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COMPARATIVE PHENOLOGICAL STUDY OF *ZIZIPHUS LOTUS* (L.) LAM. IN THE ARID AREA OF TUNISIA

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Abstract

Ziziphus lotus (L.) Lam. is spontaneous plant (Rhamnaceae). It is of great ecological value and versatile, but it is endangered. To show the variability of phenological phases of this taxon, a study of phenology was conducted in arid Tunisia: ((Bou Hedma (BH); Matmata (MM); Medenine (Amra) (MD) and Oued Zes (OZ)) during two years (2010 and 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 (intersite) and between individual (intrasite). In 2011, the leafing out from BH presents a precocity and prolongation in time compared to others. The flowering is enough spread over time and present with fruiting phase at a given time. In 2010, the provenances of MD and MM are more precocious compared to other. By against, in 2011, all the provenances bloom at the same time. In BH, the fructification is the most precocious compared to others. These variations between provenances can be explained by the influence of temperature, soil moisture, photoperiod, exposure and soil texture.

Keywords: Leafing out, Flowering, Fructification, Shrub

Introduction

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). 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 calendar to know the different phenophases (leafing out, flowering and fructification) of natives species to arid Tunisia (*Ziziphus lotus*) 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 differents provenances located in the arid regions of Tunisia, natural environment of the species studied.

Materials and Methods

Study sites: Field experiments took place at four sites in arid area of southern Tunisia (Table 1). Geographical factors, such as longitude (LONG) and latitude (LAT) was determined (Tian *et al.*, 2013).

Table 1. Bioclimatic characteristics of stations.

Stations	*Ziziphus lotus*			Co-ordinates lumbar
	Sites	Bioclimats	Variantes	
Bou Hedma Parc(BH)	Sidi bouzid	Superior arid	Mild winter	3812823 N ° 32556657 E ° 86 m
Amra (MD)	Medenine	Inferior arid	Mild winter	3698244 N ° 32643526 E ° 67 m
Oued Zes (OZ)	Medenine	Inferior arid	Mild winter	3710233 N ° 32591682 E ° 427 m
Matmata (MM)	Gabes	Superior saharan	Mild winter	3723423 N ° 32593697 E ° 158 m

Meteorological data: The meteorological stations of (IRA Medenine, National Institute of Meteorology of Tunisia and National Park of Bou Hedma) 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 Houérou, 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 figures below. They concern the study sites located in the arid bioclimatic: BH, OZ, (Amra) 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). 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 Amra (46, 59°C), MM (35, 7°C) and the lowest is registered at OZ (30, 3°C) (to the coast). February is the coldest month in most provenances. OZ (9, 4°C) has a winter less cold than MM (5, 9°C), Amra (1, 17°C). This seems to have an influence on precocity of vegetation. If we assume BH (47, 4°C) and Amra (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). 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 88,4 ; 58,5 and 39,5 mm respectively for provenances of OZ, Amra and MM (Figs. 1a and b).

Soil physical and chemical properties: soils sampled were taken from beneath the shrubs at 0-40, 40-80 and >80 cm 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 110 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 (Anon., 1987). Organic matter was determined by the partial oxidation method. Soil factors, such as soil moisture (SM), organic matter (OM), 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 *Ziziphus lotus*. 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.).

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 differents provenances of *Ziziphus lotus* especially MM, OZ and Amra lesser degree for BH. Soil organic matter differed below shrubs at different positions on the slope. 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, 1 and 0, 55% in soil organic matter. The common characteristic of all these edaphic environments remains their low chemical fertility and organic matter carbon (<1%). There is a decreasing gradient with higher OM and carbon are in the surface horizons in most profiles with max met the BH and min OZ. 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 BH with a max of 9% by> 80 cm, lesser degree for MM and low for Amra and OZ. The pH is basic in all profiles with values between 7, 95 and 8, 8. Electrical conductivity (EC) encountered in different sources is less than 2 mmhos.cm-1, which is absolutely not restrictive for plants. The higher salinity is encountered in the horizons of the surface to Amra (1,5) and BH (2,7) while in depth for MM (2,1).

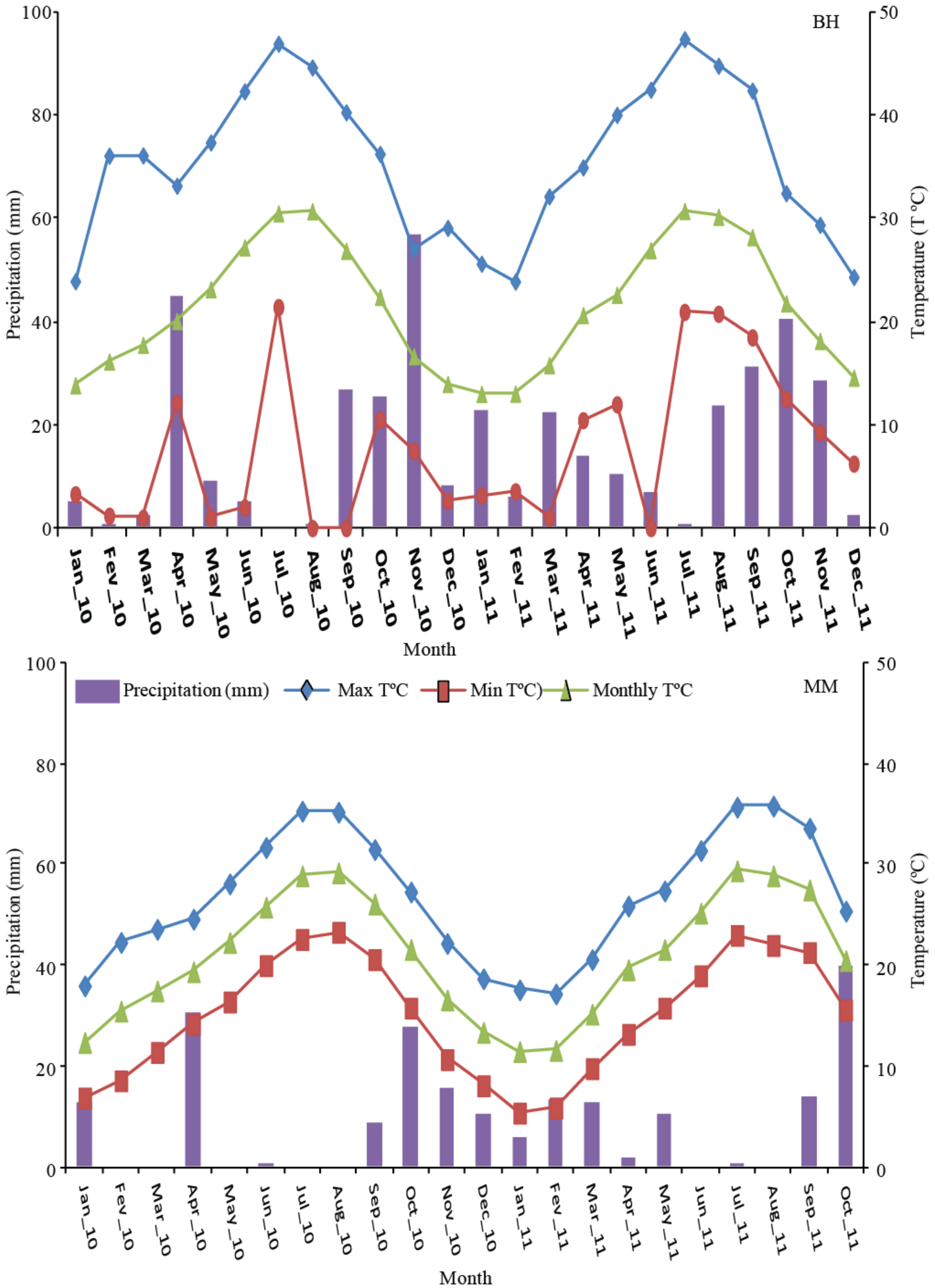
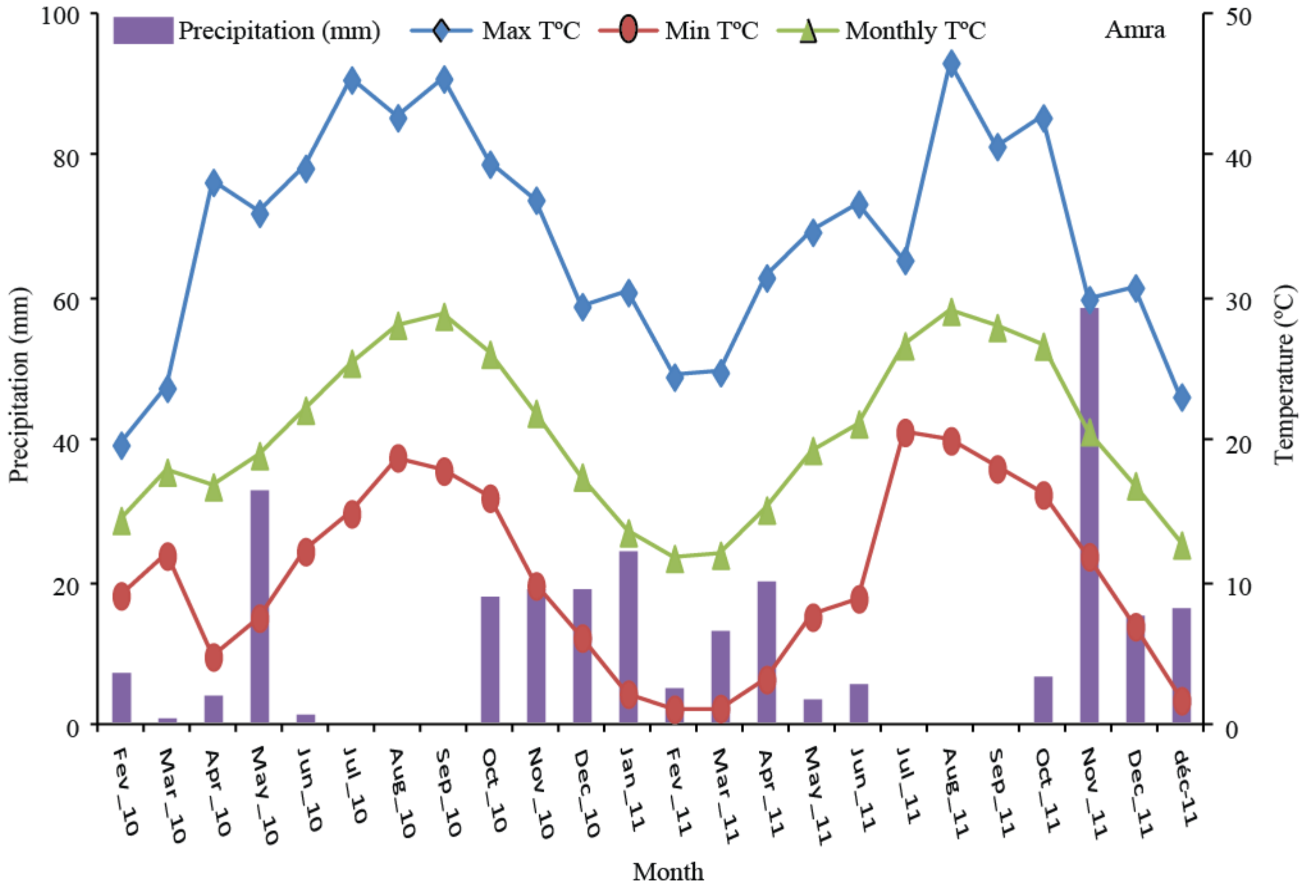


Fig. 1a. Location of the study sites within the study area and available meteorological data of the closest weather stations for the study period. Study sites (BH and MM) Total precipitation, mean monthly temperature, mean minimum temperature and mean maximum temperature correspond to data measured during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



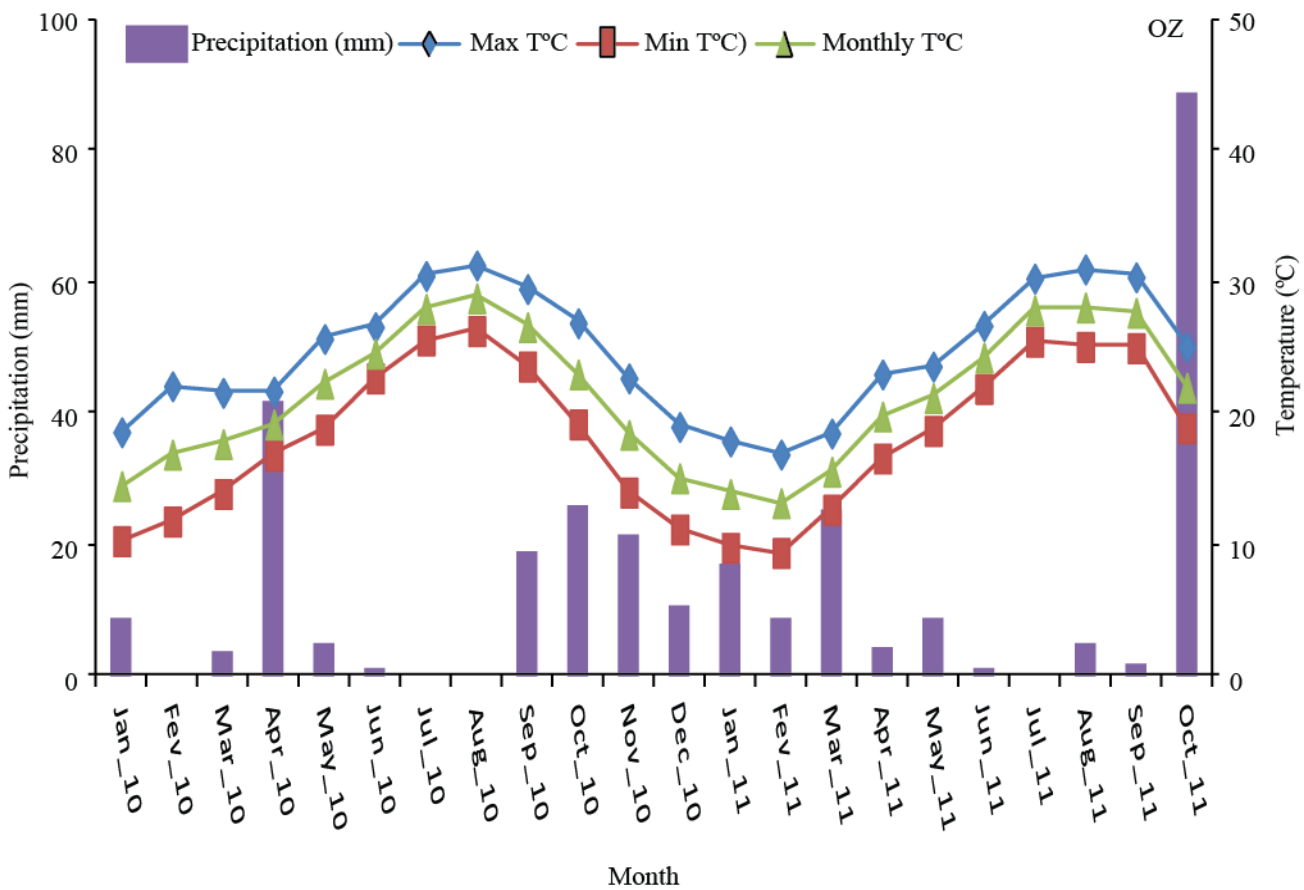


Fig. 1b. Location of the study sites within the study area and available meteorological data of the closest weather stations for the study period. Study sites (Amra and OZ) total precipitation, mean monthly temperature, mean minimum temperature and mean maximum temperature correspond to data measured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

Table 2. Phenological events considered.

Phenophase description		
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

Table 3. Physical and chemical soil properties of study sites (Amra, BH, OZ and MM) for the shrub of *Ziziphus lotus* in arid zone of Tunisia.

Soil characteristics	Study sites											
	Amra			***BH***			***OZ***			***MM***		
Depths	0-40	40-80	>80	0-40	40-80	>80	0-40	40-80	>80	0-40	40-80	>80
Clay content (%)	6,5	10,5	12	13,25	17,5	18	7	6,5	7	4,525	4,975	4,9
Silt content (%)	9,5	12	9	13,2	23,825	26	15	7,40	3,4	3,3	3,45	2,65
Sand content (%)	83	74,5	77	72,5	57,5	55,75	76,5	86	85	92,075	91,395	88
pH (1/2,5)	8,7	8,75	8,7	8,45	8,75	8,7	8,7	8,55	8,8	8,15	7,95	8,1
Soil EC (mmho/cm)	1,5	0,6	0,6	2,7	1	0,8	1,75	2,15	0,6	1,3	1,9	2,1
Total limestone (%)	2,5	3	5	7,5	7	9	3	2,5	3	5,5	6	4
Active limestone (%)	-	-	-	-	5	4	-	-	-	-	-	-
Soil organic matter (%)	0,35	0,3	0,2	0,4	0,55	0,3	0,15	0,2	0,1	0,2	0,1	0,1
Textural class	Sand	Sand	Sand	Sand	sandy clay	sandy clay silty	Sand	Sand	Sand	Sand	Sand	Sand

Interannual variations and inter-site phenophases of *Ziziphus lotus*

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 coincides with the rains of early spring. The existence of this correlation shows that this species requires sufficient moisture in the soil to trigger and maintain vegetative growth accompanied by high temperature of the summer period. We recorded a variation between provenances in the phase of leafing out. Indeed, BH is more extended in time and the earliest followed by OZ during 2011 compared to 2010. The provenances of MM and MD are more delayed in 2011. Concerning the falling leaves, provenance of MM is the earliest compared to others (Fig. 2).

Phase of flowering: The first flower buds appear during the month of April for the provenances of MD and MM. So, the latter are the earliest in 2010. This phase lasts until the 2nd decade of August 2010. By against, for 2011, all provenances bloom at the same time. Provenances of MD and OZ are the flowering phase most prolonged time. While, MM is the shortest flowering (Fig. 3).

Fructification phase: *Ziziphus lotus* starts to fructify right from the month of May for both provenances (BH and MD) during the two years (2010 and 2011). While the others complete their fruiting at June. The earliness of fruiting revealed for the provenances of BH and MD compared to others, can be explained by differences in exposure and soil texture. Whose the BH provenance is a glacis limestone exposed in the southeast. Therefore, it is more favorable situation for the early start of the phenology (Fig. 4).

Maturation phase: The provenances of MM and MD (Amra) have a precocity of maturation and dissemination for the drupes compared to other. The BH provenance shows a delayed maturation of drupes (green fruit immature in August) during 2011 compared with others whose full maturity is reached in September 2011.

Aboveground phenology of *Ziziphus lotus* (L.) Lam: (Fig. 5)

Biological cycle of *Ziziphus lotus*(L.) Lam: (Fig. 6)

The current situation of *Ziziphus lotus* from Matmata: In Matmata, the shrubs of *Ziziphus lotus* show an abortion of flowers in June 2011. Some flower buds are able to reach the stage of blossoming flowers. This situation influence on fruiting phase of this specie. The abortion of flower buds is accompanied by a yellowing and leaf curl of the year, that end up fall successively before the end of the vegetative cycle. In this provenance, the fruiting phase is reduced, the number of individual containing drupes is negligible. This deficiency of fruit is generally explained by flower abortion and their drying before developing and gives fruit. So, it is alarming status of *Ziziphus lotus* from Matmata (MM) (Fig. 7).

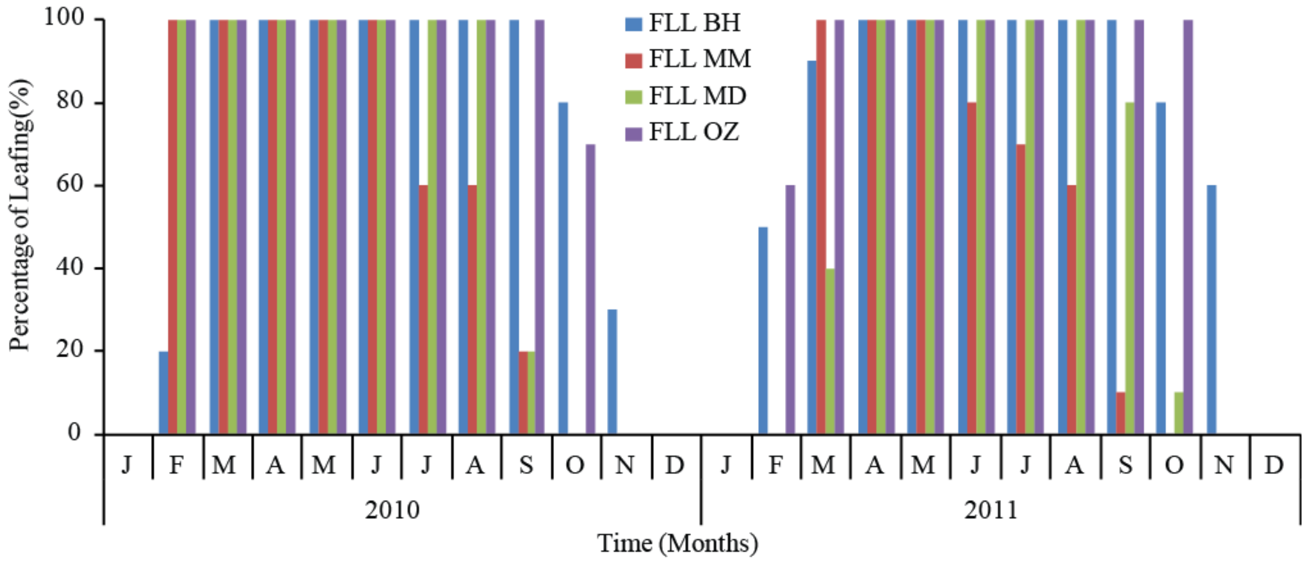


Fig. 2. Leafing out phase of *Ziziphus lotus* (L.) Lam in the different provenances for the study period (2010-2011).

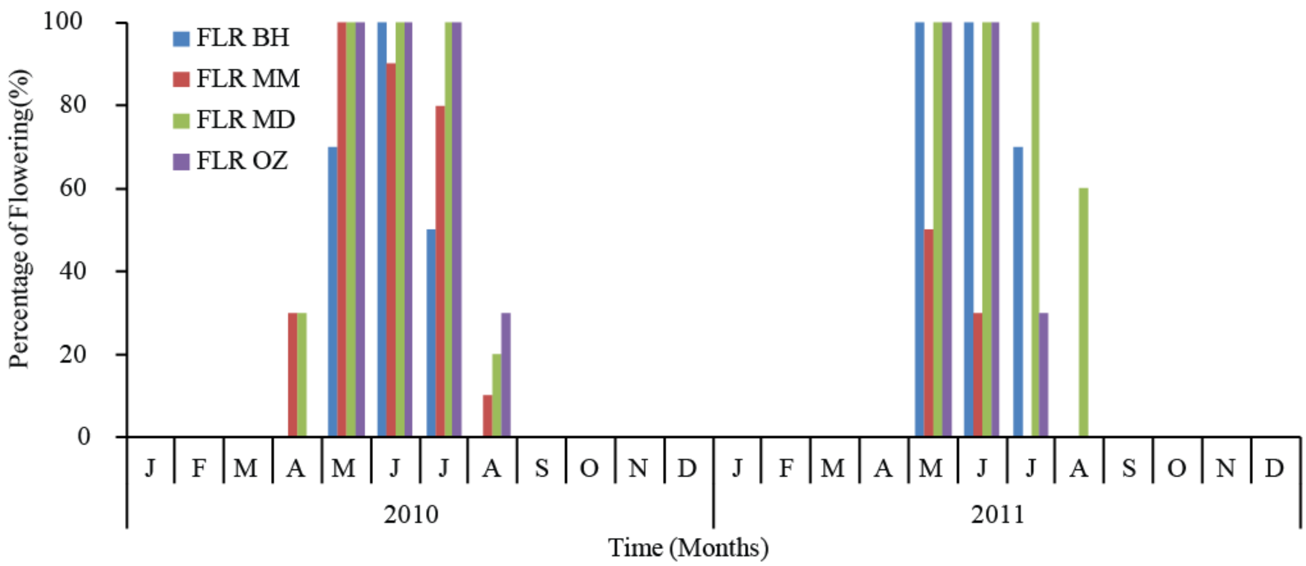


Fig. 3. Flowering phase of *Ziziphus lotus Ziziphus lotus* (L.) Lam in the different provenances for the study period (2010-2011).

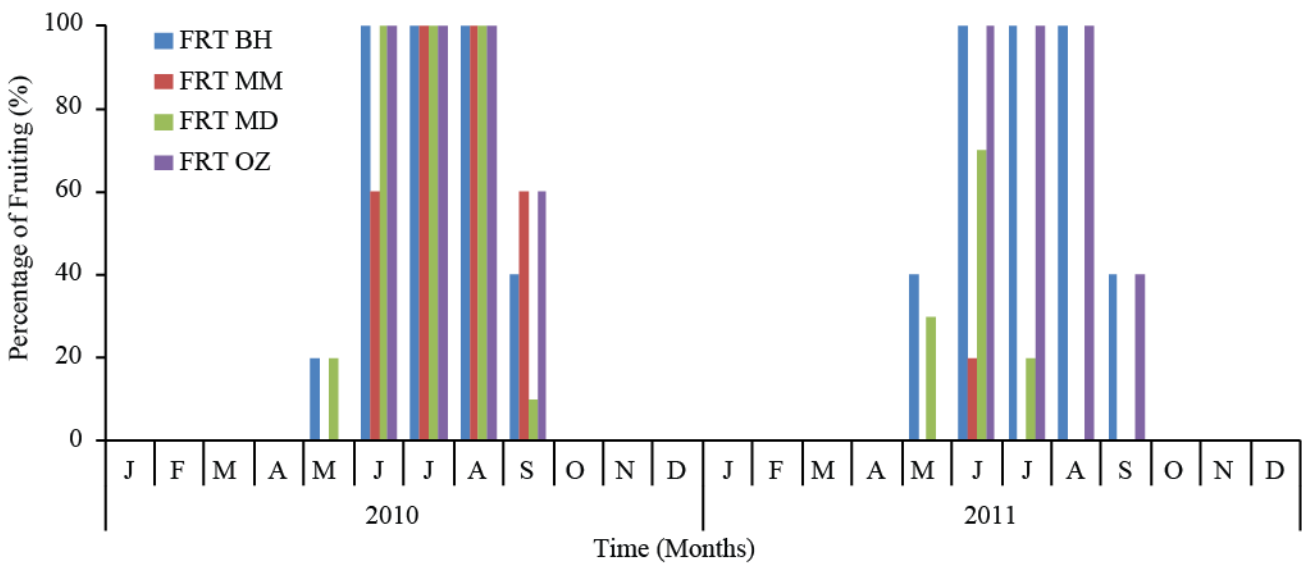


Fig. 4. Fruiting phase of *Ziziphus lotus Ziziphus lotus* (L.) Lam in the different provenances for the study period (2010-2011).

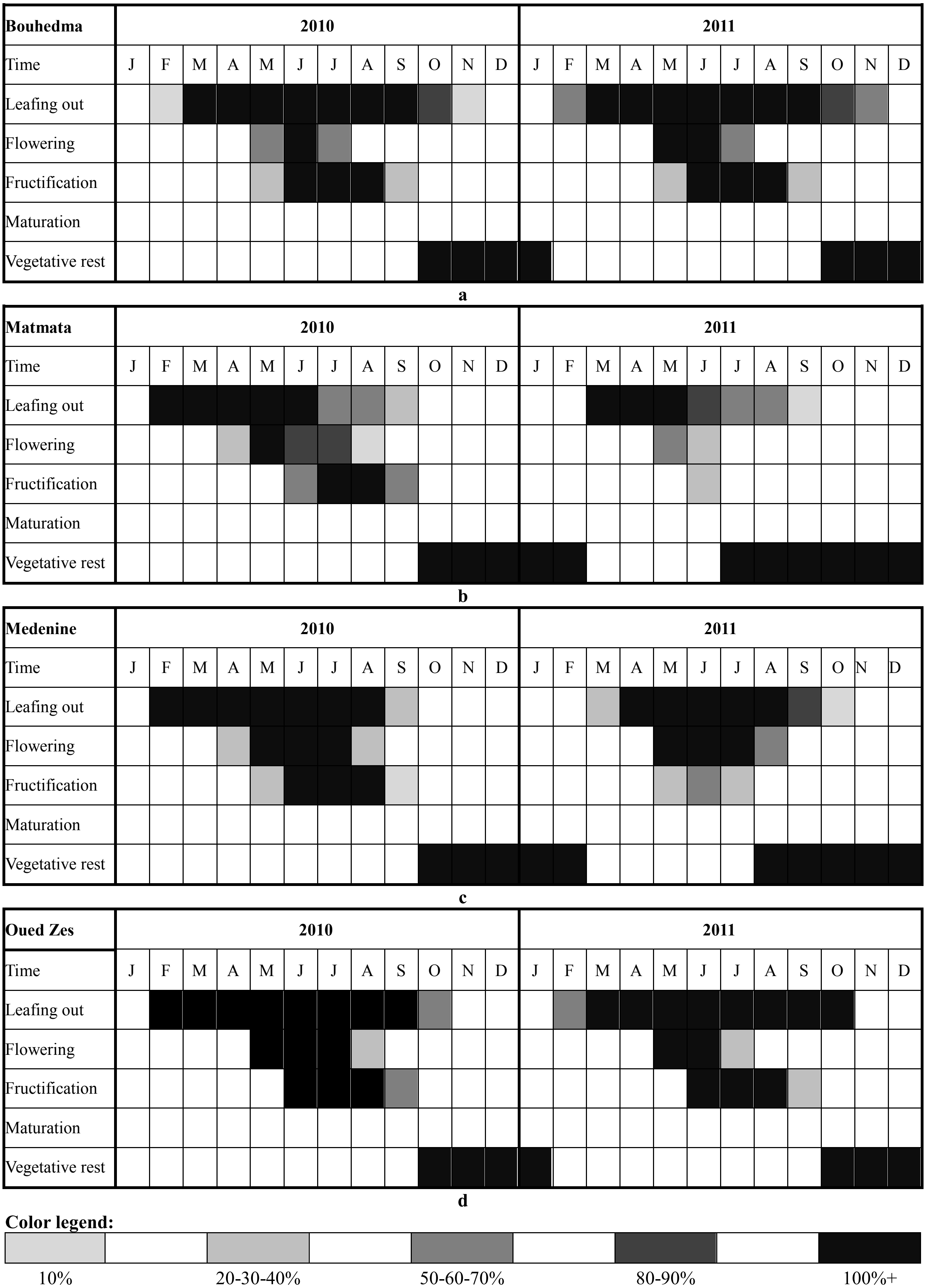


Fig. 5. Phenological calendars of *Ziziphus lotus Ziziphus lotus* (L.) Lam in the different provenances (a,b,c et d) for the study period (2010-2011).

Fig. 6. The phenological stages of *Ziziphus lotus* (L.) Lam
a: budbreak, b: start leafing out, c: full foliation, d: flower buds, e: full flowering, f, g et h: start fruiting (green drupes), i: Fruiting phase (drupes early in maturation), j: Fruiting phase (immatures drupes), k: dispersal of fruits, l: Vegetative rest.

Fig. 7. Present situation of *Ziziphus lotus* (L.) Lam in the provenance of Matmata: (a) et (b) drying and curling of leaves (c), abortion, drying of flower buds (d).

Discussion

The study of biological 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, *Ziziphus lotus* presents generally a active vegetative phase concentrated on the dry season which spreads out since March until October. In winter, this specie has a growth arrest which corresponds to the period of Basses temperatures and low light intensities. The precocity and prolongation in time of the leafing out phase revealed for the provenance of BH compared to others in 2011 can be explained by the high rainfall during the summer months since July to November 2011 in the National Park of Bou Hedma. These results confirm those of Grouzis & Sciot (1980), which showed a predominant effect of pluviometry on the determinism of phenological phases of some Sahelian woody. If we oppose Bou Hedma (47, 4°C) and Medenine (46, 59°C), we find that the two provenances have values of M are substantially identical. This determines a duration longer vegetation in thermo-Mediterranean ambiance than in meso and eu-Mediterranean. The beginning of vegetation is more early at low altitudes than high altitudes. Thermal regime appears to have a direct impact on the phenology and growth of vegetation (Chaabane, 1984). Concerning the falling leaves, provenance of MM is the earliest compared to others. This situation is explained by the lack of rain and the high temperatures registered during the dry season (June-July and August 2011) of Matmata (MM). The flowering of this specie is fairly spread out in time and it is present with fructification phase at a given time.

This stage seems to vary from one to another provenance and even from one individual to another. We also note that the emission intensity of flowers and flowering time varies according to provenance. Similar results obtained in evergreen and deciduous species from Cameroon (Marie Alain *et al.,* 2005). The provenances of MD and MM are the earliest compared to other in 2010. By against, in 2011, all provenances bloom at the same time. The flowering phase most prolonged is that of OZ and MD. By against, the provenance of MM is in the flowering phase shortest in 2011. These variations can be explained by the influence of temperature, soil moisture, photoperiod, the exposure and soil texture. However, a shift may often take place even within the same provenance. This shift could occur following to fluctuations in the climatic and edaphic factors (Grouzis, 1991). The precocity of fruiting revealed for the provenance of BH compared to others can be explained by differences in exposure and soil texture. Whose, BH provenance is a glacis limestone exposed in the South-East. Consequently, it is more favorable situation for the early start of phenology. The maturation and dissemination of drupes of *Ziziphus lotus* is more precocious for the both provenances (MM and MD (Amra) compared to others. This is due to the high temperature in these provenances during the summer period. It begins in July up to the month of August. The progress of different phenophases is realized particularly in dry summer season when the water reserves can be at their minimum. For this reason, the deep rooting of this specie would allow access to groundwater. This confirms the results obtained for *Acacia tortilis* (Noumi, 2010; Jaouadi *et al*., 2008) with vegetative cycle very close to that of *Ziziphus lotus*.

Conclusion

The synthesis of observations on *Ziziphus lotus* 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. Despite the ascended spring temperatures, this specie completes his growth and contained his cycle in summer with high temperatures. We attest a better adaptation to aridity in the adult stage to *Ziziphus lotus.* In fact, this specie has a wide geographical distribution throughout Tunisia.

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