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The effects of drought stress on Mexican pine-oak forest in the Sierra Madre Oriental

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Abstract

Mexican pine-oak forests are exposed to extreme conditions: high temperatures, scarce precipitation distributed irregularly over the year with peaks, and high pressure on tree regeneration caused by intensive silvo-pastoral activities. This and the irrational and unsustainable use of natural resources is modifying hydrological cycles, ground water supply, natural habitats of fauna, and contributes plainly to soil erosion. As an approach to understand how natural tree regeneration copes with these stress factors, the water relations in mixed pine-oak forest were studied in the Eastern Sierra Madre. Water potentials (Ψ) were related to soil water-content and evaporative demand components in natural pine-oak forest where silvo-pastoral influences could be ignored for the moment. In this way, the exclusive effects of climatic and soil variables on the forest species Quercus canbyi, Pinus pseudostrobus, Juniperus flaccida, Arbutus xalapensis, and Acacia rigidula were investigated at different aspects (north and southeast) from January 2006 until today. Environmental data (air temperature (Temp), relative humidity (RH), vapour pressure deficit (VPD), precipitation, and soil water-content) were taken simultaneously. The water potentials were measured two times a day, 6:00 a.m. and 12:00 p.m. and possibly twice a month. All studied species showed the typical diurnal pattern of variation in Ψ, high values at predawn and low values at midday. A. rigidula, Q. canbyi *and* J. flaccida *were identified as the more drought tolerant species, due to higher predawn values during the dry period or in the case of* J. flaccida *due to its high capacity to recover rapidly higher predawn values on a seasonal basis.*

3 Introduction

Mixed pine-oak forests are the most common forest type in the Eastern Sierra Madre and of importance for the rural population. Although, mentioned forests are exposed to extreme climatic conditions like high temperatures and scarce precipitation, hence water availability is a limited factor in these ecosystems, often marked by degradation and erosion. Furthermore, unsustainable management contributes to the acceleration of mentioned processes in great parts (Cantú and González 2002). Due to this, natural regeneration and reforestation are limited. In order to develop and apply sustainable management or rather reforestation plans, detailed knowledge about the characteristics of tree species and their capacity to respond to a dynamic environment is an important precondition. Identifying and characterizing suitable tree species for the restoration of degraded arid mountain areas has therefore been a major research objective. Plants are bio-indicators reflecting their environment and measuring their water potentials it is possible to quantify actual site effects on the forest vegetation (Mitlöhner 1997). So, the adaptability to climatic changes and especially water stress of five common tree species (*Acacia rigidula, Arbutus xalapensis, Juniperus flaccida, Pinus pseudostrobus, and Quercus canbyi*) has been studied measuring water potentials (Ψ) as well as environmental variables such as air temperature, relative humidity, precipitation and soil water-content at two different aspects from January until August 2006.

4 Methods

4.1 Research site

This investigation was carried out at the Experimental Forest Research Station (EF) of the Facultad de Ciencias Forestales, Universidad Autónoma de Nuevo Leon in the Sierra Madre Oriental (24º42'N; 99º51'W), located 15 km southeast of Iturbide in the state of Nuevo León, México. The mean annual air temperature is 13.9ºC and the average annual precipitation is 639 mm, while the main part occurs from May to October (Cantú and González 2002). The dominant soils are rocky and comprise upper cretaceous lutite or siltstone (Cantú and González 2002). The study was carried out in pine-oak forest distributed on two different aspects, north and southeast-south (elev. 1500 m).

4.2 Plant material and water potential measurement

Four tree species were randomly selected from a representative pine-oak forest at the north and south aspect respectively. The plant species were: *Juniperus flaccida* (Schlecht., Cupressaceae), *Pinus pseudostrobus* (Lindley, Pinaceae), and *Quercus canbyi* (Trel. Fagaceae) at both aspects, whereas *Arbutus xalapensis* (H.B.K., Ericaceae) was only present at the north and *Acacia rigidula* (Benth., Leguminosae) only at the south aspect. The leaf water potentials (Ψ, MPa) on five to six individuals of each tree species were determined at 6:00 h (Ψ_{pd}, predawn) and 12:00 h (Ψ_{md}, midday), when possible twice a month from Jan-19 until Aug-17, 2006 using a Scholander pressure bomb (Model 3005, SoilMoisture Equipment Corp., Santa Barbara, CA, USA) (Ritchie and Hinckley, 1975).

4.3 Environmental data

Microclimatic data like air temperature (ºC) and relative humidity (%) were registered on an hourly basis by using thermo-hygrometers (HOBO® Pro Series Weatherproof Data Loggers) that were located in each sampling site. Likewise, daily precipitation (mm) was obtained from self-emptying rain gauges (Onset® Data Logging Rain Gauge) installed at each aspect. The values of air temperature and relative humidity were further used to calculate vapor pressure deficit (VPD) (Rosenberg et al., 2001). Soil cores at different depths (layers) of 0-10, 20-30, 40-50, and 60-70 cm were taken using a soil sampling tube (SoilMoisture Equipment Corp.) for determining the gravimetric soil water-content at each aspect and on each sampling date.

4.4 Statistical analyses

Assumptions of normality were tested for soil water-content at a specific soil depth, Ψ_{pd} and Ψ_{md} data using the Kolmogorov-Smirnov test (Steel and Torrie, 1980). To detect significant differences among tree species in Ψ_{pd} or Ψ_{md} at each sampling date, one-way analysis of variance (ANOVA) was used for each aspect. Further, when significant variations in the ANOVA were revealed, results were validated using the Tukey's honestly significant difference (HSD) test ($p < 0.05$) (Fowler et al., 1998). To determine if significant differences exist among soil layers in soil water-content, the soil data were subjected to one-way ANOVA. The significance of differences in soil water-content among soil layers was also tested with Tukey's test ($p < 0.05$). Comparing the results at the north and south aspect, differences in soil water-content per layer, mean Ψ_{pd} and mean Ψ_{md} of each species were subjected to one-way ANOVA and further validated using Tukey's test ($p < 0.05$). Correlation coefficients between water potentials (Ψ_{pd} or Ψ_{md}) and environmental variables (mean soil water-content per aspect and sampling date, monthly mean air temperature, monthly mean relative humidity and monthly mean VPD) were quantified by the Spearman's rank order correlation analyses. Concerning the Ψ, mean species values corresponding to each sampling date were considered for this analyses. All statistical methods applied were according to The R project for statistical computing (free statistic software, The R foundation for statistical computing version 2.2.1, 2005).

5 Results

5.1 Environmental conditions during the experimental period

Trends of monthly minimum and maximum air temperatures as well as total precipitation are illustrated in Fig. 1 for both aspects.

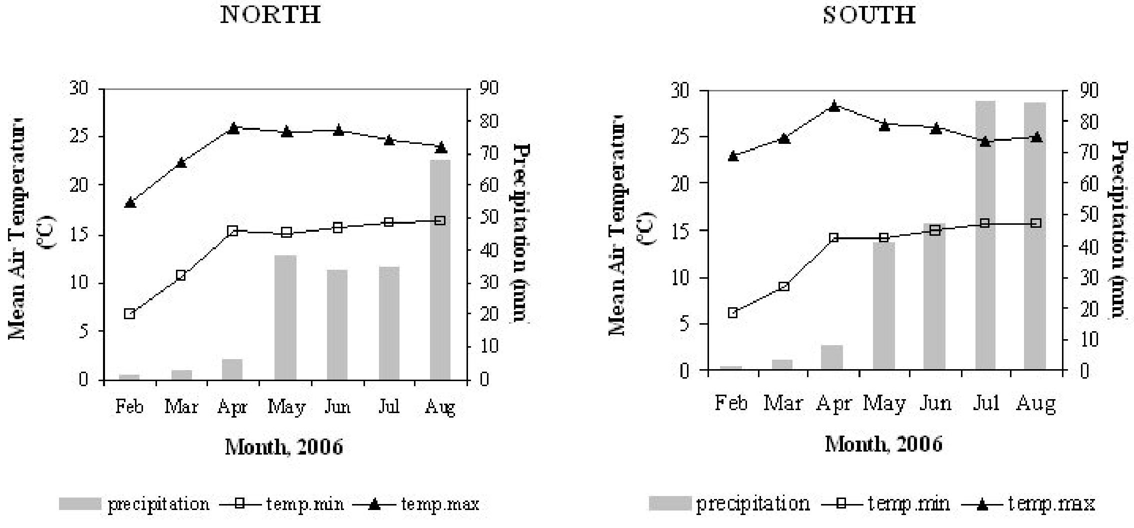

Fig. 1. Monthly minimum and maximum air temperatures, and monthly precipitation at the two research sites, north and south aspect, between February and August 2006.

5.2 Seasonal variation in soil water-content

During the experimental period, minimum air temperatures ranged from 6.83ºC (February) to 16.31ºC (August) and from 6.13ºC (February) to 15.61ºC (August) at the northern and southern aspect, respectively. Maximum air temperatures in comparison ranged from 18.29°C (February) to 25.95ºC (April) at north and from 23.05ºC (February) to 26.30ºC (May) at south. The total rainfall registered was 184.91 mm at the north and 272.03 mm at the south aspect (Fig. 1). According to one-way ANOVA statistic analysis of differences among soil layers in soil water-content, one sampling date (Jun-7) could not be analyzed due to missing data. Out of 12 sampling dates with only one exception (Jun-29, $p < 0.05$), all sampling dates were not different ($p > 0.05$) at the north aspect. At the south, 10 sampling dates of 11 showed no difference with one exception (Jul-26, $p < 0.05$). Gravimetric soil water-contents at different soil layers are shown in Fig. 2. Higher values (0.12 $kg\ kg^{-1}$; $p < 0.05$) in soil water-content at the 0-10 cm depth with respect to layer 40-50 cm occurred at the north on Jun-29. Similarly, at the southern aspect, significant differences in soil water-content were found at layer 0-10 cm in relation to the layers 40-50 cm (0.14 $kg\ kg^{-1}$; $p < 0.05$) and 60-70 cm (0.15 $kg\ kg^{-1}$; $p < 0.05$) on Jul-26.

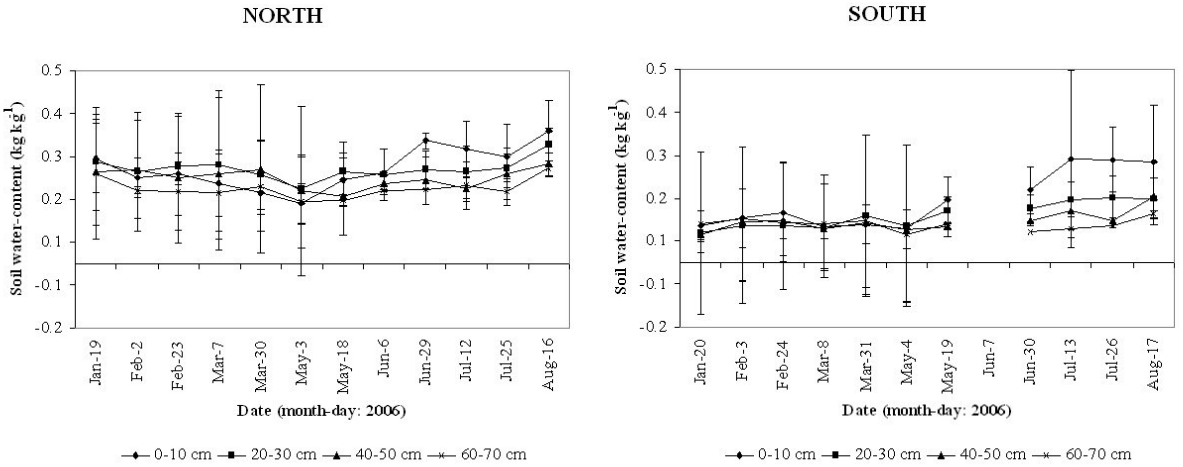

Fig. 2. Seasonal variation in gravimetric soil water-content at four soil profile depths at the two research sites, north and south. Mean values and ± standard errors (*n*=5) are illustrated.

5.3 Seasonal variation in plant water potential north aspect

One-way ANOVA revealed at the north aspect and in all sampling dates significant ($p < 0.05$) differences among tree species in Ψ_{pd} values. The seasonal variation in Ψ_{pd} for the studied tree species at the north is shown in Fig. 3.a. In general, Ψ_{pd} showed similar patterns of variation among tree species when their values were higher than -1.0 MPa; whereas this trend began to diverge among species, especially between *Q. canbyi* and *J. flaccida* or rather *P. pseudostrobus*, when observed Ψ_{pd} values declined below -1.0 MPa. Similar trends were observed between *A. xalapensis* and *J. flaccida* or rather *P. pseudostrobus*. Ψ_{pd} between *Q. canbyi* and *A. xalapensis* showed significant differences at only three sampling dates (Mar-7, Mar-30, and Jun-6), while significant differences in Ψ_{pd} among other species were observed in seven to ten sampling dates, out of 12. During the wettest month (Aug-16; VPD = 0.65 kPa) Ψ_{pd} values reached in *A. xalapensis*, *Q. canbyi,* and *J. flaccida* were significantly ($p < 0.05$) higher than those values of *P. pseudostrobus*. Conversely, during the driest month (May; VPD = 1.08 kPa) tree species showed low values of water potential ((May-3); Fig. 3.a) and experienced a clear water deficit. The annual seasonal trends of Ψ_{md} values among tree species at the north aspect are illustrated in Fig. 3.b. The One-way ANOVA detected significant ($p < 0.05$) differences among tree species in Ψ_{md} in almost all sampling dates (Fig. 3.b). Observed as a common pattern where statistical differences were shown (Fig. 3.b), *Q. canbyi* acquired significantly ($p < 0.05$) higher Ψ_{md} values than those detected for *P. pseudostrobus*, when Ψ_{md} values among tree species were higher than -1.5 MPa. In comparison, when Ψ_{md} values dropped below -1.5 MPa as during the driest month (e.g. May-3), *A. xalapensis* and *P. pseudostrobus* apparently reach higher values than *Q. canbyi* and particularly in relation to *J. flaccida*. Although significant ($p < 0.05$) differences in Ψ_{md} were only revealed between *J. flaccida* and *A. xalapensis*. Conversely, during the wettest month (August) Ψ_{md} values reached in *Q. canbyi* were significantly higher ($p < 0.05$) than the values reached in other species. The Ψ_{md} of almost all species were significantly ($p < 0.05$) different with one exception, *J. flaccida* and *A. xalapensis* that showed no significant ($p > 0.05$) differences. The widest ranges between Ψ_{pd} and Ψ_{md} values (0.52-1.07 MPa) occurred at the northern aspect in the species *A. xalapensis* and *P. pseudostrobus* during the dry and cold period. During the dry and hot period, the ranges in Ψ values of *J. flaccida* and *Q. canbyi* were much wider (0.72 MPa and 0.71 MPa, respectively). Later, during the wet and hot season, the Ψ of *Q. canbyi* reached the widest ranges (0.07-0.67 MPa). In August, the wettest month, *A. xalapensis* showed the widest range between Ψ_{pd} and Ψ_{md} values (0.06 MPa).

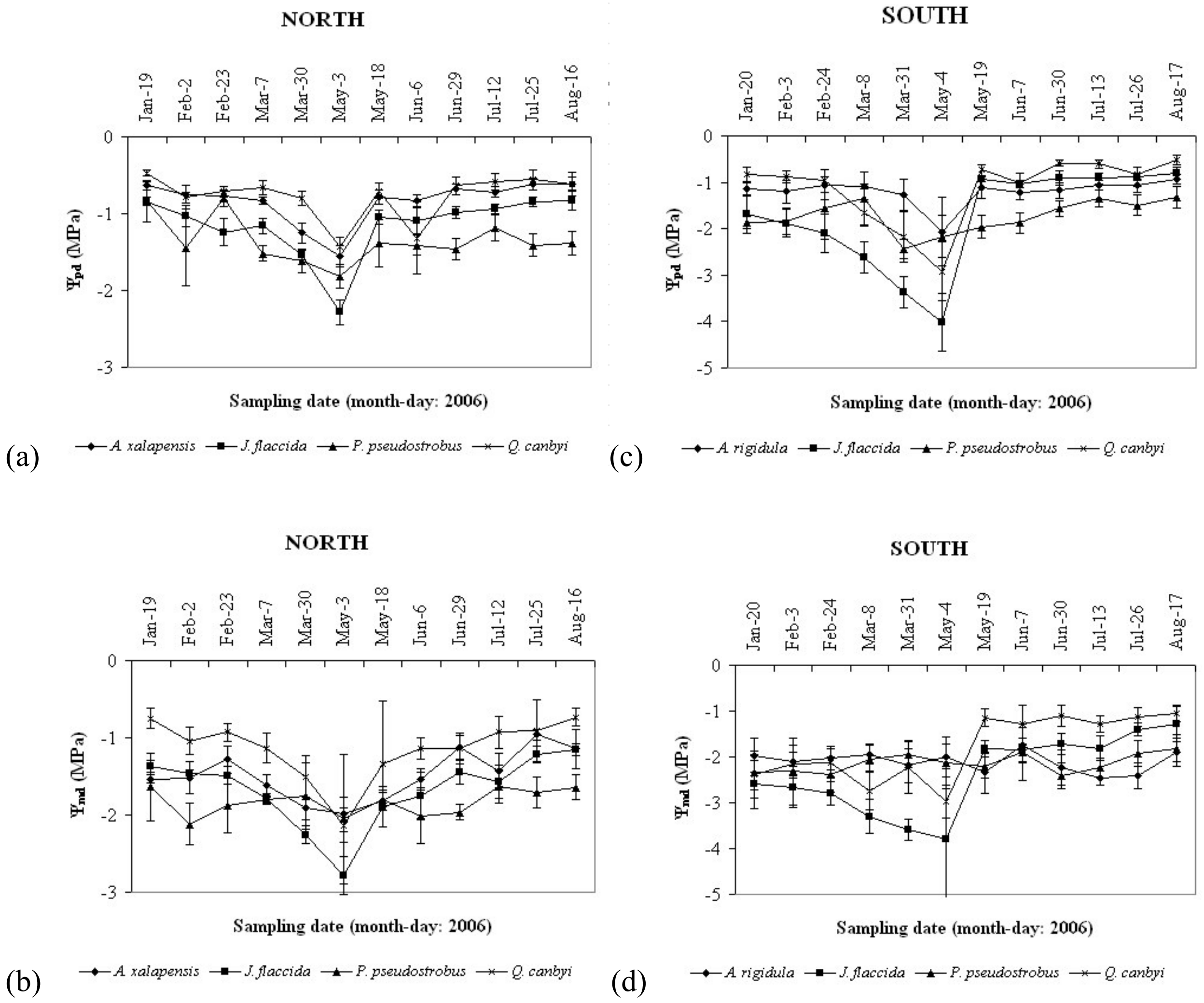

Fig. 3. Seasonal variation in predawn and midday leaf water potential in five tree species at two aspects, north and south. Values are means ± standard errors (n=5 or 6).

5.4 Seasonal variation in plant water potential south aspect

For the south aspect, one-way ANOVA revealed significant ($p < 0.05$) differences among tree species in Ψ_{pd} values in all sampling dates. Fig. 3.c shows the seasonal variation in Ψ_{pd} for the studied tree species at the southern site. As a general rule, Ψ_{pd} showed similar patterns of variation among tree species when their values were higher than -2.0 MPa; while this trend began to diverge among tree species, when the observed Ψ_{pd} declined below the mentioned value. Ψ_{pd} between *Q. canbyi* and *A. rigidula* showed significant differences only at five, out of 12, sampling dates (Mar-31, May 19, Jun-30, Jul-13, and Aug-17), while significant differences in Ψ_{pd} among other species were observed in six to nine sampling dates. During the wettest month (August; mean VPD = 0.72 kPa), Ψ_{pd} values reached in *Q. canbyi* were significantly ($p < 0.05$) higher than those values of the other species. The differences in Ψ_{pd} between the species were significant ($p < 0.05$), with one exception; only the Ψ_{pd} values *J. flaccida* and *A. rigidula* showed no significant ($p > 0.05$) differences. Conversely, during the driest months March and May (May, mean VPD = 1.14 kPa), Ψ_{pd} reached low values ((May-4); Fig. 3.c) indicating a clear water deficit. Differences in Ψ_{pd} among species were only significant ($p < 0.05$) between *J. flaccida* and the three other species. *A. rigidula* reached the highest value. Fig. 3.d shows the annual seasonal trends for Ψ_{md} values at the southern aspect. The one-way ANOVA detected significant ($p < 0.05$) differences in Ψ_{md} among tree species in nine, out of 12, sampling dates. In three sampling dates (Jan-20, Feb-3, and Jun-7) no significant ($p > 0.05$) differences were revealed (Fig. 3.d). In general, lowest Ψ_{md} values (-1.99 MPa to -3.79 MPa) were reached at May-4, one of the driest sampling dates. At this date *A. rigidula* acquired the highest value followed by *P. pseudostrobus*, *Q. canbyi*, and *J. flaccida*. However, significant ($p < 0.05$) differences were detected between *J. flaccida* and the other three species. In contrast, during the wettest sampling date (Aug-17), *Q. canbyi* showed the highest Ψ_{pd} value followed by *J. flaccida*, *P. pseudostrobus*, and *A. rigidula*. Significant ($p < 0.05$) differences in Ψ_{pd} values among species were found only between *J. flaccida* and *A. rigidula* or rather *J. flaccida* and *P. pseudostrobus*. At the southern aspect, the widest ranges (0.82-1.28 MPa) between Ψ_{pd} and Ψ_{md} values were mainly found for *Q. canbyi* and *A. rigidula* during the dry winter months. In March and May, during the hot and dry season, ranges in Ψ values of *A. rigidula* were the widest (0.92 MPa). From June on, the Ψ of mainly *P. pseudostrobus* reached the widest ranges (0.14-0.38 MPa) with the exception of August, when the range in Ψ values of *J. flaccida* was the widest (0.15 MPa).

5.5 Comparison of water potentials at north and south aspect

Comparing environmental data measured at the two aspects north and south, one-way ANOVA has not detected significant ($p > 0.05$) differences in air temperature, relative humidity and VPD, each at predawn and midday. However, there were highly significant differences between the soil water-content in different layers comparing the values of north and south aspect.

Concerning the water potentials, one-way ANOVA including the species *J. flaccida, P. pseudostrobus*, and *Q. canbyi,* present at the two aspects, showed significant ($p < 0.05$) differences in Ψ_{pd} and Ψ_{md} values mainly for the dry season (Jan-19 until May-4) (Table 2). Particularly, the Ψ_{pd} and Ψ_{md} values of *J. flaccida* were significantly ($p < 0.05$) higher at the north than at the south aspect during the first five sampling dates. Also the compared Ψ_{pd} and (partly) Ψ_{md} values of *Q. canbyi* showed significant differences between the north and south during the dry months. Conversely, the Ψ_{pd} and Ψ_{md} values of *P. pseudostrobus* were only at a few sampling dates and mainly at predawn significantly different (Table 1). Generally, Ψ values were more negative at the southern aspect as at the northern.

Table 1. One-way ANOVA results comparing the predawn (Ψ_{pd}), and midday (Ψ_{md}) water potentials of north and south aspect considering species and sampling date.

	J. flaccida				*P. pseudostrobus*				*Q. canbyi*			
	Ψ_{pd} (MPa)		Ψ_{md} (MPa)		Ψ_{pd} (MPa)		Ψ_{md} (MPa)		Ψ_{pd} (MPa)		Ψ_{md} (MPa)	
Sampling date	*F* -value	*p* -value	*F* -value	*p* -value	*F* -value	*p* -value	*F* -value	*p* -value	*F* -value	*p* -value	*F* -value	*p* -value
Jan-19/20	19.75	0.0022 *	26.94	0.0008 **	59.08	0.0001 ***	7.00	0.0295 .	27.90	0.0007 **	47.94	0.0001 ***
Feb-2/3	32.40	0.0005 **	36.25	0.0003 **	2.35	0.1641	0.34	0.5773	1.80	0.2165	65.33	0.0000 ***
Feb-23/24	18.42	0.0026 *	104.30	0.0000 ***	6.31	0.0363 .	4.86	0.0586	4.93	0.0572	65.52	0.0000 ***
Mar-7/8	83.43	0.0000 ***	75.81	0.0000 ***	0.43	0.5317	3.10	0.1165	55.62	0.0001 ***	57.41	0.0001 ***
Mar-30/31	145.20	0.0000 ***	136.60	0.0000 ***	52.19	0.0001 ***	0.77	0.4060	31.07	0.0005 **	6.27	0.0368 .
May-3/4	43.61	0.0001 ***	3.26	0.1010	3.29	0.0997	0.03	0.8604	32.47	0.0002 **	23.23	0.0007 **
May-18/19	7.66	0.0199 .	0.31	0.5912	12.39	0.0055 *	11.67	0.0066 *	0.32	0.5830	0.31	0.5881
Jun-6/7	0.57	0.4693	0.44	0.5200	19.17	0.0014 *	0.16	0.6968	2.30	0.1604	0.67	0.4336
Jun-29/30	1.05	0.3292	5.49	0.0411 .	1.30	0.2817	2.70	0.1317	0.58	0.4654	0.10	0.7538
Jul-12/13	0.22	0.6495	3.14	0.1067	2.66	0.1340	7.53	0.0207 .	0.18	0.6821	0.78	0.3990
Jul-25/26	0.14	0.7134	7.25	0.0226 .	0.61	0.4514	0.08	0.7860	9.99	0.0102 .	0.01	0.9244
Aug-16/17	0.05	0.8296	0.54	0.4806	0.34	0.5749	1.64	0.2293	1.75	0.2156	13.18	0.0046 *

5.6 Relationships between plant water potentials (Ψ_{pd} and Ψ_{md}) and environmental variables

Ψ_{pd} showed significant ($p < 0.05$) and positive correlations with soil water-content at 0-10 cm soil depth in all species and both aspects, with the exception of *P. pseudostrobus* at the south aspect ($p > 0.05$) (Table 2). Conversely, significant ($p < 0.05$) and positive correlations of Ψ_{pd} with the water-content of soil layer 20-30 cm showed three species (*A. xalapensis*, *P. pseudostrobus*, and *Q. canbyi*) at the north aspect and two species (*J. flaccida* and *Q. canbyi*) at the south.

Table 2. Spearman's correlation coefficient values (n = 12) for predawn and midday leaf water potential in relation to soil water-content, mean monthly air temperature, mean monthly relative humidity, mean monthly vapor pressure deficit, and monthly precipitation in four tree species at two aspects, north and south.

Environmental variable	Tree species at the north aspect				Tree species at the south aspect			
	A. xalapensis	*J. flaccida*	*P. pseudostrobus*	*Q. canbyi*	*A. rigidula*	*J. flaccida*	*P. pseudostrobus*	*Q. canbyi*
Predawn leaf water potential (Ψ_{pd})								
Soil water-content								
Depth of 0-10 cm	0.875 **	0.851 **	0.584 .	0.724 *	0.613 .	0.879 **	0.528 ^{NS}	0.824 *
Depth of 20-30 cm	0.595 .	0.532 ^{NS}	0.539 .	0.643 .	0.417 ^{NS}	0.732 .	0.399 ^{NS}	0.685 *
Depth of 40-50 cm	0.389 ^{NS}	0.396 ^{NS}	0.119 ^{NS}	0.301 ^{NS}	0.606 .	0.326 ^{NS}	0.874 **	0.312 ^{NS}
Air temperature	0.210 ^{NS}	0.354 ^{NS}	0.002 ^{NS}	0.244 ^{NS}	-0.133 ^{NS}	0.464 ^{NS}	-0.032 ^{NS}	0.363 ^{NS}
Relative humidity	0.561 ^{NS}	0.713 .	0.247 ^{NS}	0.593 ^{NS}	0.345 ^{NS}	0.768 *	0.447 ^{NS}	0.602 .
Vapor pressure deficit	-0.598 ^{NS}	-0.474 ^{NS}	-0.478 ^{NS}	-0.428 ^{NS}	-0.511 ^{NS}	-0.867 **	-0.550 ^{NS}	-0.745 *
Precipitation	0.210 ^{NS}	0.382 ^{NS}	0.099 ^{NS}	0.280 ^{NS}	0.299 ^{NS}	0.731 .	0.406 ^{NS}	0.547 ^{NS}
Predawn leaf water potential (Ψ_{md})								
Soil water-content								
Depth of 0-10 cm	0.838 **	0.837 **	0.508 ^{NS}	0.744 *	-0.576 ^{NS}	0.865 **	0.279 ^{NS}	0.888 **
Depth of 20-30 cm	0.423 ^{NS}	0.625 .	0.478 ^{NS}	0.694 .	-0.543 ^{NS}	0.719 .	0.583 ^{NS}	0.824 *
Depth of 40-50 cm	0.133 ^{NS}	0.471 ^{NS}	0.313 ^{NS}	0.488 ^{NS}	0.175 ^{NS}	0.297 ^{NS}	0.410 ^{NS}	0.331 ^{NS}
Air temperature	0.253 ^{NS}	0.106 ^{NS}	0.115 ^{NS}	-0.203 ^{NS}	0.166 ^{NS}	0.475 ^{NS}	0.349 ^{NS}	0.529 ^{NS}
Relative humidity	0.464 ^{NS}	0.437 ^{NS}	0.581 ^{NS}	0.143 ^{NS}	-0.129 ^{NS}	0.751 *	0.662 .	0.713 .
Vapor pressure deficit	-0.575 ^{NS}	-0.694 .	-0.350 ^{NS}	-0.818 *	0.127 ^{NS}	-0.845 *	-0.394 ^{NS}	-0.801 *
Precipitation	0.005 ^{NS}	0.032 ^{NS}	0.396 ^{NS}	-0.180 ^{NS}	-0.281 ^{NS}	0.710 .	0.635 .	0.658 .

NS = not significant at $p > 0.05$; .$p < 0.05$; *$p < 0.01$; **$p < 0.001$.
Correlations are on a seasonal basis.

Significant correlations of Ψ_{pd} with the soil depth 40-50 cm were only found at the southern aspect for the species *A. rigidula* and *P. pseudostrobus*. Significant ($p < 0.05$) and positive correlations with climatic variables were detected for *J. flaccida* between Ψ_{pd} and with relative humidity (0.713**.**) at the north, and Ψ_{pd} with relative humidity and precipitation at the south. The Ψ_{pd} of *Q. canbyi* in comparison showed only significant ($p < 0.05$) and positive correlations with relative humidity at south. Significant ($p < 0.05$) and negative correlations were found for the Ψ_{pd} of *J. flaccida* and *Q. canbyi* with the vapor pressure deficit at the southern aspect.

Ψ_{md} at both aspects showed even less correlations with environmental data (Table 2). So, significant ($p < 0.05$) and positive correlations of Ψ_{md} with soil water-content at 0-10 cm soil depth were found in *A. xalapensis, J. flaccida*, and *Q. canbyi* at the north, as well as *J. flaccida*, and *Q.* canbyi at the southern aspect. The Ψ_{md} of last mentioned species showed also significant ($p < 0.05$) and positive correlations with the soil layer 20-30 cm at the south, while no further correlations of Ψ_{md} with deeper soil layers were found at the north. Correlations of Ψ_{md} with other environmental variables were mainly found in the species *J. flaccida* and *Q. canbyi* and at the southern aspect; so exist significant and positive correlations with relative humidity and precipitation. Conversely, Ψ_{md} values showed significant ($p < 0.05$) and negative correlations with vapor pressure deficit for the last mentioned species at both aspects.

6 Conclusions

As a summary, *A. rigidula*, *Q. canbyi* and *J. flaccida* were identified as the more drought tolerant species, due to higher predawn values during the dry period or in the case of *J. flaccida* due to its high capacity to recover rapidly higher predawn values on a seasonal basis. In general, plant water potentials were less correlated with climatic variables but significantly with soil water-content. Although in other studies, highly significant correlations of water potentials with environmental data were described. In the present study, the availability of soil water and with that the species capacity to access soil water seems to be important variables. Concerning our study, rooting systems and other plant physiological characteristics as well as detailed soil properties were not determined. Nevertheless, we recommend including further plant and soil physiological variables in future studies for a better characterization and identification of suitable tree species for ecosystem restoration.

7 References

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