Pre-transplant Root Ball Condition Influences Growth of *Plumbago* During Establishment

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SUMMARY. Three root ball conditions—nonroot-bound (NRB), root-bound (RB), and root-bound sliced (RBS)—were evaluated for their effect on plant growth of plumbago (*Plumbago auriculata*) during establishment and postestablishment in the landscape. At transplant, NRB plants were smaller than other treatments. Canopy size, shoot dry weight, root dry weight, and total biomass growth rates were faster for NRB plants compared with RB or RBS. By 6 and 8 weeks after transplanting, respectively, biomass and canopy size were similar among treatments. Rootbound and RBS plants were similar indicating root ball slicing does not affect growth in the landscape.

Consumers consider plant quality an overwhelmingly important factor when purchasing landscape plants (Brand and Leonard, 2001; Khatamian and Stevens, 1994). Quality considerations include dark green foliage (Baker, 1965), evidence of new growth, and absence of discolored or damaged leaves (Brand and Leonard, 2001). There is little evidence that indicates consumers pay attention to root ball condition at purchase, yet landscape establishment is affected by the condition of root systems at transplant. Arnold and Struve (1989) and Struve (1993) report delayed landscape establishment when transplanting container-grown plants with overly developed (i.e., root-bound) root systems. The most critical factor affecting landscape establishment appears to be root growth (Watson and Himelick, 1997) and rapid expansion of roots (Blessing and Dana, 1987; Woods, 1959) into surrounding soil.

Landscape service providers and homeowners often manipulate root balls when installing landscape plants to promote root development and correct circling roots, yet evidence supporting or refuting the practice

is mixed. Shoot and root growth of European white birch (*Betula pendula*) decreased with progressive root removal (Bellet-Travers et al., 2004). Pre-transplant root pruning stimulated shoot and root growth for southern magnolia (*Magnolia grandiflora*) the first year in a landscape (Gilman, 1992), yet Farmer and Pezeshki (2004) reported adverse effects on height among seedling nuttall oaks (*Quercus nuttalli*). Root pruning had no effect on trunk growth or height of pecan (*Carya illinoensis*) (Wood, 1996) nor shoot or root growth of 'Radiant' crabapple (*Malus ×hybrida*) (Schnelle and Klett, 1992).

Gilman et al. (1996) reported that with daily irrigation, slicing of root balls did not affect shoot or root growth in 'Burdfordii Nana' holly (*Ilex cornuta*) 4 months after transplanting into a landscape. Mechanical root disruption of container-grown 'Sea Green' juniper (*Juniperus chinensis*) produced greater dry weight of new roots but less shoot growth than undisturbed root balls in loam soil. However, in clay soil, root ball manipulations reduced new root growth (Blessing and Dana, 1987).

Objectives of this research were 1) to evaluate the effect of root ball conditions at transplanting on canopy growth and biomass production and 2) to determine if root ball slicing is beneficial during landscape establishment of plumbago.

Materials and methods

Root-bound and nonroot-bound plumbago started at a commercial nursery in Dec. 2003 and Feb. 2004, respectively, were transplanted on 1 June 2004 into a well-drained sandy soil (Apopka fine sand) in an open-sided clear polyethylene-covered shelter. During production, plants were grown in a container substrate composed of 70 pinebark:30 peat:5 sand by volume (C & C Fancy Peat, Tampa, FL) in No. 1 containers. They received one application of 20N-4.4P-8.3K Polyon controlled-release fertilizer (J.R. Simplot Company, Lathrop, CA) 2 months after planting at a standard rate of 1.85 lb/ft². Eight transplant beds, each measuring 4 × 44 ft, were amended with composted yard waste (Orange County Solid Waste Management, Orange County, FL) at a rate of 58 ft³ per transplant bed by incorporation in the top 6 inches of soil. Areas between transplant beds were covered with a 2-ft-wide polypropylene ground cloth (Imperial Building and Supply, Apopka, FL) to inhibit weed growth. Three root ball classes were evaluated: nonroot-bound (NRB), root-bound (RB), and root-bound sliced (RBS). NRB plants were characterized by presence of small root tips on the substrate surface. RB plants had numerous roots encircling outside of the substrate. Four vertical slices, each 2 inches deep, were made at a 90° angle through the bottoms of root balls of RB plants to achieve RBS treatment. The experimental layout was a randomized complete block design

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.3048	ft	m	3.2808
0.0283	ft ³	m ³	35.3147
2.5400	inch(es)	cm	0.3937
4.8824	lb/ft ²	kg·m ⁻²	0.2048
28.3495	oz	g	0.0353
(°F - 32) ÷ 1.8	°F	°C	(1.8 × °C) + 32

with three treatments and four blocks of single-plant replicates for a total of four replicates per treatment per sampling period.

Beds were managed with University of Florida/Institute of Food and Agricultural Sciences best management practices (Black and Gilman, 1998). Plants were spaced 2.5 ft on center and irrigated daily at a rate of 0.5 inch with microspray stakes (Dan Sprinklers, Kibbutz Dan, Israel) equipped with a Rondo strip spreader/diffuser (Plastro Irrigation, Gvat, Israel). Spray heads were installed in a linear pattern spaced 5 ft apart with the first head located at one end of each planting bed and mounted 1 ft above ground level. Before planting, emitters were adjusted to maintain a minimum Christiansen coefficient of 0.7 (Haman et al., 2005). Each planting bed was independently controlled as a separate zone using an automated irrigation time clock (model Sterling 12; Superior Controls Co., Valencia, CA). Irrigations began at 0200 HR and completed by 0300 HR.

Initial growth indices (GI) were obtained by measuring height, widest canopy width, and width perpendicular to widest width ($GI = \text{height} \times \text{width } 1 \times \text{width } 2$). Before root ball manipulations, initial shoot and root dry weight were calculated for NRB, RB, and RBS plants. Shoots and roots were separated, dried at 140 °F for 72 h, and weighed. Two weeks after transplanting (WAT), and continuing every 2 weeks until 24 WAT, four replicates of each treatment were measured for GIs and destructively harvested. Shoot-to-root ratio was calculated for each replicate by dividing shoot dry weight by root dry weight. Total biomass was calculated by combining shoot and root dry weight for each plant.

Shoot and root dry weight, total biomass, and shoot-to-root ratio were analyzed over time by linear regression with three root ball classes and four replicates per class per sampling period. Single-df contrasts (Snedecor and Cochran, 1980) were used to compare slopes of regression equations. Slope was equivalent to growth rate. Differences in growth rates were calculated as the quotient of the slopes. Shoot and root dry weight, total biomass, and shoot-to-root ratio from each sampling period

were also analyzed separately as a one-way GLM. Mean separation, when overall F tests were significant, was by Fisher's protected least significant differences. All analyses were conducted using SAS (version 9.1.3; SAS Institute, Cary, NC).

Results and discussion

At transplant, canopy size, total biomass, shoot dry weight, and root dry weight were smaller for NRB plants than RB or RBS (Table 1). Canopy size (GI) of NRB increased at a rate 1.1 and 1.15 times greater ($P < 0.05$) than RB or RBS, respectively (Fig. 1). Total biomass increased 1.3 and 1.6 times faster ($P < 0.05$) than

RB or RBS, respectively (Fig. 2A). Similarly, shoot dry weight had accumulation rates 1.3 and 1.6 times faster ($P < 0.05$) than RB and RBS, respectively (Fig. 2B). Root production was 1.3 and 1.7 times more rapid than RB and RBS, respectively ($P < 0.05$; Fig. 2C). Shoot-to-root ratios among root ball classes were similar throughout the study ($P > 0.05$; data not shown).

By 12 WAT, canopy size of NRB, RB, and RBS were similar ($P > 0.05$) (Table 2). Differences in total biomass, shoot dry weight, and root dry weight were also no longer measurable at 6 WAT (Table 2). At 22 WAT, NRB were larger than RB or RBS; however, results are likely a

Table 1. Mean initial growth measurements for plumbago subjected to three root ball conditions: nonroot-bound (NRB), root-bound (RB), and root-bound sliced (RBS).

Treatment	Growth index (m^3) ^z	Shoot dry wt (g) ^y	Root dry wt (g)	Biomass (g)
NRB	0.026 b ^x	4.39 b	0.95 b	5.34 b
RB	0.083 a	23.24 a	3.50 a	26.73 a
RBS	0.089 a	22.50 a	3.76 a	26.26 a
<i>P</i>	0.0009	0.0002	0.0031	0.0003

^zGrowth index = height $\times$ width 1 $\times$ width 2; $1 \text{ m}^3 = 35.3147 \text{ ft}^3$.

^y1 g = 0.0353 oz.

^xMeans representative of four single-plant replicates per sampling. Mean separations within columns using Fisher's protected least significant difference at $P < 0.05$. Means within a column with the same letter are not significantly different from one another.

Fig. 1. Effect of three root ball conditions on final growth indices of plumbago during 24 weeks of establishment and growth period in a landscape. Each point is the mean of four plants. Equations were fitted to each data set using SAS (version 9.1.3; SAS Institute, Cary, NC) and correlation coefficients (r^2) calculated ($1 \text{ m}^3 = 35.3147 \text{ ft}^3$).

Fig. 2. Effect of three root ball conditions on (A) total biomass, (B) shoot dry weight, and (C) root dry weight of plumbago during 24 weeks of establishment and growth in a landscape. Each point is the mean of four plants. Equations were fitted to each data set using SAS (version 9.1.3; SAS Institute, Cary, NC) and correlation coefficients (r^2) calculated (1 g = 0.0353 oz).

sampling artifact. Rapid growth using smaller transplant sizes has been reported for both herbaceous and woody ornamentals. Lauderdale et al. (1995) found smaller transplants of 'October Glory' red maple (*Acer rubrum*) produced better plant height, trunk diameter, and shoot elongation during posttransplant growth in a landscape. Shoot dry weight increases were greater for smaller marigold (*Tagetes erecta*) transplants after landscape installation (Latimer, 1991). Smaller pecan transplants increased in height 138% compared with a 48% increase for large transplants (Wood, 1996).

Although plants with fuller canopies provide better aesthetic appeal in the landscape, it is not the only criteria for plant selection. Our results indicate canopy sizes were comparable among root ball conditions within 2 to 3 months of transplant. Faster growth rates are beneficial during establishment because slower root growth has been associated with increased water stress that could increase supplemental irrigation demands (Beeson and Gilman, 1992; Montague et al., 2000).

Root ball slicing did not affect canopy size, total biomass, or shoot dry weight because growth rates were

similar between RB and RBS (Figs. 1 and 2A–B). Root dry weight accumulation rates were faster ($P < 0.05$) for RB compared with RBS (Fig. 2C). Our results concur with those of Blessing and Dana (1987) and Gilman et al. (1996). Struve (1993) also observed no effect of root ball slicing on shoot or trunk growth of trees after transplanting. Data indicate root ball slicing does not stimulate root or shoot growth and may be a wasteful practice under these conditions. Landscape service providers incur large expenses on labor wages (Hodges and Haydu, 2002; Hodges et al., 2001). Bypassing root ball

Table 2. Mean final growth indices, shoot dry weight, root dry weight, and biomass for plumbago subjected to three root ball conditions [nonroot-bound (NRB), root-bound (RB), and root-bound sliced (RBS)] harvested every 2 weeks after transplanting (WAT).

Treatment	Final growth indices (m ³) ^z											
	2 WAT	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT	14 WAT	16 WAT	18 WAT	20 WAT	22 WAT	24 WAT
NRB	0.021 b ^y	0.057 b	0.052 b	0.123 a	0.126 b	0.117 b	0.221 a	0.272 a	0.339 a	0.342 ab	0.408 a	0.409 a
RB	0.066 a	0.129 a	0.105 a	0.191 a	0.212 a	0.204 a	0.364 a	0.328 a	0.311 a	0.420 a	0.407 a	0.452 a
RBS	0.079 a	0.091 ab	0.109 a	0.131 a	0.208 a	0.186 ab	0.250 a	0.286 a	0.440 a	0.295 b	0.360 a	0.447 a
P	0.0083	0.0407	0.0319	0.1691	0.0213	0.0861	0.194	0.6316	0.2782	0.093	0.6117	0.9547
Shoot dry wt (g) ^x												
NRB	13.13 b	25.17 b	27.59 b	43.81 a	62.00 a	71.65 a	108.35 a	127.43 a	186.00 a	187.48 a	244.35 a	192.83 a
RB	29.58 a	39.26 a	39.93 a	62.26 a	81.23 a	93.63 a	110.15 a	110.43 a	123.13 a	182.40 a	193.68 ab	194.65 a
RBS	26.33 a	30.80 ab	38.32 ab	41.42 a	75.62 a	75.78 a	100.90 a	88.98 a	138.83 a	134.30 a	138.55 b	176.53 a
P	0.0045	0.0447	0.0779	0.2717	0.3167	0.3273	0.8816	0.2802	0.2867	0.1090	0.0072	0.9416
Root dry wt (g) ^x												
NRB	1.79 b	2.43 b	3.37 a	6.93 a	9.20 a	11.28 a	19.15 a	20.23 a	25.50 a	32.43 a	38.38 a	39.78 a
RB	3.95 a	4.86 a	6.02 a	8.14 a	11.24 a	16.07 a	19.35 a	18.18 a	20.00 a	26.48 a	29.83 b	36.23 a
RBS	4.14 a	4.50 a	5.38 a	5.95 a	9.15 ab	11.87 a	16.03 a	12.53 a	19.53 a	16.55 b	17.10 c	38.48 a
P	0.0425	0.001	0.1065	0.6258	0.2396	0.3116	0.6846	0.1876	0.4018	0.0059	0.0006	0.9368
Biomass (g) ^w												
NRB	14.92 b	27.60 b	30.96 b	50.74 a	71.20 a	82.93 a	127.50 a	147.65 a	211.50 a	219.90 a	282.73 a	232.60 a
RB	33.53 a	44.12 a	45.95 a	70.40 a	92.47 a	109.69 a	129.50 a	128.60 a	143.13 a	208.88 ab	223.50 a	230.88 a
RBS	30.47 a	35.30 ab	43.69 ab	47.37 a	84.77 a	87.65 a	116.93 a	101.50 a	158.35 a	150.85 b	155.65 b	215.00 a
P	0.0038	0.0247	0.0673	0.3023	0.3189	0.2937	0.8490	0.2535	0.2836	0.0666	0.0034	0.9586

^zFinal growth index = height × width 1 × width 2; 1 m³ = 35.3147 ft³.

^yMeans representative of four single-plant replicates. Mean separations within columns using Fisher protected least significant difference at $P < 0.05$. Means within a column with the same letters are not significantly different from one another.

^xShoot dry weight and root dry weight were calculated after 72 h of oven drying at 140 °F (60.0 °C); 1 g = 0.0353 oz.

^wBiomass = shoot dry weight + root dry weight.

manipulations may save time and money for the industry.

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