Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 7, No. 1, p. 15-30, 2015
http://www.innspub.net

INNSPUB
RESEARCH PAPER

Variation of morphological and structural traits in natural cork oak populations along temperature and precipitation gradient in Northern Tunisia

Amel Ennajah[1], Salma Say Kachout[1], Abd El Wehed Laamouri[1], Mariem Elaloui[1], Florent Mouillot[2], Garchi Salah[1]

[1]Institut National de Recherches en Génie Rural, Eaux et Forêts, Rue HédiElkarray, Elmenzah IV, BP10, Ariana 2080, Tunisie

[2]Centre d'Ecologie Fonctionnelle et Evolutive CNRS – 1919, route de Mende. 34293 Montpellier cedex. France

Key words: Kroumirie, Cork oak, Structural parameters, Terminal branches, Dendrometric parameters.

Abstract

It tested the hypothesis that contrasting climate and elevations affect the growth and productivity of more than 47 cork oak populations in the Kroumirie (Mediterranean forest in the north west of Tunisia). Study increases the terminal branches, nodes marked by annual leaf production, leaf number, life leaves, number of branches, their length, diameter and biomass inform the annual productivity of trees and this by turning up the last 4 or 5 years. Similarly, the study of dendrometric parameters and foliar structural parameters like the leaf mass per area (LMA) are parameters the variability of which informs about the architectural plasticity. It observed a significant difference in LMA, tree height and circumferences according to altitude and climate. Highest LMA values were obtained at the less favourable sites. For terminal branches, only the biomass of four consecutive years reveal significant differences between populations in response to climate and the altitudinal gradient. The results indicate changes in the annual growth and productivity of these populations under near future drier and warmer conditions. They also point to alterations in their competitive abilities, which could lead to changes in the composition of this ecosystem in the long term.

***Corresponding Author:** Amel Ennajah ✉ aennajah@yahoo.fr

Introduction

Mediterranean vegetation includes more than one hundred arboreal taxa (Le Houérou, 1980) including the genus *Quercus* which play a major role like in Tunisia (Quezel, 1976). The cork oak is the native hardwood forest species the most represented in the Tunisian territory. Tunisian cork oak forest exist in the northwestern provinces starting from the Mediterranean coast extending southwards over the Kroumirie Mountains to the Mejerda Plain located about 50 km inland (Boudy, 1955). From a climate perspective, the cork oak is more Mediterraneo-atlantic than Mediterranean species. Its absence in the eastern Mediterranean is related to the length and the intensity of summer drought and also to the increased of continentality. On Emberger climagramme, it situates in the warm and temperate variants of humid and sub-humid Mediterranean bioclimates. In Tunisia, this forest spans a gradient of temperature and precipitation (500mm to 1500mm) and reaches the southern limit of the range of this species.

Climate scenarios for the 21st century provided show a tendency to decrease in summer rainfall and higher temperatures suggesting that the forest could be affected in terms of productivity and mortality. Climate projections predict drier and warmer conditions in the Mediterranean basin in the next decades (Houghton *et al.,* 2001). They can have significant influences on tree establishment and on forest structure and dynamics (Barbero *et al.,* 1990; Améztegui *et al.,* 2010; Chauchard *et al.,* 2010; Gimmi *et al.,* 2010). Factor that may limits tree growth (Ogaya *et al.,* 2003; Linares *et al.,* 2010) and forest regeneration (Pulido and Díaz, 2005). In addition, inter-annual variability in precipitation and temperatures significantly affects annual tree growth (Urbieta *et al.,* 2008). The current climate changes appear as factors aggravating the decline of Cork oak species. Indeed, the cork oak forest is located in a region with climatic conditions and natural binding affected by periods of drought often acute, exacerbated by the topography and varying in intensity from one year to another (Braun-Blanquet *et al.*, 1952; Quezel *et al.*, 1980). This situation has become worse because of the lack of natural regeneration and the technical operations as protection and renewal.

Forest productivity is determined by the climate (temperature and water stress) and properties of soil (rich in nutrients, water content of the soil). It is estimated by increases in height and trunk diameter tree during national forest inventories (Urbieta *et al.,* 2008; Ennajah 2013). The frequency of these inventories is quite long and does not provide an estimate of the interannual variability of the productivity. Dendrochronology (study tree rings on the cross sections of trunks) provides an approach to this interannual variability over long periods. This method is very difficult to implement for hardwoods such as cork oak, which the most external rings (and thus the most recent) are difficult to read (Ennajah *et al.,* 2009b). An alternative method is the study of increases in terminal branches, nodes marked by annual leaf production (Llorens *et al.,* 2009). Hence, the present study deals with to estimate the spatial and temporal variability of the productivity of cork oaks in northern Tunisia on 4/5 years and to identify the spatial pattern of productivity oak correlating with analysis of interannual climate variability and known soil properties.

Materials and Methods

Study Sites

The study area covers the whole of the Tunisian cork oak (69780ha), 100km from east to west and 50km from north to south. Elevations range from 0m to 1400m on the coast, and induces a temperature and precipitation gradient. In this zone, the General Directorate of Tunisian Forests sampled in 1995, 2005 and 2010, 977 plots in forest inventory (number of trees, circumferences, heights, under wood, cork etc.), so 350 plots are cork oak populations (Tunisian National Forest Inventory, 2005).

In the study and from the forest inventory, it takes 47 cork oak provenances according to a gradient (Fig. 1) with two factors: altitude and climate. In these provenances, the plant materials were collected.

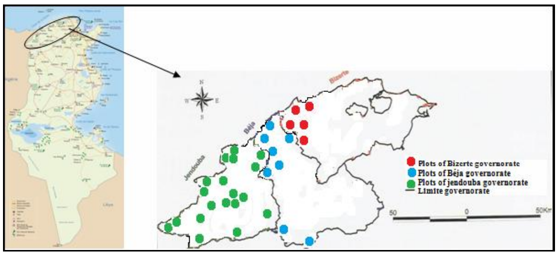

Fig. 1. Study plots in the Kroumirie (North West Tunisian forest).

Plant material

The study was conducted in 2012. A sample of three terminal branches was performed on 6 dominant trees of each cork oak population. The sampling is done in winter on 50 cork oak populations (Table 1), after the growing season. On each branch, 4 units of growth (U.C) are retained since 2009.

Table 1. Origin and geographic position of cork oak provenances.

Site name	Symbol	Area	Altitude (m)	Geographic coordonates	
				Widht N	***Length E***
Bizerte	**BZ1**	Bellif I	122	37,03996	9,07805
	BZ2	Bellif I	223	37,03308	9,06697
	BZ3	Bellif II	107	37,04177	9,10572
	BZ4	Bellif II	196	37,04443	9,11546
	BZ5	Sejnene	177	37,07799	9,15689
Beja	**BJ1**	Tabouba	346	36,89515	9,06742
	BJ2	Tabouba	365	36,90243	9,06105
	BJ3	Ain Zana	922	36,72937	8,86411
	BJ4	Mekna II	286	36.93643	8.87633
	BJ5	Mekna I	284	36.93272	8.83365
	BJ6	MeknaIV	483	36.91322	8.89949
	BJ7	Dmeyene	280	37,05724	9,00317
	BJ8	Khergalia	175	37,07287	9,05154
	BJ9	Tabouba	295	36,88652	9,08545
	J1	Ain Drahem I (babouche)	651	36,78323	8,65622
	J2	Tabarka III	340	36.82563	8.870038
	J3	Ain Drahem III (dar fatma)	862	36,7892	8,74219
	J4	Bou Hertma	253	36,69094	8,77463
	J5	Ain Drahem III (dar fatma)	788	36,77903	8,72167
	J6	El ghorra	613	36,56184	8,41147
	J7	Ain Drahem IX (bni mtir)	652	36,72729	8,70556
	J8	Fernena I(Sidi Saaid)	401	36.64567	8.63349
	J9	Ouled Ali II (El ghorra)	653	36,56963	8,40924
	J10	Fernena I (Sidi Saaid)	354	36.64765	8.66519
	J11	El ghorra	901	36,60356	8,42508

Site name	Symbol	Area	Altitude (m)	Geographic coordonates	
				Widht N	*Length E*
Jendouba	**J14**	Feyja III (Ain Soltane)	843	36,52215	8,33803
	J15	Melloula I (Tabarka)	302	36,95787	8,7294
	J16	hammem bourguiba	277	36.75609	8.59026
	J17	Feyja VIII	716	36,45762	8,23812
	J18	Feyja V	646	36,47501	8,25268
	J19	Ain Drahem X	493	36.73994	8.60806
	J20	Tegma I	256	36,76607	8,50212
	J21	Feyja II (mejene)	970	36,50176	8,26633
	J22	Oued Zen III	595	36,7989	8,81555
	J23	Oued Zen I	623	36,83615	8,81245
	J24	hammem bourguiba	346	36.77497	8.61000
	J25	Feyja II (mejene)	933	36,49895	8,26285
	J26	El Feyja IV	810	36,5025	8,31047
	J27	Melloula IV (Tabarka)	241	36,94517	8,70315
	J28	Melloula II (Tabarka)	358	36,91328	8,67146
	J29	Ain Drahem IX (bni mtir)	593	36,70709	8,67126
	J30	Bou Hertma	259	36,68874	8,77061
	J31	Ain Drahem I	454	36.79930	8.66145
	J32	Feyja VIII	769	36,45457	8,23906
	J33	Mhamdia	224	36.89015	8.77727
	J34	El ghorra	617	36,53453	8,4006
	J35	El ghorra	589	36,55182	8,40693

Additional data

The Directorate General of Water Resources has a network of 45 rainfall stations. Regional climate analysis was made using data of daily precipitation over the period 2003-2012 from DGRE and daily temperatures recorded via buttons Thermo Type 22L (-40 / +85 ° C) located in the kroumirie. In addition to this information, we used biometric measurements from the DGF forest inventory (number of trees, height and diameter).

Statistical analyses

The relationships between leaf traits, and dendrometric parameters (DBH, H) were described using the software STATITCF (Ver.F). The measureswere the object of an analysis of the variance to one or two factors following the case, significance levels were established at P<0.05. It was completed by a multiple comparison of the averages by the test of Newman-Keuls test (at 5%) according Dagnelie (1986). The graphical exits are realized with the software Excel 2000.

The differences between populations for the investigated variables were tested with a Principal Component Analysis (PCA). An average value for each trait was calculated. A dispersion and central tendency descriptive analysis was applied to estimate the variability existing in the collection.

Each unit several parameters are measured (length, diameter, number of branches and leaves, leaf area and weight) (Fig.2).

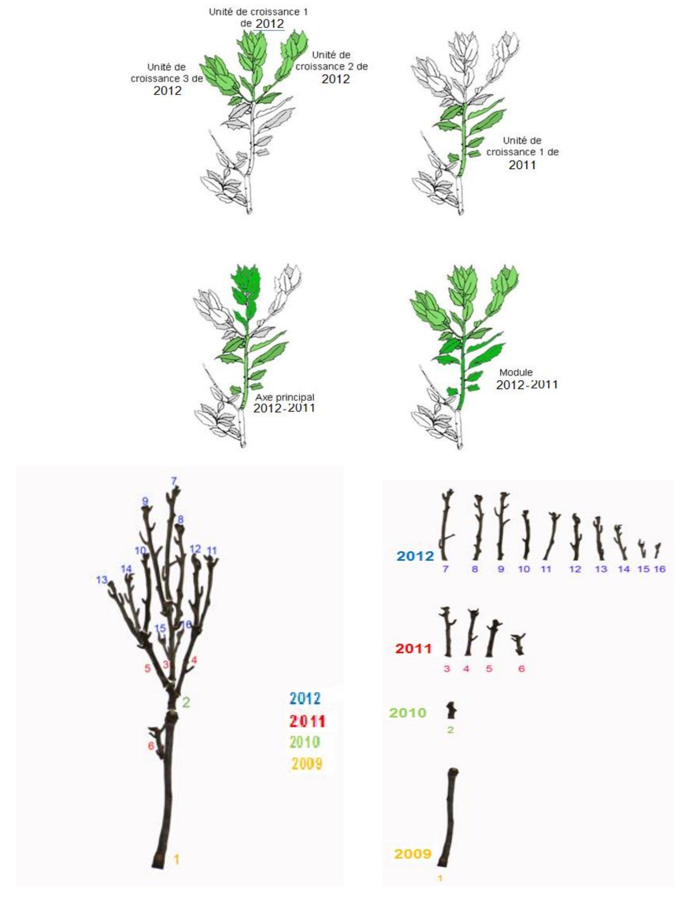

Fig. 2. Twigs sampling and counting method of growth units.

Results

Regional climatic analysis

A detailed analysis for the climate at the three governorates clearly reflected differences in temperature and precipitation. Differences appear between the governorates and between years (Fig 3).The mean monthly values of rainfall showed a decrease from year to year for each governorate especially in 2012.

However, 2009 is considered the wettest year with a precipitation peak in April and Bizerte governorate present the highest rainfall for four consecutive years. A significant variability in the monthly rainfall in autumn and spring periods was also noticed for ach region each year (Fig. 3). There is a decrease in precipitation in May and in August 2012 for each governorate, which leads to an extension of summer period and drought duration. Furthermore, in November 2012, we note a significant decrease in the precipitation for the three regions.

For the average monthly temperature, we note an increase year by year especially in 2012. The highest value is recorded at Jendouba followed by beja (in August). Bizerte is also the coolest region with a maximum of temperature in July (27, 72°C).

Morphological measurements

The mean values of the morphological parameters (DBH and height) were significantly different among cork oak populations (one way ANOVA, $p \leq 0.05$). The results showed a significant variation according to the altitude (Table 2 and 3): Population from J22 (oued zena) illustrated the highest DBH and height of trees; whereas BJ4 (Mekna), J13 (Tegma), J21 (Feyja), and J34 (Ghorra) showed the lowest values of morphological parameters.

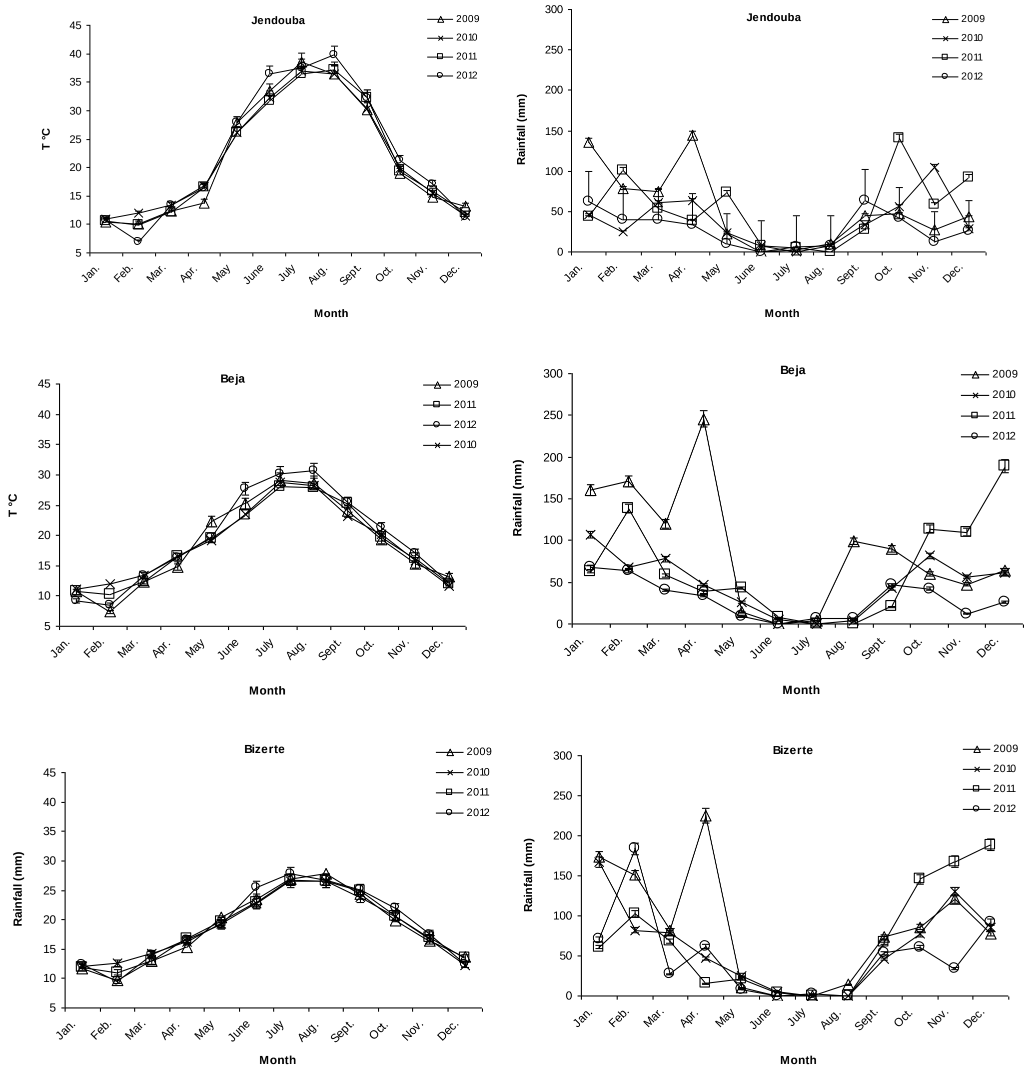

Fig. 3. Average monthly temperature and rainfull at the tree governorates (Jendouba, Beja and Bizerte). Data were obtained from the nearest meteorological station.

Table 2. Quantitative parameters mesured in Cork Oak populations.

Site name	***Symbol***	***Area***	***DBH (m)***	***Height (m)***
Bizerte	**BZ1**	Bellif I	0,38 ± 0,38	3,48 ± 0,86
	BZ2	Bellif I	0,31 ± 0,22	3,22 ± 0,25
	BZ3	Bellif II	0,21 ± 0,25	1,30 ± 0,22
	BZ4	Bellif II	0,17 ± 0,15	1,13 ± 0,24
	BZ5	Sejnene	0,32 ± 0,49	2,73 ± 0,51
Beja	**BJ1**	Tabouba	0,34 ± 0,23	2,75 ± 0,29
	BJ2	Tabouba	0,26 ± 0,71	3,80 ± 0,71
	BJ3	Ain Zana	0,19 ± 0,45	2,96 ± 0,29
	BJ4	Mekna II	0,16 ± 0,18	2,43 ± 0,18

Site name	*Symbol*	*Area*	*DBH (m)*	*Height (m)*
	BJ5	Mekna I	0,28 ± 0,52	5,28 ± 1,95
	BJ6	MeknaIV	0,20 ± 0,34	2,36 ± 0,43
	BJ7	Dmeyene	0,24 ± 0,51	4,18 ± 0,85
	BJ8	Khergalia	0,45 ± 0,49	6,36 ± 0,80
	BJ9	Tabouba	0,25 ± 0,42	4,36 ± 0,50
Jendouba	**J1**	Ain Drahem I (babouche)	0,23 ± 0,54	2,64 ± 0,37
	J2	Tabarka III	0,24 ± 0,51	4,18 ± 0,85
	J3	Ain Drahem III (dar fatma)	0,36 ± 0,13	9,77 ± 1,14
	J4	Bou Hertma	0,27 ± 0,23	3,60 ± 0,23
	J5	Ain Drahem III (dar fatma)	0,37 ± 0,51	8,20 ± 0,67
	J6	El ghorra	0,34 ± 0,57	4,88 ± 0,61
	J7	Ain Drahem IX (bni mtir)	0,30 ± 0,37	6,69 ± 0,52
	J8	Fernena I (Sidi Saaid)	0,21 ± 0,59	2,13 ± 0,57
	J9	El ghorra	0,24 ± 0,39	3,70 ± 1,25
	J10	Fernena I (Sisi Saaid)	0,24 ± 0,39	3,37 ± 0,74
	J11	El ghorra	0,30 ± 0,24	10,33 ± 1,82
	J12	Tabarka III	0,24 ± 0,38	3,02 ± 0,59
	J13	Tegma I	0,16 ± 0,69	2,15 ± 0,98
	J14	Feyja III (Ain Soltane)	0,24 ± 0,54	4,18 ± 0,90
	J15	Melloula I (Tabarka)	0,20 ± 0,36	3,73 ± 0,58
	J16	hammem bourguiba	0,32 ± 0,19	6,40 ± 1,22
	J17	Feyja VIII	0,26 ± 0,57	4,20 ± 1,76
	J18	Feyja V	0,23 ± 0,52	4,23 ± 0,40
	J19	Ain Drahem X	0,31 ± 0,38	4,15 ± 0,70
	J20	Tegma I	0,27 ± 0,21	3,60 ± 0,12
	J21	Feyja II (mejene)	0,16 ± 0,42	3,27 ± 0,46
	J22	Oued Zen III	0,58 ± 0,30	10,26 ± 1,41
	J23	Oued Zen I	0,29 ± 0,56	6,34 ± 0,73
	J24	hammem bourguiba	0,33 ± 0,29	6,40 ± 1,92
	J25	Feyja II (mejene)	0,32 ± 0,53	5,11 ± 1,65
	J26	El Feyja IV	0,33 ± 0,21	4,12 ± 0,20
	J27	Melloula IV (Tabarka)	0,37 ± 0,51	8,2 ± 0,68
	J28	Melloula II (Tabarka)	0,25 ± 0,52	4,18 ± 0,81
	J29	bni mtir	0,36 ± 0,54	4,23 ± 0,42
	J30	Bou Hertma	0,21 ± 0,45	2,13 ± 0,57
	J31	Ain Drahem I	0,32 ± 0,63	6,44 ± 0,22
	J32	Feyja VIII	0,22 ± 0,22	2,28 ± 0,65
	J33	Mhamdia	0,27 ± 0,34	3,62 ± 0,45
	J34	Ouled Ali II (El ghorra)	0,16 ± 0,33	3,26 ± 0,19
	J35	Ouled Ali II (El ghorra)	0,20 ± 0,41	3,12 ± 0,39

Table 3. Results of ANOVA for analysed varaibles.

Variables	*Source of variation*	*DL*	*MC*	*F*
DBH	Altitude	15	6180,24	80788,6***
H	Altitude	15	5303,77	2657,28***
Leaf biomass	Altitude	47	1799,43	64052,12***
	Year	1	157566,6	119,0022***
	Altitude x Year	47	1439,449	51238,33***
Wood biomass	Altitude	47	536,3939	15160,27***
	Year	1	3003,659	123356,3***
	Altitude x Year	47	109,2535	3087,87***
LMA	Altitude	81	1893,6	7,819**
	Year	1	0	0 NS
	Altitude x Year	47	182	1,27 NS

*** : significant difference at the 0,0001

NS : not significant difference

In this study, it provides evidence for the significance of reduced leaf mass per area (LMA) in the less favourable sites (Fig. 4). Plant leaf parameter (LMA) differed significantly between populations (Table 3) and not between years. Populations from BZ3 (Bellif, 107m of altitude), BJ7 (Dmeyene, 280 m), J27 (Feyja, 716m), J3 (Dar Fatma, 862m) and J21 (Mejene, 970m) presented higher LMA, consistent with the hypothesis of cork oak response to unfavourable conditions for growth. However, it is noted that LMA decreased in medium altitude especially in Fernana populations (J8 at 401m and J10 at 454m) and increased in very low and high altitude.

Fernana populations are found in an Ain Drahem region of Jendouba (Kroumirie Mountains) characterized by a rather humid climate with cold winters and modest warm summers (Fig. 5). They have average values of growth (DBH and height) compared with the rest of populations.

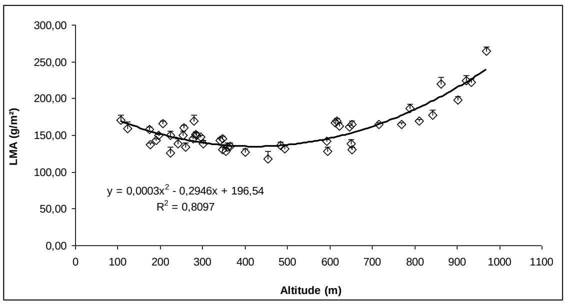

Fig. 4. LMA (leaf mass per area) of *Q. suber* populations according to the altitude.

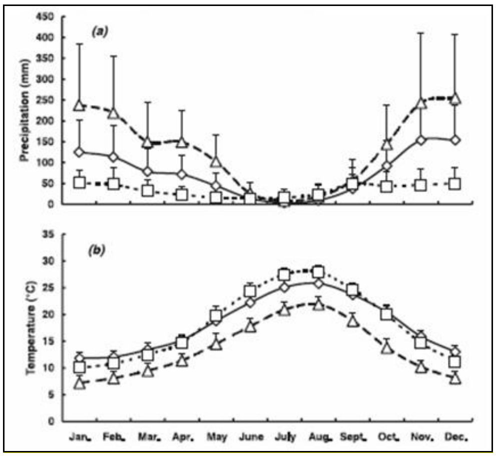

Fig. 5. Annual course of (*a*) precipitation and (*b*) air temperature at the three stations Tabarka (6858.21'N, 008853.41'E, 50 m) (diamonds), Ain Draham (triangles) (36846.98'N, 008843.79'E, 800 m), and Jendouba (squares) (36838.84'N, 008839.56'E, 340 m);in northern Tunisia (Jendouba Governorate) representing subhumid, humid, and semi-arid climate conditions, respectively (Gounot and Le Houerou 1967). Data are monthly means + SD over a 38-year period (1975–2012) (source Direction Generale des Ressources en Eau, Tunis).

Mean length of Growth units from 2009 till 2012 were found to be highly in cork oak populations located at medium altitude like Fernana populations (J8 and J10) (Fig. 6). However, Bellif, Babouch and

Bni Mtir Populations (BZ3, BZ5, J1 and J7) showed also highly significant values of length growth units.

These results are confirmed by the biomass values of u.c increasing at medium altitudes especially in Fernana populations. Similarly, bellif, Babouch and bni Mtir populations have highly significant values of u.c biomasses (Fig.7).

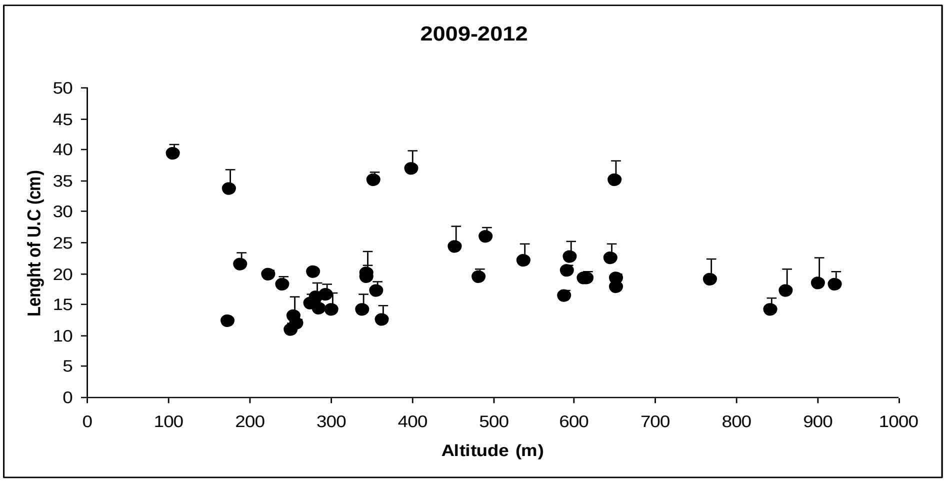

Fig. 6. Mean length of growth units (u.c) from 2009 till 2012 of cork oak populations.

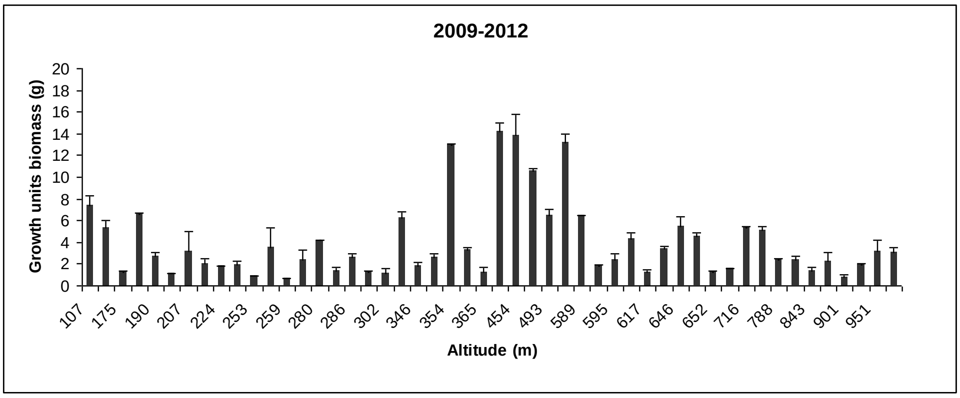

Fig. 7. Growth units biomasses of cork oak populations according to the Altitude.

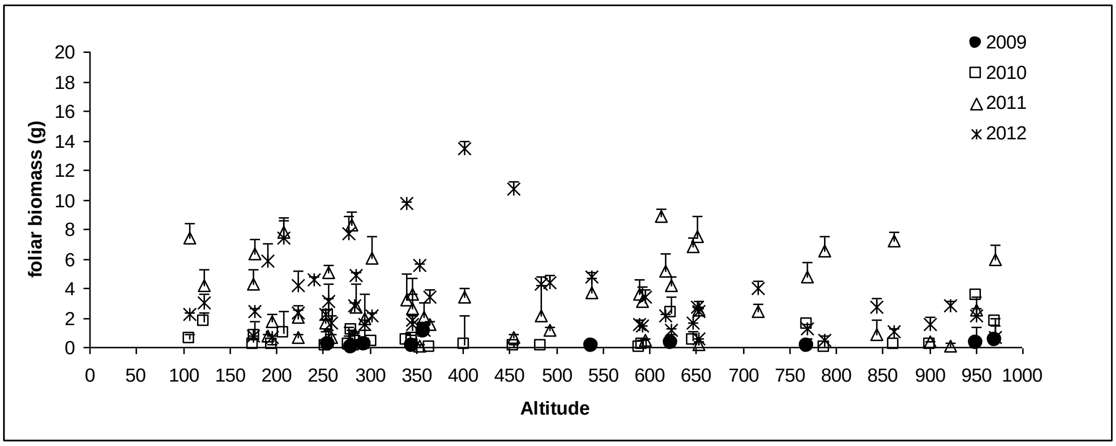

Fig. 8. Foliar biomass per growth unit according to the altitude.

For the foliar biomass production, ANOVA revealed highly significant differences between populations and years (Table.3). In 2012, populations at medium altitude (350 till 590m) presented maximum leaf production especially in Fernana sites. The cork oak is an evergreen species (2-3 years), however according to our results; some cork oak populations have kept a few leaves for a period of 4 years. Indeed, in 2009, we found leaves in some u.c as in Tabbouba populations (BJ1, BJ9), Melloula (J27) and Feyja populations (J21, J25, J32) (Fig.8).

Discussion

In the Mediterranean basin, summer drought is the main constraint on tree growth with great interannual variations in duration and intensity (Le Houerou, 2005; Girard *et al.,* 2012). For the twenty-first century, climate models predict in the Mediterranean basin a faster warming than in most other areas in the word, associated with a reduction of rainfall during the growth season (Gibelin and Deque, 2003; Hesselbjerg-Christiansen and Hewitson, 2007). In addition, extreme climatic events are prone to be recurrent (Meehl and Tebaldi, 2004). The response of forests to the forecasted increase in drought occurrence is considered a key issue in climate change scenarios (Hesselberg-Christiansen and Hewitson, 2007). Rapid decline in precipitation and higher temperature are already noticeable in some areas in the Mediterranean basin. In Tunisia, especially in Kroumirie (North West Forest), very low rainfalls were observed each year for more than 10 years (INM Tunisia). The selection of trees adapted for future environmental and climatic conditions, with special reference to the resistance to drought stress, is of primary importance for forestry in a climate change scenario. This selection is based on the identification and quantification of functional traits associated with drought resistance, and the correspondent genetic features.

Plant phenotypic responses are generally characterized by response curves or norms of reactions to the environment, which for complex traits are inherently, and mostly nonlinear (Fiorani and Schurr, 2013). So, to understand the evolution of adaptative traits, it is necessary to study structural traits variation within populations and assess the adaptative value of these variations.

This study showed that cork oak populations have different significant structural traits according to the climate and altitude as indicated by their morphological and biometric parameters. Differences were evident for growth traits through comparisons between provenances (populations) (Table 3). This large-scale analysis using both the biomass inventory and the growth productivity estimated over 5 consecutive years with contrasting climatic conditions, allowed to identify the temporal variability of the cork oak, especially its spatial variability. This spatial variability has allowed us to identify the most intense vulnerability areas on which future research should be intensified in order to maintain sustainable forestry.

The results aim to elucidate the impact of environmental conditions on the distribution of cork oak (*Quercus suber* L.). Under harder climatic conditions such as lower water availability and high temperatures; cork oaks tend to have low values of biometric and morphological parameters. Indeed, phenotypic plasticity is the capacity of a genotype to produce functionally different phenotypes in different environments (Sultan, 1995; Pigliucci, 2001). Responses to different environments may include highly specific developmental, morphological and physiological adjustments that can enhance survival and persistence in those novel environments, and therefore, phenotypic plasticity is a major mode of adaptation in plants (Sultan, 1995, 2000, 2003; Pigliucci, 2001; Valladares *et al.,* 2006; Ghalambor *et al.,* 2007). At very low and high elevations, cork oak trees have lowest values of morphological parameters and highest values of LMA parameter (Table 2, Fig.4).

Leaf mass per area is leaf trait that plays central roles in plant growth rate and survival (Lamber and

Poorter, 1992; Grime *et al.*, 1997; Wright *et al.*, 2004; Ramirez-Valiente *et al.*, 2014). This parameter has been proposed to be universally important for plant fitness (Poorter *et al.*, 2008). The ratio between leaf mass and surface is an architectural parameter. At any given time, for a same quantity of biomass, leaf surfaces and architectures may differ according to LMA. Many authors consider variations in LMA according to the environment to be an adaptative strategy of the plant (Li *et al.,* 1999; Qaderi *et al.,* 2006; Gamage and jesson, 2007; Jullien *et al.,* 2009). High LMA values in populations at lower altitude like (Bellif, 107m of altitude), BJ7 (Dmeyene, 280 m), and at high altitude like J27 (Feyja, 716m), J3 (Dar Fatma, 862m) and J21 (Mejene, 970m); are related to leaf resistance to dry conditions (Niinemets, 2001) and to high vapour pressure deficit and potential evapotranspiration (Wright *et al.,* 2004). These populations showed also the lowest values of their morphological parameter (DBH and height) (Table 2). The lower LMA values at the drier sites are likely due to lower photosynthetic rates (Ogaya and Penuelas, 2003), and lower carbon allocation to leaves. These decreases in LMA were produced by the decreases in leaf thickness. Lower leaf area and leaf thickness could be explained by the decline in cell expansion imposed by drought during leaf growth (Hsiao *et al.*, 1985; Niinemets and Kull, 1998), when the area of shoots and needles are sensitive to resources availability (Pokorny *et al.*, 2004). In this study, LMA decreased in medium altitude especially in Fernana populations (J8 at 401m and J10 at 454m) (Fig.4). The lowest LMA are interpreted by favourable conditions for growth (rather humid climate with cold winters and modest warm summers). Similarly, Bellif, Babouch and Bni Mtir populations (BZ3, BZ5, J1 and J7) presented the same results. Even at low altitude, these populations are located on soils with high water reserves. Bellif is a cork oak forest near a large dam and Bni Mtir forest is located on the north side of Ain Drahem. Here we talk about optimal water conditions (heavy rainfall and soft summer more high water reserve).

Mean annual growth units elongation and leaf production were found to be highly correlated to medium altitudes (cumulative rainfall and temperature), especially in Fernana populations (Fig.6, 7 and 8). They were mainly dependent on the favorable conditions preceding the time of major growth activity (Pinto *et al.,* 2011).

However, trees that have kept their leaves for a period of 4 years, as in Tabbouba populations (BJ1, BJ9), Melloula (J27) and Feyja populations (J21, J25, J32), could be arranged according to their functional and structural crown architectures, and this arrangement was consistent with their environmental conditions (Esteso-Martinez *et al.*, 2006). Similar ordinations have been found according to traits related to water-stress resistance (Kikuzawa, 1995).

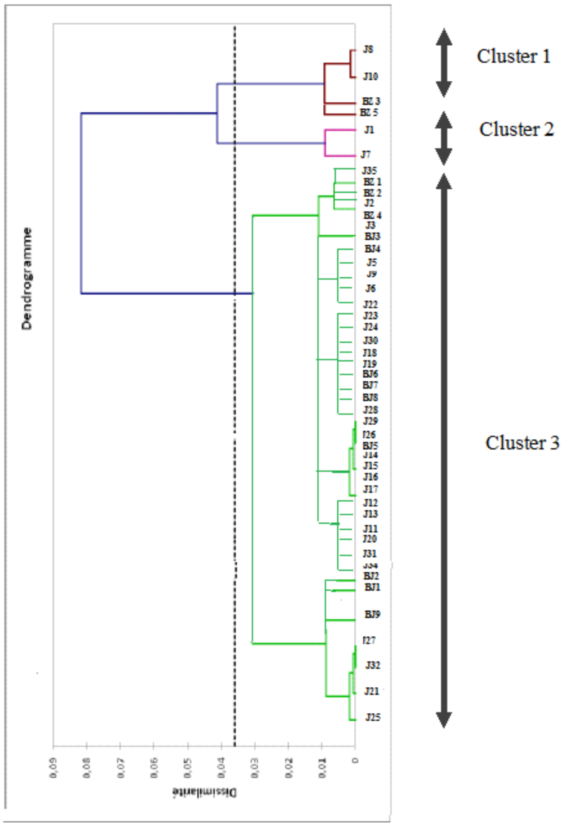

Fig. 9. Dendrogram of Cork oak populations clustered based on Dissimilarity of Person Method (Aggregation).

In order to examine if the differentiation is a consequence of genetic drift and/or of natural selection, it has performed a cluster analysis. Dissimilarity of Pearson based on aggregation method was found to separate the provenances into three clusters at a mean distance of 0.35 : cluster 1 included J8, J10, BZ3 and BZ5 populations; Cluster 2 with J1 and J7 populations and cluster 3 included the rest of populations (Fig.9).According to the amount of variation of some parameters, populations from J25, J21, J32, J37 and Bj9 were clearly separated from the rest of populations. These areas have unfavourable climatic conditions (high altitude with hard climate conditions). It was distinguishable by the high LMA, low structural and morphological parameters. In the end, this analysis allowed us to identify the most fertile populations, most resistant face future climates hardening (cluster 1 and 2) including Fernana and Bellif populations.

Conclusion

This study showed that cork oak populations have significant levels of phenotypic differentiation as indicated by their morphological and structural traits. Differentiation was evident for growth traits. It is now accepted that the best provenances come from Fernana region, especially J8 and J10 populations that could be considered as an ecotypes of reforestation in the future.

The expected impact of climate change on different tree provenances will differ according to their geographical distribution and ecological features. Populations with a narrow range of genetic variability are likely the most threatened by environmental changes (Bussotti *et al., 2015)*. These populations require a proactive management (strategy of resistance), including the restoration of the habitats and ex-situ conservation. It is the case of Feyja, Tabbouba, Mejene, Dmeyen and melloula populations (BJ1, BJ9, BJ7, J21, J25, J27, J32).

Rapid climate change combined with forest fragmentation and the presence of anthropogenic barriers may constitute an insuperable obstacle for the spontaneous evolution of the forest. Direct action of foresters is therefore necessary to avoid loss of forest cover due to insufficient natural flow of suitable reproductive materials. The problems related to forest management under climate change have been addressed by many researchers (Bussotti *el al.,* 2015; Lindner, 2000; Lindner *et al.,* 2010; Hemery, 2008, Bolte *et al.,* 2009, 2014; D'Amato *et al.,* 2011; Milad *et al.,* 2011; Temperli *et al.,* 2012; Hanewinkel *et al.,* 2013). This study provides background information for the conservation and management of population growth of cork oak, which are classified along a gradient of fertility. It allowed us to distinguish between provenances and to validate the morphological approach as a tool for early selection of provenances for forestation. In addition, this work provides useful information about *Quercus suber* spp. Variability, either in this project or in future ecological and genetic investigations.

References

Améztegui A, Brotons L, Coll L. 2010. Land-use changes as major drivers of mountain pine (*Pinus uncinata* Ram.) expansion in the Pyrenees. Global Ecology and Biogeography **19**, 632–641.

Barbero M, Bonin G, Loisel R, Quézel P. 1990. Changes and disturbances of forest ecosystems caused by human activities in the western part of the Mediterranean Basin. Vegetatio **87**, 151–173.

Bolte A, Ammer C, Lof M, Madsen P, Nabuurs GJ, Schall P, Rock J. 2009. Adaptative management in central Europe: climate change impacts, strategies and integrative concept. Scand. Journal of Forest Research **24**, 471-480.

Boudy P. 1955. Economie forestière nordafricaine. Description forestière de l'Algérie et de la Tunisie. T 4. Larose Ed, Paris 483 p.

Braun-Blanquet J, Roussine N, Nègre R. 1952. Les groupements végétaux de la France méditerranéenne. Dir. Carte Group. Vég. Afr. Nord, CNRS 292 p.

Bussotti F, Pollastrini M, Holland V, Bruggemann W. 2015. Functional traits and adaptative capacity of European forests to climate change. Environmental and Experimental Botany **111**, 91-113.

Chauchard S, Beilhe F, Denis N, Carcaillet C. 2010. An increase in the upper treelimit of silver fir (Abiesalba Mill.) in the Alps since the mid-20th century: a landuse change phenomenon. Forest Ecology and Management **259**, 1406–1415.

D'AmatoAW, Bradford JB, Fraver S, Palik BJ. 2011. Forest management for mitigation and adaptation to climate change: insights from long-term silviculture experiments. Forest Ecology and Management **262**, 803-816.

Dagnelie P. 1986. Analyse statistique à plusieurs variables. Gembloux, Presses agronomiques 362 p.

Ennajah A, Azri W, Sai-Kachout S, Taibi K, Guibal F. 2013. Growth and productivity of three Tunisian cork oak populations along a climatic gradient: dendrochronological approach and validation by SIERRA model. Wulfenia Journal No. **6(20),** 239-265.

Ennajah A, Mouillot F, Joffre R, Garchi S, Rejeb N. (2009a). Variation des paramètres structuraux du feuillage d'arbres de chênes lièges de la Subéraie Occidentale Tunisienne. Geo-Ecotrop, n° 33.

Esteso-Martinez J, Valladares F, Camarero JJ, Gil-Pelegrin E. 2006. Crown architecture and leaf habit are associated with intrinsically different light-harvesting efficiencies in Quercus seedlings from contrasting environments. Annals of Forest Science **63**, 511-518.

Fiorani F, Schurr U. 2013. Future Scenarios for plant phenotyping. Annual Review of Plant Biology **64**, 267-291.

Gamage HK, Jesson L. 2007. Leaf heteroblasty is not an adaptation to shade: seedling anatomical and physiological responses to light. New Zealand Journal of Ecology **31**, 245-254.

Ghalambor CK, Mckay JK, Reznick DN. 2007. Adaptive versus non-adaptive phenotypic plasticity and the potential for contemprary adaptation in new environment. Functional Ecology **21**, 394-407.

Gibelin ALA, Deque M. 2003. Anthropogenic climate change over the Mediterranean region simulated by a global variable resolution model. Climate Dynamics **4**, 327-339.

Gimmi U, Wohlgemuth T, Rigling A, Hoffmann CW, Bürgi M. 2010. Land-use and climate change effects in forest compositional trajectories in a dry Central- Alpine valley. Annals of Forest Science p. 67-69.

GirardF, Vennetier M, Guibal F, Corona C, Ouarmim S, Herrero A. 2012. Pinus halepensis Mill. Crown development and fruiting declined with repeated drought in Mediterranean France. European Journal of Forest Research **13**, 919-931.

Grime JP, Thompsonn K, Hunt R, Hodgson JG, Cornelissen JHC, Rorison IH, Hendry GAF, Ashenden TW, Askew AP, Band SR, Booth RE, Bossard CC, Campbell BD, Cooper JEL, Davison AW, Gupta PL, Hall W, Hand DW, Hannah MAM, Hillier SH, Hodkinson D.J., Jalili A., Liu Z., Makey J.M.L., Mattews N., Mowforth M.A., Neal A.M., Reader RJ, Reiling K, Ross-Fraser W, Spenser RE, Sutton F, Tasker DE, Thorpe PC, Whitehouse J. 1997. Integrated screening validates primary axes of specialisation in plants. Oikos **79**, 259-281.

Hanewinkel M, Cullmann DA, Schelhaas MJ, Nabuurs GJ, Zimmermann NE. 2013. Climate change may cause severe loss in the economic value of European forest land. Nature Climate. Change **3**, 203-207.

Hemery GE. 2008. Forest management and silvicultural responses to projected climate change impacts on European broadleaved trees and forests. International Forest Review **10**, 591-607.

Hesselbjerg-Christiansen J, Hewitson B. 2007. Regional climate projection. *In: Climate Change 2007: The physical Science Basis Contribution of Group I to the Fourth Assessment* Report of the Intergovernmental Panel on Climate Change. Cambridge (U.K and New York (U.S.A): Cambridge University Press p. 847-940.

Houghton JT, Meira Filho LG, Callander BA, Harris N, Kattenberg A, Maskell K. 2001. Climate Change: The Science of Climate Change. Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA 572 pp.

Hsiao TC, Silt WK, Jing J. 1985. Leaf growth and water deficits: biophysical effects. - In: Baker N.R., Davies W.J., Ong C.K., (ed): Control of leaf growth. Cambridge University Press, Cambridge p. 239-266.

Inventaire forestier National Tunisien (deuxième). 2005. Direction générale des forêts et centre nationale de la télédétection 129pp.

JullienA, Allirand J-M, Mathieu A, Andrieu B, Ney B. 2009. Variations in leaf mass per area according to N nutrition, plant age, and leaf position reflect ontogenetic plasticity in winter oilseed rape (*Brassica napus* L.). Field Crops Research **114**, 188-197.

Kikuzawa K. 1995. Leaf phenology as an optimal strategy for carbon gain in plant, Canadian Journal of Botany **73**, 185-163.

Lamber H, Poorter H. 1992. Inherent varaiation in growth rate between higher plants : a search for physiological causes and ecological consequences. Advances in. Ecological Research **23**, 187-261.

Le Houérou H N. 1980. The role of browses in the Sahelian and Sudanian zones. In: Browse in Africa, the current state of knowledge. H. N. Le Houérou (ed.), ILCA, Ethiopian Journal of health Development p.83-100.

Le Houerou HN. 2005. The Isoclimate Mediterranean Biomes: Bioclimatology, Biversity and Phytogeography Vol 1 and 2, Copymania Publication, Montpellier (France).

Li B, Suzuki JI, Hara T. 1999. Competitive ability of two Brassica varieties in relation to biomass allocation and morphological plasticity under varying nutrient availability. Ecological Research **14**, 255-266.

Linares JC, Camarero JJ, Carreira JA. 2010. Competition modulates the adaptation capacity of forests to climatic stress: insights from recent growth decline and death in relict stands of the Mediterranean fir Abies pinsapo. Journal of Ecology **98**, 592–603.

Lindner M. 2000. Developing adaptative forest management strategies to cope with climate change. Tree Physiology **20**, 299-307.

Lindner M, Maroschek M, Netherer S, Kremer A, Barbati A, Garcia-Gonzalo J, Seidi R, Delzon S, Corona P, Kolstrom M, Lexer MJ, Marchetti M. 2010. Climate change impacts adaptative capacity and vulnerability of European forest ecosystems. Forest Ecology and Management **259**, 698-709.

Llorens L, Penuelas J, Estiarte M, Bruna P. 2009. Contrasting growth changes in two dominant species of a mediterranean shrubland submitted to experimental drought and warming. Annals of botany **94**, 843-853.

Meehl GA, Tebaldi C. 2004. More intense, more frequent, and longer lasting heat waves in the 21st centuray. Science **5686**, 994-997.

Milad M, Schaich H, Burgi M, Konold W. 2011. Climate change and nature conservations in Central European forets: a review of consequences, concepts and challenges. Forest Ecology and Management **261**, 829-843.

Niinemets U, Kull O. 1998. Stoichiometry of foliar carbon constituents varies along light gradients in temperate woody canopies: implications for foliage morphological plasticity. Tree Physiology **18**, 467-497.

Niinemets U. 2001. Global-scale climate controls of leaf dry per area, density, and thickness in trees and shrubs. Ecology **82**, 453-469.

Ogaya R, Penuela J. 2003. Comparative field study of *Quercus ilex* and *Phyllarea latifolia*: photosynthetic response to experimental drought conditions. Environmental and. Experimental Botany **50**, 137-148.

Pigliucci M. 2001. Phenotypic plasticity: Beyond nature and nurture. The Johns Hopkings University Press.

Pinto CA, Henriques MO, Figueiredo JP, David JS, Abreu FG, Pereira JS, Correia I, David TS. 2011. Phenology and growth dynamics in Mediterranean evergreen oaks: Effects of environmental conditions and water relations. Forest Ecology and Management **262**, 500-508.

Pokorny R, Urban O, Marek MV. 2004. Effect of Norway spruce planting density on shoot morphological parameters. Plant Biology **48**, 137-139.

Poorter I, Wright SJ, Paz H, Ackerly DD, Condit R, Ibarra-Manriquez G, Harm KE, Licona JC, Martinez-Ramos M, Mazer SJ, Muller-Landau HC, Pena-Claros M, Webb CO, Wright IJ. 2008. Are Functional traits good predictors of demographic rates? Evidence from five neotropical forests. Ecology **89**, 1908-0920.

Pulido FJ, Díaz M. 2005. Regeneration of a Mediterranean oak: a whole-cycle approach. Ecoscience **12**, 92–102.

Qaderi MM, Kurepin IV, Reid DM. 2006. Growth and physiological responses of canola (*Brassica napus*) to three components of global climate change: temperature, carbone dioxide and drought. Physiology Plant **128**, 710-721.

Quezel P. 1980. Biogéographie et écologie des coniftères sur le pourtour Meditérranéen. *In Pesson :* Actualité d'Ecologie Forestière. Bordas Edition, Paris p. 205-256.

Quézel P. 1976. Les forêts du pourtour méditerranéen. In Forêts et maquis méditerranéens: écologie, conservation et aménagements. Paris, UNESCO, Note technique MAB **2**, 9-33.

Ramirez-Valiente J.A, Valladares F, Sanchez-Gomez D, Delgado A, Aranda I. 2014. Population variation and natural selection on leaf traits in cork oak throught its distribution range. Acta Oecologica **58**, 49-56.

Sultan SE. 1995. Phenotypic plasticity and plant adaptation. Acta Botanica,Neerlandica **44**, 363-383.

Sultan SE. 2000. Phenotypic plasticity for plant development. Function and life history. Trends in Plant Science **5**, 537-542.

Sultan SE. 2003. Phenotypic plasticity in plants: a case study in ecological development. *Evol. Dev* **5**, 25-33.

Temperli C, Bugmann H, Elkin C. 2012. Adaptative management for competing forest goods and services under climate change. Journal of Applied Ecology **22**, 2065-2077.

Urbieta IR, Zavala MA, Maranon T. 2008. Human and non human determinants of forest composition in southern Spain : evidence of shifts towards cork oak dominance as a result of management over the past century. Journal of Biogeography **35**, 1688-1700.

Valladares F, Sanchez-Gomez D, Zavala M. 2006. Quantitative estimation of phenotypic plasticity: Bridging the gap between the evolutionary concept and its ecological application. Journal of Ecology **94**, 1104-1116.

Wright IJ, Reich PB, Westoby M, Ackerly DD, Baruch Z, Bongers F, Cavender-Bares J, Chapin T, Corneslissen JHC, Diemer M, Flexas J, Garnier E, Groom PK, Gulias J, Hikosaka K, Lamont BB, Lee T, Lee W, Lusk C, Midgley JJ, Navas ML, Niinemets U, Poorter H, Poot P, Prior L, Pyankov V, Roumet C, Thomas SC, Tjoelker MG, eneklaas EJ, Viliar R. 2004. The wordwide leaf economics spectrum. Nature **428**, 821-827.

Wright JW, Montes RC. 2005. Variation in parameters related to leaf thickness in common bean (Phaseolus vulgaris L.). Field Crops Research **91**, 7-21.