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Ecology and phenology of *Rhus tripartitum* (Ucria) grande species situated in arid area in Tunisia

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Abstract

Rhus tripartitum (Ucria) Grande is a spontaneous plant (Anacardiaceae). It has a great ecological value and versatile, but it is endangered. In order to characterize the variability of phenological phases of this taxon, a study of phenology in his natural environment, was carried out in the arid areas of Tunisia: ((Bou Hedma (BH); Matmata (MM); Beni khedache (BKH) and Djerba (DJ)) during two years (from 2010 to 2011). Our results show that the different phases, especially the flowering and fruiting coincide with the dry season. The observation of these shrubs in different phenological states shows a high variation between provenances and between individual. Indeed, the leafing out from BH and DJ are prolonged in time during the two years of observation (2010 and 2011). But in 2011, BKH and MM are earliest compared to others. The flowering is very limited in time (2 months). The fructification of *Rhus tripartitum* began in december for all provenances and during two years (2010 and 2011). But the provenance of MM is prolonged in time (June 2011) compared to others. These variations between provenances can be explained by the influence of temperature, soil moisture, photoperiod, exposure and soil texture.

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Introduction

Sumac (*Rhus tripartitum* (Ucria) Grande), belonging to the Anacardiacea family, is a small tree or shrub twigs, very spiny, toothed leaves glaucous. This is a pastoral, medicinal and food species. It to an anti-erosive role if reforestation troughs. It grows in Mediterranean countries, North Africa and in the Middle East.

In Tunisia, it colonizes the dorsal, central and southern. The combined action anthropic and climatic factors caused a progressive threat of plant heritage in particular *Rhus tripartitum*. For this reason, it is very significant to study the biological cycle and the phenology of this species threatened of disappearance.

Plant phenology is the study of the emergence of annual events, cyclic and periodic. Growth is determined by seasonal variations in climate (bud, fruit, etc.) (Beaugrand *et al.*, 2008, Zouaoui, 2014). It constitutes an important tool in the study of climate change. Fully understand how environmental conditions directly affect the development of the tree, day by day, during the growing season can help us anticipate the impacts of climate change (Wood *et al.*, 2008; Soudani *et al.,* 2008). The evaluation of the growth of the species made on the basis of vegetative bud reflects the rate of vegetative growth of the species (Zaâfouri, 1993). It also allows to identify the different phases of biological activity of plant (Chaieb, 1989). Moreover, the biological and ecological knowledge on native species in arid constitutes a limit and a big handicap for the development, operation and especially the conservation of endangered genetic resources. Works on the phenology of plant species in arid area are comparatively few. In this context, we are interested in establishing a timetable to know the different phenophases (leafing out, flowering and fructification) of natives species to arid Tunisia (*Rhus tripartitum*) by using an ecological approach. So, we will release as much information and detail on its biological cycle.

In addition, we will study the correlations between morphological and physiological changes shrubs (periodicity) and fluctuations of environmental variables. Especially, we will explain and predict their reactions to changes in environmental variables some of which phenomena (phenological shift) appear. This study is a synthesis of observations in different provenances located in the arid regions of Tunisia, natural environment of the species studied.

Materials and methods

Study sites

The study sites are situated in arid area of southern Tunisia. We chose four experimental provenances (National Parc of Bou Hedma (BH); Benikhedeche (BKH); Djerba (DJ) and Matmata (MM)) **(**Table 1). The bioclimatic, geographical factors, such as longitude (LONG) and latitude (LAT) was determined (Tian *et al.*, 2013).

Table 1. Bioclimatic characteristics of stations.

Rhus tripartitum				
Stations	***Sites***	***Bioclimats***	***Variantes***	***Co-ordinates lumbar***
National Parc of Bouhedma (BH)	*Sidi bouzid*	*arid superior*	*mild winter*	*4078522 N ° 32606527 E ° 23 m*
Benikhedeche (BKH)	*Medenine*	*Aride inferior*	*mild winter*	*3682139 N ° 32618759 E ° 340 m*
Djerba (DJ)	*Medenine*	*Aride inferior*	*mild winter*	*3744115 N ° 32666784 E ° 12 m*
Matmata (MM)	*Gabes*	*Saharan superior*	*mild winter*	*3710218 N ° 32591720 E ° 428 m*

Meteorological data

The meteorological stations of (IRA Medenine, National Institute of Meteorology of Tunisia and National Park of bouhedma) provided reference information for climatic factors of differents provenances. As a result of irregular rainfall in arid zones generally (Noy-Meir, 1973) and pre-Saharan Tunisia in particular (Le Houerou, 1959; Floret & Pontanier, 1982), it is suitable for assessing the behavior of the plant to make observations during two years of study. The climatic data provided by the meteorology: temperature and rainfall are shown in the Fig.s below. They concern the study sites located in the arid bioclimatic: BH; BKH; DJ and MM registered during the study period (from 2010 to 2011). The study sites are characterized by significant thermal variation seasonal and monthly even daily. Temperatures are generally high for an extended period of the year and constitute a very ecological factor constraining to the physiological activity of plants (Tarhouni, 2008; Noumi, 2010). It may be noted that the extreme temperature differs between the provenances. Concerning the maxima of the hottest month (M), the highest temperature is registered during the summer month (July) with 47.4°C in 2011 at BH (more continental side) followed by BKH (46.59°C), MM (35.7°C) and the lowest is registered at DJ (33.6°C) (an island). The coldest month in most provenances is February.

The island of DJ (between 10 and 11°C) has a winter less cold than MM (5.9°C), BKH (1.17°C). This seems to have an influence on precocity of vegetation.If we assume BH (47.4°C) and BKH (46.59°C), we find that the two stations have values of M are substantially identical. This determines a duration longer vegetation in thermo-Mediterranean ambiance than meso and eu-Mediterranean. Recovery of vegetation is more precocious in the low altitudes than high altitudes. The thermal regime appears to have a direct impact on the phenology and growth of vegetation (Chaabane, 1984).

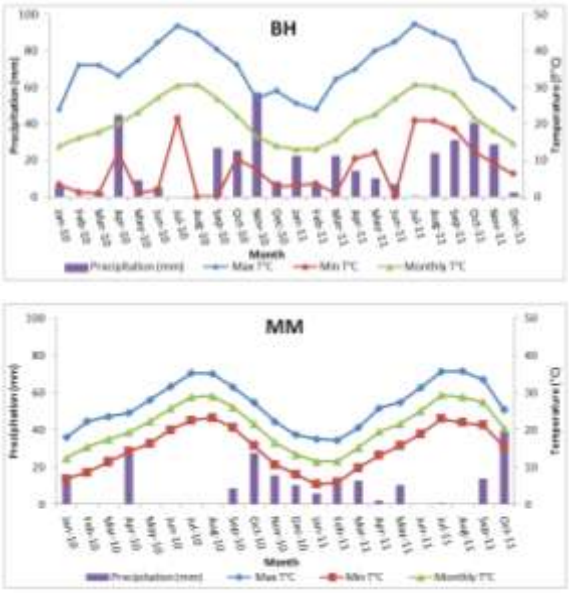

Fig. 1a. Location of the study sites within the study area and available meteorological data of the closest weather stations for the study period. Study sites (BH and MM) Total precipitation, mean monthly temperature, mean minimum temperature and mean maximum temperature correspond to data measured during the study period by the weather stations.

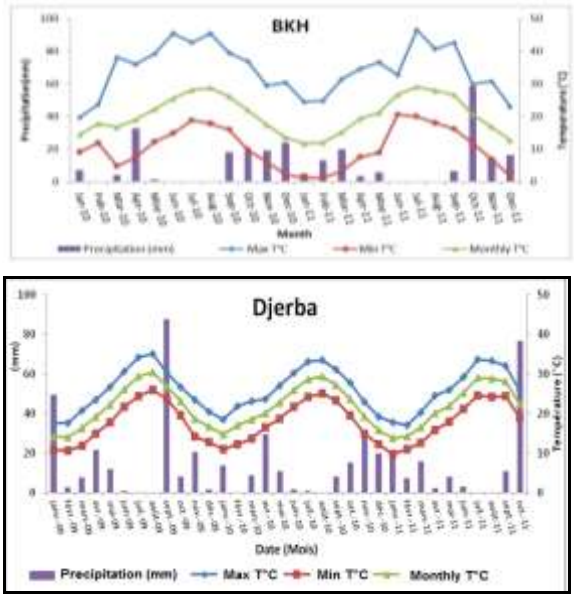

Fig. 1b. Location of the study sites within the study area and available meteorological data of the closest weather stations for the study period. Study sites (BKH and DJ) total precipitation, mean monthly temperature, mean minimum temperature and mean maximum temperature correspond to data measured during the study period by the weather stations.

The distribution of annual rainfall registered during the experiment is characterized by an apparent variation between the different provenances during the two years of study (from 2010 to 2011). In BH, rainfall presents a maximum of 82.8 mm in January 2009 and 57 mm in November 2010. It was registered a maximum average monthly rainfall in October 2011 with 87.7; 58.5 and 39.5 mm respectively for provenances of DJ, BKH and MM (Fig. 1a and b).

Soil physical and chemical properties

Soils sampled were taken from beneath the shrubs at 0-40, 40-80 and >80cm depth using an auger. Soil samples were weighed directly with a field balance to determine fresh weight, and soil water-content was determined by drying the samples in the laboratory at 11°C for 48 h. Soil water content was expressed on a fresh weight basis. Soil samples were passed through a 2mm mesh sieve and subjected to various analyses. Soil pH and electrical conductivity (EC) were determined by the saturated paw method (AFNOR, 1987). Organic matter was determined by the partial oxidation method (Wallkey & Black, 1934). Soil factors, such as soil moisture (SM), organic matter (SOM), available phosphorus (AP), available potassium (AK), pH value (PH) and electricity conductivity (EC) (Atta *et al.*, 2012 : Tian *et al.,* 2013).

Phenological tracking method

This study is based on the dynamic aspect of the phenology of *Rhus tripartitum* (Ucria) Grande. It aims to analyze the organization of phenological phases during the year to determine the vegetative cycle of this specie in the different provenances. The plant material used is composed of adult shrubs growing naturally in the arid regions of Tunisia spread over 4 stations from the prospection of 2009. Phenological observations were carried on subjects numbered from 1 to 10. The rhythm of observation is 1 time / month, observations took place during 2010 and 2011. They are recorded on individual cards. A number of parameters have been determined. The temporal components: it is to determine the duration of different phases: flowering, fruiting, vegetative buds and rest.

Data collection

Phenological specter is constructed by calculating the frequency of individuals at leafing out (V%), flowering (f%) and fructification (F%) for each observation date by provenance (Grouzis & Sicot, 1980) Frequent visits were made in different seasons (Badshah *et al.*, 2013).

The relationship is as follows : P (%) = (n / N) * 100

P (%) = Percentage of individuals by provenance for each phase (leafing out, flowering and fructification)

n: number of individuals in each phase.

N: total number of individuals by provenance

A development phase is considered to be reached when an individual is present in one of the three following stages: 2, 3 and 4. Stages 1 and 5 correspond installation and end (disappearance) phase (Table 2).

Table 2. Characterization of the different stages in each phase of phenology.

Phenological phases		
Leafing out	**Flowering**	**Fructification**
V1 : buds swell, no leaves developed	f1 : only buds flower	F1 : fruit set
V2 : leaf buds + leaves blooming (+of 10% and – of 50% branches of individual)	f2 : buds flower and blooming flowers (+ of 10% et – of 50%)	F2 : stage of evolution of fruit to their normal size.
V3 : leaves majority blooming	f3 : + of 50% branches are open flowers.	F3 : fruit maturation
V4 : green leaves + dry leaves (+ of 10% and – of 50%)	f4 : buds flower + dry flower (+ of 10% and – of 50%)	F4 : mature fruits + beginning of dissemination (fruit fall)
V5 : + of 50% an individual branches are dry leaves.	f5 : dry flower majority (falls floral parts)	F5: completely dry fruit and full

Results

Site conditions

As shown in Table 3, soil texture was almost similar in all provenances. It is sandy, but with differences in the proportions of clay and silt. There is a high sand content for different provenances of *Rhus tripartitum* especially DJ. Soil organic matter differed below shrubs at different positions on the slope. The examination of the profiles studied shows that the percentage of organic matter in the different profiles decreased with soil depth. This decrease can be explained by the lack of incorporation of organic matter in depth. The values vary between 0.3 and 0.7% in soil organic matter. The common characteristic of all these edaphic environments remains their low chemical fertility and organic matter carbon (<1%). The total limestone content varies depending the provenances and selected horizons. It increases with depth for most provenances except for MM. The highest levels were observed in BKH with a max of 52% by> 80cm, lesser degree for MM (23%) and low for BH (13%). The pH is basic in all profiles with values between 7.8 and 9.1 (BKH). Electrical conductivity (EC) varies between 0.5 (BKH) and 17.4 mmhos.cm-1 (BH) in the surface horizon.

Table 3. Physical and chemical soil properties of study sites (Djerba (Dj), Bou Hedma (BH), Matmata (MM) and Beni khedache (BKH)) for the shrub of *Rhus tripartitum* in arid zone of Tunisia.

	Study sites											
Soil characteristics	*DJ*			*BH*			*MM*			*BKH*		
Depths	0-40	40-80	>80	0-40	40-80	>80	0-40	40-80	>80	0-40	40-80	>80
Clay content (%)	7	12	2	6,525	3,85	17,7	10,975	13,225	18,6	8	8,875	10
Silt content (%)	16	19,25	19,5	44,21	42,965	36,4	25,5	25,35	32,7	15,5	21,7	27,7
Sand content (%)	77	56,5	59	40,65	47,5	40,75	63,025	59,825	48,65	76,5	66,45	60,55
pH (1/2,5)	8,13	8,075	8,14	7,8	7,95	7,8	8,55	8,6	8,2	9	9,1	9
Soil EC (mmho/cm)	3,4	3,1	3,5	88,8	63	17,4	2,75	1,55	3,6	0,7	0,5	0,5
Total limestone (%)	13,5	13,5	19	26,5	25	13	22,5	19	23	20	30	52
Active limestone (%)	6	6	9	10,5	12	6	9	7,5	11	8,5	13,5	25
Soil organic matter(%)	0,5	0,3	0,4	0,45	0,45	0,3	0,35	0,4	0,4	0,7	0,3	0,3
Textural class	Sand	Sand	Sand	silty	silty	clay silty	Sandy silty	Sandy silty	Clay silty	Sand	Sandy silty	Sandy silty

Interannual variations and inter-site phenophases of Rhus tripartitum

Phase of leafing out

the phase of leafing out includes the development, elongation and branching of the aerial parts (stems and leaves) and underground parts (roots). During this phase, we see the emergence of new shoots which develop in leafy and thorny stems. This phase is synchronized with the rains of the autumn. The existence of this correlation shows that this species requires sufficient moisture in the soil to trigger and maintain vegetative growth. We recorded a variation between provenances in the phase of leafing out. Indeed, leafing out of BH and DJ are more extended in time during the two years of observation (2010 and 2011). Whereas of BKH and MM are earliest during year 2011 (Fig. 2).

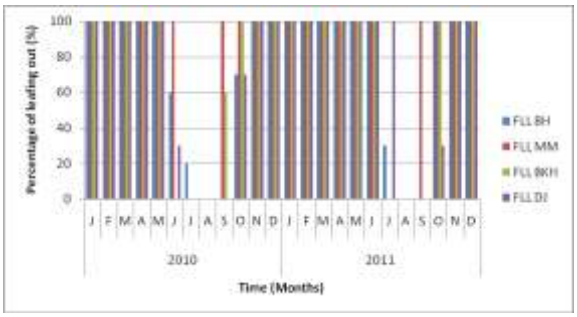

Fig. 2. Leafing out phase of *Rhus tripartitum* (Ucria) Grande in the different provenances for the study period (2010-2011).

Flowering phase

The phase of flowering started in November of BH, BKH and DJ during year 2010. So, the latter are earliest in 2010. It is spread out until the first decade of january 2011 for MM, BKH and DJ. Whereas it is limited to December for BH. On the other hand, in

2011, all provenances flower at the same time. The phase of flowering is very limited in time (Fig. 3).

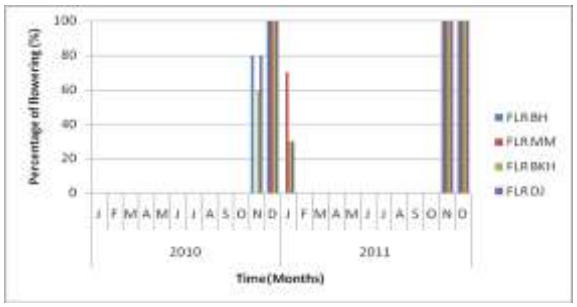

Fig. 3. Flowering phase of *Rhus tripartitum* (Ucria) Grande in the different provenances for the study period (2010-2011).

Fructification phase

Fructification phase of *Rhus tripartitum* began in December for all the provenances during the two years of observation (2010 and 2011). It is spread out until June, of which the most prolonged in time is that of MM (Fig. 4).

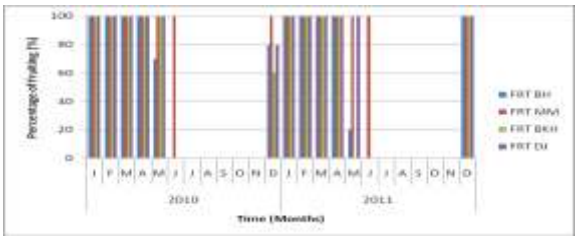

Fig. 4. Fruiting phase of *Rhus tripartitum* (Ucria) Grande in the different provenances for the study period (2010-2011).

Bou Hedma	2010												2011											
Time	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Leafing out	■	■	■	■	■	■	▒	▒			▒	■	■	■	■	■	■	■	■	▒			■	■	■
Flowering												■	■											■	■
Fructification	■	■	■	■	▒							■	■	■	■	■	▒								■
Maturation																									
Vegetative rest						■	■	■	■									■	■	■	■				

(a)

Matmata	2010												2011											
Time	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Leafing out	■	■	■	■	■	■			■	■	■	■	■	■	■	■	■	■			■	■	■	■
Flowering												■	▒										■	■
Fructification	■	■	■	■	■	■						■	■	■	■	■	■	■						■
Maturation																								
Vegetative rest							■	■											■	■				

(b)

Beni khedache	2010												2011											
Time	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Leafing out	■	■	■	■	■				▒	■	■	■	■	■	■	■	■	■				■	■	■
Flowering											▒	■	▒									■	■	■
Fructification	■	■	■	■	■							▒	■	■	■	■								■
Maturation																								
Vegetative rest						■	■	■											■	■	■			

(c)

Djerba	2010												2011											
Time	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Leafing out	■	■	■	■	■	▒				▒	■	■	■	■	■	■	■	■	■			▒	■	■
Flowering											■	■	▒										■	■
Fructification	■	■	■	■	■							▒	■	■	■	■	■							■
Maturation																								
Vegetative rest							■	■	■											■	■			

(d)

Color legend:

10%	20-30-40%	50-60-70%	80-90%	100%+

Fig. 5. Phenological calendars of *Rhus tripartitum* (Ucria) Grande in the different provenances (a,b,c et d) for the study period (2010-2011).

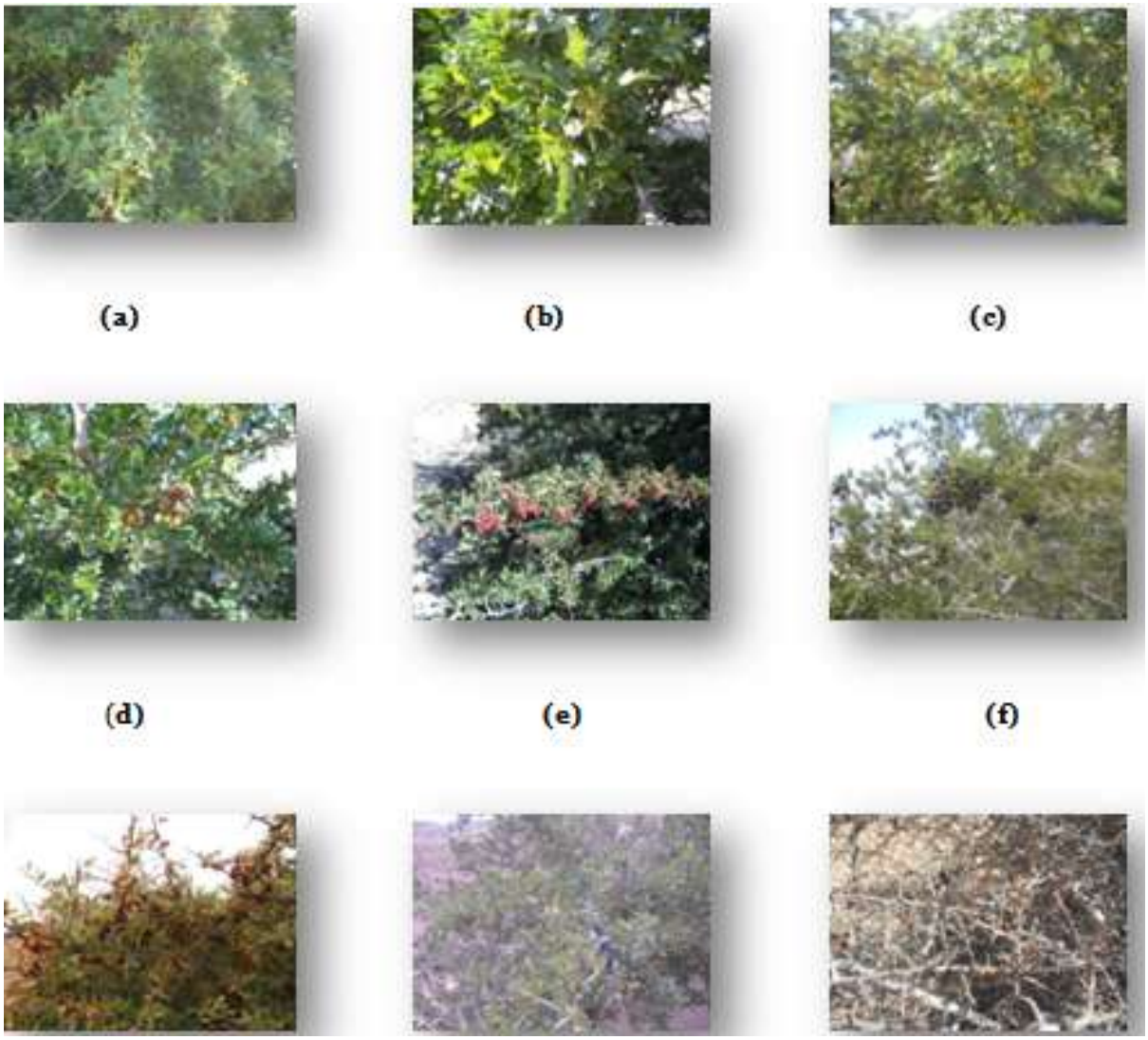

Fig. 6. Phenological stages of *Rhus tripartitum* (Ucria) Grande
a : full foliation, b : full flowering, c : start fruiting (green drupes), d : Fruiting phase (drupes early in maturation), e : Fruiting phase (immatures drupes)f : Fruiting phase(matures drupes), g : dispersal of fruits, h : full dispersal and i : Vegetative rest.

Maturation phase

the provenance of BH has a precocity of maturation (March 2011) and dissemination (May 2011) of the drupes compared with the other provenance into 2011. Whereas the others (BKH, MM and DJ) show a delay of maturation (April 2011).

Discussion

The study of the vegetative cycle of a xerophytic plant species not only contributes to better write the species but also to enhance its pastoral potential and its ability to endure water stress (Abdallah *et al.*, 1999).

Under the climatic conditions of different provenances, *Rhus tripartitum* presents generally a active vegetative phase concentrated on the humid season which spreads out since September until may. In summer, this specie has a growth arrest which corresponds to the period of high temperatures and high light intensities.

Rhus tripartitum is characterized by foliation stage and fruiting very spread out and a short flowering phase.

These phases are synchronized with the wet period of the year. The existence of this correlation shows that this species requires the moisture in the soil in sufficient quantity in order to trigger and maintain their development and continue their vegetative cycle. We observed a variation in different phases between provenances even in the same provenance.

Leafing provenance of Bou Hedma (BH) and Djerba (DJ) are the most prolonged in time for the two years of observation (2010 and 2011). This situation is explained by the done that from Djerba (Island) is the most humid station during year. For this reason, this species keeps the leaves for a longer period compared to others. The extension of the foliation phase revealed for Bou Hedma in 2011 can be explained by the high rainfall during the summer months of July to November 2011 in the park.

These results confirm those of Grouzis and Sciot (1980), which revealed a major effect of rainfall on the determinism of phenological phases of some Sahelian woody. While BKH and MM are the earliest in 2011. These two stations are in the mountains. So, the leafing in mountain is earlier compared to the plains, because this is the wettest place because of the decrease in temperature with altitude. The altitude has a strong impact on the start of the vegetation and therefore causes a delay of flowering and fruiting. This is the case of Matmata (MM). It has a late flowering accompanied by a fairly prolonged fruiting phase in time during the two years of observation compared to others. It lasts until June. This may be explained by the decrease in temperature caused by elevation (approximately 0.5° every 100 m) which has a strong influence the period of plant growth (Jeangros *et al.*, 2005). An advancement of the maturation period (March 2011) and dissemination (May 2011) from the Bou Hedma is possible with global warming. Climate change is therefore likely to lead to a change in temperature and photoperiod inducing early different phenological phases. (Vitasse *et al.*, 2009; Kaesha *et al.*, 2010). Our results are confirmed by the studies of Lesica *et al.*, (2010) and Pinna *et al.*, (2010) which show that the phenological behavior of forest species depends on climatic factors also show an annual variation and rhythmicity. These factors (photoperiod, water stress, insolation and temperature) act at various levels of floral induction at anthesis (flowering). The temperature and the insolation activate and accelerate fruit maturation (Ulrich, 1952).

Biological and ecological knowledge of indigenous species of drylands is a limit and a big handicap for the development, operation and especially the conservation of genetic resources in danger of extinction. About phenology, very little work has been carried out on Tunisian south species. So, the synthesis of observations on *Rhus tripartitum* in different provenance of arid Tunisia shows there is inter-annual and intersite variation can be explained by the variation of temperature and soil water reserves. This species completes their growth cycle in winter with high humidities. We confirm their requirement to water.

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