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Omission of Lime Reduces Mouse-ear Symptoms in Container-grown Pecan Trees

William D. Goff and Gary J. Keever
Department of Horticulture and Alabama Agricultural Experiment Station Auburn University, AL 36849

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Abstract. **Container-grown pecan *[Carya illinoensis* (Wangenh.) C. Koch] trees with "mouse-ear" symptoms, characterized by small, rounded, cupped, and slightly wrinkled leaflets, were repotted into two types of media amended with three rates of dolomitic limestone (0, 5.4, or 10.7 kg·m^{-3}). In both media [4 milled pine bark: 1 sand; 1 soil : 1 peat : 1 perlite (by volume)], mouse-ear symptoms in the season following repotting were dramatically reduced at the lower lime application rates. Medium Fe, Ca, Cu, and Mn and foliar Ca, Mg, Mn, Zn, and B were affected by lime rate 10 months after repotting in one or both media. Medium pH increased quadratically as lime rate increased. Greatest plant recovery occurred when no lime was added, resulting in a pH of 3.9 in the bark-sand medium and 4.2 in the soil-peat-perlite medium.**

"Mouse-ear" describes abnormal growth in pecan trees characterized by small, rounded, cupped, and slightly wrinkled leaves (Gammon and Sharpe, 1956). In orchards, it has been associated with soil pH of 6.5 to 8.0 and was thought to be caused by Mn deficiency (Gammon and Sharpe, 1956). Later research (Gallaher and Jones, 1976; Grauke et al., 1983; Worley, 1979) found similar symptoms in nonmanganese-deficient trees, suggesting a more complex or different problem. Gallaher and Jones (1976) suggested Ca deficiency, but their research showed higher Ca, Mn, Fe, Cu, Zn, and Mo and less Mg in leaf and stem tissue from affected trees. Worley (1979) reported elemental concentrations of normal and mouse-eared leaflets differed among cultivars, with inconsistencies and reversals in element concentrations of affected leaflets occurring for particular cultivars and locations. Grauke et al. (1983) observed higher N, P, Ca, S, and Mn and lower Fe in mouse-eared leaves from container-grown trees. They suggested that high N levels were lowering the N : S ratio and that correspondingly high levels of S may be needed for normal growth.

Two container pecan nurseries in Alabama reported trees with mouse-ear symptoms in 1985. Several experiments were undertaken in an attempt to alleviate symptoms on affected trees and to reduce the disorder in new nursery plantings. This study evaluated the effects of repotting affected trees into two media with three rates of dolomitic limestone.

The nursery trees selected for this experiment were growing in 11.4-liter containers in a 3 milled pine bark : 1 sand medium (v/v) amended with (kg·m^{-3}) 8.9 dolomitic limestone, 3.6 Sierrablen Nursery Mix 18N-3. 0P-8.3K-1Fe (Grace-Sierra), Milpitas, Calif.), 0.65 gypsum, and 0.9 Micromax micronutrients (Grace-Sierra). Supplemental applications of 14.2 g of Sta-Green Nursery Special (12N-2.6P-5.0K) (Sta-Green Plant Food Co., Sylacauga, Ala.) per container had been applied monthly from Mar. to Oct. 1984 and from Mar. to June 1985. Before beginning the treatments in July 1985, leaf samples were taken from 25 randomly selected trees exhibiting mouse-ear symptoms and from 25 healthy trees. These leaves were analyzed for B, Ca, Cu, Fe, Mg, Mn, P, and Zn.

In July 1985, 126 trees exhibiting severe mouse-ear symptoms were selected and subjected to a factorial combination of two repotting media [4 milled pine bark : 1 sand or 1 soil : 1 peat : 1 perlite (by volume)] and three rates of incorporated dolomitic limestone (20% Ca, 8.0% Mg) at 0, 5.4, or 10.7 kg·m^{-3}. Selected trees of uniform height were assigned at random to the treatment media and were repotted on 3 July 1985. All combinations were amended with (kg·m^{-3}) 5.9 Osmocote 18N-2.6P-1 0.0K, 1.2 gypsum, 1.2 superphosphate (0N-8.6P-0K), and 0.9 Micromax. Trees grown in nonlimed media received monthly applications of 18 g of gypsum plus 5.7 g Epsom salt/pot to supply Ca and Mg. Treatments were completely randomized, with seven three-tree replicates per treatment combination.

Media were analyzed on 12 July 1985, 10 days after repotting, for B, Ca, Cu, Fe, K, Mg, Mn, P, and Zn and for pH and soluble salts using the saturated media extraction

Fig. 1. Mouse-ear symptoms on container-grown pecan trees on 25 Apr. 1986, 10 months after repotting severely affected trees into media into which dolomitic lime at 0 (left), 5.4, or 10.7 kg·m^{-3} had been incorporated. Note almost complete recovery from symptoms in plants where lime was omitted.

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Table 1. Effect of lime in repotting media on recovery of container-grown pecan trees from mouse-ear symptoms (1986).

Medium	Lime applied ($kg \cdot m^{-3}$)	Severity rating[z] 25 Apr.	Severity rating[z] 24 Sept.	Leaf length[y] (cm) 25 Apr.	Plant ht (cm) 25 Apr.
Bark–sand (BS)	0	4.9	4.3	30.3	94.3
	5.4	2.9	4.1	17.0	88.5
	10.7	2.4	3.3	15.0	86.5
Soil–peat–perlite (SPP)	0	4.9	4.3	29.1	73.9
	5.4	3.5	4.2	17.0	77.3
	10.7	2.9	3.7	14.2	71.6
Overall effect	0	4.9	4.3	29.8	84.1
	5.4	3.2	4.1	17.0	82.9
	10.7	2.6	3.5	14.6	79.0
Significance					
Medium		**	NS	NS	***
Lime		***	***	***	NS
Medium × lime		NS	NS	NS	NS
Contrasts					
Lime, linear		***	***	***	*
Lime, quadratic		***	NS	***	NS
Lime, linear in BS		***	***	***	*
Lime, quadratic in BS		***	NS	***	*
Lime, linear in SPP		***	**	***	NS
Lime, quadratic in SPP		*	NS	***	NS

[z]Scale of 1 to 5, where 1 = severely mouse-eared and 5 = normal; ratings made 25 Apr. 1986 were ≈10 months after affected trees were repotted and those made 24 Sept. 1986 were ≈15 months after repotting.
[y]Length of compound leaf in middle of current season's shoot.
NS,*,**,***Not significant or significant at $P = 0.05$, 0.01, or 0.001, respectively.

method of Warnke and Krauskopf (1983). Foliar samples were taken from treated trees 10 months after repotting (May 1986). The samples consisted of a single compound leaf collected from the middle of current season's shoots on each plant and analyzed for B, Ca, Cu, Fe, K, Mg, Mn, P, and Zn using a dry ashing technique (Hue and Evans, 1986).

Foliage was rated for mouse-ear severity (1-5 scale, where 1 = severely mouse-eared and 5 = healthy) on 25 Apr. 1986 and again on 24 Sept. 1986. Plant height and leaflet length were measured on 25 Apr. 1986.

Ten and 15 months after repotting, mouse-ear symptoms were dramatically reduced (Fig. 1, Table 1) as lime application decreased. Leaf length, another measure of symptom expression, followed a similar pattern, with short deformed leaves present on plants grown in the highest lime application and a quadratic increase in leaf length as lime application decreased (Table 1). Plant height also increased quadratically in the bark–sand medium as the amount of lime decreased, but was unaffected by lime in the soil–peat–perlite medium.

Pretreatment foliar elemental concentrations of Ca, Mg, P, and Cu in trees exhibiting mouse-ear symptoms were higher *(P < 0.05)* than in normal trees, while concentrations of Mn, K, Zn, and B were lower in

Table 2. Foliar nutrient levels pretreatment and 10 months after repotting of pecan trees as affected by lime application.

Condition or medium	Lime applied ($kg \cdot m^{-3}$)	Ca (%)	K (%)	Mg (%)	P (%)	B ($\mu g \cdot g^{-1}$)	Cu ($\mu g \cdot g^{-1}$)	Fe ($\mu g \cdot g^{-1}$)	Mn ($\mu g \cdot g^{-1}$)	Zn ($\mu g \cdot g^{-1}$)
		Concn (dry-wt basis) of elements in foliage[z]								
Pretreatment[y]										
Mouse-ear		0.80 a	0.48 a	0.38 a	0.12 a	26.7 a	6.7 a	191 a	116 a	63 a
Normal		0.64 b	0.56 b	0.21 b	0.09 b	46.4 b	5.6 b	131 a	550 b	81 b
Interactions										
Bark–sand (BS)	0	0.64	0.85	0.24	0.22	18.2	5.6	90	421	139
	5.3	1.39	0.83	0.69	0.23	30.6	5.0	179	290	177
	10.7	1.21	0.96	0.75	0.30	34.4	2.5	164	116	128
Soil–peat–perlite (SPP)	0	0.96	0.92	0.21	0.23	31.0	30.1	110	455	173
	5.3	1.38	0.83	0.56	0.21	51.8	21.2	125	611	189
	10.7	1.13	0.95	0.51	0.27	33.8	11.4	179	272	119
Main effects										
	0	0.80	0.89	0.23	0.23	24.6	17.9	100	438	156
	5.3	1.39	0.83	0.63	0.23	41.2	13.1	152	451	183
	10.7	1.17	0.95	0.63	0.28	34.1	7.0	172	194	124
Significance										
Media		NS	NS	***	NS	*	**	NS	***	NS
Lime		***	*	***	**	*	NS	*	***	**
Media × lime		*	NS	*	NS	NS	NS	NS	***	NS
Contrasts										
Lime, linear		***	NS	***	**	NS	NS	**	***	*
Lime, quadratic		***	*	***	NS	*	NS	NS	***	**
Lime, linear in BS		***	NS	***	**	*	NS	*	***	NS
Lime, quadratic in BS		***	NS	***	NS	NS	NS	NS	NS	*
Lime, linear in SPP		NS	NS	***	NS	NS	*	*	***	*
Lime, quadratic in SPP		**	NS	***	NS	**	NS	NS	***	*

[z]Determined from whole compound leaves collected from the middle of current season's shoots in May 1986.
[y]Pretreatment foliar samples taken 2 July 1986. Mean separation within elements by Fisher's F test, $P = 0.05$.
NS,*,**,***Not significant or significant at $P = 0.05$, 0.01, or 0.001, respectively.

Table 3. Nutrientlevels, pH, and soluble salts in repotting media on 12 July 1985, 10 days following repotting of pecan trees.

Medium	Lime applied (kg·m⁻³)	pH	Conductivity (mmhos/cm)	Concn of elements in media (mg·liter⁻¹ in solution) B	Ca	Cu	Fe	K	Mg	Mn	P	Zn
Interactions												
Bark–sand (BS)	0	3.9	4.5	0.27	2.7	0.26	6.7	5.5	1.3	0.06	2.7	0.01
	5.4	5.4	3.0	0.27	2.7	0.26	6.7	5.8	1.4	0.07	2.5	0.02
	10.7	5.8	3.5	0.58	3.0	0.26	6.7	13.7	2.5	0.25	3.8	0.19
Soil–peat–perlite (SPP)	0	4.2	3.3	0.58	3.0	0.26	6.7	13.1	2.5	0.25	3.9	0.18
	5.4	5.6	2.4	0.67	7.6	0.27	6.9	15.4	3.0	0.35	4.1	0.20
	10.7	5.8	2.1	0.58	42.4	0.32	8.0	14.7	4.3	0.69	6.0	0.47
Main effects												
	0	4.0	3.9	0.43	2.8	0.26	6.7	9.3	1.9	0.16	3.3	0.10
	5.4	5.5	2.7	0.47	5.1	0.27	6.8	10.6	2.2	0.21	3.3	0.11
	10.7	5.8	2.8	0.58	22.7	0.29	7.3	14.2	3.4	0.47	4.9	0.33
Significance												
Media		***	*	NS	**	**	**	NS	NS	*	NS	NS
Lime		***	NS	NS	**	**	**	NS	NS	NS	NS	NS
Media × lime		**	NS	NS	**	**	**	NS	NS	NS	NS	NS
Contrasts												
Lime, linear		***	NS	NS	**	**	**	NS	NS	NS	NS	NS
Lime, quadratic		***	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Lime, linear in BS		***	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Lime, quadratic in BS		***	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Lime, linear in SPP		***	NS	NS	***	***	***	NS	NS	*	NS	NS
Lime, quadratic in SPP		***	NS	NS	*	NS	*	NS	NS	NS	NS	NS

NS,*,**,*** Not significant or significant at $P = 0.05$, 0.01, or 0.001, respectively.

mouse-ear trees (Table 2). Leaf Ca, Mg, Mn, Zn, and B were clearly affected by lime application 10 months after plants were repotted in the treatment media. Foliar Ca was lowest without added lime, peaked at the intermediate level, then fell at the high level.

We do not know why foliar Ca decreased at the highest lime level, but observations of treated plants (Fig. 1) suggest two possible explanations. The disorder obviously severely affected plant function. Root function could have been disrupted to the point that the expected continued rise of foliar Ca was prevented because of poor root condition. Also, the foliar samples collected from normal leaves (Fig. 1, left) represent plant tissue considerably different from the tissue collected and analyzed from severely mouse-eared foliage (Fig. 1, right). The relative proportion of leaf blade to stems and veins appears much greater in normal than in affected leaves, which have very little leaf blade development. This tissue dissimilarity could explain some of the otherwise confusing results we and others have obtained.

Foliar Mg followed a similar pattern as Ca in the soil–peat–perlite medium, but was higher at 10.7 than at 5.4 kg·m⁻³ in the bark-sand medium. Foliar Mn declined sharply in the bark–sand medium with an increase in lime application, but in soil-peat-perlite, Mn was highest with lime at 5.4 kg·m⁻³, then dropped sharply with lime at 10.7 kg·m⁻³. Foliar Zn followed the same pattern. Leaf B concentrations were positively related to lime rate in the bark–sand medium, but were curvilinearly related to lime rate in soil–peat–perlite.

In both media, there was an increase in pH with an increase in lime application (Table 3). The plants that had the fewest mouse-ear symptoms were those grown without lime, with a pH of 3.9 in the bark–sand medium and 4.2 in soil–peat-perlite.

Nutrients significantly affected by lime rate in one or both media (Table 3) were Fe, Mn, Cu, and Ca. Fe, Mn, and Cu all increased linearly with lime application in soil-peat–perlite but not in bark-sand. Calcium increased quadratically with the amount of lime applied to the soil-peat-perlite but also did not change in bark-sand.

Correlations of mouse-ear ratings with media and foliar elemental levels were computed. Magnesium level and pH of media solution 10 months after repotting were significantly ($P \leq 0.05$) correlated with mouse-ear incidence. Foliar concentrations of Mg, Mn, Zn, and Fe were also significantly correlated with mouse-ear incidence.

Regression analyses for leaf and media elemental levels with mouse-ear rating were conducted, and standardized b (stb) values (Steele and Torrie, 1980) were used to indicate relative importance of each variable. In media, pH was more important (stb = 0.56) than Mg (stb = 0.44). Leaf Mg was the most important element (stb = 0.55) and Fe was second (stb = 0.37), while Zn and Mn had relatively little influence on mouse-ear symptoms (stb = 0.11 for each).

Results of this study and review of earlier work suggest that mouse-ear is a complex problem resulting from nutrient imbalance and that no single cause can explain all cases of symptom occurrence. Media pH, however, clearly influenced mouse-ear symptoms. A consistent observation from reviewed work, as well as the present study, is that Ca concentration of affected leaves is higher than or equal to the Ca concentration of normal leaves. This is in agreement with our observation that using little or no lime can correct the problem. Our work also agrees with that of Gammon and Sharpe (1956) in that low Mn, perhaps lime-induced (Sanchez and Kamprath, 1959), may contribute to the occurrence of mouse-ear symptoms in some instances. We observed no mouse-ear symptoms and good growth of several hundred container-grown pecan trees in a pine bark medium of similar composition to that which resulted in severe symptoms. The apparent major difference in the two media was that the lime rate in the medium producing plants with symptoms was high (8.9 kg·m⁻³), while it was low (3.0 kg·m⁻³) in the medium producing plants with no symptoms. This observation suggests that nursery workers may be able to avoid the mouse-ear problem by using little or no lime. Omitting lime in our experiment worked well as a corrective treatment on plants already exhibiting symptoms, but some lime may be needed for optimum performance of normal trees. We added supplemental Ca and Mg to the 0 kg lime/m³ treatment, which also may be required if further experimentation shows that very low amounts of lime are necessary to eliminate this disorder.

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