Jonathan W. Wright †

JONATHAN W. WRIGHT, pioneer tree breeder and long time co-editor of *Silvae Genetica* died at his Okemos, Michigan home on October 3, 1986, at the age of 70. JON was associated with *Silvae Genetica* for nearly 30 years during which he assisted scores of young scientists, as well as the more established, in preparation of journal articles.

During his long professional career, JON WRIGHT had many roles, as a geneticist, tree breeder, taxonomist, forester, botanist, and teacher, and he excelled in all of these roles. He began his forestry career in 1938 with a B.S. in Forestry from the University of Idaho. He then went to Harvard University for an M. F. in 1939, an M.S. in Botany in 1941, and a Ph.D. in Botany in 1942. His first position was as an instructor in Forestry at Purdue University from 1942 to 1945. At Purdue he taught nursery management, silviculture, silvics, dendrology and first year college mathematics. He was a radioman in the U.S. Navy in 1945—46 then joined the staff of the U.S. Forest Service as a geneticist at Northeastern Forest Experiment Station at Philadelphia. While there he began his extensive research on species hybridization and genetic testing which led to many significant research publications.

JONATHAN'S vigor and dedication to the field of forest genetics intensified with his move to the staff of Michigan State University at East Lansing, Michigan in 1957. He served as a professor of forest genetics until his retirement in 1981. Even after retirement he maintained an active interest in his work as a professor emeritus of forestry and continued to edit for *Silvae Genetica*. During his years at Michigan State University Jon achieved prominent status as an international tree breeder. He authored nearly 100 research articles, bulletins, reviews and popular articles. His writings have not only reported on the results of a diverse and prolific research program, but of even greater significance, they have stimulated much thinking and discussion about important topics in tree breeding. In 1962 he published the first American text on the "Genetics of Forest Tree Improvement" which was subsequently translated into several languages and used as a reference around the world. This work was followed in 1976 by another important textbook titled, "Introduction to Forest Genetics."

In addition to his great contributions to the science of forest genetics, JON was a dedicated teacher who felt and demonstrated an intense interest in students. His mind and his office were always open and receptive to the inquiring student. He spared no effort in clarifying concepts for students. His philosophy of teaching was that students must learn to think independently and in depth. He was successful in his lectures towards these ends.

JON carried his interest and enthusiasm for tree improvement around the world during his frequent travels, usually accompanied by his delightful wife MARION. Their travels included countries throughout Europe and Asia, often visiting and consulting with former graduate students, many of whom occupied responsible positions in their countries.

JON WRIGHT'S accomplishments were recognized by Michigan State University in 1974 when he received the Distinguished Faculty Award. And in 1980 he was awarded the 27th Barrington Moore Memorial Award by the Society of American Foresters for his work in forest genetics.

The readers of *Silvae Genetica*, and the world community of forest geneticists, his close colleagues and all who knew him have derived immense benefit and pleasure from JONATHAN W. WRIGHT, the man and his work.

J. W. HANOVER

Resin Monoterpenes in Range-Wide Provenance Trials of Pinus halepensis Mill. in Israel

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Abstract

Xylem resin monoterpene composition as related to seed source was studied in 472 trees from 22 circum-Mediterranean populations of Aleppo pine *(Pinus halepensis* MILL.), grown in provenance trials in Israel. Except for the Greek and Israeli provenances, monoterpene composition was found to be related to latitude and climate. In spite of the wide range of the species, variation between seed sources in monoterpene composition is very low, yet three distinct groupings Greek, West European and North African — can be distinguished.

Susceptibility to *Matsucoccus josephi* of seven seed sources was related to cortex resin monoterpene composition. Results show that resistance, or lack of resistance, can be related to the monoterpene composition, which differs significantly between the provenances.

Key words: *Pinus brutia, Matsucoccus josephi*, xylem resin, cortex resin.

Zusammenfassung

Die Monoterpen-Zusammensetzung im Harz des Xylem der Aleppokiefer (*Pinus halepensis* MILL.) wurde gaschromatographisch untersucht. Zur Untersuchung diente das

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Harz von 472 sieben Jahre alten Bäumen aus 22 Samenherkünften rund um das Mittelmeer, die auf Versuchsflächen in Israel wachsen.

Es wurde festgestellt, daß außer in den griechischen und israelischen Provenienzen, die Monoterpen-Zusammensetzung vom Breitengrad und vom Klima beeinflußt ist. Im Gegensatz zu der weiten Verbreitung der Aleppokiefer ist die Variation in der Monoterpen-Zusammensetzung sehr gering. Trotzdem war es möglich, die Samenherkünfte aufgrund der Monoterpen-Zusammensetzung in drei Gruppen einzuteilen, d.h. in griechische, westeuropäische und nordafrikanische Herkünfte.

Ebenso wurde die Monoterpen-Zusammensetzung des Rindenharzes von sieben Samenherkünften der Aleppokiefer, die unterschiedliche Resistenz gegen *Matsucoccus josephi* aufweisen, gaschromatographisch untersucht. Es wurde festgestellt, daß die Resistenz zur Monoterpen-Zusammensetzung in Beziehung steht, die zwischen den Provenienzen sehr stark variiert.

Introduction

In a recent study, genetic variability of Aleppo pine (*Pinus halepensis* Mill.) throughout its wide geographic range was investigated by isoenzyme electrophoresis (G. Schiller, C. Grunwald, and M. T. Conkle, unpublished). It was found that in comparison with other pines, heterozygosity of Aleppo pine is very low. The number of electrophoretically discernible proteins is, in fact, very small and, as a result, only part of the variaation shows up in isoenzyme studies (Ramshow *et al.*, 1979). An additional approach, the analysis of monoterpene composition, was selected for a more thorough evaluation of the variation (Squillace, 1976).

Xylem resin monoterpenes of Aleppo pine were analyzed by Alette and Banister (1962), Iconomou *et al.* (1964) and Mirov *et al.* (1966). Twig and needle resin was analyzed by Zafra and Peregrin (1976). These studies were, however, of limited scope, consisting of samples of a small number of trees only from one or two seed sources.

The objectives of the present study were to study the relation between monoterpene composition and seed origin of Aleppo pine; and to investigate the relation of monoterpene composition to resistance or lack of resistance of various seed sources to the Israeli pine bast scale *Matsucoccus josephi* Bodenheimer et Harpaz.

Accordingly, this paper presents data on xylem monoterpene composition of 22 provenances from most of the range of Aleppo pine; and on cortex monoterpene composition of seven provenances of different susceptibility to *Matsucoccus*.

Materials and Methods

The study was conducted with xylem and cortex resin collected from 7-year-old trees from different seed origins (*Table 1*), growing in experimental plots at Ramat ha Nadiv (32° 22' N, 34° 56' E) and Nahshon (31° 50' N, 34° 38' E). Full details of the plots were given by Weinstein 1982).

In June 1983, xylem resin was obtained from the stem at a height of 30 cm above ground according to the method of Smith (1977). Twenty-two provenances (3—35 trees per seed source) were investigated· The vials were removed after 2—24 hours, when sufficient resin for an analysis had accumulated, closed with a rubber stopper and stored in a refrigerator at 4° C. One microliter of a 1:3 mixture of xylem resin and analytically pure acetone was used in the analysis.

Table 1. — Geographical location of Aleppo pine provenances.

No.	IUFRO No.	Country	Provenance	Lat. (0 ')	Long. (0 ')	Alt. m.	No. of trees tapped
1	A-22	Greece	Elea	37 46 N	21 32 E	200	29*
2	A-33	Greece	Euboea	38 58 N	23 18 E	250	35*
3	A-16	Spain	Soportujar	37 10 N	3 15 W	800	15
4	A-17	Spain	Guadalmedia	37 02 N	2 15 W	1000	19
5	A-18	Spain	Maria	37 40 N	2 10 W	1200	16
6	A-19	Spain	Cehegin	38 05 N	1 55 W	850	27
7	A-20	Spain	Jarafuel	38 55 N	1 00 W	600	22
8	A-21	Spain	Serra	39 50 N	0 28 W	300	22*
9	A-12	Morocco	Zaouia ifrana	33 15 N	5 23 W	1200	15
10	A-13	Morocco	J.Afra selminte	30 44 N	7 55 W	1700	22*
11	A-14	Morocco	Quardane bouksone	35 03 N	5 08 W	950	13
12	A-15	Morocco	Tamga xaonia	32 02 N	6 07 W	2000	18
13	A-11	Algeria	Aures tababuel	35 10 N	6 50 E	--	3
14	A-29	Algeria	Aures bnai melloul	35 10 N	6 50 E	--	24
15	A-30	Algeria	Senalba	--	--	--	13*
16	A-31	Algeria	Telagh	34 40 N	1 08 W	--	31
17	A-32	Algeria	Quarsenis	35 05 N	5 04 E	--	22
18	A-8	Tunisia	Sakiet sidi	36 15 N	8 25 E	--	21
19	A-9	Tunisia	Um djeddur	35 38 N	8.57 E	--	25
20	A-10	Tunisia	Djabel selloum	35 05 N	8.40 E	--	22
21	A-6	Israel	Shahariyya	33 36 N	34 50 E	200	26*
22	A-7	Israel	Elqosh	33 01 N	35 18 E	500	33*

*Cortex resin composition was also analysed.

In March 1983, cortex resin was obtained from elongated branch tips before needle initiation from 13—35 trees each of seven provenances. Branch tips of each tree were collected separately, dried at room temperature for 3 days and then ground; 7 g of the ground material was mixed with 45 ml of analytically pure acetone to extract the resin. After 10 days the mixture was dissolved with a micronic sieve and 5 microliter was used in the analysis.

Monoterpene were analyzed with a Packard 7400 gas-liquid chromatograph fitted with an ionization detector, using a glass column 4 m in length and 2 mm in diameter. The column was packed with 8% silicone 0V-101 (100% methyl fluid) on chromosorb w-60/80. Operating conditions were 220° C on the injector, 220° C on the detector, and 50° C to 180° C on the column, increasing at a rate of 3° C/min. Nitrogen was used as carrier gas at a flow rate of 25—30 ml/mn. A gas chromatograph mass spectrometer (Dupont 490B) for chemical ionization, with isobutane as a reagent gas, was used to separate the monoterpene from the other compounds. The monoterpenes were identified by comparison with pure standards.

Peak areas of the monoterpenes on the graphs were measured and then expressed as percentage contribution of each component to the total monoterpenes (100%). Percentages of various components were then transformed into arcsin-square root functions (Shaw *et al.*, 1982) for principal component, discriminant and cluster analysis and multiple analysis of variance. Since only very small and limited differences in resin monoterpenes composition were found between trees of the same provenance grown in different plots, the data were analyzed together.

Results and Discussion

The technique used produced a chromatograph with 18 peaks (i.e., compounds), 12 of them occurred in measurable amounts in the xylem resin and 16 in the cortex resin; only ten compounds could be identified.

Xylem resin monoterpenes

Mean xylem monoterpene composition of 22 provenances under investigation is given in *Table 2*. α-pinene constitutes 82.34% of the total, β-pinene −1.90%, myrcene −7.20%, phellandrene −3.40%, 3 - carene −2.50% and terpinolene −1.40%. Together they amount to about 98% of the total monoterpene. Camphene was identified in all samples, but because of our work procedure its small peak was not distinct from that of α-pinene; therefore, it was not included in our calculations. Our results (*Table 2*) differ significantly from those obtained by ALLETTE and BANISTER (1962), ICONOMOU *et al.* (1964) and MIROV *et al.* (1966), who found only small amouts of myrcene, 3-carene, terpinolene, and phellandrene.

These differences in xylem resin monterpene composition could be result of factors such as tapping method, tapping height, tree age (FRANKLIN, 1976) or laboratory technique, e.g. the use of undistillated resin (SMITH, 1977).

Although there is considerable variation in monoterpene composition from tree to tree within seed sources, the latter differ significanntly (P = 0.0001) when analyzed by multiple analysis of variance and Duncan's range test (SAS, 1982). Between provenance variation in monoterpene composition can be estimated with the help of the standard deviations (S.D.) of the overall means (X) given in *Table 2*. In comparison with North African provenances, Greek seed sources are relatively high in α-pinene, 3-carene and compound 18, and low in myrcene and γ-terpinene. This conspicuous difference may be the result of introgression of Aleppo pine by *P. brutia* Ten. (M. T. CONKLE, G. SCHILLER, and G. GRUNWALD, unpublished), as the latter is known for its high amount of 3-carene in xylem oleoresin (ICONOMOU *et al.*, 1964). Spanish provenances are relatively low in α-pinene, medium in myrcene and high in phellandrene and terpinolene. Unfortunately, the two Israeli provenances under investigations are derived from planted forests of unknown seed origin. (The report on a more detailed study by the authors of monoterpenes in natural and planted populations in Israel is in preparation). The Shahariyya (No. 21) provenance has monoterpene composition similar to that of the Greek provenances, whereas the Elqosh (No. 22) population is similar to the North African seed sources. These data confirm earlier results obtained by analysis of isoenzymes, that seed from Greek and West Mediterranean, in addition to seed from natural stands in Israel (genetically similar to same North African provenances), was used for refor-

Table 2. — Mean monoterpene composition of xylem resin from various seed sources of Aleppo pine (%).

Seed	Measurable compounds											
Source	1	3	4	5	6	7	8	9	10	15	17	18
21	86.91	1.90	4.01	1.90	2.70	.04	.04	1.37	.24	.09	.08	.74
22	80.40	2.00	9.70	3.20	2.40	.03	.04	1.39	.16	.11	.05	.52
1	86.41	1.80	2.80	3.40	3.20	.03	.03	1.37	.16	.04	.22	.54
2	87.67	1.80	2.90	1.70	3.20	.05	.04	1.33	.33	.10	.09	.79
3	76.98	1.78	5.30	9.50	3.30	.05	.11	2.06	.42	.05	.11	.34
4	80.60	1.60	6.70	5.60	2.40	.04	.04	1.58	.37	.49	.12	.46
5	82.07	1.65	5.00	5.50	2.40	.09	.05	1.81	.49	.24	.06	.64
6	80.71	2.40	6.01	6.20	2.20	.02	.04	1.51	.37	.07	.11	.37
7	82.12	1.43	6.20	5.10	2.20	.03	.05	1.54	.36	.15	.45	.37
8	77.66	1.75	8.90	6.20	2.60	.04	.06	1.82	.37	.04	.09	.47
9	83.21	1.70	8.60	2.20	2.20	.03	.03	1.12	.31	.07	.13	.30
10	82.90	1.39	9.00	1.90	2.10	.03	.04	1.14	.30	.87	.07	.26
11	83.90	1.23	9.70	1.20	1.90	.03	.08	0.88	.46	.22	.29	.13
12	83.50	1.43	5.10	3.20	2.90	.04	.05	1.58	.43	1.24	.09	.44
13	84.72	3.00	7.20	0.90	2.30	.02	.04	1.00	.28	.04	.24	.18
14	83.41	1.65	8.40	2.20	2.20	.04	.04	1.23	.20	.07	.12	.44
15	80.51	2.50	9.10	2.90	2.70	.04	.15	1.14	.30	.08	.18	.40
16	82.21	1.87	10.20	1.40	2.20	.04	.03	1.12	.28	.28	.10	.27
17	82.10	3.04	8.40	1.40	2.70	.04	.04	1.24	.42	.05	.10	.47
18	81.50	1.60	8.70	3.40	2.00	.03	.16	1.74	.28	.04	.13	.42
19	81.32	1.70	7.90	3.80	2.60	.04	.17	1.38	.39	.08	.08	.54
20	80.53	2.60	8.90	2.80	2.70	.04	.09	1.40	.32	.12	.13	.37
$\bar{X}$	82.34	1.90	7.20	3.40	2.50	.04	.06	1.40	.33	.21	.14	.43
S.D.	2.60	0.50	0.50	2.13	0.39	.01	.04	0.29	.09	.30	.09	.16

Compounds; 1-α-pinene; 3-β-pinene; 4- myrcene; 5- phellandrene; 6- 3-carene; 7- limonene; 8-γ-terpinene; 9 terpinolene; 10-γ-terpineol;
Compounds 15, 17, 18 unidentified.
$\bar{X}$ = Overall mean. S.D. Standard deviation.

Table 3. — Mean monoterpene composition (%) of the four chemotypes present in range-wide Aleppo pine provenances.

Chemotype	Number of trees	%	Compound No. 1	3	4	5	6	7	8	9	10	15	17	18
A	324	68.6	82.40	1.87	7.10	3.40	2.54	.04	.06	1.41	.32	.20	.13	.46
B	69	14.6	71.39	2.37	7.94	11.09	3.18	.05	.08	2.51	.58	.12	.06	.62
C	31	6.6	84.42	1.57	7.02	8.06	2.19	.03	.18	1.14	.26	.05	.65	.42
D	48	10.2	83.04	1.81	5.43	1.86	3.51	.09	.05	1.54	.50	.96	.05	1.13

estation in this country (C. GRUNWALD, C. SCHILLER and M. T. CONKLE, unpublished).

Fastclus procedure (SAS, 1982) was used to distinguish between the xylem monoterpene composition of the 472 trees tested. Four chemotypes which occur at very different frequencies were identified (*Table 3*), thereby implying the occurence of genotypic variation within populations and between geographic regions. Chemotype A is present in all populations, whereas chemotype B occurs in 18 out of 22 (81.8%); chemotype C in 12 out of 22 (54.5%); and chemotype D in 13 out of 22 (59.0%). The frequency of chemotype A within populations ranges from 33.3% to 100% of the trees; of chemotype B, from nil to 46.7%; of chemotype C, from nil to 27.3%; and of chemotype D, from nil to 40.0% of the trees. The frequencies of chemotype A are lower, and of B higher, in Spanish population than in other seed sources.

Table 4. — Canonical discriminant analysis of 12 compounds in 22 seed sources of Aleppo pine.

Compound	Standardized canonical coefficient				
	Can-1	Can-2	Can-3	Can-4	Can-5
α-pinene	-.336	1.324	1.717	2.506	-.295
β-pinene	.032	.128	.576	.417	.543
myrcene	.679	-1.000	1.440	1.778	-.395
phellandrene	-.295	-1.765	.528	.373	-.597
3-carene	-.709	-.141	.087	-.225	-.633
limonene	.121	.183	-.030	-.074	.315
γ-terpinene	.188	.125	.433	-.540	.204
terpinolene	-.075	-.004	.101	1.235	.402
γ-terpineol	.300	-.270	-.315	-.018	.802
Compound 15	.313	.195	-.583	.415	-.482
Compound 17	-.057	.217	-.150	.337	.007
Compound 18	.514	.036	.389	.446	.094

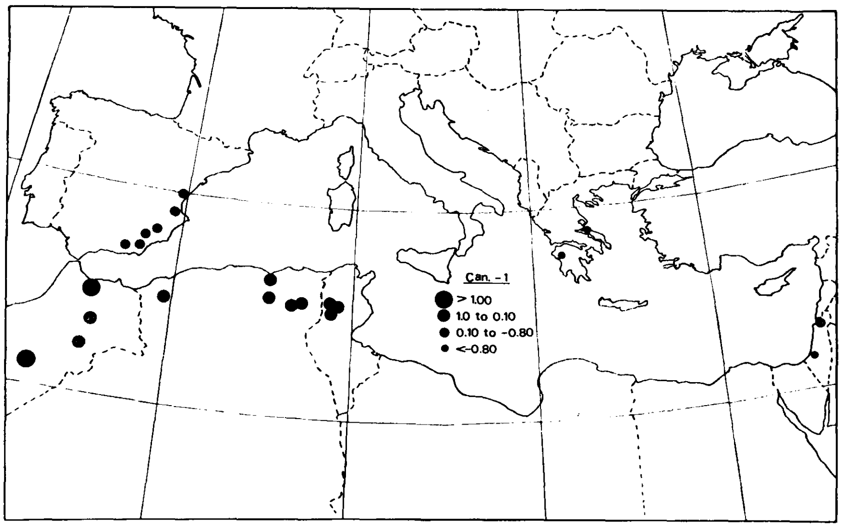

Fig. 1. — Scores of canonical coefficients as related to geographic location of seed origin.

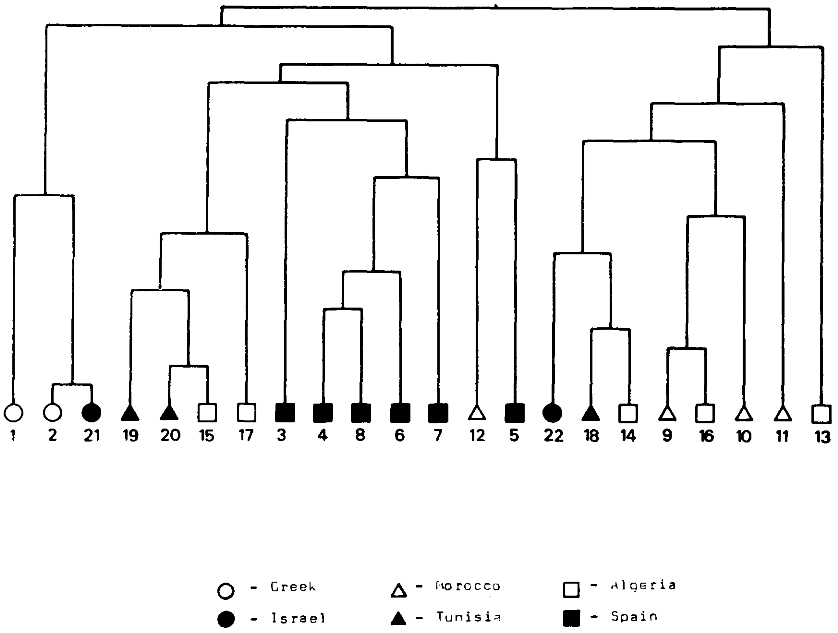

Fig. 2. — Cluster analysis of 22 seed sources based on monoterpene composition.

Using canonical discriminant analysis (SAS, 1982) an attempt was made to relate xylem monoterpene composition to geoclimatic parameters at the seed source. The results are given in *Table 4* and *Fig.1*. *Table 4* shows the standardized canonical coefficients (can.). The first coefficient is typified by 3-carene and myrcene; the second by α-pinene, myrcene and phellandrene; the third by α-pinene and myrcene; the fourth by α-pinene, myrcene and terpinolene; and the fifth by γ-terpineol and 3-carene. The scores of the canonical coefficients in relation to seed origin are presented in *Fig. 1*. Whereas can.-4 and can.-5 cannot be readily interpreted, can.-1 groups the 22 provenances into three main assemblages of Greek, Spanish and North African origin, respectively. The North African group splits into two subgroups. The two Israeli provenances No. 21 and 22 form part of the North African and the Greek group respectively. Except for the Greek provenances, can.-2 arranges the provenances according to a latitudinal gradient. Can.-3 classifies the provenances, again with the exception of the Greek populations, according to the xerothermic index (UNESCO-FAO, 1962). The Greek provenances do not conform to either the latitudinal gradiant or the xerothermic index, possibly because of the introgression of *P. brutia*, as mentioned above. *Figure 2* presents the results of cluster analysis (SAS, 1982) of the 22 provenance. Three major groupings were obtained, which correspond essentially to the geographic distribution of the population, i.e., North Africa, West Europe and the Balkans. The first (left) and the third (right) groups consist exclusively of Greek and North African provenances, respectively, except for the Israeli populations; the second (central) group includes both Spanish and North African provenances.

Table 6. — Average amounts (%) and coefficients of variation of five monoterpene in different pine species.

Species	No. of population		α-pinene	β-pinene	3-carene	myrcene	limonene
P. sylvestris[1]	9	$\bar{X}$	8.90	11.66	47.58	17.76	3.49
cortex resin		C.V	20.75	21.66	18.10	25.29	29.22
P. contorta[2]	14	$\bar{X}$	5.81	18.95	11.37	--	5.04
cortex resin		C.V	76.59	55.14	72.11	--	47.02
P. brutia[3]	14	$\bar{X}$	21.70	29.34	6.33	5.05	0.28
cortex resin		C.V	11.76	12.22	33.60	30.56	36.05
P. halepensis	7	$\bar{X}$	25.74	3.45	1.75	49.69	0.28
cortex resin		C.V	12.49	17.90	35.37	8.62	25.80
P. ponderosa[4]	38	$\bar{X}$	12.10	25.31	38.44	9.84	9.74
xylem resin		C.V	137.19	52.29	50.83	40.06	75.50
P. halepensis	22	$\bar{X}$	82.34	1.90	2.50	7.20	0.04
xylem resin		C.V	3.21	26.31	15.35	30.55	25.00

1. After Forrest, G.I. (1980)
2. After Forrest, G.I. (1978)
3. G. Schiller and C. Grunwald (unpublished
4. After Smith, R.H. (1977)

The comparison between the results of the discriminant analysis and the cluster analysis reveals that the North African provenances form an aggregate which splits into two groups; the first with monoterpene composition similar to that of West European (Spanish) provenances, and the second with a distinctly North African monoterpene composition. The first group is composed mainly of provenances from East Algeria and Tunisia and one from Morocco and may be a remnant of a shift in distribution area due to climatic events in the Quaternary which obliterated to some extent the geographical barrier of the Mediterranean Sea between Sicily and Tunisia (Fairbridge, 1966; Ruggieri, 1967). The small but significant difference in monoterpene composition between the above-mentioned group and the second group from mainly Morocco and West Algeria, with two provenances from East Algeria and Tunisia, may be due to their very long isolation, as conifers evolve very slowly in comparison with other flowering plants (Prager *et al.*, 1976). Therefore, these provenances may be remnants of

Table 5. — Mean cortex resin monoterpene composition (%) in seven circum-Mediterranean Aleppo pine provenances.

Provenance	Measurable compound No.							
No.	1	3	4	5	6	7	8	9
1	30.465 a	2.363 cd	45.338 a	7.006 a	1.665 b	.260 a	.127 b	1.291 c
2	29.777 a	2.245 d	43.377 a	5.569 a	3.131 a	.222 a	.053 c	.620 d
21	23.263 ab	3.353 b	51.015 a	4.909 a	1.394 b	.287 a	.188 ab	2.144 b
22	24.761 ab	3.831 ab	49.749 a	6.385 a	1.415 b	.428 a	.208 ab	2.700 ab
10	24.088 ab	4.719 a	52.706 a	4.076 a	1.670 b	.214 a	.234 a	3.249 a
8	22.039 b	3.154 bc	56.269 a	7.323 a	1.433 b	.249 a	.217 ab	2.241 b
15	25.837 ab	4.513 c	49.938 a	4.619 a	1.547 b	.296 a	.255 a	3.620 a

Provenance	Measurable compound No.							
No.	10	11	13	14	15	16	17	18
1	.047 d	.135 b	.098 b	.770 b	.822 a	.656 ab	.254 c	1.498 d
2	.076 cd	.134 b	.174 ab	1.163 ab	.973 a	1.209 a	.136 c	2.724 c
21	.116 cd	.280 ab	.246 a	1.502 a	.740 a	.752 ab	.527 ab	5.208 a
22	.344 a	.189 ab	.321 a	.610 b	.341 c	.531 b	.610 a	4.814 ab
10	.246 ab	.246 ab	.297 a	.753 b	.683 ab	.552 b	.318 abc	3.556 bc
8	.288 ab	.244 ab	.194 ab	.580 b	.461 bc	.449 b	.279 bc	2.225 cd
15	.164 bc	.366 a	.246 a	.845 ab	.365 c	.628 ab	.495 ab	3.118 c

Means not sharing a common letter are significantly different at $P = 0.05$, using Ducan's Multiple Range Test.

Compounds: 1- α-pinene; 3-β-pinene; 4- myrcene; 5- phellandrene; 6- 3-carene;
7- -limonene; 8-γ-terpinene; 9- terpinolene; 10-γ-terpineol;

Compounds 11-18 unidentified.

an ancient Aleppo pine population growing in North Africa since the Tertiary (Melville, 1967; Mirov, 1967; Nahal, 1962).

Cortex resin monoterpene

Table 5 shows the mean monoterpene composition in the cortex resin of seven populations with different susceptibility to the Israeli pine bast scale. The data do not agree with those obtained by Zafra and Peregrin (1976), as we did not identify any sabinene in the cortex resin. As shown also in *Table 6*, mean cortex resin monoterpene composition, when analyzed by multiple analysis of variance and Ducan's range test (SAS, 1982), differs significantly between provenance.

A comparison of the results given in *Table 2* and *5* shows significant differences, within the same provenance, between xylem and cortex monoterpene composition. The amount of α-pinene is significantly lower in cortex resin than in xylem resin, whereas most of the other compounds are at a significantly higher level in the former than in the latter.

Relative amounts of 16 cortex monoterpenes in each of the trees investigated were related to the scored injury by the pine bast scale (from 0-unaffected, to 6-very affected, see Mendel, 1984). Using stepwise regression, eight monoterpenes were entered into the regression equation according to their F-value. The highest correlation coefficient obtained was $r = 0.442$, $F = 4.92$ ($P = 0.0001$), D.F. 170. It was found that increasing amounts of myrcene, terpinolene, γ-terpineol and compounds 16 and 18, and decreasing amounts of limonene, phellandrene and compound 17, are related to increased injury by the pest.

Of these, terpinolene, compound 16 and phellandrene have the highest F-value and probability. Results given in *Table 5* show that, in contrast to Greek provenances, West Mediterranean populations have in general larger amounts of myrcene, terpinolene, γ-terpineol and compound 18, and lower amounts of phellandrene whereas the two Israeli seed sources occupy an intermediate position. Although no significant differences where found between means of myrcene phellandrene and limonene, between-tree differences in the amounts of these compounds might be the cause of different susceptibility to *Matsucoccus* within the same populations (see Mendel, 1984). According to Mendel (1984), the Greek provenances are resistant to *Matsucoccus*, whereas the West Mediterranean populations are very susceptible. The two planted populations in Israel (of unknown seed origin) are less resistant than the Greek provenances. Monoterpenes as the determining factor for host resistance or susceptibility to pests of Pinaceae are well documented Cates and Alexander 1982); as shown above, resistance or susceptibility to *M. josephi* can be related to monoterpene composition also in *P. halpensis*.

Table 6 summarizes the coefficients of variation of five monoterpenes in the xylem and cortex resin of various pines. The table shows that the coefficients are generally lower in Aleppo pine than in other pines. The low variation between and within sources in monoterpene composition supports earlier data from isoenzyme analysis which revealed that Aleppo pine has a very low polymorphism G. Schiller, C. Grunwald and M. T. Conkle, unpublished).

To conclude, results of xylem and cortex resin analysis have revealed a very low variation in monoterpene composition within and between seed sources of Aleppo pine from the Mediterranean region. Yet, Aleppo pine can be divided into distinct groups according to monoterpene composition and chemotype frequencies in the populations, which are related to geographical and climatic factors. This conclusion supports earlier data obtained from isoenzyme analysis which leads to the division of the Aleppo pine, according to its allele frequencies, into four groups: Near Eastern, East European, West European and North African; whereas the North African group splits into two sub-populations, one from mainly Tunisia and East Algeria, and the second from mainly Morocco and West Algeria.

Resistance, or lack of resistance, to the Israeli pine bast scale was shown to be related to cortex monoterpene composition. This finding could be of value for seed selection and seed orchard establishment for the improvement of planting stock of Aleppo pine.

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References

Alette, L. W. and Banister, H. M.: Composition of gum turpentines from twenty-two species of pines grown in New Zealand. J. Pharm. Sci. **51**: 970—975, (1962). —— Gates, C. R. and Alexander, H.: Host resistance and susceptibility in: Mitton, E. J. and Sturgeon, K. B. (Eds.) Bark Beetles in North American Conifers. University of Texas Press, Austin, TX, (1982). —— Fairbridge, W. R. (Ed.): The Encyclopedia of Oceanography. vol. I. Rheinhold Publishing Co., New York, NY, (1966). —— Forrest, G. I.: Monoterpene variation in Lodgepole pine *(P. contorta* Dougl.) and Scots pine *(P. sylvestris* L.). *in:* Dag, R. (Ed.) Proceedings of the Conference on Biochemical Genetics of Forest Trees. Report No. 1. Department of Forest Genetics and Plant Physiology, Umeo, Sweden, (1978). —— Forrest, G. I.: Genotypic variation among native Scots pine populations in Scotland based on monoterpene analysis. Forestry **53**: 101—128, (1980). —— Franklin, E. C.: Within-tree variation of monoterpene composition and yield in Slash pine clones and families. For Sci. **22**: 185—191, (1976). —— Iconomou, N., Valkanas, C. and Buchi, J.: Composition of gum turpentines of *Pinus halepensis* and *P. brutia* grown in Greece. J. Chromatog **16**: 29—33, (1964). —— Melville, R.: The distribution of land around the Tethys Sea and its bearing on modern plant distribution. In: Adams, C. G. and Ager, D. V. (Eds.) Aspects of the Tethyan Biogeography **7**: 291—312, (1967). —— Mendel, Z.: Provenance as factor in susceptibility of *Pinus halepensis* to *Matsucoccus josephi*. Forest Ecol. Mgmt. **9**: 259—266, (1984). —— Mirov, M. T.: The Genus *Pinus*. Ronald Press Co.., New York, NY, (1967). —— Mirov, M. T., Zavarin, E. and Snajberk, K.: Chemical composition of the turpentines of same Eastern Mediterranean pines in relation to their classification. Phytochemistry. **5**: 97—102, (1966). —— Nahal, I.: Le Pin d'Alep: Etude taxonomique, phytogéographique, écologique et sylvicole. Ann. Ec. Eaux. For. Nancy **19** (4): 1—207, (1962). —— Prager, M. E., Fowler, P. D. and Wilson, C. A.: Rates of evolution in conifers *(Pinaceae)*. Evolution **30**: 637—649, (1976). —— Ramshow, J. A. M., Coyne, J. A., and Lewontin, R. C.: The sensitivity of gel electrophoresis as a detector of genetic variation. Genetics **93**: 1019—1037, (1979). —— Ruggieri, C.: The Miocene and later evolution of the Mediterranean Sea. *in:* Adams, C. G. and Ager, D. V. (Eds.) Aspects of the Tethyan Biogeography **7**: 283—289, (1967). —— SAS: User's Guide, SAS Inst Inc. Raleigh, NC, (1982). —— Shaw, D. V., Yazdani, R. and Muona, C.: Methods for analyzing data on the relative proportions of monoterpenes in conifers. Silvae Fennica (in press). Quoted after Yazdani, R. *et al.* (1982) Hereditas **97**: 261—272, (1982). —— Smith, H. R.: Monoterpene of Ponderosa pine xylem resin in Western United States. U.S. Dep. Agric. Forest Service, Tech. Bull. **1532**, (1977). —— Squillace, A. E.: Analysis of monoterpene of conifers by gas-liquid chromatography. in: Miksche, I. P. (ED.) Modern Methods in Forest Genetics. Springer, Berlin, (1976). Weinstein, A.: Effect of seed origin on early growth of *Pinus halepensis* Mill. and *P. brutia* Ten. La Yaaran **32**: 5—12 (Hebrew), 65—67 (English), (1982). —— Zafra, M. and Peregrin, G. E.: Seasonal variation in the composition of *Pinus halepensis* and *P. sylvestris* twigs and needle essential oil. J. Agric. Sci. Camb. **86**: 1—6, (1976).