water status of Aleppo pine (*Pinus halepensis*) in different bioclimatic stages

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ABSTRACT

The forests that are now regenerating will have to adapt with the climatic conditions that will prevail for several decades, even more than a century. These terrestrial ecosystems participate an important role against the increase of GES in the atmosphere and therefore in the prevention of climate change that significantly modifies the ecophysiological response of trees and profoundly affects ecosystems.

The objective of our work is to compare the water status of three Aleppo pine sites from different bioclimatic stages, Djebel Zaghouan(DZ), Djebel Mansour (DM) and Djebel El Sarj(DS), based on soil-plant-atmosphere continuity. The experimental approach is based on monitoring soil water behavior, gas exchange and hydraulic conductivity with climatic variability.

First results showed that DZ is both tolerable water status and physiology compared to the others sources DM and DS, it was ranked the best performing in terms of adaptation with a low average of ET_0 (3.2 mm / d) while DM and DS recorded 5.3 and 5.5 mm / d respectively. In addition, DZ showed a significant relative humidity in the soil with 26% and a xylemic conductivity with 16.3% of embolism compared to DM and DS which have the highest percentages related to the increase in drying up.

Key words: Aleppo pine, climate change, gas exchange, conductivity, water status,

INTRODUCTION

The forest sector is a vital natural resource in the world. It is closely related to the water sector, beeing capable of modifying its quality and availability. The forest, through its biological functions, plays an indispensable role by reducing surface runoff and improve water storage. It is as an essential filter of pollutants for the conservation of biodiversity. In Tunisia, forests, maquis and garrigue trees reach 686459 ha and almost half of the surface is occupied by Aleppo pine, which remains an important plant in terms of productivity at national level (DGF, 2016). One third of Aleppo pine plantations (115045 ha) are located in northeast Tunisia in the regions of Zaghouan and Siliana. These regions were affected by the adverse effects of climate change which had been caused the destruction of quite 6158 ha in the last decade (DGF, 2016). These effects are mainly explained by the increase of greenhouse gas (GHG) emissions due to the anthropogenic activity.

The manifestations of climate change such as the arising temperatures, the decrease in rainfall, the appearance of extreme events, fires were affected our country more deeply from south to north, which is proven by an increase in aridity from which the forestry sector, like other sectors, is actually increasingly threatened.

Climatic disturbances are also causing the decrease of summer soil humidity (Douville *et al*, 2002, Christensen *et al*, 2007), the increase of evaporation in all Mediterranean regions and the accentuation of extreme events such as droughts ; they become more intense and more severe, leading to water deficits and decreasing availability of water resources.

Tunisia was therefore facing a situation of water scarcity, which could be intensified further with the potential different scenarios of the future climate changes; bearing in mind that the volume of available water would be only around 360 m^3/year/inhabitant by 2030 (MEDD-ANPE, 2008).Furthermore, ground water resources at the ground water level will decrease by 28% in 2030, while, the decrease in surface water will be around 5% at the same horizon (MARHP, 2011).

The forests service in providing water was the objective of several studies, that have a key role, hence the reforestation projects around the world are increasing (Farley et al 2005). In Tunisia forestry studies, about adaptation and their productivity in relation to present and future climatic disturbances remain unsatisfactory. The aim of the present study was to create a model of hydrological, climatic and physiological study of the Aleppo pine trees to improve the knowledge of their general status and their spatiotemporal variability in three different geographical zones from Tunisia namely Jebel Zaghouan (DZ), Jebel Mansour (DM) and Jebel el Sarj (DS).

MATERIALS & METHODS

Plant materiel

The experimental Sites were located in Northeast of Tunisia (Figure1).
Geographical characteristics of sites is illustrated in Table 1.

Table 1: Location of study plots by GPS within 3 sites

Site	Location by GPS
Djebel Zaghouan	36° 22.981' N , 010° 07.060' E , 321m
Djebel El Serj (région de Siliana).	35° 57.309' N , 009° 33.230' E , 794m
Djebel Mansour (région de Zaghouan).	36° 15.998' N ,009° 47.982' E , 405m

Measured parameters

Determination of water balance terms

❑ **Relative sol humidity**

Measured by TDR (Time domain reflectometry)

Soil water content was monitored weekly by time domain refractometry (TDR, Trase system I, Soil moisture Equipment Corp., USA).

❑ **Leaf Water potential**

Leaf water potential (LWP) was determined using the pressure chamber technique. Small twigs were cut and put in a pressure chamber (Arimad 2®, A.R.I, Kfar Charuv, Israel) fed by a Nitrogen gas cylinder and equipped with a lamp-carrying magnifying glass.

❑ **Evapotranspiration**

Evapotranspiration was determined using The 'MABIA-ET0' software according to the FAO-PENMAN-MONTHEITH method (Allen et al, 1998):

$$ETo = \frac{0.408\Delta(Rn - G) + \gamma \frac{900}{T+273} u2\,(es - ea)}{\Delta + \gamma(1 + 0.34u2)}$$

ET_o = reference evapotranspiration [mm / day].
R_n = net radiation on the culture surface [MJ / m^2 / day].
G = soil heat flux density [MJ / m^2 /day] negligible (G = 0).
$T_{moyenne}$ = average air temperature [° C].
u_2 = wind speed measured at 2 m height [m / s].
e_s = saturation vapor pressure [kPa].
e_a = actual vapor pressure [kPa].
$e_s - e_a$ = saturation vapor pressure deficit [kPa].
D = slope vapor pressure curve [kPa / ° C].
g = psychrometric constant [kPa / ° C].

RESULTS

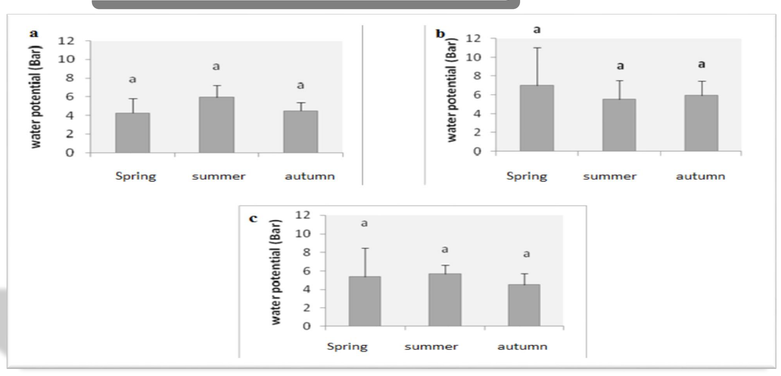

Figure 1: Leaf water potential in (a) Djbel Zaghouan, (b) Djbel Mansour, (c) Djbel Sarj.

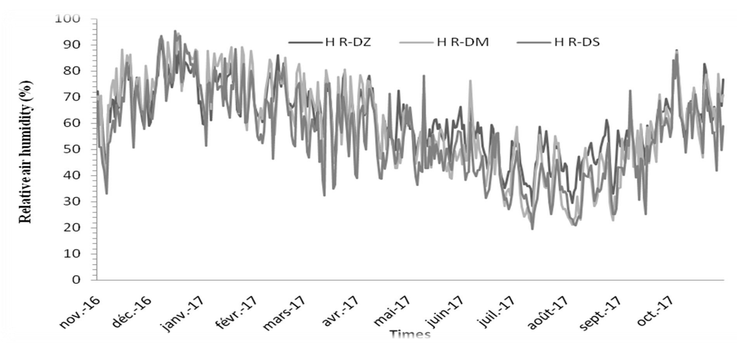

Figure 2: Evolution of the percentage of relative air humidity in three sites.

Leaf water potential:

We observed that in DZ, water potential values (Figure 1) varied between 4.5 and 5.9 Bar. This variability is highly significant between seasons one can note that there was low variability between measurements on the same trees in different seasons. This variability reflects, as a first approximation, differences in water consumption, due to the low inputs they receive, especially during the summer.

While, it was observed for DM (Figure 1, b), water potential were higher than those obtained in the DZ site. They were between 7 and 5.5 Bar in both spring and summer but increase more for the DS site (Figure 1, c) but no significant differences were recorded between sites.

DISCUSSION

Drought tolerance is a known characteristic of Aleppo pine trees compared to other species, and is probably due to efficacy stomatal control. The closure and opening of stomata are strongly related mainly to water availability (Comstock, 2002). In the studied sites, DZ presented the site with the lowest stomatal conductance when compared to the other two sites. It gathers then the character of the most tolerant source of climate variability. The increase in pH was considered as a drought alert state of the studied species because the more it increases the more water tends to leave this compartment the lower the humidity on the ground (Lucot E et al, 1994). This increase was more observed in DS than DM and DZ in relation to the increase in stomata conductance in the same site.

It was found that the level of embolism in DZ is lower than the other two sites studied. This low rate can be an index of the adaptation of this site to the drought, which increased more and more when considering the other two sites. These results are in agreement with those of Sperry et al. (2005) and Salleo et al. (2001) who showed that xylemian hydraulic conductance was controlled by physical processes such as vessel dimensions, wall structure that can be disturbed by the creation of embolism or bubbles of air and water vapor that chase the liquid phase. The vessel is then called cavity or embolized (Tyree et al, 1989). It was also reported that cavitation occurs particularly in case of soil drought (Vilagrosa et al, 2003, Ennajeh et al, 2008).

It can also be seen that the stomatal conductance followed the same aspect of variation in the xylem conductance shown, these findings are proven by (Cornic G, 2007). These results are in agreement with those described by Cruiziat et al. (2001) who found that the variation of the stomatal conductance was positively correlated with the opening and closing of the stomata.

The variation of photosynthesis is dependent of temperature. By causing stomata closure, the water deficit prevents gas exchange and thus a reduction in photosynthesis (Prytz et al, 2003) as the case studied in the three sites during the summer season.

Leaf transpiration is a parameter of the water status of the plant. Its variation is related to that of photosynthesis, at the same stages. The reduction of transpiration was observed mainly in the DS site with increasing temperatures.

The analysis of these parameters shows that the water status of DZ despite increasing temperatures and lowering precipitation is the most resilient site in terms of adaptation to climate change.

CONCLUSION

The adaptability of the Aleppo pine species to climatic factors, such as the variability of temperatures and the reduction of cumulative rainfall, which consider themselves as inhibiting factors of its resilience, does not prevent it from to be more productive and tolerant in more sites than others.

The comparison of the three provenances DZ, DM and DS requires a good knowledge of the soil-plant-atmosphere system during the same periods of study (March-October, 2017).

Principal component analyzes (PCA) after experimental analyzes at the three provenances indicated positive correlations between tree gas exchange, conductivity, and water profile during seasonal variability with maximum spring averages.

Modeling of ET0 using the Penman-Montheith method (FAO-56) by MABIA-ET0 revealed that the DZ site is the most tolerant, with the lowest average (3.2 mm / d).

Using the statistical study of physiological data (stomatal, xylemian conductance) of Aleppo pine trees, a positive correlation was confirmed. These are related to the seasonal variability that affects stomatal status in all sites.

DZ has a lower conductivity than DM and DS which gives it the character of the source having more stomatal control.

In the same context, the decrease in the values of the physiological parameters due to the summer drought is accompanied by an increase in the water potential in the three provenances.According to all this results, Jebel Zaghouan has the most favorable characteristics for the development of Aleppo pine and the lowest vulnerability to the climatic disturbances that Jebel Mansour and Djebel El Sarj.