	72.2 ns	0.007 ns	9.4 ns	29.3 **	354.8 **	47.7 **	325.4 **	1456.8 ns	565.6 **	285.7 **
Locality x date	32	142.8 **	33.8 **	111.5 **	2.7 ns	62.2 ns	9.7 ns	0.02 ns	11.3 ns	20.4 **	136.7 **	69.8 **	242.2 **	5225.8 ns	23.7 ns	4.7 ns
Season x locality x date	64	68.7 **	38.4 ns	40.8 ns	1.9 ns	77.4 ns	2.9 ns	0.7 ns	7.6 ns	2.3 ns	13.9 **	20.2 **	95.9 **	4226 **	43.1 **	14.3 ns
Season x tree / locality	174	764.1 **	383.5 **	119.9 **	34.4 **	1221.8 **	302.6 **	0.1 ns	72.9 ns	35.6 **	161.1 **	82.8 **	192.4 **	6874.5 **	181.6 **	207.1 **
Tree / locality x date	1392	47.8 **	33.5 **	10.2 **	1.7 **	31.9 ns	7.4 ns	0.007 ns	1.5 ns	2.1 ns	10.3 **	4.3 **	11.5 ns	880.8 **	7.9 ns	5093.1 ns
Season x tree / locality x date	2784	38.1 ns	25.2 ns	6.1 **	1.7 *	27.1 ns	6.3 ns	0.01 ns	1.4 ns	2.1 ns	8.8 **	3.6 **	8.7 **	755.8 **	23.1 **	4151.6 **
Error	4590	39.9	30.3	5.6	3.34	264.3	77.3	3.9	135.8	2.3	6.8	2.4	6.1	551.6	16.9	5005.5

ns: Not significant, *: Significant at 5%, **: Significant at 1%.

Table 2. Maximum (Max), minimum (Min), average (Avg) and coefficient of variation for morphological traits observed in the three localities.

Character	Season \ Locality																
		AM				AR				AB				Avg			
		Max	Min	Avg	CV	Max	Min	Avg	CV	Max	Min	Avg	CV	Max	Min	Avg	CV
RV / 100 cm	1	71.1	0	3.2	279.9	31.3	0	0.9	369.7	38	0	2.8	248.7	46.8	0	2.32 b	299.4
	2	53.8	0	6.44	160.7	92.1	0	7.59	177.3	63.4	0	8.4	152.4	69.8	0	7.46 a	163.5
	3	42.5	0	1.88	257.6	34.9	0	0.99	396	50	0	4.1	190.9	42.5	0	2.31 b	281.5
	Avg	55.8	0	3.84 b	232.7	52.8	0	3.16 c	314.4	50.5	0	5.1 a	197.3	53.01	0	4.03	248.1
RVE / 100 cm	1	63.6	0	0.99 b	583.04	12.5	0	0.19 c	713.2	31.5	0	0.26 b	868.3	35.9	0	0.48 b	721.5
	2	53.8	0	3.46 a	244.24	85.7	0	5.32 a	224.3	120	0	2.58 a	432.5	86.5	0	3.79 a	300.3
	3	30	0	0.42 c	677.4	34.9	0	0.49 b	681.3	9.6	0	0.08 c	976.9	24.8	0	0.33 b	778.6
	Avg	49.13	0	1.62	501.6	44.4	0	2	539.6	53.69	0	0.97	759.2	49.1	0	1.53	600.1
RI / 100 cm	1	26.7	0	1.53 b	236.07	7.3	0	0.1	666.5	33.5	0	0.48	618.3	22.5	0	0.71 b	506.9
	2	31.1	0	3.53 a	164.4	8.9	0	0.47	351.1	33.5	0	3.01	179.6	24.5	0	2.33 a	231.8
	3	9.68	0	0.55 c	293.1	6.1	0	0.15	570.1	21.69	0	2.3	209.9	12.5	0	1 b	357.7
	Avg	22.49	0	1.87 a	231.2	7.4	0	0.24 b	529.3	29.6	0	1.93 a	336.0	19.8	0	1.35	365.5
RIE / 100 cm	1	4.5	0	0.1	582.6	0	0	0	-	0	0	0	-	1.5	0	0.03 b	-
	2	31.1	0	1.04	328.7	8.9	0	0.34	405.7	28.7	0	0.72	455.3	22.9	0	0.7 a	396.6

Table 2. Contd

	3	0	0	0	-	0	0	0	-	0	0	0	-	0	0	0 b	-
	Avg	11.87	0	0.38	-	2.97	0	0.11	-	9.6	0	0.24	-	8.13	0	0.24	-
	1	81.82	2.6	23.7	62.9	100	0	25.6	68.7	63.4	0	23.2	66.17	81.7	0.87	24.2	65.9
RII / 100 cm	2	100	4.4	30.8	62.7	133.3	0	33.4	71.4	80	0	32.9	55.11	104.4	1.47	32.4	63.1
	3	109.1	4.7	34.9	60.6	168.3	0	39.5	73.7	93.3	0	39.9	48.7	123.6	2.58	38.1	60.9
	Avg	96.97	3.9	29.8	62.1	133.9	0	32.8	71.3	78.9	0	32.0	56.7	103.3	1.64	31.6	63.3
	1	30.1	0	3.89	190.7	54.1	0	3.91	219.4	36.7	0	3.53	192.8	42.9	0	3.78 c	200.9
RIII / 100 cm	2	69.23	0	6.75	178.1	56.8	0	5.42	176.5	40.8	0	5.91	145.9	55.6	0	6.03 b	166.8
	3	74.36	0	8.62	171.1	56.8	0	6.62	155.4	40.8		7.56	125.1	57.3	0	7.6 a	150.5
	Avg	60.56	0	6.42	179.9	55.8	0	5.32	183.7	39.5	0	5.67	154.6	51.9	0	5.8	172.8
	1	8.7	0	0.23	507.8	21.6	0	0.52	567.7	0	0	0	-	10.11	0	0.25	-
RIV / 100 cm	2	8.7	0	0.23	507.8	24.3	0	0.55	576.7	4.44	0	0.05	958.2	12.5	0	0.27	680.9
	3	8.7	0	0.23	507.8	24.3	0	0.56	580.1	4.44		0.07	-	12.5	0	0.29	618.8
	Avg	8.7	0	0.23	507.8	23.4	0	0.54	574.8	2.96	0	0.04	-	11.7	0	0.27	-

Means followed by letters are significantly different to 5%. AM: Ait Melloul; AR: Argana; AB: Ait Baha. (2004-2005=season 1; 2005-2006=season 2; 2006-2007=season 3)

in Ait Melloul than in Ait Baha and Argana. Annual shoots production was higher (12.6) in very humid season, than in dry (5.51) and humid (4.31) seasons. Overall, more annual shoots were formed in Ait Baha and Ait Melloul than in Argana especially in first and third season. Budburst of annual shoots stops at the end of April in the three seasons.

+ Green shoots spiny: Apical meristem of annual shoot was transformed into spine the second week of April during the dry and hot, in January in very wet season and in the first week of March in the humid season (Figure 4). In August of the first season, 37.3% at Ait Melloul, 25.8% at Argana and 10.7% at Ait Baha of green shoots were spiny. During the second season, in the second week of May, 59.8% of green shoots become spiny. In dry season, there were more green shoots spiny in Ait Melloul, than in Ait Baha and in Argana, but we find that in very wet season, at Argana site, RVE was more important (80.8%), than in Ait Melloul (59.4%) and in Ait Baha (40.2%). During the third season, more RVE was recorded in Argana (57.2%), than Ait Melloul (24.3%) and Ait Baha (2.7%).

+ Shoots to indefinite growth: Whatever the season, changes in number of shoots to indefinite growth (RI) was similar to RV. However, the maximum reached for RI was always less than RV (Figure 4). The initiation of shoot extension occurred during the third week of September, the first week of November, the second week of December respectively in dry, very humid and humid season. This occurrence was early in Ait Melloul than Argana but late in Ait Baha. The shoot extension remained low in autumn and become higher after significant rainfall occurred during the period from January to April. More RI was recorded in Ait Melloul and Ait Baha than in Argana. Shoot extension stops in June in dry and very humid season but at the end of March in humid season.

+ Shoots to indefinite growth which acquire spine: Changes in the number of RIE in the second season of this study were similar to that of spiny green branches although the maxima were different (Figure 4). In the first season number of RIE was low. During the third season, no RI was turned to RIE. More the season was humid; acquisition of spine was most early.

+ Secondary branches: Approximately 81.2% in a dry season, 85.4% in very wet season, 88.4% of RV formed during the wet season were the second order (Figure 5). Argan in field, branching is essentially second order.

Length growth

Season effect was highly significant for LMV, LXV and LXI (Table 1). It was not significant for LMI

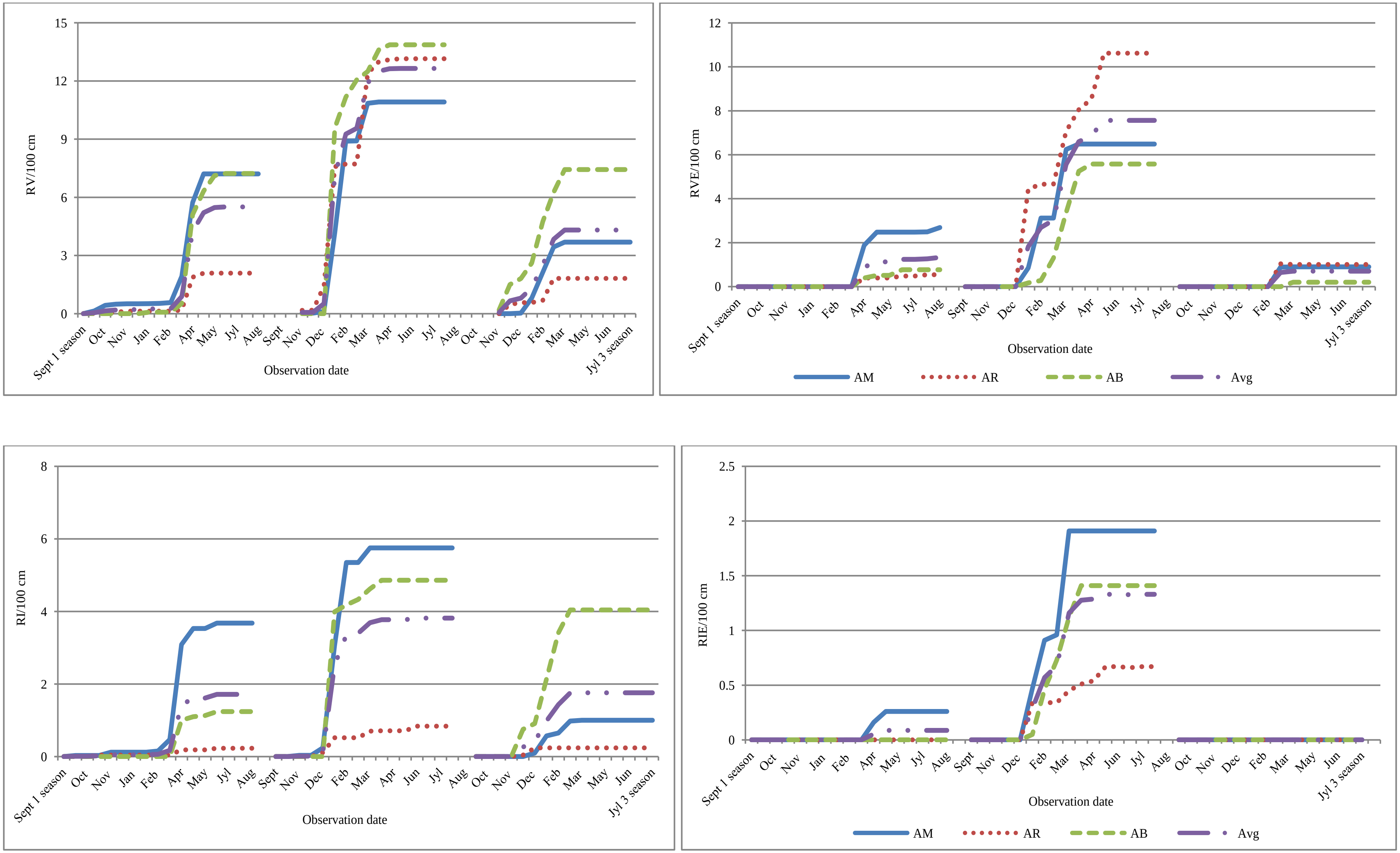


Figure 4. Average number of annual shoots (RV), annual shoots spiny (RVE), shoots to indefinite growth (RI) and shoots to indefinite growth acquiring spine (RIE) observed in the three localities: Ait Melloul (AM); Argana (AR); Ait Baha (AB). (2004-2005=season 1; 2005-2006=season 2; 2006-2007=season 3).

and LB. Shoot growth (LMV, LXV and LXI) was higher in very wet season (2) than in wet (3) and dry (1) seasons. More the season was humid, more shoot growth was considerable and variation was less important (Table 3). Observation date, season x observation date, locality x observation date, season x observation date x locality interactions were significant for length of the smallest (LMV) and greatest green shoot (LXV), and length of the smallest (LMI) and greatest shoot to indefinite growth (LXI). They were not significant for the main branch length (LB).

+ Green shoots: Shoot elongation of RV occurs in the same time of budburst of annual shoots and differs between sites and years. It is generally characterized by three phases. An initial slow phase, between autumn and early winter dry (Figure 6). Shoot extension becomes rapid during the most favourable period of water availability within the growing season from March to June after rainfalls of winter and spring. LMV and LXV were respectively from 2.09 to 2.36 and 0.3 cm to 7.73 cm in very humid season. Shoot elongation stops from April to June and was higher in Ait Melloul and Ait Baha than in Argana.

+ Shoots to indefinite growth: Extension of RI restarted again in autumn (September) in dry season, (November) in humid season and (second week of December) in humid season. It was continuous, but slowed in autumn and winter but was strong in spring from March to June after rainfalls of winter and spring. Shoot elongation finished between April and May after a gain of 1.2, 6.4 and 1.8 cm respectively in dry, very humid and humid season. It was higher in Ait Melloul than Ait Baha and Argana.

Leaf phenology

Climatic season was significant for FSV and FSI but not significant for NFG (Table 1). The production of simple leaves was higher in very wet season than in wet season. But, during the dry season, very few leaves were formed. Variability for FSV and FSI was greater in dry season than in humid seasons (Table 4). Season x observation date interaction was significant for FSV and FSI and not significant for NFG. Locality x observation date interacttion was not significant for NFG, FSV and FSI. Season x observation date x locality interaction was significant for the three characters. Observation date was significant for NFG, but not significant for FSV and FSI (Table 1).

+ Grouped leaves: The formation of grouped leaves occurs mainly in autumn (September) in dry season, (November) in very humid season and (second week of December) in humid season. It was variable in the three sites and in each year and reached respectively 74.77, 70.4 and 67.72 in first, second and third season after cumulative rains of winter and spring (Figure 7). Leaf drop was early in the third week of May in dry season. It becomes intense during summer resulting in loss of 44.7% of total leaves. Leaf fall was more intense in Ait Baha (85.2%) than Argana (39.4%) and Ait Melloul (17.4%). This defoliation reached 71.5% in the first week of November second season, despite some rains in September and October. It reached 56.9% at Ait Melloul and 65.3% in Argana in the first week of November, and 98.8% in Ait Baha in the last week of November in second season after dry summer. Leaf fall was later (last week of June) and very low during summer in very humid season, since only 11.4% of total grouped leaves are lost. It was continuous reached in November of the third season 50% in Ait Baha, 16.9% in Argana and 39.2% in Ait Melloul. Leaf loss was later (May) in humid season and was smaller since only 4.8% of total leaves, (2.1%) in Ait Melloul, (7.5%) in Argana and (7.8%) in Ait Baha in late of July were losses. Thus foliation period without grouped leaves drop during dry season lasted only 60 days (April and May), about 90 days at Argana, 60 days at Ait Melloul and Ait Baha. It was longer and lasted 120 days (March to June) in very humid season and 90 days in humid season.

+ Simple leaves: Simple leaves of RV were relatively similar of FSI and they emerged in autumn (third week of September) in dry season, (first week of November) in very humid season and (third week of November) in humid season (Figure 7). This emergence was variable between sites, continuous and reached from March to June 3.16, 6.15 and 2.47 units respectively in first, second and third season following rainfalls of February to April. Leaf drop was later (last week of July) and was more intense in Ait Baha (28.1%) than Argana (15.9%) and Ait Melloul (5.1%). Simple leaves are more persistent, their fall is less intense since 57.4% of the total leaves were losses during December in second season. All time, it was more marked in Ait Baha (85.1%) than Argana (62.6%) and Ait Melloul (38.1%). In summer of the second and third season, only 4.1% and 11.3%.of leaves have been lost. It reached 70.1% in December of the third season and was more marked in Argana (75.2%) than Ait Melloul (33.4%) and Ait Baha (30.1%). Foliation period without fall during the first and second season lasted more than 60, 140 days respectively in dry and very wet season.

DISCUSSION

The study areas are semi-arid or arid regions, in which the dry and hot season coincides with the period from May to beginning of September, producing therefore water deficit during late spring and summer. Water availability varies throughout the year since the first rains begin in September, the last occurs during the period May-June especially at Argana and Ait Melloul. Inter-

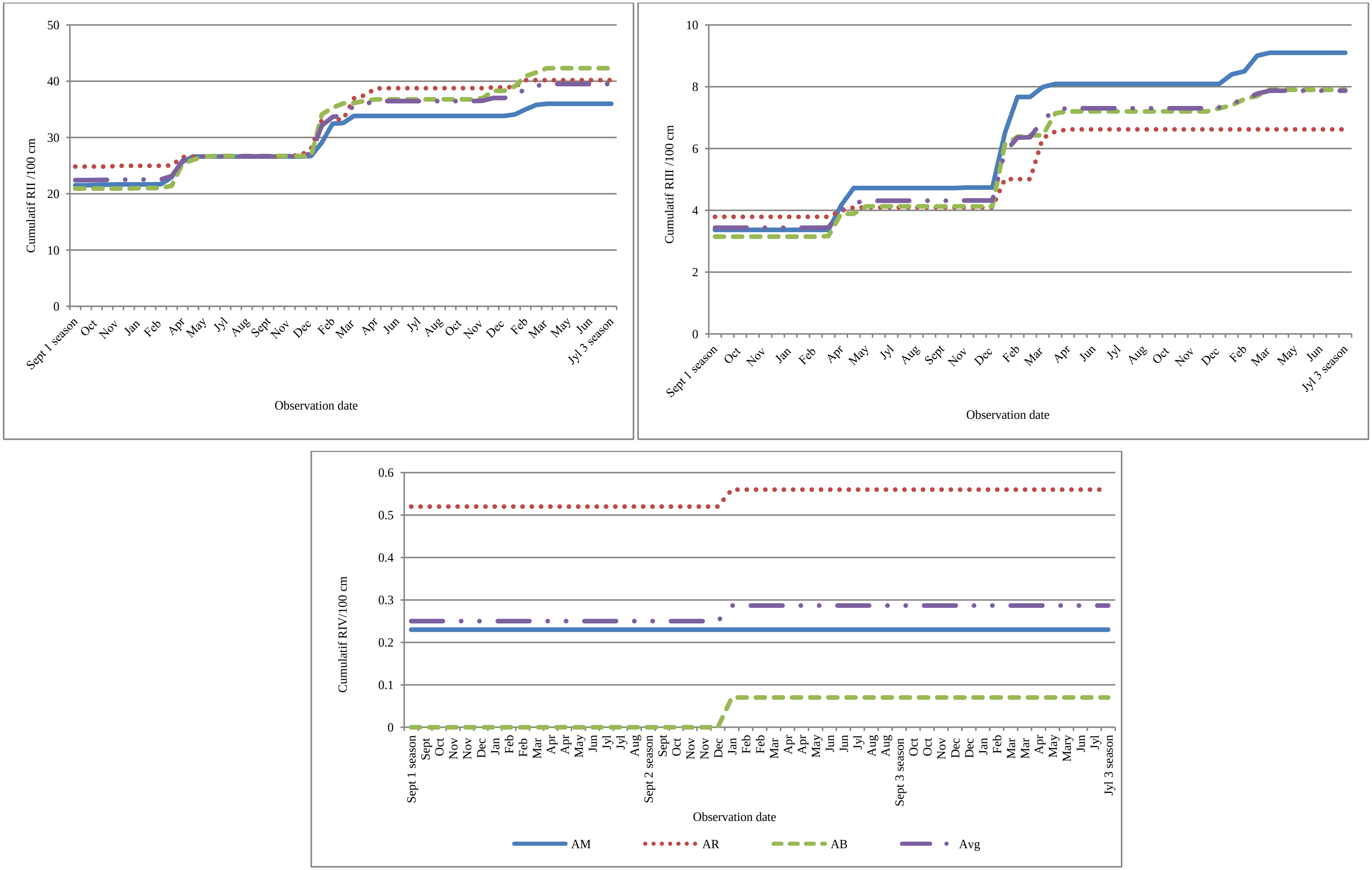


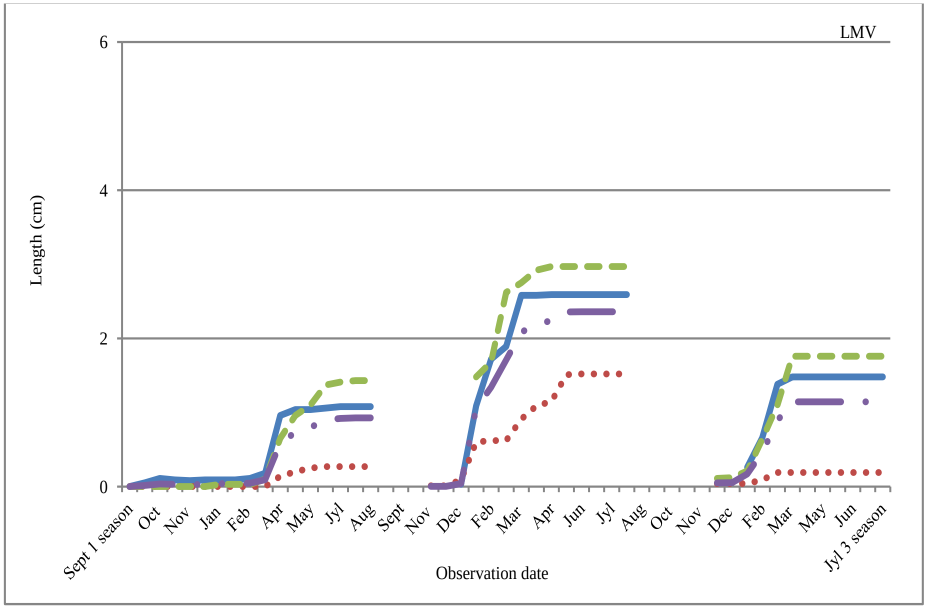
Figure 5. Average number of secondary (RII), tertiary (RIII) and quaternary (RIV) shoots observed for three consecutive seasons in the three localities: Ait Melloul (AM); Argana (AR); Ait Baha (AB). (2004-2005=season 1; 2005-2006=season 2; 2006-2007=season 3).

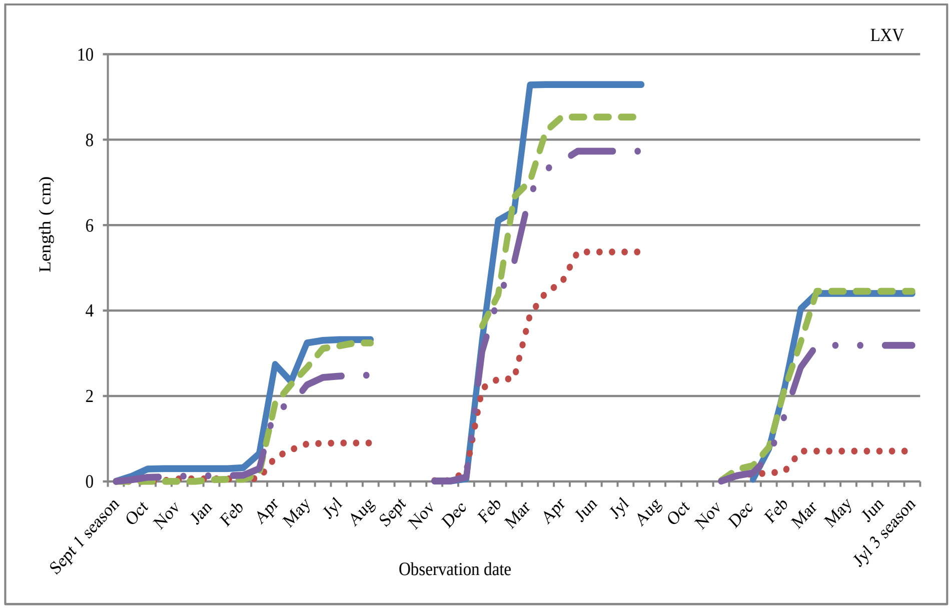
Table 3. Maximum (Max), minimum (Min), average (Avg) and coefficient of variation for morphological traits observed in the three localities.

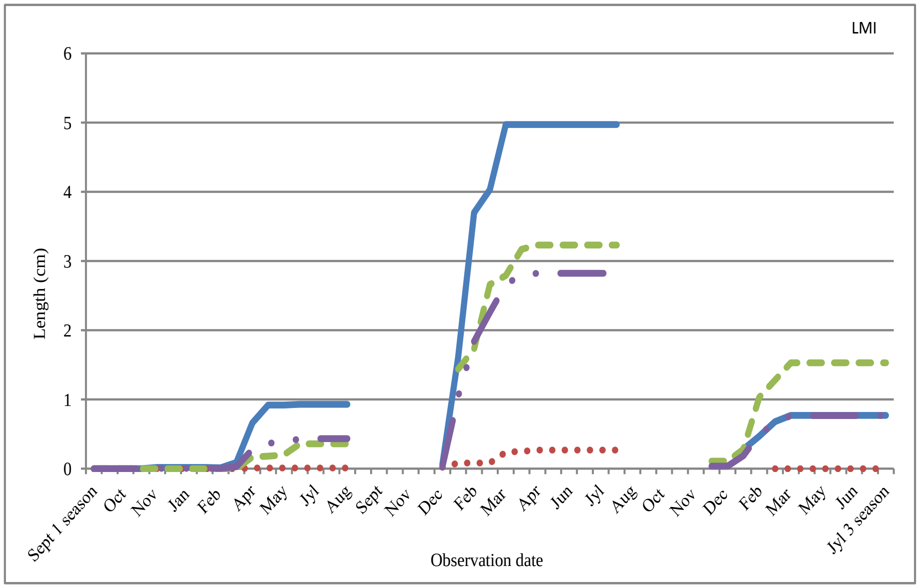
Character		Season \ Locality															
		AM				AR				AB				Average			
		Max	Min	Avg	CV	Max	Min	Avg	CV	Max	Min	Avg	CV	Max	Min	Avg	CV
LB	1	100	22.0	46.6 b	37.3	76.0	16	34.9	41.4	68.2	15	32.06	36.36	81.4	17.67	37.86	38.4
	2	100	22.0	48.1 a	38.5	76..0	16	35.0	41.3	68.2	15	32.06	36.36	81.4	17.67	38.4	38.7
	3	100	22.0	48.1 a	38.5	76.0	16	35.2	41.5	68.2	15	32.06	36.36	81.4	17.67	38.45	38.8
	Avg	100.0	22.0	47.6	38.1	76.0	16	35.03	41.4	68.2	15	32.06	36.36	81.4	17.67	38.23	38.6
LMV	1	11	0.2	0.48 c	282.9	3.5	0.2	0.1 b	484.2	11.4	0.1	0.5 c	300.61	8.63	0.17	0.36 c	355.9
	2	12	0.4	1.5 a	168.8	6.8	0.1	0.75 a	176.5	14.6	0.2	1.72 a	170.13	11.13	0.23	1.23 a	171.8
	3	22.5	2.5	0.75 b	350.4	3.5	2.5	0.1 b	521.04	10.5	1.2	0.85 b	252.7	12.2	2.07	0.57 b	374.7
	Avg	15.2	1.03	0.91 b	267.4	4.6	0.93	0.31 c	393.9	12.2	0.5	1.02 a	241.1	10.65	0.82	0.75	300.8
LXV	1	16.6	0.5	1.49 c	212.2	8.0	0.5	0.36 b	315.7	14.2	0.6	1.17 c	249.4	12.93	0.53	1.01 c	259.1
	2	28	0.2	5.3 a	129.8	23.0	0.3	2.77 a	157.8	28.2	0.3	4.77 a	135.23	26.4	0.27	4.28 a	140.9
	3	24.2	2.2	2.18 b	212.3	5.7	1.5	0.38 b	292.2	16.5	0.5	2.24 b	164.7	15.5	1.4	1.6 b	223.03
	Avg	22.9	0.97	2.99 a	184.8	12.2	0.77	1.2 c	255.2	19.6	0.47	2.72 b	183.1	18.3	0.73	2.3	207.7
LMI	1	5.1	0.6	0.38 b	266.1	0.6	0.6	0.01 b	1203.6	7.5	1.2	0.12 b	660.4	4.4	0.8	0.17	710.01
	2	22	0.5	2.89 a	182.1	5.9	1.2	0.14 a	528.1	22.0	0.4	1.83 a	223.6	16.6	0.7	1.62	311.3
	3	18.5	2.4	0.4 b	580.9	0.0	0.0	0 b	-	11.5	0.6	0.8 c	282.1	10.0	1.0	0.4	-
	Avg	15.2	1.2	1.22 a	343.03	2.2	0.6	0.05 c	-	13.7	0.73	0.92	388.7	10.34	0.83	0.73	-
LXI	1	7.5	0.5	1.02 b	193.9	3.0	1.5	0.08 b	573.3	12.8	0.4	0.41 c	449.8	7.77	0.8	0.5 c	405.6
	2	29.2	1.1	6.6 a	139.04	7.4	0.8	0.36 a	356.7	28.7	1.1	3.89 a	165.6	21.77	1.0	3.63 a	220.5
	3	26.5	1.2	1.1 b	347.5	4.5	1.1	0.1 b	599.3	16.5	0.8	1.71 b	216.1	15.83	1.03	0.96 b	387.6
	Avg	21.1	0.93	2.9 a	226.8	4.97	1.63	0.65 c	318.7	206.2	0.77	2 b	277.2	77.39	1.11	1.86	274.2

Means followed by letters are significantly diffétentes to 5%. AM: Ait Melloul; AR: Argana; AB: Ait Baha. (2004-2005=season 1; 2005-2006=season 2; 2006-2007=season 3)

annual variability of winter precipitation was higher than temperatures except first season. These results complement those found before (Ferradous et al., 1996; Bani-Aameur and Ferradous, 2001). Geographic origin; climatic season, genotype (tree /locality) and observation date influence differently shoot branching; shoot elongation and leaf phenology in argan tree in the field. Annual shoots did not appear until January in oued Cherrate in a humid climate (Metro, 1952). This study shows that budburst date changes by season, locality and between seasons within the same locality. It was earlier in September after dry season, in November after very dry or very humid season. Therefore, it is probably that the duration of the drought and rainfall amounts received from March to April of the year n - 1 are determinants of budburst date of annual shoots or shoot to indefinite growth in season n. So more drought period was long, and spring rainfalls were lower, annual shoot budburst was early. Annual shoot budburst depends also on the tree genotype. So, in trees (4, 5 and 9) of Ait Melloul green shoots emerged in September in a dry season, from November to December in humid seasons. In tree (5) of Argana, emergence of green shoots occurs in November in dry season and in December in humid seasons. Tree (4) of Ait Baha, budburst of green shoots occurs in January in dry season and very humid season, but in November in humid season. Similar results were found in *M. spinosum* in which extension of shoots occurs in the most favorable water availability periods, during spring to early summer or in early autumn (Damascos et al., 2008) or in Q. suber since shoot growth was resumed later in the wet autumn when tree water status recovered







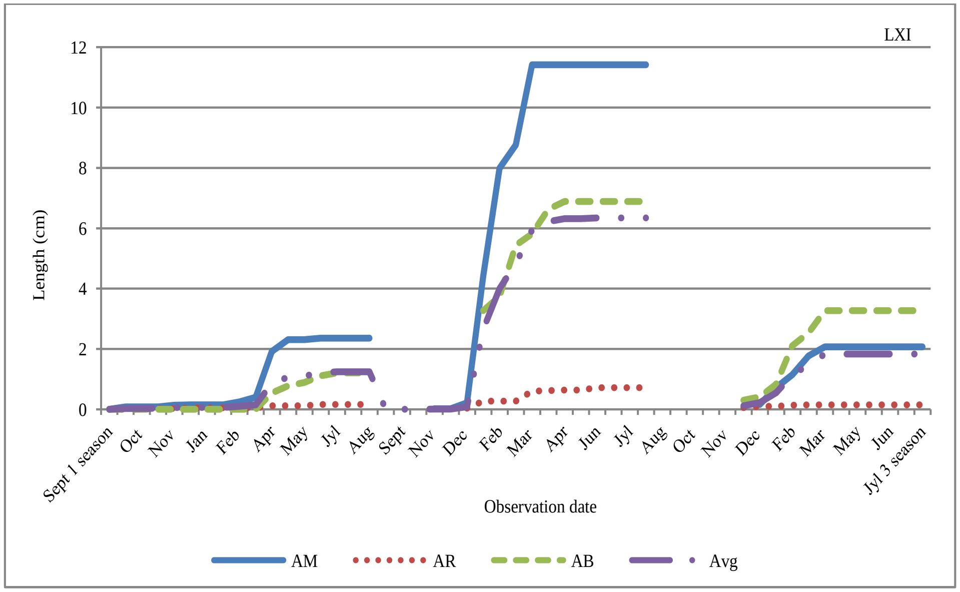


Figure 6. Length of the smallest (LMV), greatest green branch (LXV), the smallest (LMI) and the longest (LXI) shoot to indefinite growth observed in the three localities: Ait Melloul (AM); Argana (AR); Ait Baha (AB). (2004-2005 = season 1; 2005-2006 = season 2; 2006-2007 = season 3).

Table 4. Maximum (Max), minimum (Min), average (Avg) and coefficient of variation for morphological traits observed in the three localities.

Character		Season\Locality															
		AM				AR				AB				Average			
		Max	Min	Avg	CV	Max	Min	Avg	CV	Max	Min	Avg	CV	Max	Min	Avg	CV
NFG / 100 cm	1	180	0	49.3	66.79	273.5	0	70.6	73.36	169.7	0	25.9	143.89	207.7	0	48.63	94.7
	2	142.2	0	43.8	65.9	261.2	0	74.1	65.37	193.9	0	40.4	108.41	199.1	0	52.76	79.9
	3	148.2	0	50.2	59.9	200.0	0	81.3	45.4	180.0	0	45.9	72.7	176.1	0	59.2	59.4
	Avg	156.8	0	47.8	64.2	244.9	0	75.3	61.38	181.2	0	37.43	108.34	194.3	0	53.52	77.9
FSV	1	23	0	1.6	271.2	19.0	0	0.38	575.79	21	0	1.54	285.9	21.0	0	1.17 c	377.6
	2	33	0	4.45	155.4	28	0	3.5	190.96	25	0	4.99	131.62	28.7	0	4.31 a	159.3
	3	33.00	0	3.7	150.5	28.0	0	2.12	236.1	24.0	0	3.56	144.6	28.3	0	3.12 b	177.1
	Avg	29.7	0	3.24	192.4	25.0	0	2.0	334.3	23.3	0	3.36	187.4	26.0	0	2.87	238.0
FSI	1	14	0	1.28	275.5	8	0	0.03	1605.15	17	0	0.48	515.78	13.0	0	0.6 c	789.8
	2	32	0	5.28	152.8	12	0	0.26	582.24	27	0	3.32	181.9	23.7	0	2.96 a	305.6
	3	32.0	0	3.26	185.1	12	0	0.26	576.96	27.0	0	2.75	187.3	23.7	0	2.09 b	316.5
	Avg	26.0	0	3.27	204.5	10.7	0	0.18	921.45	23.7	0	2.19	294.99	20.11	0	1.88	473.5

Means followed by letters are significantly diffétentes to 5%. AM: Ait Melloul; AR: Argana; AB: Ait Baha. (2004-2005=season 1; 2005-2006=season 2; 2006-2007=season 3)

again (Pinto et al., 2011). In *Picea crassifolia* from four sites in the arid and semi-arid region of northwestern China, the significant limiting factor on tree growth was spring precipitation (Gou et al., 2005). Annual shoots and shoots to indefinite growth production stops during period of 60 days (March to May) shows the link between shoot growth and annual precipitation during the annual growth period which seems to be usually between early December and late March. This link was more pronounced in very humid season since number of RV and RI produced was 2 times higher than in dry season. Shoot growth was mainly dependent on cumulative rainfall recorded in autumn and winter, but rains after April have no direct effect on shoots emergence in the same season. Cumulative rainfall during November to April was lower in the three sites in dry season than in humid seasons. In addition, with 100 mm of rain between November and April in dry season or more than 300 mm of rain during the same period in humid season in the three sites, shoot growth was identical Table 5. So in argan tree, a minimum of 100 mm of rainfall distributed between autumn and winter was useful for shoots budburst. Ferradous et al. (1996) indicated that 100 mm of rain in autumn in season of fruit maturation ensures the fruiting in argan in the field. Shoot elongation was also very dependent on climatic season and site; it occurs in September and November respectively in dry and humid seasons. Shoot elongation stops from April to June. Shoot elongation observed during summer (July) in dry season was probably related to vigor of some shoots in relation of resources and distinct physiological states as was found by El Aboudi (1990). Similarly to shoot growth, elongation was also dependent on cumulative rainfall recorded in autumn and winter. It was higher in Ait Melloul and Ait Baha compared to Argana. Values observed in Argana when water was not the limiting factor suggested that low temperatures as reported by Ferradous et al. (1996), recorded during the favourable period growth will be an important factor limiting shoot elongation. Similar findings were observed in for Q. suber in which budburst date was much more dependent on average maximum than average minimum daily temperature (Pinto et al., 2011). Temperature is also an important environmental factor affecting tree phenology, especially oaks (Spark and Carey, 1995).

Producing of leaves was early and occurred in November or December respectively in dry and humid seasons after first rains recorded in autumn. This is in accordance to the results reported by El Aboudi (1990). It was in September after dry period and after hot wind ‘chergui’ in summer. This result was observed especially in genotype 24 from Ait Melloul, completely defoliated in

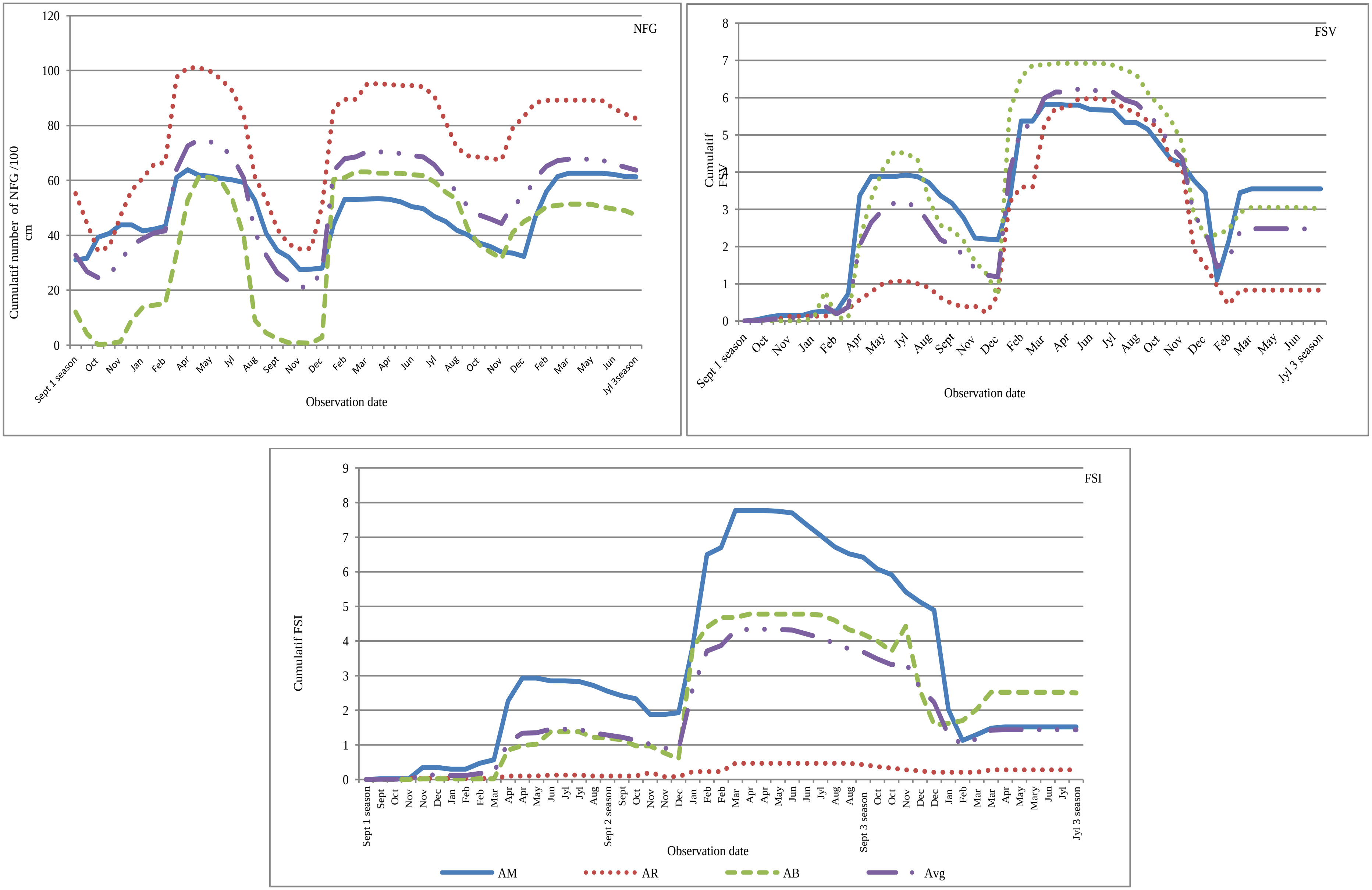


Figure 7. Average number of grouped leaves (NFG), simple leaves on the green branch (FSV) and on the branch to indefinite growth (FSI) observed in the three localities: Ait Melloul (AM); Argana (AR); Ait Baha (AB). (2004-2005=season 1; 2005-2006=season 2; 2006-2007=season 3).

Table 5. Relationship between Rainfall and shoot growth rate.

Season	Period	Ait Melloul	Argana	Ait Baha
	December - March	90.7	133.1	88.3
1	November – March	95.6	133.2	95.3
	November - April	99.0	142.5	109.3
	December - March	481.6	870.8	388.2
2	November – March	576.1	979.1	449.2
	November - April	583.7	981.8	449.2
	December - March	277.2	394.5	246.5
3	November – March	330.6	504.8	288.5
	November - April	336.3	543.2	344.5

Table 6. Relationship between leaf fall and climatic season.

	September -December				January – August			
Season	AM	AR	AB	Avgerage	AM	AR	AB	Average
1	104.3 b	104 b	27 b	78.4 b	210.3	213.7 b	154.3 b	192.8 b
2	107.7 b	96.7 c	14.7 c	73 b	216.3	218.3 ab	220 a	218.2 a
3	117.7 a	119 a	113 a	116.5 a	219.3	220 a	219.7 a	219.6 a
Average	109.9 a	106.6 a	51.6 c	89.3	215.3 a	217.5 a	198 b	210.2

Means followed by letters are significantly different at 5%. (2004-2005=season 1; 2005-2006=season 2; 2006-2007=season 3)

summer dry season. After first rains received in September, leaves were emerged in October. Leaf drop occurs in June in dry seasons (Ferradous et al., 1996) or in August (Metro, 1952; El Aboudi, 1990) in humid season. It appears that leaf fall was dependent on climatic season. It was very early (May) in dry and humid season, in June in the very humid season. From January to August, trees were covered during 192.8 days in dry season, during 218.2 and 219.6 days in humid seasons, thus leaf drop during this period was low. It becomes more intense from September to December since trees were covered during only 78.4, 73 and 116.5 days in this period respectively in dry and humid seasons. When Means followed by letters are significantly different to 5% (2004-2005=season 1; 2005-2006=season 2; 2006-2007=season 3) (Table 6); water stress is high, trees were stressed and leaf fall was more intense since 75.4% and 78.9% of leaves were loss in late summer of the first and second season. But after lower or moderate water deficit, leaf drop was less important since only 57.7% of leaves were loss after very humid season. Thus, those leaves were deciduous, two processes were involved; the physiological leaves drop in response to water stress and the lifetime of grouped leaves that was spread on a single cycle. These findings confirm the idea suggested by Ferradous et al. (1996); since each genotype was sensitive in a given environment, to water deficit threshold from which, it begins to lose its leaves. Stationnel microclimate promotes more or less this reaction, since losses were more intense in Ait Baha (arid site), than in Ait Melloul and Argana. Stomata do not close completely (Peltier et al., 1990), to reduce water loss through evapotranspiration as was seen in many xerophytes (Gorenflot, 1986), tree adjusts leaf number by losing some grouped leaves. It thus adopts strategies to escape strict conditions as it was reported by El Aboudi (1990) and Ferradous et al. (1996). Argan tree by its behaviour would be among the species in arid environments that share physiological and morphological strategies to reduce plant transpiration and protect leaves from excessive radiation and desiccation of the wind, they differ significantly in growth form, architecture of air, and the turnover rate of leaves (Gorenflot, 1986; Damascos and al., 2008). However, if dry conditions spread over a longer period, trees are completely defoliated. Thus, among the 90 trees in the three stations, 44.5% and 45.6% of them were completely defoliated respectively in autumn of the first and the second season, while only 2.2% of them were completely defoliated in autumn of the third season. Simple leaves were relatively less frequent and more persistent than grouped leaves. Only 57.4% and 36.5% of simple leaves (71.5% and 37.1% of grouped leaves) were lost in November second and third season. Our results are in accordance to several findings in other species. Thus, in Acacia tortilis ssp. Raddiana, it appears that inter-annual variation of canopy phenology as timing of leaf flush peak and leaf fall peak were mainly tuned to atmospheric conditions. Such behavior maximizes the duration of high photosynthetic activity below a threshold of evaporative demand (Do et al., 2005). In nineteen woody species growing in the semi-arid region, leaf fall in these species occurred during the transition period between the rainy and the dry season, and it occurred earlier than in species with denser wood. Leaf fall in these species occurred during the dry season and depends on tree genotype (Lima and Rodal, 2010).

Conclusion

Plant phenology characterises the seasonal cyclicity of biological events such as budburst, flowering, fructification and leaf drop. These biological events in argan tree in the field are strongly modulated by climatic conditions, particularly temperature and water availability. Budburst date is changed by genotype, season, site and between seasons within the same locality. Shoot growth, shoot elongation and leaf emergence were mainly dependant on cumulative rainfall recorded in autumn and winter. Leaf drop in argan represents an adaptive advantage in the arid environment. But, more than 55% of the trees are covered with leaves during drought period. This result suggests that some genotypes are resistant to dry conditions and will be useful for selecting plus trees which are essential for management and conservation practices of genetic resources in order to minimize the risk of planting of unsuitable individuals. In several species, the leaf is a key ecosystem parameter controlling carbon and water fluxes and affecting forest dynamics. Therefore, the use of cultural practices can be useful for improving the productivity of the forest ecosystem since only 100 mm of rainfall can ensure leaf emergence, shoot growth and fruit productivity. We did not measure oil content in this study, so we can only speculate on the possible role of the production, storage of oil related to phenology.

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