Table 2. Effect of nutrition on the nutrient concn of leaves of pecan seedlings, dry wt basis.

Nutrient	Nutrient omitted		Nutrient added	
	Mean^z	Range	Mean	Range
N (%)	1.66	1.48–1.85	3.10	2.68–3.36
P (%)	.08	.07–.10	.23	.20–.25
K (%)	.44	.25–.69	1.65	.96–2.30
Ca (%)	.12	.07–.19	2.51	1.98–3.47
Mg (%)	.08	.06–.10	.64	.57–.75
S (%)	.08	.07–.10	.33	.22–.49
Fe (ppm)	102	80–119	126	99–146
Mn (ppm)	71	43–108	138	108–171
B (ppm)	6	4–13	41	36–50
Cu (ppm)	18	15–25	20	15–25
Zn (ppm)	31	24–37	37	26–47

^{z}Except for Cu and Zn, the omission of any nutrient decreased the concn of that nutrient in the dry matter, 5% level.

The nutrient concn in leaves (Table 2) associated with N, P, K, Ca, and Mg deficiencies are within the range previously proposed for these nutrients (1, 8, 9, 13, 17). The leaf concn associated with Mn deficiency in pecan is unknown but the value obtained in the minus Mn treatment was less than the proposed sufficiency range (4). Although Mn deficiency symptoms were not induced, the growth suppression from omission of Mn (Table 1) and the lower value of the range suggest Mn concn in some seedlings was approaching a deficiency level. The Zn concn was higher than previously reported for Zn deficiency (7), but the leaf tissue analyzed was a mixture of all leaves from the same plant which included both normal and mildly deficient leaves. The values for B and S deficiencies have not been previously reported for pecan. Omitting Cu and Fe from the nutrient solution suppressed seedling growth (Table 1). However, the corresponding Cu and Fe values in the leaves (Table 2) are within the proposed range (2, 4) and greater than sometimes found in apparently healthy trees growing in the field (10, 12, 16). The growth suppression in the minus Fe and Cu treatments may have been due to the mild Zn deficiency associated with these treatments, but other factors may have been involved.

When the complete nutrient solution was added, the mean concn of N, P, Mg, Fe, Mn, B and Cu (Table 2) was within the sufficiency range proposed for pecan (4, 9, 13, 17), but Ca and K were higher than recommended and Zn was lower. The low Zn reflected the mild Zn deficiency (Table 1).

The close agreement of these data (Table 2) with proposed deficiency (1, 8, 9, 13, 17) and sufficiency (4, 9, 13, 17) values for pecan leaves further support the reliability of leaf analysis as a method of predicting the nutrient needs of pecan. However, the ranges associated with the means (Table 2) indicate that the limits of the critical values for each nutrient, except N (13), need to be delineated. For example, vegetable growth and yield of pecan has been shown to increase up to about 2.7% N in the leaf (9, 13) which greatly exceeds the N range associated with N deficiency in Table 2.

Literature Cited

1. Alben, A. O. 1947. Analysis of pecan leaves as an aid in fertility studies. *Proc. Okla. Pecan Growers Assoc.* 1947:38-45.
2. Amling, H. J. 1965. Alabama leaf analysis service. *Proc. S.E. Pecan Growers Assoc.* 58:25-32.
3. Hoagland, D. C. and D. I. Arnon. 1950. The water culture method for growing plants without soil. *Calif. Agr. Expt. Sta. Cir.* 347.
4. Jones, J. B., Jr. 1972. General fertilizer recommendations for pecans. *Proc. S.E. Pecan Growers Assoc.* 65:101-112.
5. ________. 1977. Elemental analysis of soil extracts and plant tissue ash by plasma emission spectroscopy. *Commun. Soil Sci. Plant Anal.* 8:349-365.
6. ________ and R. A. Isaac. 1972. Determination of sulfur in plant material using a Leco sulfur analyzer. *J. Agr. Food Chem.* 20:1292-1294.
7. Lane, R., H. F. Perkins, and F. E. Johnstone, Jr. 1965. Studies on the relationship of calcium, zinc, and pH in pecan nutrition. *Proc. S.E. Pecan Growers Assoc.* 58:21-24.
8. Sharpe, R. H., G. H. Blackmon, and N. Gammon, Jr. 1951. Magnesium deficiency of pecans. *Proc. S.E. Pecan Growers Assoc.* 44:23-28.
9. Sparks, D. 1968. Some effects of nitrogen on young pecan trees. *Proc. S.E. Pecan Growers Assoc.* 61:93-102.
10. ________. 1976. Iron deficiency in pecans. *Pecan South* 3:448-449.
11. ________. 1977. Effect of nutrition on dieback of germinating 'Curtis' pecan seedlings. *HortScience* 12:496-497.
12. ________ and G. D. Madden. 1977. Method of grove establishment and elemental concentration of pecan leaves. *HortScience* 12:69-71.
13. ________ and D. H. Baker. 1975. Growth and nutrient response of pecan seedlings, *Carya illinoensis* Koch, to nitrogen levels in sand culture. *J. Amer. Soc. Hort. Sci.* 100:392-399.
14. ________, J. W. Chapman, and D. W. Lockwood. 1974. Stratification promotes germination. *Pecan Quart.* 8(1):13.
15. Steel, R. G. and J. H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill Book Co., Inc., New York.
16. Sullivan, D. T. and H. J. Munoz. 1976. Nutrition and yield of young 'Western Schley' and 'Wichita' pecan trees. *Annu. Rpt. North. Nut Growers Assoc.* 67:64-67.
17. Upson, J. R., Jr. and D. Sparks. 1969. Growth response of one-year-old pecan seedlings, *Carya illinoensis* Koch, in sand culture to various levels of potassium. *J. Amer. Soc. Hort. Sci.* 94:125-127.

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Cold Hardiness of Young Hybrid Trees of *Eremocitrus glauca* (Lindl.) Swing[1]

G. Yelenosky[2], H. Barrett[3], and R. Young[2]

Agricultural Research Service, U.S. Department of Agriculture, 2120 Camden Road, Orlando, FL 32803

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Abstract. **Available young hybrid trees of *Eremocitrus glauca* with 'Valencia' orange (*Citrus sinensis* (L.) Osbeck), Sicilian sour orange (*C. aurantium* L.), 'Nagami' kumquat (*Fortunella margarita* (Lour.) Swing.), and Koethen sweet orange (*C. sinensis*) were more cold hardy than the *Citrus* or kumquat parent in natural and controlled freezes. *Eremocitrus* may be a useful source of cold hardiness for breeding cold-hardy citrus hybrids.**

Eremocitrus glauca (Australian desert lime) is a monotypic relative of *Citrus*. The species is indigenous to the semiarid regions of Australia where extremes of heat, drought, and low temp are common. *Eremocitrus* hybridizes with, and grafts readily on some citrus (1). Reciprocal grafts can be highly incompatible, although sour orange grows well on *E. glauca*. Since the 1880's various observations have shown that the species is one of the more xerophytic and cold hardy in the subfamily *Aurantioideae*. In Australia, *Eremocitrus* has a pronounced period of dormancy and survives $-24^{\circ}C$ (2). This paper reports on the inheritance of cold hardiness in young F_1 hybrids of *E. glauca*.

Hybrids were obtained from hand-pollinations of *E. glauca* with pollen of

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[2] Plant Physiologist.

[3] Research Geneticist.

'Valencia' and Koethen sweet orange, Sicilian sour orange, and 'Nagami' kumquat. Budwood of available hybrids and the parental types was propagated on cold-sensitive rough lemon rootstock and grown outdoors. *Eremocitrus glauca* seedlings were included in some tests. All trees were grown in a soil mixture of 1 part sand: 2 parts vermiculite: 4 parts of sphagnum moss in 37-liter containers. Trees were maintained with routine cultural practices. Two-year-old potted trees were tested in natural and controlled freezes.

Natural-freeze tests were conducted in central Florida in a low-ground location subject to frequent freezes. Potted trees were moved to the location before damaging freezes developed and were maintained with standard cultural practices. Temp were recorded with a hygro-thermograph in a standard weather shelter. Similar trees were also tested in controlled-freeze facilities previously described (3).

Controlled freeze studies began with 6 consecutive weeks of cold hardening temp immediately before the tests. The first 2 weeks of cold hardening were at 21.1°C with 12-hr day and 10° night, followed by 2 weeks of 15.6° day and 4.4° night, and finally, 2 weeks of 10° day and 1.1° night. Light intensity (86% cool white fluorescent and 14% incandescent) averaged 500 $\mu E/m^2$ per sec (PAR) at the top of the trees. Freeze tests started at 2.2°, and after 2 hr at 2.2°, the temp was cooled 1.1° per hr to $-8.9° \pm 0.5°$ for 4 hr. Warming temp increased at a rate of 1.1° per hr to 2.2° and were held there for 2 hr. Trees were kept at about 23° for an additional 3 hr, and then returned to the outdoors. In controlled freeze tests, temp were maintained without lights and with relative humidity of 50 ± 5%. Six weeks after freeze tests, at least 5 trees per selection were available and rated on average leaf and stem kill.

Table 1. Average freeze injury to 2-year-old *Eremocitrus glauca* hybrids and respective parents on rough lemon rootstock after −7.2°C in the field.

Selection	ID no.	Leaf kill (%)	Stem kill (%)
E. glauca × 'Valencia' orange	74-23-11	100	12 ab[z]
	74-23-15	100	24 bc
	74-23-6	100	54 defgh
E. glauca × 'Nagami' kumquat	74-17-2	100	38 bcde
E. glauca × Sicilian sour orange	74-14-6	100	40 cdef
	74-14-5	100	46 cdefg
E. glauca × Koethen sweet orange	74-427-1	100	66 hij
E. glauca[y]	–	30	0 a
'Valencia' orange	–	100	78 ijk
'Nagami' kumquat	–	100	84 jk
Sicilian sour orange	–	100	90 jk
Koethen sweet orange	–	100	86 jk

[z] Means followed by the same letter are not significantly different at the .05 confidence level.

[y] Test trees of *E. glauca* were seedlings.

Table 2. Average freeze injury to 2-year-old *Eremocitrus glauca* hybrids and respective parents on rough lemon rootstock after a controlled freeze at −8.9°C for 4 hr.

Selection	ID no.	Cold hardened Leaf kill (%)	Cold hardened Stem kill (%)	Unhardened Leaf kill (%)	Unhardened Stem kill (%)
E. glauca × 'Valencia' orange	74-23-11	100	11 a[z]	100	100
	74-23-15	100	12 a	100	100
	74-23-6	87	8 a	100	100
E. glauca × 'Nagami' kumquat	74-17-2	100	29 b	100	100
E. glauca × Sicilian sour orange	74-14-6	100	50 c	100	100
	74-14-5	100	45 c	100	100
E. glauca × Koethen sweet orange	75-427-1	100	45 c	100	100
E. glauca[y]	–	–	10 a	–	–
'Valencia' orange	–	100	52 c	100	100
'Nagami' kumquat	–	100	51 c	100	100
Sicilian sour orange	–	100	60 cd	100	100
Koethen sweet orange	–	100	70 d	100	100

[z] Means followed by the same letter are not significantly different at the .05 confidence level.

[y] Test trees of *E. glauca* were seedlings.

Results showed that the young hybrid trees of *E. glauca* × 'Valencia', *E. glauca* × Koethen sweet orange, *E. glauca* × Sicilian sour orange, and *E. glauca* × 'Nagami' kumquat subjected to natural and controlled freezes were more cold hardy than the *Citrus* or kumquat parent. *E. glauca* × 'Valencia' orange (ID No. 74-23-11) was one of the least injured in the field during a severe freeze with −7.2°C minimum and 4 hr of −5.5° and colder (Table 1). Two weeks immediately before the freeze, days were 24° and higher, while nights cooled to 7.8°. These temp are not considered favorable cold-hardening temp for citrus. This is evident from the citrus parent trees in which stem kill was greater than 75%. However, these temp apparently induced cold hardening in *Eremocitrus* seedlings and selected hybrids. *Eremocitrus* wood was not injured, whereas stem kill of the available hybrids ranged from 12% to 54%.

Similar results were observed after controlled freeze tests. The *Eremocitrus* hybrids were injured less than the citrus parents, and a selection of *E. glauca* × 'Valencia' orange was the least injured hybrid (Table 2). Controlled freezes were colder than natural freezes, but cold hardening was also more favorable. This was evident from the stem injury of less than 75% to citrus parents, regardless of the colder freeze of −8.9° for 4 hr.

In a comparative study of dormancy under natural conditions, all of the *Eremocitrus* hybrids were 2 to 3 weeks later in bud break in the spring than were the *Citrus* parents. This supports the hypothesis that *Citrus* cultivars exhibiting late bud break tend to be more cold hardy than those cultivars with early bud break. *Eremocitrus* has pronounced periods of summer dormancy in its xerophytic habitat; drought tolerance is another factor often associated with cold tolerance in trees.

Our results indicate that *E. glauca* transmits a useful degree of cold hardiness to its offspring. *Eremocitrus glauca* may be a new and potentially valuable source of cold hardiness in citrus breeding.

Literature Cited

1. Swingel, W. T. 1914. *Eremocitrus,* a new genus of hardy, drought resistant citrus fruits from Australia. *U.S. Dept. Agr., J. Agr. Res.* 2:85-100.
2. ————, and P. C. Reece. 1967. Botany of citrus. Pages 339-344. *In* W. Reuther, H. J. Webber, and L. D. Batchelor (eds.). *The Citrus Industry Vol. I,* Univ. California, Div. Agr. Sciences, Berkeley.
3. Yelenosky, G. 1975. Cold hardening in citrus stems. *Plant Physiol.* 56:540-543.