HRI's Mission:

To direct, fund, promote and communicate horticultural research, which increases the quality and value of ornamental plants, improves the productivity and profitability of the nursery and landscape industry, and protects and enhances the environment.

The use of any trade name in this article does not imply an endorsement of the equipment, product or process named, nor any criticism of any similar products that are not mentioned.

Research Reports

A Survey of the Depth of the Main Lateral Roots of Nursery Trees in Ohio Before and After Harvest[1]

Richard G. Rathjens[2], T. Davis Sydnor[2], and David S. Gardner[3]
School of Environment and Natural Resources
The Ohio State University, 2021 Coffey Road, Columbus, OH 43210

Abstract

Deciduous trees in Ohio were surveyed before harvest (seven nurseries) and after harvest (eight brokerage facilities) to determine the depth of their main lateral roots. Main lateral roots originate at the root-shoot junction in trees and are also referred to as the root flare or buttress roots. In the nursery survey, differences in the depth of main lateral roots were found among nurseries and production year with main lateral roots an average of 6.1 cm (2.4 in) deep in the soil profile. From the broker survey, both brokers and propagation methods showed differences in depth with an average of 8.6 cm (3.4 in) of excess soil over the main lateral roots. The main lateral roots for most trees were greater than 2.5 cm (1 in) in depth which was deeper than industry standards allow.

Index words: root depth, planting depth, excess soil, root flare.

Significance to the Nursery Industry

There is concern within the green industry about the number of established landscape trees that are declining or dying with excess soil over the main lateral roots. Death in the landscape is often delayed by a decade or more after planting. The excess soil over the roots may be deposited during production, harvest, landscape installation, or during the subsequent landscape maintenance. This has led to finger pointing among green industry segments and the need to identify where some of the excess soil might be deposited such that it can be corrected to prevent early decline and death from this cause.

[1]Received for publication August 2, 2006; in revised form June 22, 2007. This research project was funded in part by the Tree Research and Education Endowment Fund's Hyland R. Johns Grant Program and by the Davey Tree Expert Company, Kent, OH.

[2]Graduate Student and Professor of Urban Forestry, respectively.

[3]Assistant Professor of Horticulture and Crop Science, The Ohio State University, 2001 Fyffe Court, Columbus, OH 43210.

Two ideas are hypothesized. First, during the various stages of tree production, roots are planted and grown without excess soil over the root system. Second, if excess soil is placed over the main lateral roots during production, it is removed during harvest as required by industry standards (3).

Landscape and maintenance contractors would normally assume that trees are produced according to industry standards. Excess soil can be removed from the main lateral roots during landscape installation or during landscape maintenance if contractors knew that it was required. Costs to remove the excess soil will be ultimately borne by the final consumer and that cost will be a function of where corrections were being made. Consumers, of course would like to minimize costs to the extent possible.

Introduction

Patterson et al. (9) stated that 80% of shade tree disorders could be attributed to the tree's soil environment**.** One soil-

The *Journal of Environmental Horticulture* (ISSN 0738-2898) is published quarterly in March, June, September, and December by the Horticultural Research Institute, 1000 Vermont Avenue, NW, Suite 300, Washington, DC 20005. Subscription rate is $65.00 per year for scientists, educators and ANLA members; $95.00 per year for libraries and all others; add $25.00 for international (including Canada and Mexico) orders. Periodical postage paid at Washington, DC, and at additional mailing offices. POSTMASTER: Send address changes to Journal of Environmental Horticulture, 1000 Vermont Avenue, NW, Suite 300, Washington, DC 20005.

related cause of unhealthy trees in urban landscapes could be the depth of the main lateral roots.

Trees growing too deep in the soil profile can suffer several detrimental effects on plant growth and development including increased mortality, decreased growth, nutrient deficiencies, increased susceptibility to insect and disease attack and the formation of stem girdling roots (4, 5, 7 and 10).

Excess soil over the root system of trees is caused by a variety of practices including improper production and harvesting techniques as well as improper planting and landscape maintenance procedures (7). The fact that excess soil may be placed above main lateral roots at various times during plant production, installation and/or maintenance requires identifying when the root depth issue develops so that corrective measures can be taken. A main lateral root is defined as a root originating at the root-shoot junction in trees, growing mostly parallel to the soil surface. A main lateral root is composed of woody tissue whose function is to give structural stability to the plant. Main lateral roots are also reported as root flare or buttress roots.

The purpose of this study was to determine the impact of current nursery production practices on the depth of the main lateral roots from the soil surface. To accomplish this objective, trees growing in field nurseries were surveyed to determine if there was excess soil over the main lateral roots during production. If excess soil was present during production, brokerage facilities were surveyed to determine if nursery harvesting techniques removed the excess soil from balled and burlapped (B&B) trees during harvest.

Materials and Methods

Nursery survey. During the summer and fall of 2004, deciduous trees growing in several Ohio nurseries were surveyed to assess the impact of nursery production practices on the depth of main lateral roots. Nine nurseries were chosen at random for the survey. The nurseries were members of the Ohio Nursery and Landscape Association and had a gross annual sales volume of at least $1,500,000 (2). Larger firms were selected to ensure the diversity and quantity of trees needed for the survey. Even larger nurseries plant trees in blocks and dig several years from a large block before planting those same taxa again.

Trees propagated by seed, budding and cutting were included in the survey. Propagation method was determined by interviewing nursery growers and nursery suppliers. Sampling of trees by propagation method was done to determine if method of propagation influenced depth of the main lateral roots. For example, nurseries sometimes plant trees propagated by budding deep in the soil to hide the bud union to satisfy some retail purchasers who consider it unsightly (11).

In addition to propagation method, trees were surveyed based on time in production. At each nursery, the depth of the main lateral root was determined for trees in their first and third year of production. Trees ranged from branched whips in year one to trees up to 5 cm (2 in) caliper in their third year. Trees in the third year of production were chosen because faster growing species can be harvested within three years after planting in Ohio. The premise of sampling by production year would clarify if field cultivation caused an accumulation of soil on the root system over time (5).

The location of the main lateral root depth of each tree was determined by probing down into the soil immediately adjacent to the trunk using a surveyor's chaining pin. A surveyor's chaining pin (also called a taping arrow) is a metal rod about 31 cm (1 ft) long. It has a circular eye at one end and a point for pushing it into the ground at the other. The pin was inserted into the soil repeatedly around the trunk until main lateral roots were struck. The length of the pin below ground was used as a measure of the depth of the main lateral root. Two to four roots per plant were measured. The average depth of main lateral roots for each plant is reported. If the main lateral root was exposed at the soil surface, the depth was recorded as zero and no probing was done.

Ten trees were selected at random for each propagation method and production time resulting in 60 trees being surveyed per nursery. Taxa varied for propagation method and year of production depending on the inventory of the nursery being surveyed.

A nested experimental design was used with propagation methods and production times nested within nurseries. The measurements were subjected to an analysis of variance and means were separated using Fisher's Protected LSD at $\alpha = 0.05$ (1).

Broker survey. During the spring of 2004 and summer of 2005, B&B deciduous trees in brokerage facilities were surveyed for the depth of the main lateral roots in the root ball. Brokers or rewholesalers offer plants for sale to landscape contractors from a variety of nurseries. The identity of the nurseries supplying the brokers surveyed was not determined so as to represent brokers rather than suppliers. Ohio is a net importer of nursery stock; thus it is assumed that some of the stock surveyed came from other states.

The depth of the main lateral roots of trees planted in the nursery prior to harvest does not necessarily mean the depth will be the same when harvested. Some harvesting methods allow the depth of the main lateral roots in the root ball to be adjusted during harvest. Thus, it was necessary to survey plants after harvest and before planting in the landscape.

For this survey, brokerage firms were more difficult to identify than nurseries. To determine firms who were brokers, municipal arborists, nursery growers and brokers were asked to identify brokers operating in the state of Ohio. Only larger brokers who had fifteen or more trees propagated from seed, or by budding and cutting were included in the survey.

Sampled trees ranged in size from 4.4 cm (1.8 in) to 8.9 cm (3.5 in) caliper at the time they were surveyed. This is the size range of trees normally planted in Ohio landscapes.

The measurement of the depth of the main lateral roots was accomplished as described for the nursery grower survey. The only difference was that the chaining pin was first pushed through the burlap at the top of the root ball then into the soil. The burlap was pressed against the root ball in areas where multiple layers of burlap were not present.

As in the nursery grower survey, trees propagated by seed, budding, and cutting were included in the survey. Ten trees were selected at random for each propagation method resulting in 30 trees being surveyed for each broker. A nested experimental design was used with propagation method nested within brokers. The measurements were subjected to an analysis of variance and means were separated using Fisher's Protected LSD at $\alpha = 0.05$ (1).

Results and Discussion

Nursery survey. Two of the nine nurseries inspected did not have trees growing in their third year of production; there-

Table 1. Depth of main lateral roots of trees measured during production in seven Ohio nurseries.

Nursery	Root depth[z] (cm)
1	9.9a
2	7.6b
3	6.9bc
4	6.4c
5	4.8d
6	4.3d
7	2.3e
Avg.	6.1

[z]Means followed by different letters are significantly different from each other at the $\alpha = 0.05$ level using Fishers Protected LSD.

fore the main lateral root depth of trees in seven nurseries is reported.

The tree species most frequently used in the survey that were propagated by seed, budding, or cutting were pin oak, *Quercus palustris* Meunchh.; honeylocust, *Gleditsia triacanthos* L.; or red maple, *Acer rubrum* L., respectively.

The depth of the main lateral roots varied significantly among nurseries (Table 1). In fact differences among nurseries accounted for 63% of the total variation observed in this study. Since the main effects were dominant, the majority of the discussion will concentrate on main effects of nursery and production year (8).

The deepest main lateral root was 9.9 cm (3.9 in) surveyed at nursery 1, while nursery 7 had trees with the shallowest main lateral roots with a depth of 2.3 cm (0.9 in). The average root depth for all seven nurseries was 6.1 cm (2.4 in).

In Section 1.6.3 of the American Standard for Nursery Stock (3) it states *'Depth of the ball is measured from the top of the ball which in all cases shall begin at the root flare. Soil above the root flare shall not be included in ball depth measurement and should be removed.'* Thus, there should be no soil located above the root flare. In our survey, all nurseries had excess soil over the main lateral roots on average. All plants surveyed were growing vigorously and gave no indication of problems that might arise later in the landscape. However, trees with an average of 2.5 cm (1 in) or less of soil over the main lateral roots, as would be the case for nursery 7, would be acceptable from a practical standpoint. Allowing 2.5 cm (1 in) or less of soil would be permissible since removing all soil may result in mechanical damage to the main lateral roots.

There was no difference in depth to the main lateral roots among trees based on propagation method. Depth of the main lateral roots was 6.4, 6.1 and 5.6 cm (2.5, 2.4 and 2.2 in) for budded, cutting, and seedling trees, respectively.

A significant difference in the depth to the main lateral roots was found for production year. Trees in their first year of production had an average main lateral root depth of 6.6 cm (2.6 in) while trees in their third year of production averaged 5.3 cm (2.1 in). This finding suggests that rather than accumulating soil around the trees' base from cultivation, soil loss occurs. This could be attributed to erosion or weed management (hoeing) during nursery production.

Differences among propagation methods and production years were found within the same nursery (Figs. 1–3). For example, the main lateral roots were deeper for trees propagated by budding at nursery 1, cutting propagation at nursery 6, and seed propagation at nursery 3 (Fig. 1). Similarly, main lateral roots were deeper at nurseries 1, 4, and 6 in their first year than in their third production year (Fig. 2). The depth of the main lateral roots was also influenced by propagation method and production year. Main lateral roots were deeper for trees propagated from budding and cutting in their first production year (Fig. 3). The differences are most probably due to individual field management practices and years within nurseries and are not, necessarily, a reflection of Ohio nursery industry practices.

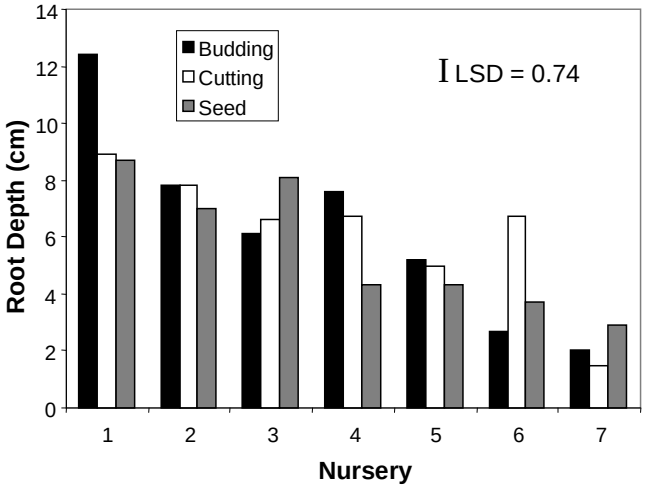

Fig. 1. Depth of main lateral roots of Ohio field grown nursery trees as influenced by nursery producer and propagation method. Bar denotes minimum significant difference for comparison across nurseries and propagation methods according to Fisher's LSD.

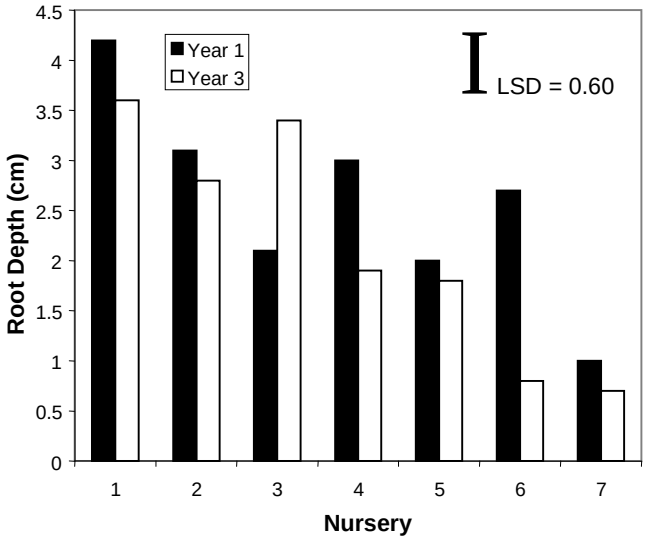

Fig. 2. Depth of main lateral roots of Ohio field grown nursery trees as influenced by nursery producer and years in production. Bar denotes minimum significant difference for comparison across nurseries and production years according to Fisher's LSD.

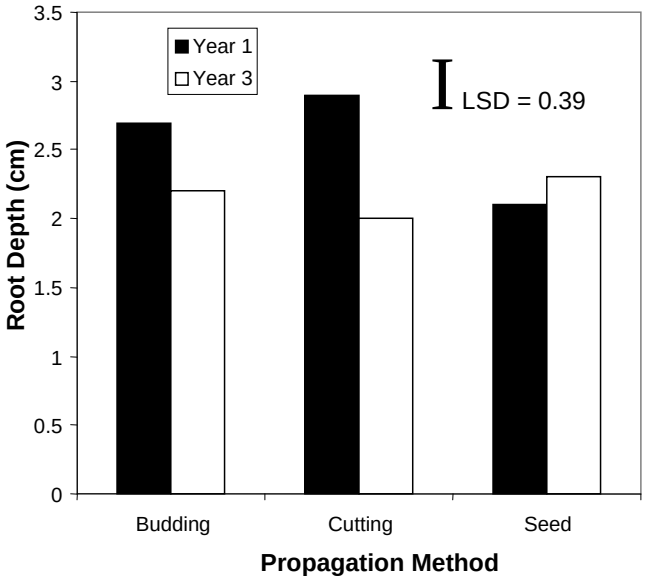

Fig. 3. Depth of main lateral roots of Ohio field grown nursery trees as influenced by propagation method and years in production. Bar denotes minimum significant difference for comparison across propagation methods and production years according to Fisher's LSD.

Broker survey. One of the nine brokers did not have trees representing all three propagation methods; therefore the main lateral root depth of only eight brokers is reported.

The genera most frequently used in the broker survey that were propagated from seed were the oaks. Honeylocust and Callery pear, *Pyrus calleryana* were the trees used most often for plants propagated by budding. Red maple was the tree most frequently measured for main lateral root depth for trees propagated by cutting.

A significant difference existed among brokers for the depth of main lateral roots within the root balls of B&B trees offered for sale (Table 2). The deepest main lateral root was 11.2 cm (4.4 in) below the burlap at broker 1. Brokers 7 and 8 had 6.9 cm (2.7 in) of excess soil over the main lateral roots. The average depth to the main lateral roots for all eight brokers was 8.6 cm (3.4 in). This would require that the excess soil be removed by the landscape contractor during planting and it is likely that the resulting root ball would not then meet industry standards for root ball depth, width, or volume.

Discussions with nursery owners indicated that adjusting the root depth during harvest was standard practice in their nurseries. To the contrary, comparison of the average main lateral root depth in the nursery [6.1 cm or (2.4 in)] with that obtained in the brokerage facility [8.6 cm or (3.4 in)] indicated a gain in depth of soil over the main lateral roots. The increase in excess soil over the main lateral roots from the nursery (pre-harvest) to the brokerage facility (post-harvest) suggests, at a minimum, that soil is not being removed during harvest by the suppliers represented on the brokerage facilities studied.

There was a significant difference among propagation methods in the broker survey. Trees propagated by cutting had a deeper main lateral roots [9.9 cm or (3.9 in)] than trees propagated by either budding [7.9 cm or (3.1 in)] or seed [7.9 cm or (3.1 in)]. Propagation and/or planting techniques used by a number of Ohio growers could offer a possible explanation for this result (6). To give vertical stability, individual cuttings are planted 7.6 to 10.2 cm (3 to 4 in) deep in a pot. After root initiation, the cutting is removed from the pot and planted in the field without removing the excess substrate over the root system.

Table 2. Depth of main lateral roots of B&B trees being offered for sale in Ohio brokerage locations after nursery harvest.

Broker	Root depth[z] (cm)
1	11.2a
2	10.1ab
3	9.1b
4	9.1bc
5	7.6cd
6	7.1d
7	6.9d
8	6.9d
Avg.	8.6

[z]Means followed by different letters are significantly different from each other at the $\alpha = 0.05$ level using Fishers Protected LSD.

Trees were growing vigorously in nursery production facilities and gave no indication of problems that may arise later in the landscape. Producers may not have made adjustments to production practices, because they do not see a production problem nor perceive the future landscape problem. The depth of the main lateral roots does not appear to be an issue until the trees has been planted in a landscape for a number of years. Arborists are the ones likely to be contracted to remove soil in the landscape and charge an average of $125 dollars per tree (data not shown) for this service.

Literature Cited

1. Anonymous. 1990. Statistical Analysis System. Version 6.12. SAS Institute, Cary, NC.

2. Anonymous. 2002. Ohio Nursery Stock Survey. Ohio Nursery Landscape Assoc., Westerville, OH. 348 pp.

3. Anonymous. 2004. American Standard for Nursery Stock ANSI Z60.1 — 2004. American National Standards Institute, Washington, DC. 113 pp.

4. Broschat, T.K. 1995. Planting depth affects survival, root growth, and nutrient content of transplanted pygmy date palms. HortScience. 30:1031–1032.

5. Browne, C. and K. Tilt. 1992. Effects of planting depth on three ornamental trees. Proc. Southern Nurserymen's Res. Conf. 37:123–125.

6. Hendricks, William. 2004. Personal communication. Managing Partner, Klyn Nurseries Inc. Perry, OH.

7. Johnson, G.R. and R.J. Hauer. 2000. A practitioner's guide to stem girdling roots of trees: Impacts on trees, symptomology and prevention. Univ. Minnesota Extension Bulletin BU-7501-S. 20 pp.

8. Keppel, G. and T.D. Wickens, 2004. Design and Analysis: A Researchers Handbook (4 ed.). Prentice-Hall, New York, NY. 624 pp.

9. Patterson, J.C., J.J. Murray, and J.R. Short. 1980. The impact of urban soils on vegetation. Proc. Metropolitan Tree Improvement Alliance 3:33–56.

10. Smiley, E.T. and D.C. Booth. 2000. Grown to die? Amer. Nurseryman. March 15, 2000. p. 48–50, 54, 55.

11. Starbuck, C.J. 2005. Bud unions are beautiful. Missouri Environ.Garden Newsletter. Univ. Missouri 11(1):3, 4, 7.