Soil pH and Fertility Affect Growth of Leyland Cypress Christmas Trees[1]

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Abstract

Containerized liners of Leyland cypress [*Callitropis* × *leylandii* (syn. *Cupressus leylandii*, × *Cupressocyparis leylandii*)] were treated with two fertilizer rates [0.6 and 2.4 kg/m^3 (1 lb/yd and 4 lb/yd^3) of 15N–4.0P–10.0K (15N–9P_2O_5–12K_2O) Osmocote] in Norfolk loamy sand topsoil amended with three rates of dolomitic limestone to obtain target pH values of 4.1, 5.1, and 6.1. Soil pH and fertility both affected plant growth, with negligible interaction. Averaged over both fertilizer rates, total dry weight, which increased linearly with pH, was 24 to 30% higher at the highest pH level (pH 5.9 to 6.5) than in the lowest (pH 4.7 to 4.8). After one growing season, differences among the treatment extremes (low fertility, low pH vs. high fertility, high pH) for height, shoot dry weight, root dry weight, and total dry weight were 19, 71, 44, and 64% respectively.

Index words: Soil testing, plant tissue analysis, foliage nutrient concentrations, mineral nutrition.

Species used in this study: Leyland cypress [*Callitropis* × *leylandii* (syn. *Cupressus leylandii*, × *Cupressocyparis leylandii*)].

Significance to the Nursery Industry

Leyland cypress is important to the nursery industry and Christmas tree industry in the southeastern United States. At each of two fertilizer rates (0.6 and 2.4 kg/m^3) in loamy sand soil, growth of containerized plants was best at pH 5.9 to 6.5. Growth was also increased by fertilization. The information in this report suggests improved soil test recommendations for Leyland cypress Christmas trees and helps with other management decisions, e.g., whether to grow Leyland cypress in pure stands, or in a mixture with other species.

Introduction

Leyland cypress is important to the choose-n-cut Christmas tree industry in the southeastern United States (15, 17). Recommendations for fertilization and liming of field-grown trees (10) are based on soil samples collected annually or every 2 to 3 years. Although many tree species tolerate a wide range of soil pH, each species tends to have an optimum range (9). Current soil testing recommendations issued by the Agronomic Division, North Carolina Department of Agriculture & Consumer Services (NCDA&CS) use a target pH of 5.5 to 5.8 for Leyland cypress, as suggested for blue spruce (*Picea pungens* Englem.) (5, 10). Owing to its importance in the Christmas tree industry, specific recommendations are needed for Leyland cypress (15). Experience in Christmas tree plantations suggests Leyland cypress grows best at pH ≥ 6.0 (17), but this has not been studied. Therefore, the objective of this research was to examine the growth of Leyland cypress over a range of soil pH and fertility levels.

Materials and Methods

In April 2006, topsoil of a Norfolk loamy sand (fine-loamy, kaolinitic, thermic Typic kandiudult) (19, 20) was collected from a 40-year-old, unmanaged stand of loblolly pine (*Pinus taeda* L.) at the Central Crops Research Station near Clayton, NC. The Norfolk series is common in the Coastal Plain of North Carolina and several other states in the southeastern United States. Soil was air-dried on greenhouse benches and sieved through a 6-mm (0.24 in) screen. Air-dry soil (18 kg; 40 lbs) for each of 90 pots was weighed into plastic bags and mixed with fertilizer and powdered dolomitic lime (calcium carbonate equivalent = 103%) to attain factorial combinations of two fertilizer rates [0.6 or 2.4 kg/m^3 (1 or 4 lb/yd^3) of 15N–4.0P–10.0K (15N–9P_2O_5–12K_2O) Osmocote, 12–14 month southern blend] (Scotts-Sierra Hort. Products Co., Marysville, OH) and three target pH levels (4.1, 5.1, and 6.1) as determined by soil test methods (4, 5, 11, 12, 13). Nitrogen was 8% NH_4^+ and 7% NO_3^-. Lime rates were 0.0, 1.14, and 2.28 g per kilogram of air-dry soil.

In April 2006, uniform, well-rooted liners of Leyland cypress (7) were planted (one plant per pot) into 15-liter (4-gal) polyethylene pots containing the amended soil. Plants initially averaged 40 cm (16 in) tall and 7.0 g (0.25 oz) total dry weight. Pots were lined with drainage cloth to retain the dry soil and were thoroughly irrigated immediately after planting. Plants were kept under 50% shade during the 2006 growing season and watered with overhead irrigation as needed. Shade was removed on October 1, 2006, and white polyethylene was placed over the frame in early December. Ambient temperatures during the hottest part of the summer ranged from 31 to 37C (88 to 99F).

The experimental design was a randomized complete block with 15 blocks (15 blocks × 6 treatments = 90 pots). Two fertilizer rates were combined factorially with three lime rates. Each block contained a row of six contiguous pots arranged in a row, and row spacing was ≈ 0.5 m.

Foliage was sampled December 5, 2006. For each treatment, a current-year shoot was collected from the middle portion of the crown of each tree and combined into aggregate samples for blocks 1–3, 4–6, 7–9, 10–12, and 13–15. Plant nutrient analysis was conducted by NCDA&CS. Prior to analysis, tissue samples were dried overnight at 80C (176F);

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then, ground with a stainless steel grinder (Wiley Mini-Mill, Thomas Scientific, Swedesboro, NJ) through 20-mesh screen [1.0 mm (0.04 in)] (3). Total N was determined by oxygen combustion with an elemental analyzer (NA1500; CE Elantech Instruments, Milan, Italy) (2). Total P, K, Ca, Mg, S, B, Cu, Fe, Mn, Zn, and Na concentrations were determined by EPA Method 200.7 with an ICP spectrophotometer (Optima 3300 DV ICP Emission Spectrometer; PerkinElmer Corporation, Wellesley, MA), following open-vessel HNO_3 digestion in a microwave digestion system (CEM Corp., Matthews, NC) (4).

On December 7, 2006, a standard 2.5-cm (1 in) diameter soil sampling tube was used to collect two 15-cm (6 in) cores from each pot. Cores were combined into aggregate samples for blocks 1–3, 4–6, 7–9, 10–12, and 13–15. Soil test analysis was conducted by NCDA&CS. Soils were extracted with Mehlich-3 solution (11) using a 1:10 soil to solution ratio. Analysis was made for P, K, Ca, Mg, S, Na, Mn, Cu, and Zn using the ICP. Cation exchange capacity (CEC) was determined by summation of basic cations (excluding sodium) and buffer acidity (13). Base saturation was calculated as the percentage of the CEC occupied by basic cations (excluding Na). Soil pH was determined on a 1:1 soil/water volume ratio. Humic matter determinations were made using a NaOH digestion with colorimetric determination (12).

On December 7, 2006, total height and stem diameter 2 cm (0.8 in) above the soil surface were measured for each plant. Using a digital caliper, two stem diameter measurements were taken in opposite directions to account for any eccentricity. Stem cross-sectional area was calculated as the area of a circle with a diameter equal to the average of the two diameters. Shoots were severed at ground-line, and roots were washed free of soil. Shoot and root samples were dried for 1 week at 65C (149F) and weighed. Data were subjected to GLM procedures in SAS (16). Contrasts (1-df) were used to test certain *a priori* treatment comparisons for growth and foliar nutrient concentrations. Results are presented in tables and graphs.

Results and Discussion

Soil. Prior to amendment, the soil was strongly acidic with an initial pH of 4.1 and 16% base saturation (Table 1). With the addition of lime, soil acidity decreased while base saturation and related levels of Ca and Mg increased (Table 1). For both fertilizer rates, exchangeable acidity decreased and extractable Ca and Mg increased with increasing lime rates (Table 1). With respect to final pH, there was an interaction between fertilizer rate and lime rate (Table 1). At the low lime level for both fertilizer rates, the final soil pH was ≈ 4.7, an increase of ≈ 0.5 unit above the initial soil pH of 4.1, although no lime was applied (Fig. 1A). The change in soil pH with additions of lime was greatest at low fertility, e.g., at the high lime rate, final soil pH was 6.5 at the low fertilizer rate versus 5.9 at the high rate (Table 1).

Growth. The main effects of fertilizer rate and lime rate were highly significant, with negligible interaction (Table 2). Height and total dry weight — pooled over lime rates — were 13 and 30% higher, respectively, at high fertility compared to low fertility (Table 2). In addition, plants grown at the highest pH were an average of 5% taller and 26% heavier than those at the lowest pH. At the treatment extremes (low fertility and low lime versus high fertility and high lime) differences in height and dry weight were 19 and 64%, respectively (Fig. 1B).

Foliage. Foliar concentrations of Ca and Mg increased with lime rate, whereas most nutrients decreased (N, K, S, Fe, Mn, Zn, Cu, and B) (Table 3), especially when pH increased from the lowest level (≈ pH 4.7) to the mid-range. This pat-

Table 1. Soil characteristics for Norfolk loamy sand topsoil treated with two fertilizer rates and amended to three pH levels[z].

Fertilizer level[y] (kg/m^3)	pH level[x]	Reps	pH	Acidity[w]	Ca	Mg	K	Base saturation[w] (%)
				------ $cmol/dm^3$ ------				
				Initial values[v]				
—	—	—	4.1	3.2	0.38	0.15	0.05	16
				December 2006				
0.6	Low	5	4.70	2.84	0.63	0.31	0.05	26
0.6	Med	5	5.66	1.66	1.52	0.84	0.06	59
0.6	High	5	6.54	0.88	2.42	1.14	0.05	80
2.4	Low	5	4.76	2.40	0.84	0.52	0.11	38
2.4	Med	5	5.22	2.08	1.27	0.71	0.11	50
2.4	High	5	5.92	1.30	2.17	1.06	0.11	72
Fert			**	*	NS	NS	**	NS
Lime			**	**	**	**	NS	**
Fert × Lime			**	**	**	*	NS	**
R^2			0.98	0.97	0.97	0.85	0.88	0.98

[z]Leyland cypress was grown 8 months in 4-gal pots; sampled in December 2006.

[y]15–9–12 Osmocote 12–14 month release (1 and 4 lbs/yd^3).

[x]Dolomitic lime; target pH levels: 4.1, 5.1, and 6.1.

[w]Sum of exchangeable H^+ and Al^{+++}. Base saturation = percentage of CEC occupied by basic cations (Ca^{++}, Mg^{++}, K^+).

[v]Density = 1.37 g/cm^3, humic matter = 0.8%, and CEC = 3.8 $cmol/dm^3$.

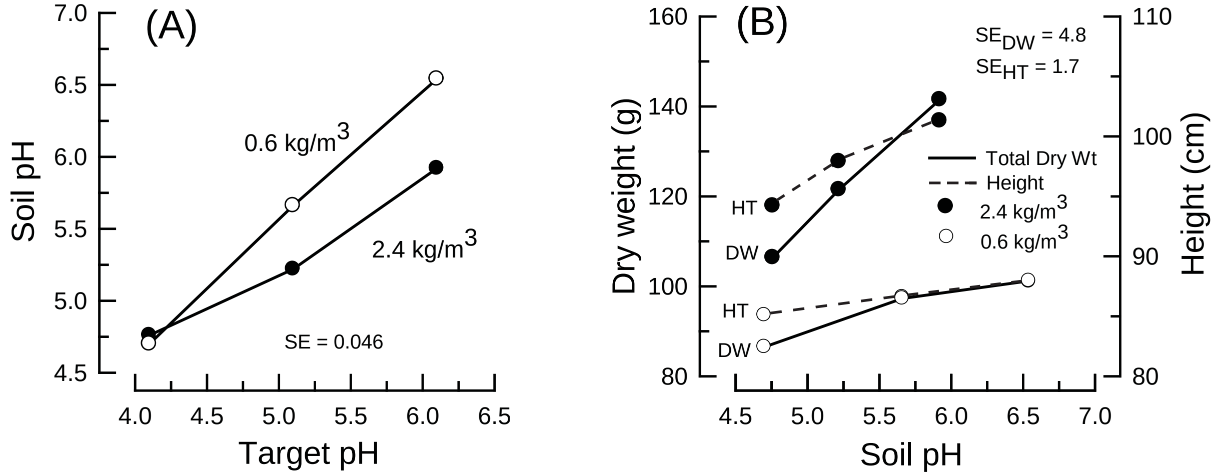

Fig. 1. (A) Final soil pH versus target pH for Norfolk loamy sand amended with three levels of dolomitic lime (0.0, 1.14, and 2.28 g/kg air-dry soil) and two rates of controlled-release fertilizer [0.6 or 2.4 kg/m³ (1 lb/yd³ or 4 lb/yd³), and (B) total dry weight and height of Leyland cypress as affected by two fertilizer rates and three pH levels. Basis: n = 5 composite samples for each point in panel (A); n = 15 for each point in panel (B). SE = standard error of the mean.

tern was most evident with Cu and Zn. Phosphorus was the only nutrient that showed no change with pH. Nitrogen and Mn concentrations in the foliage decreased almost linearly with increasing pH. Magnesium and Mn were the only mineral nutrients with a significant lime × fertilizer interaction (Table 3). These interactions probably occurred because the response curve at low fertility was more quadratic in shape compared to a more linear response at the high fertilizer rate (Fig. 2).

A similar experiment (unpublished) was conducted in 2005 using five target pH levels (4.5, 5.0, 5.5, 6.0, and 6.5) and one fertilizer rate [4.8 kg/m³ (8 lbs/yd³)] of controlled-release fertilizer), and the influence of pH on plant weight was not significant. Since pH affects nutrient availability (1, 2, 8, 14), we surmised that the fertilizer rate was high enough to possibly mask some effect of pH on nutrient availability. Consequently, the experiment in 2006 used lower levels of fertility [0.6 or 2.4 kg/m³ (1 or 4 lbs/yd³)]. In the present experiment, however, differences in dry weight and height as a function of pH were larger at the high fertilizer rate, and less apparent at the low rate (Fig. 1B).

In the 2006 experiment, Leyland cypress grew better at high fertility (Table 2, Fig. 1B). The optimum soil pH could not be identified, but the response curve was still rising at a value of 6.5 in the low-fertility treatment (Fig. 1B). After one growing season, plants grown at the high pH level were 26% (averaged over both fertilizer rates) heavier than plants grown at the low pH level. Compounding these differences

Table 2. Height and dry weight of Leyland cypress as affected by fertilizer rate and lime rate.[z]

Fertilizer rate[y] (kg/m3)	Lime rate[x]	n	Height (cm)	Dry weight (g) Shoot	Roots	Total
0.6	—	45	86.6	70.0	25.0	95.0
2.4	—	45	97.8	92.0	31.1	123.1
—	Low	30	89.7	70.5	25.9	96.4
—	Med	30	92.3	80.8	28.6	109.4
—	High	30	94.6	91.7	29.7	121.4
Fertility rate			**	**	**	**
Lime rate			*	**	*	**
low vs. med			NS	**	NS	**
med vs. high			NS	**	NS	*
Fert × lime			NS	NS	NS	NS
R^2			0.61	0.58	0.42	0.56

[z]Plants were grown 8 months in 15-liter (4-gal) pots; sampled in December 2006.

[y]15–9–12 Osmocote 12–14 month release [0.6 or 2.4 kg/m³ (1 or 4 lb/yd³)].

[x]Dolomitic lime; target pH levels: 4.1, 5.1, and 6.1.

NC, *, ** Nonsignificant or significant at P = 0.05 or 0.01, respectively.

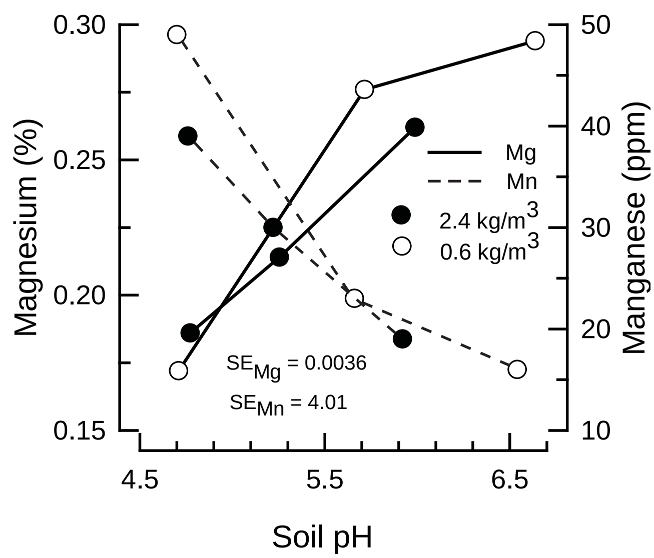

Fig. 2. Interaction between soil pH and fertility for Mg and Mn concentrations in foliage of Leyland cypress. Basis: n = 5 composite samples for each data point. These were the only two nutrients with a significant pH × fertility interaction (Table 3). SE = standard error of the mean.

Table 3. Foliage analysis for Leyland cypress grown at two fertilizer rates and three lime rates.[z]

Treatment	Reps	N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu	B
		(%)						(ppm)				
						Fertilizer rate[y]						
Low	15	0.60	0.09	0.78	0.74	0.25	0.057	51	29	17	4.4	20
High	15	0.88	0.13	0.99	0.75	0.22	0.068	51	29	19	5.1	22
						Lime rate[x]						
Low	10	0.86	0.11	0.96	0.59	0.18	0.068	55	44	27	5.1	25
Medium	10	0.71	0.11	0.86	0.81	0.24	0.061	57	27	14	4.6	20
High	10	0.66	0.11	0.83	0.84	0.28	0.059	42	17	13	4.5	18
Fert. rate		**	**	**	NS	—[w]	**	NS	—[w]	NS	**	**
Lime rate		**	NS	**	**	—	**	**	—	**	*	**
low vs. med.		**	NS	**	**	—	**	NS	—	**	*	**
med. vs. high		NS	NS	NS	NS	—	NS	**	—	NS	NS	**
Fert. × lime		NS	NS	NS	NS	**	NS	NS	**	NS	NS	NS
R^2		0.87	0.89	0.86	0.93	0.94	0.85	0.61	0.94	0.72	0.62	0.87

[z]Plants were grown 8 months in 15-liter (4-gal) pots containing Norfolk loamy sand; sampled in December 2006.

[y]15–9–12 Osmocote, 12–14 month release. Low = 0.6 kg/m^3 (1lb/yd^3), and high = 2.4 kg/m^3 (4 lb/yd^3).

[x]Dolomitic lime; target pH levels: 4.1, 5.1, and 6.1.

[w]Main effects are not shown owing to significant fertilizer × lime interaction.

NS, *, ** Nonsignificant or significant at $P = 0.05$ or 0.01, respectively.

over a period of 4 to 6 years could easily yield plants twice as heavy as those grown at low fertility and low pH.

Lime applied at both fertilizer rates, as compared to initial soil conditions, reduced exchangeable acidity thereby increasing pH and base saturation as Ca and Mg occupied a higher proportion of the exchange sites (Table 1). This change in soil chemistry is well documented in the literature (1, 6, 8).

Final pH values at the low fertilizer rate (pH 4.7, 5.7, 6.5) were ≈ 0.5 pH unit above desired targets (Table 1, Fig. 1A). At the high fertilizer rate, final soil pH was near target values, except for the low lime rate where pH was similar (4.5 to 4.7) for both fertility levels. Higher pH than desired in some treatments may be partly explained due to alkalinity of source water. Alkalinity of source water was low (≈ 35 ppm), but the cumulative alkalinity added during the study might have caused pH to rise, since most water was supplied by irrigation.

At the medium and high lime rates, greater plant growth (Fig. 1) and foliar concentration of basic cations (Table 3) occurred in the high fertilizer rate. Lower amounts of residual soil Ca and Mg (i.e., that remaining at the conclusion of the experiment) in treatments involving medium and high lime rates in combination with high fertility was probably a direct effect of uptake and treatment since higher pH due to more lime was associated with more growth and more uptake of Ca/Mg, leaving less Ca/Mg in the soil (Table 1). Foliar concentration of Ca in plant tissues also increased with increasing lime rates (Table 3). Uptake of basic cations (Ca, Mg, and K) by plants and corresponding maintenance of charge balance (expulsion of H^+ ions) can contribute to formation of soil acidity (6, 14) — possibly accounting for soil pH values that were lower than target values for medium and high lime rates in the high fertilizer rate (Fig. 1). Nitrification, leaching of nutrients, and acid rainfall could also reduce soil pH.

Christmas tree growers often must decide whether to plant certain species in mixture or in pure culture, e.g., Leyland cypress with Virginia pine (*Pinus virginiana* L.). Virginia pine tolerates a wide range of soil pH (20), but is usually targeted for pH 5.0 to 5.5 in Christmas tree culture (10). The optimum soil pH for Leyland cypress could not be identified in this experiment although growth increased up to the maximum pH of 6.5. Eastern redcedar (*Juniperus virginiana* L.), another Christmas tree species grown in the southeastern United States, is tolerant of soil pH ≥ 6.0 (18), making it more compatible with Leyland cypress compared to Virginia pine.

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