Needle xylem water potential and water saturation deficit in provenances of *Pinus halepensis* Mill. and *P. brutia* Ten[(1)]

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Introduction

Pinus halepensis Mill. and *P. brutia* Ten. subsp. *brutia* Nahal are important trees in countries of the Mediterranean region and are major conifers used in hillside afforestation. Recently, *P. brutia* subsp. *eldarica* (Medw.) Nahal has been introduced over wide areas.

Large-scale planting of *P. halepensis,* the only native pine in Israel, started in the 1920s and extended to poorer and drier sites than those of the native relict forests (Schiller, 1982). Use was made of seed from exotic sources in North Africa, Western Europe, the Balkan peninsula and from only a few trees in native relict forests. All these sources are genetically different (Grunwald *et al.,* 1986; Schiller *et al.,* 1985).

Lately, plantations of *P. halepensis* were severely damaged by periodic drought. The damage has been aggravated by *Matsucoccus josephi* Bodh. et Harpaz, an endemic scale on *P. halepensis.* Native relict forests appear to be able to survive drought more successfully and they are less susceptible to the scale damage. This phenomenon suggests the possibility that the decline may be related to the use of unsuitable seed sources. Therefore, resistance to both drought and *Matsucoccus* is a highly desirable attribute of pines for afforestation in Israel. Resistance to the scale was investigated in provenance trials (Mendel, 1984) of *P. halepensis, P. brutia* subsp. *brutia* and subsp. *eldarica,* which were established as part of an IUFRO-FAO project in 1976.

However, only limited and contradictory information is available regarding the ability of these species to endure summer drought (Dafis and Moulopolus, 1969; Leshem, 1967; Oppenheimer, 1967; Panetsos, 1981; Shomer-Ilan, 1968). In a few papers the water potentials of *P. halepensis* and *P. brutia* (Aussenac and Valette, 1982; Heth, 1974a, b, 1980; Karschon *et al.,* 1976) are discussed, but their relevance to our work is limited since they involved either *P. halepensis* or *P. brutia* of unknown seed origin and did not include data on response of different provenances to drought.

Seed lot No.	Species and provenances	Lat. N. (0')	Long E. (0')	Altitude (m)	Bioclimate and duration of the dry season (days)*
	P. halepensis				
					Thermomed.
A-2	Elea, Greece	37°46'	21°32'	200	100 - 125
A-3	Euboea, Greece	38°58'	23°18'	200	125 - 150
A-7	Elqosh, Israel	33°01'	35°18'	500	125 - 150
	P. brutia subsp. brutia				
					Mesomed.
B-11	Barkara, Turkey	36°09'	32°43'	200	75 - 100
B-14	Baspinar, Turkey	37°48'	35°15'	-	40 - 75
	P. brutia subsp. eldarica				
					Thermomed.
eld.	Karadj, Iran	35°56'	51°00'	-	125 - 150

* From: Bioclimatic Map of the Mediterranean Zone, Ecological Study of the Mediterranean Zone, UNESCO Arid Zone Research - XXI, 1963.

Table I. Seed origin of the provenances tested.

* Died October 1987.

** Department of natural resources, ARO, Bet Dagan 50250, Israel.

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The objective of the present study was to investigate variations in xylem water potential and water saturation deficit between and within species of provenances resistant to the *Matsucoccus* scale growing under the usual drought conditions prevailing in Israel.

Materials and methods

The study was conducted on trees in a 7-year-old provenance trial plot at Ramat haNadiv (32°23'N, 34°56'E) located on a spur of Mt. Carmel, at an altitude of 125 m, on an almost level plateau on deep brown rendzina (Weinstein, 1982). Six seedlings of each of 22 provenances were planted at random in each of the four replications of the trial. Rainfall in the winter preceding our measurements was 720 mm, with no rain from April to November.

Needle wylem water potential (ψ_w) and water saturation deficit (WSD) were measured on three representative trees (**Table II**) in each of three provenances of *P. halepensis,* two of *P. brutia* subsp. *brutia,* and one of *P. brutia* subsp. *eldarica* (**Table I**). All were found to be resistant to the *Matsucoccus* scale (Mendel, 1984) and have displayed superior growth rates in comparison with other provenances in trials in Israel and elsewhere (Eccher *et al.,* 1982; Palmberg, 1975; Spencer, 1985; Weinstein, 1982).

The trees that were sampled had a consistently greater height and diameter than the provenance mean. The standard errors were greater within provenances than within the sample.

Xylem water potential (ψ_w) was measured by means of a pressure chamber (P.M.S. Instruments Co., Corvallis, OR) after Scholander *et al.* (1965), and water saturation deficit (% of water at turgor) by the method of Stocker (1929). Measurements were done four times at 2-month intervals during the hot, dry season between April and October. The critical measurements were those taken during the hot part of the day between 0900 h. and 1600 h. Each datum is an average of measurements done on five branchlets on each of three trees per provenance for needle ψ_w (*i.e.,* 15 measurements); and seven samples of three brachyblasts on each of three trees per provenance for WSD determination (*i.e.,* 21 measurements).

The material tested consisted of fully developed current year's growth obtained from all parts of the crown at 1.8-2.0 m above ground.

The data obtained were analyzed with the General Linear Model (GLM) procedure of the SAS package (SAS, 1982).

Species and provenances	Average +- S.E. of provenances (n=40)			Average +- of sample tree (n=3)		
	$\bar{H}$ m	$\bar{d}_{1.3}$ m	$\bar{V}$ m3	$\bar{H}$ m	$\bar{d}_{1.3}$ m	$\bar{V}$ m3
P. halepensis						
Elea (A-2)	6.14±1.72	11.9±4.4	0.0645±0.1240	6.90±0.49	12.62±0.78	0.0512±.0059
Euboea (A-3)	5.52±1.19	11.2±3.3	0.0580±0.1130	5.80±0.61	12.10±0.69	0.0402±.0062
Elqosh (A-7)	5.56±3.22	8.8±4.5	0.0281±0.0278	5.28±0.66	8.02±0.93	0.0183±.0042
P. brutia subsp. *brutia*						
Bakara (B-11)	4.33±1.00	6.1±1.9	0.0106±0.066	4.85±0.70	6.78±1.45	0.0134±.0066
Baspinar (B-14)	3.67±1.38	5.3±2.0	0.0085±0.0053	4.44±0.59	5.70±1.48	0.0096±.0047
P. brutia subsp. *eldarica*						
Karadj(eld.)	4.26±1.20	6.30±2.5	0.0126±0.0113	4.63±0.50	6.13±1.46	0.0106±.0052

Table II. Average height, diameter, and volume of the provenance and sample trees.

P. halepensis			*P. brutia*		
Item	WSD %	ψ_w -MPa		WSD %	ψ_w -MPa
Provenance			Provenance		
Euboea (A-3)	20.2 A	2.58 A	eld.	15.8 A	2.27 A
Elqosh (A-7)	18.9 B	2.39 B	Bakara(B-11)	13.9 B	2.20 B
Elea (A-2)	16.5 C	2.39 B	Baspinar (B-14)	12.0 C	2.18 B
F	54.25	40.70	F	54.03	4.44
PR > F	0.0001	0.0001	PR > F	0.0001	0.0143

* Means with the same letter are not significantly different (P = 0.05).

Table III. Multiple Analysis of Varaince and Duncan's Multiple Range Test of WSD and ψ_w in different provenances of *Pinus halepensis* and *P. brutia.*

Results

Average height, diameter and volume of each provenance and of the three trees per provenance used in our investigation are given in *Table 2.* The height and diameter growth of Aleppo pine provenances was better than that of the *P. brutia* provenances. Among the Aleppo pine provenances, the differences in height, diameter and volume are significant at P = 0.01. Trees of the Elea (A-2) provenance grew better than those of the Euboea (A-3) provenance, whereas the Elqosh (A-7) provenance had the lowest growth rate.

Among the *P. brutia* subsp. *brutia* provenances the Bakara (B-11) provenance grew better than the Baspinar (B-14) seed source. *P. brutia* subsp. *eldarica* from Karadj grew better than the subsp. *brutia* provenances.

Figures 1 and 2 show the daily course at three dates in summer of 1983, of WSD (%) and ψ_w (MPa) in Aleppo pine and *P. brutia* provenances. In all the species and provenances, WSD and ψ_w vary throughout the day and according to season of the year in relation to climatic factors and soil water content.

In Aleppo pine (**Fig. 1**), ψ_w and WSD ranged from − 1.42 to − 2.76 MPa and from 11.6 % to 21.8 %, respectively; mean daily differences between the maximum and minimum values were − 0.83 MPa and 4.4 %, respectively. Trees of the Euboea (A-3) provenance developed a distinctly higher WSD and lower ψ_w than trees of the Elea (A-2) provenance, whereas the trees of the Elqosh (A-7) provenance were intermediate. Trees of this provenance developed a WSD similar to that of the Euboea provenance, but ψ_w was more similar to the Elea provenance. Still, there were significant differences between provenances in their WSD, and ψ_w as can be seen from **Table III,** which gives the results of the Multiple Analysis of Variance and Duncan's Multiple Range Test. The relatively large Standard Error (S.E.) within every provenance results from the fact that every datum is the mean of measurements on only three individual trees. **Table IV** shows the results of analysis of variance, it can be seen that there are very significant differences between provenances in their relations of WSD to ψ_w. But there are also significant differences within provenances, amongst trees in the relations of WSD to ψ_w. **Figure 3** shows the regressions of Ln.WSD over Ln ψ_w, for every provenance. The Euboea (A-3) provenance had the smallest decrease in ψ_w for a unit increase in WSD, whereas the Elqosh (A-7) provenance had the highest WSD at low ψ_w, but the largest decrease of ψ_w per a unit change in WSD. The Elea (A-2) provenance had the lowest WSD at a given ψ_w. The regression equation and analysis by Manova (SAS.1982) on the significance of the difference between the regressions are given in **Table VI.** From the table it can be seen that there are significant differences between the regression equation of the Elea and the Euboea and the Elqosh provenances, but there is no significant difference between the two latter provences.

In *P. brutia* (**Fig. 2**), ψ_w and WSD ranged from − 0.49 to − 2.50 MPa

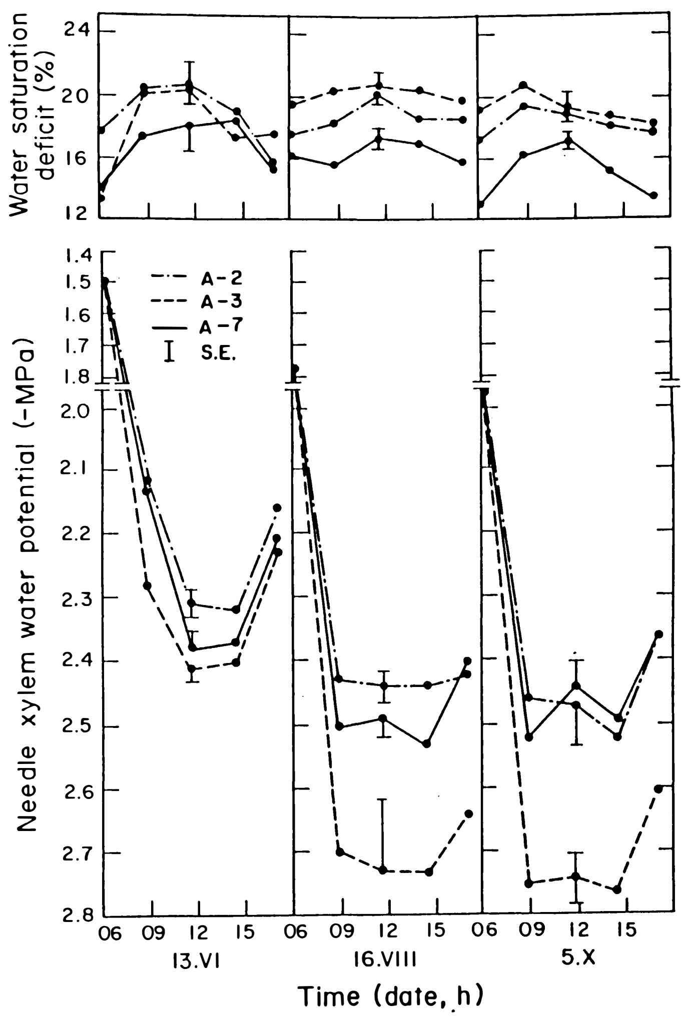

Figure 1. — Daily course of needle xylem water potentials (− MPa) and water saturation deficits (%) of *Pinus halepensis* provenances at Ramat haNadiv.

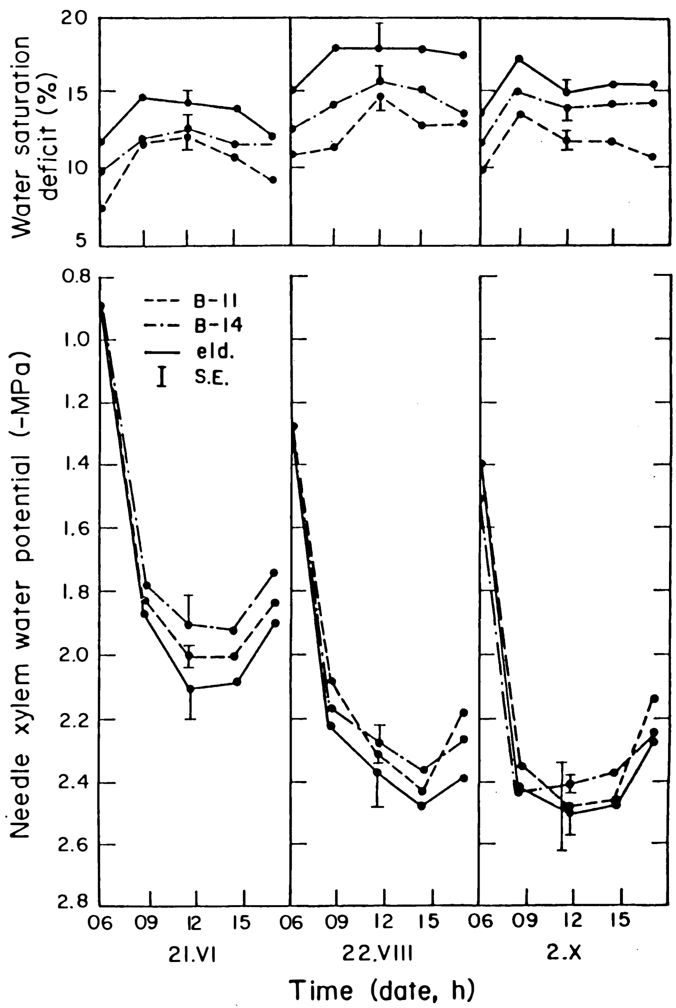

Figure 2. — Daily course of needle xylem water potentials (− MPa) and water saturation deficit (%) of *Pinus brutia* subsp. *brutia* and subsp. *eldarica* provenances at Ramat haNadiv.

Source	D.F.	F	PR > F
Provenance	2	21.49	0.0001
Tree with. Prov.	6	3.38	0.0040
Date	3	7.03	0.0002
Hours	4	6.13	0.0002
Log ψ_w	1	88.40	0.0001
Log ψ_w X Prov.	2	8.29	0.0004

Table IV. Analysis of variance presenting the significance of the effect of the different factors and log (ψ_w) on log (WSD) in *P. halepensis.*

and 6.7 % to 17.9 %, respectively, average daily differences were − 1.01 MPa and 2.7 %, respectively. At all dates, ψ_w of subsp. *brutia* provenances and subsp. *eldarica* did not differ consistently, but the WSDs of the subsp. *brutia* provenances were markedly higher than those of subsp. *eldarica.* Still, **Table III** shows that all the three provenances differ significantly in their WSD, whereas significant differences in ψ_w occur only between the subsp. *eldarica* and the two provenances of subsp. *brutia.* Also here, in **Figure 2**, the relatively large S.E. for subsp. *eldarica* results from the fact that the data are averages of measurements carried out on only three trees per provenance. **Table V** shows the results of analysis of variance, it can be seen that there are very significant differences between the provenances in the relations of WSD to ψ_w, there are also differences between trees within provenances. **Figure 4** shows the regression Ln.WSD over Ln. ψ_w for every provenance. The Bakara (B-11) provenance had the lowest WSD at a given ψ_w; trees of this provenance tended to have the largest decrease in ψ_w per unit increase in WSD. Whereas the Karadj provenance of subsp. *eldarica* had the highest WSD at a given ψ_w; trees of this provenance tended to have the smallest decrease of ψ_w for a unit increase in WSD.

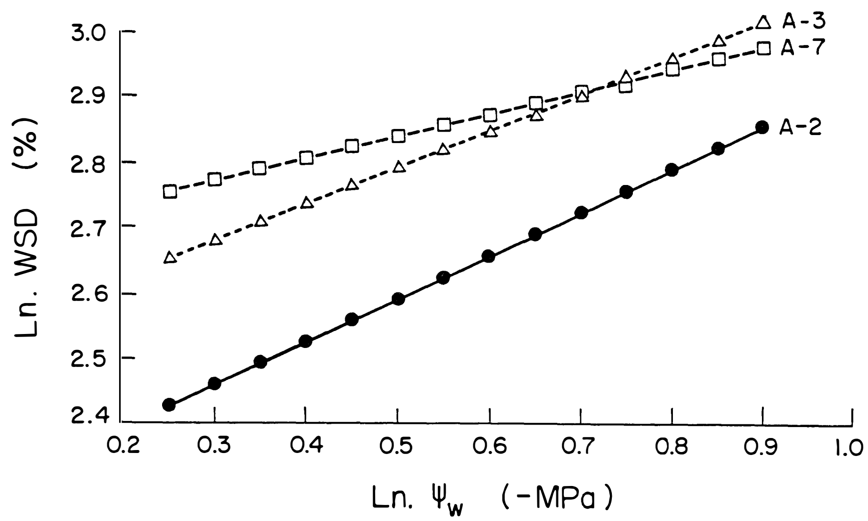

Figure 3. — Relation between water saturation deficit (%) and needle xylem water potential in *Pinus halepensis* provenances.

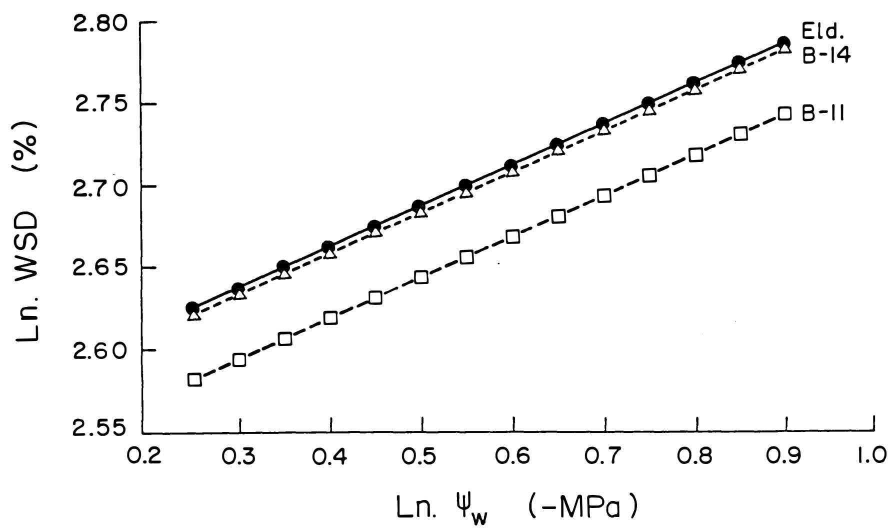

Figure 4. — Relation between water saturation deficit (%) and needle xylem water potential in *Pinus brutia* provenances.

Discussion

Trees of *P. halepensis* reached higher mean WSD (%) and lower ψ_w (MPa) than those of the *P. brutia* complex (**Figs. 1 and 2**). The values of ψ_w and WSD measured in Aleppo pine were quite normal, since ψ_w as low as − 3.0 or − 3.6 (MPa) was reported by Aussenac and Valette (1982) and Karschon *et al.* (1976); and WSD (%) as high as 23 % by Berlinger (1956). The occurrence of lower ψ_w in *P. halepensis* than in *P. brutia* growing in mixed stand on the same site, was confirmed in additional field trials (Schiller and Heth, unpublished data) and laboratory tests (Oppenheimer, 1967). Since neither pine species displayed any sign of drought injury in any of these studies, it may be that the differences in ψ_w of trees growing at the same site, are related to morphological and anatomical characters (Abido, 1983). Moreover, higher ψ_w before sunrise and during the day in *P. brutia* than in *P. halepensis* may be the result of a deeper root system in the former that could absorb moisture from a bigger soil volume than the relatively shallow root system of *P. halepensis* (Dafis and Moulopoulos, 1969).

Although these Mediterranean pine species are xerophytes, Aleppo pine is regarded as relatively more drought tolerant because of its ability to develop higher "suction power" to extract water from the soil (Shomer-Ilan, 1968) and to continue to transpire at a lower soil moisture content than *P. brutia,* thus enduring higher WSD and lower ψ_w without damage (Oppenheimer, 1967). This assumption is also in agreement with the geographical distribution of these species.

Within species, provenances differ in growth rate (**Table 2**) in WSD and ψ_w (**Figs. 1 and 2**), and they too can be divided according to the relations of WSD to ψ_w (**Tables V and VI, Figs. 3 and 4**).

In the same environment, growth of the A-2 provenance was greater than that of either the A-3 or A-7 provenances of Aleppo pine. Yet, WSD was lower at a given ψ_w in the former than in the two other provenances. The A-2 provenance appeared to be able to avoid drought stress and grew better than the two other provenances, A-3 grew much better than the A-7 provenance, but the response of both to summer drought (*i.e.,* the relation of WSD to ψ_w) was similar. Under the study conditions, the native A-7 provenance showed no advantage either in growth or in drought tolerance. Under more severe circumstances it may perform better, as has been suggested by others (Oppenheimer, 1967; Shomer-Ilan, 1968), but this cannot be concluded from the present data. As can be seen from **Fig. 3,** a change in WSD implies a bigger change of ψ_w in the Elqosh (A-7) provenance than in the Elea (A-2) and Euboea (A-3) provenances. According to Jarvis and Jarvis (1963), trees from which a loss of a small volume of water results in a larger decrease in ψ_w, have better chances of survival at times of severe water stress, but those trees are comparatively sensitive to small moisture stresses and respond with the reduction of growth. Melzack *et al.* (1985) have shown that in 2-year-old native Israeli Aleppo pine seedlings, ψ_w of − 0.8 MPa is a threshold beyond which the net assimilation rate is reduced dramatically. Between-provenance variation in relationship of WSD to ψ_w may also be related to differences in anatomy. A count of stomata done along two mm-long mid portion of the needle on ten mature needles on each of ten trees per provenance revealed significant differences between the Israeli Elqosh and the Greek Elea provenances : 49.3 ± 2.3 stomata per unit area in the latter and 38.9 ± 1.6 in the former. Calamassi (1986), too, has found significant differences between provenances in the number of stomata.

Source	D.F.	F	PF > F
Provenance	2	42.66	0.0001
Tree with. Prov.	6	2.25	0.0429
Date	3	14.73	0.0001
Hours	4	1.14	0.3413
Log ψ_w	1	4.48	0.0362
Log ψ_w X prov	2	0.60	0.5523

Table V. Analysis of variance presenting the significance of the effects of the different factors and log (ψ_w) on log (WSD) in *P. brutia.*

		r	F	PR > F
P. halepensis				
A. A-2	log y = 2.271 + 0.624 log ψ_w	0.538***	19.530	0.0001
A-3	log y = 2.513 + 0.521 log ψ_w	0.776***	63.672	0.0001
A-7	log y = 2.660 + 0.317 log ψ_w	0.584***	26.413	0.0001
B. A-2/A-3			21.14	0.012
A-2/A-7			17.38	0.024
A-3/A-7			3.38	0.170
P. brutia				
A. B-11	log y = 2.564 + 0.2349 log ψ_w	0.777***	70.380	0.0001
B-14	log y = 2.560 + 0.2349 log ψ_w	0.831***	96.032	0.0001
eld.	log y = 2.522 + 0.2349 log ψ_w	0.777***	70.226	0.0001
B. eld/B-11			129.92	0.0001
eld/B-14			11.62	0.0380
B-11/B-14			6.64	0.0790

y = WSD

Table VI. A : Regression equations and correlation coefficients of Log (WSD) on log (ψ_w) for each species and provenance. B : MANOVA tests between provenances for each species based on the variables log (WSD) and log (ψ_w).

Among the subsp. *brutia* provenances, the Bakara (B-11) provenance seemed to be most capable of avoiding drought stress and had the highest growth rate, whereas the Karadj provenance of subsp. *eldarica* developed the most severe drought stress and maintained a good growth rate compared with the subsp. *brutia* provenances (**Table II**). Under drier environmental conditions, subsp. *eldarica* may be more successful, as suggested by various workers (Eccher *et al.*, 1982; Weinstein, 1984), but under the study conditions, the sample trees showed no advantage over the other subsp. *brutia* provenances. Within the *P. brutia* complex, a count of stomata and the number of resin canals in mature needles done in several provenances of subsp. *brutia* and subsp. *eldarica* (Grunwald, unpublished data), cortex resin monoterpene analysis (Schiller and Grunwald, 1987) and seed megagametophyte isoenzyme analysis (Conkle *et al.*, 1988) has revealed significant differences among provenances and has shown that the two provenances of subsp. *brutia* belong to different genetic groups within the subspecies.

Conclusions

P. halepensis shows greater sensitivity to summer drought than *P. brutia,* as indicated by the relations of WSD to ψ_w, but it grew more rapidely during the first 7 years. Within both the Aleppo pine and the *P. brutia* complex, the provenances that grew quicker had maintained a lower WSD at a given ψ_w than the other provenances, during the summer. Under the conditions of the study site, the Elea (A-2) provenance among *P. halepensis* and the Bakara (B-11) provenance among subsp. *brutia* are best adapted. Under more severe drought conditions, the Elqosh (A-7) and the Karadj provenance of subsp. *eldarica* may grow better than the other provenances examined, as has been suggested by other authors, (Maksymov, 1982; Weber, 1981), but that cannot be concluded from the present study.

Within species, the eco-geographical distribution of the provenances would suggest that the Elqosh and Karadj provenances are from drier environments and therefore should have better drought tolerance. However, these characteristics do not appear to confer any advantage to the provenances when grown under more favourable circumstances. It appears that these provenances from drier environments, maintain behaviour suited to such environments even when grown under more humid conditions, and even when such behaviour is not advantageous to growth. In that case, high WSD at equivalent ψ_w, measured on trees growing in an introduction trial, may be a good indicator of drought resistance also at site where conditions are not necessarily harsh.

Finally, the results presented in this study illustrate the existence of variation within and between species among provenances in drought tolerance, as has been suggested by Grunwald and Karschon (1982) and Ladiges (1974). Under normal summer drought conditions use should be made of seed from the Elea (A-2) and Bakara (B-11) provenances. Under more arid conditions, i.e. close to the boundary of aridity (Ganor, 1963), the use of native Israeli provenances may be advantageous. Further investigations on drought tolerance and growth rate of subsp. *eldarica* provenances should be undertaken, to evaluate differences within this interesting subspecies, as only one provenance was included in our study.

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Summary

Xylem water potentials and water saturation deficits were examined in field trials of three seed sources of Pinus halepensis *Mill., two seed sources of* P. brutia *Ten. subsp.* brutia, *Nahal and one of* P. brutia *subsp.* eldarica *(Medw.) Nahal. Significant differences were found between and within species in adaptation to drought, namely, low xylem water potentials and reduced water saturation deficits associated with high production in* Pinus halepensis *and* P. brutia *subsp.* brutia, *and relatively high water potentials and water deficit and relatively high growth rate in* P. brutia *subsp.* eldarica. *For use in reforestation of* P. halepensis *and taxa of the* P. brutia *complex layout of provenance trials, it is recommended to select the most promising seed sources displaying high productivity coupled with adequate drought tolerance.*

Additional key words *:* Pinus eldarica, *drought tolerance.*

Résumé

Potentiel d'eau et déficit de saturation d'eau des aiguilles de différentes provenances de Pinus halepensis *Mill. et* Pinus brutia *Ten.*

Le pin d'Alep et différents taxa groupés sous le nom de pin brutia contribuent largement aux reboisements dans les pays méditerranéens et leur rôle pourrait être accru par une meilleure connaissance des provenances convenant aux différentes stations. Tandis que le pin d'Alep est essentiellement une essence de la Méditerranée occidentale, le pin brutia est caractéristique de la Méditerranée orientale, et certaines de ses sous-espèces poussent sur les côtes de la Mer Noire et s'étendent jusqu'à l'Iraq et l'Iranet, sans doute, l'Afghanistan. L'importance particulière de P. brutia *réside dans sa résistance à* Matsucoccus josephi, *une cochenille endémique à Israël (et éventuellement dans les pays limitrophes) endommageant les forêts naturelles et ravageant les plantations de pin d'Alep. Il est curieux de noter que les opinions sont partagées en ce qui concerne la tolérance de la sécheresse des pins d'Alep et brutia vu le manque d'investigations comparatives portant sur les provenances d'origine des deux espèces. La présente recherche a été entreprise pour combler, au moins partiellement, cette lacune regrettable.*

Notre étude a été faite dans les parcelles expérimentales comparant le comportement et la croissance d'un grand nombre de provenances de P. halepensis. P. brutia *subsp.* brutia *et d'une seule provenacne de* P. brutia *subsp.* eldarica. *Les parcelles, âgées de sept ans, sont situées dans la partie sud du Mt. Carmel, a une altitude de 125 m, sur un plateau à rendzine brune assez profonde. Trois provenances de pin d'Alep, trois provenances de* P. brutia *subsp.* brutia *et la seule et unique provenance de subsp.* eldarica *ont été examinées. L'examen a porté sur trois arbres de chaque provenance. Le potentiel d'eau (ψ_w) et le déficit de saturation d'eau (%) des aiguilles ont été mesurés par les méthodes de Scholander et* al. *et Stocker, respectivement, à quatre dates à deux mois d'intervalle d'Avril à Octobre, de six heures du matin à six heures du soir.*

Pour les résultats le lecteur est prié de se rapporter aux tableaux et figures. Ils montrent que chez le pin d'Alep le potentiel d'eau est plus bas (c.a.d. plus négatif) et le déficit de saturation est plus élevé que chez les pins brutia. Comme aucune des provenances examinées n'a souffert de la sécheresse, il se peut que cette différence dans le comportement écophysiologique soit due à des différences dans la morphologie et l'anatomie des aiguilles et au système radiculaire plus profond des pins brutia (le pin d'Alep est connu pour son système de racines extrêmement superficiel).

Il y a donc lieu de conclure que le pin d'Alep est décidément plus résistant à la sécheresse que le pin brutia.

*La distribution des provenances examinées suggère que celles d'Elquosh (*P. halepensis*) et Karadj (*P. brutia *subsp.* eldarica*) sont originaires de stations sèches et devraient donc être plus résistantes à la sécheresse. Toutefois, ce caractère ne semble guère être avantageux lorsque ces provenances sont cultivées sous conditions plus favorables. Il semble que des provenances d'environnements plus secs maintiennent leur comportement même sous conditions plus humides et cela lorsqu'un tel comportement ne confère aucun avantage à leur croissance. Dans un tel cas, un déficit d'eau plus élevé pour une pression d'eau donnée mesuré dans les parcelles expérimentales, peut être un bon indicateur de la tolérance de la sécheresse même sur une station relativement favorable.*

Le fait le plus notable qui ressort de nos recherches, et qui est d'applications générale, consiste dans les différences obtenues pour différentes provenances de la même espèce sur la même station. Bien entendu, sur d'autres stations il y a lieu de s'attendre à ce que d'autres classements entre provenances soient obtenus. Ainsi, sous conditions normales en Israël (précipitations annuelles de l'ordre de 600 mm), les graines de pin d'Alep d'Elea (Grèce) et de P. brutia *subsp.* brutia *de Bakara (Turquie) donnent les meilleurs résultats tant du point de vue de leur productivité que de leur résistande à la sécheresse et au* Matsucoccus. *L'expérimentation de subsp.* eldarica *mériterait d'être étendue à un plus grand nombre de provenances.*

Finalement, les forestiers français auraient tout intérêt à expérimenter l'usage du pin d'Alep d'origine grecque (résultat de l'introgression par P. brutia*) et de* P. brutia *subsp.* brutia *qui est différent du pin d'Alep 'classique' par leur fut droit.*

Riassunto

Potenziale in acqua e disavanzo di saturazione in acqua degli aghi delle differenti provenienze di Pinus halepensis *Mill e* Pinus brutia *Ten.*

Il pino d'Aleppo e differenti specie raggruppate sotto il nome di pino brutia contribuiscono largamente ai rimboscamenti nei paesi mediterranei e la loro parte potrebbe essere accresciuta de una conoscenza migliore delle provenienze che convengono alle differentistazioni. Mentre il pino d'Aleppo è essenzialmente una essenza del mediterraneo occidentale, il pino brutia è caratteristico del mediterraneo orientale e alcune specie cresciono sulle coste della mar Nera e si stendono fino a l'Iraq et l'Iran e forse l'Afghanistan. L'importanza particolare del pino brutia reside nella sua resistenza a Matsucoccus josephi, *una cocciniglia endemica a Israele (e forse ai paesi limitofi) danneggiando le foreste natrurali e devastando le piantagioni di pino d'Aleppo. E curioso notare che le opinioni sono divise riguardando la tolleranza alla siccità estiva dei pini d'Aleppo e brutia vista la mancanza di investigazioni comparative fatte sulle provenienze di origine delle due specie. La presenta ricerca è stata intrapresa per colmare, almeno parzialmente, questa lacuna spiacevole.*

Il nostro studio è stato fatto negli appezzamenti sperimentali comparando il comportamento e la crescenza di un gran numero di provenienze di P. halepensis, P. brutia *subsp.* brutia *e di una provenienza sola di* P. brutia *subsp.* eldarica. *Gli appezzamenti in età di sette anni sono situati nella parte sud del Monte Carmelo, a un'altitudine di 125 m, sopra un altiplano a rendzina bruna abbastanza profonda. Tre provenienze di pino d'Aleppo, tre provenienze di* P. brutia *subsp.* brutia *e la sola unica provenienza di subsp. eldarica sono state esaminate. L'esame ha portato su tre alberi di ogni provenienza. Il potenziale di acqua (ψ_w) et il disavanzo di saturazione in acqua (%) degli aghi sono stati misurati dai metodi di Scholander e* al. *e Stocker, rispetivamente, a quatro date a due mesi d'intervallo d'Aprile a Ottobre, dalle sei della matina alle sei della sera.*

Per il risultato il lettora è pregato di riferirsi agli specchietti e alle figure. Mostrano che per il pino d'Aleppo il potenziale in acqua à più basso (cioè più negativo) e il disavanzo di saturazione è più alto del pino brutia. Siccome nessuna provenienza esaminata non ha sofferto della siccità, è possibile che questa differenzia nel comportamento sia dovuta a differenzie nella morfologia e nell'anatomia degli aghi e al sistema radiculare più profonde dein pin brutia (il pino d'Aleppo è conosciuto per il suo sistema di radici estremamente superficiale).

C'è mottivo, dunque, di concludere che il pino d'Aleppo è davvero più resistente alla sicità del pino brutia.

*La distribuzione delle provenienze esaminate suggerisconoche quelle di Elquosh (*P. Halepensis*) e Karadj (*P. brutia *subsp.* eldarica*) sono originarie di stazioni asciute e dovrebbero dunque essere più resistente alla siccità. Tuttavia, questo carattere non sembra essere molto vantaggioso quando quelle provenienze sono coltivate in condizioni favorevoli. Sembra che provenienze d'ambiente più asciuto mantengono il loro comportamento anche sotto condizioni più umide e ciò quando questo comportamente non concede nessuno vantaggio alla loro crescenza. In tale caso, un disavanzo più alto per una data pressione d'acqua misurata negli appezzamenti sperimentali può essere un'indicatore buono della tolleranza alla siccità anche in una stazione relativamente favorevole.*

Il fatto più notabile che risulta delle nostre ricerche e che viene d'applicazione generale consiste nelle differenze ottenute per differenti provenienze della stessa specie sulla stessa stazione.

Naturalmente, su altre stazioni c'è mottivo di aspettarsi che altre classificazioni tra provenienze siamo ottenute. Cosi, sotto condizioni normali in Israele (precipitazioni annue circa 600 m), i semi di pino d'Aleppo d'Alea (grecia) e di pino brutia subsp. brutia di Bakara (Turchia) danno i migliori risultati tanto dal punto di vista della loro produttività quanto della loro resistenza alla siccità e al Matsucoccus. *La sperimentazione de subsp. eldarica meriterebbe d'essere stesa a un numero più grande di provenienze.*

Finalemente, i forestali francesi avrebbero affatto interesse a sperimentare l'uso del pino d'Aleppo di origine greca (risultato dell'introduzione da P. brutia *subsp.* brutia *che sono differenti del pino d'Aleppo "classico" dal loro fusto diritto.*