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Growth and stability of deep planted red maple and northern red oak trees and the efficacy of root collar excavations

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ABSTRACT

Trees with root systems established well below grade due to deep planting or soil disturbance are common in urban landscapes, yet the long term effects of buried trunks and subsequent remediation strategies, such as root collar excavation are poorly documented. We evaluated the consequences of deep planting over a 10-year period on tree growth and stability, with and without root collar excavation, for red maple [*Acer rubrum* L. Red Sunset® ('Franksred')] and Northern red oak (*Quercus rubra* L.) planted at grade or 30-cm below grade. Sleeves to prevent soil-trunk contact were installed around trunks on a subset of deep trees. Root collar excavations were made during the 6th growing season for both species and trees were grown for an additional 4 and 3 growing seasons for red maples and Northern red oaks, respectively. Within two weeks of root collar excavations, pulling tests compared the effect of treatments on stability of red maples. Deep planting generally slowed growth of red maple but had no clear effect on Northern red oak. Root collar excavation had no lasting effect on growth of either species. Approximately 55% of deep red maples and 33% of deep Northern red oaks had roots crossing and in intimate contact with buried trunks, suggesting a potential for future girdling roots. Approximately 25% of deep maples had substantial adventitious rooting. All deep Northern red oaks had new roots emerging just above the first original structural roots but none were clearly adventitious. Trunk sleeves had no effect on growth for either species. Neither deep planting nor root collar excavation resulted in a loss of tree stability compared to trees planted at grade, although failure patterns varied among treatments. Overall, the biggest long term concern for deep-planted trees is the potential for girdling root formation.

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1. Introduction

Tree decline associated with deep structural roots of amenity trees has long been a concern of arborists and landscape managers (Partyka, 1982; Berrang et al., 1985; Smiley, 1991; Watson et al., 2014; Gilman et al., 2015). Deep structural roots can be the result of nursery, planting, or grading practices, and the decline is thought to be a result of altered soil water conditions, poor aeration, girdling roots against buried trunks, or increased likelihood of disease. Concerns over the apparent wide-spread incidence of deep structural roots and a dearth of significant published research led to the creation of a national (USA) working group in 2004 to address the issue, resulting in a focused research effort by a national green industry working group and a Best Management Guide (Watson, 2005a,b). Much of the work by this group as well as causes and concerns are synthesized in a review by Day et al. (2009).

The early adverse effects of deep planting of landscape trees is most likely due to altered watered relations, either because irrigation or rainfall may not adequately reach the deep roots or hypoxic conditions resulting from poor soil and high water tables are present deep in the soil profile (Berrang et al., 1985; Gilman and Grabosky, 2004; Harris, 2007; Bryan et al., 2010; Bryan et al., 2011). Wet soils increasingly restrict oxygen diffusion from the atmosphere into root zones as soils become more saturated, eventually resulting in depravation for respiring roots (Currie, 1962, 1983). Good aeration of the root zone is a critical factor in overall tree growth (Gaertig et al., 2002; Weltecke and Gaertig, 2012). Compacted soils exacerbate oxygen deficiency since the small pores retain water (Currie, 1984). Soil that is well drained and above the water table most likely supports adequate oxygen diffusion (Day

Abbreviations: σ, bending stress; τ, shear stress; l, lever arm length.

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and Bassuk, 1994; MacDonald et al., 2004), allowing for good root growth of deep trees. New roots of established trees that were planted deep will likely grow upward and remain at similar depths to roots of trees planted at grade, and these deep trees may be as vigorous as trees originally planted at grade (Day and Harris, 2008). However, roots of deep trees may grow back across buried trunks regardless of their vigor, (Wells et al., 2006; Day and Harris, 2008; Harris and Day, 2010), resulting in girdling of trunks and raising concern about future tree decline. In addition to concern over girdling roots, direct contact between trunk and soil on a deep planted tree is thought to damage bark and lead to infection from soil-borne diseases such as *Phytopthora* and *Armillaria* root rots. Drilias et al. (1982) found that *Fusarium* and *Phytopthora* species commonly related to sugar maple decline were associated with deep planted trees. These concerns have led, in part, to the widespread use of "root collar excavations" by arborists. This procedure removes soil from around the trunk of trees down to where the root flare is visible. Eastern white pine (*Pinus strobus* L.), sugar maple (*Acer saccharum* Marsh.), and dogwood (*Cornus florida* L.) are among those thought to especially benefit from these excavations (Smiley, 1992). These species are sensitive to poor drainage, suggesting that benefits observed after root collar excavations could be related to improved oxygen availability in the soil. In addition, root collar excavations have been effective for treating deep-planted wine grapes showing symptoms of *Armillaria* infestation (Baumgartner, 2004). Although research reports are scarce, root collar excavations are a common remediation process.

Although concern over the decline of deep-planted urban trees has been noted for over thirty years (Partyka, 1982), there are few reports from long term controlled experiments on tree vigor and no reports on how deep planting affects tree stability. Gilman and Grabosky (2011) reported on live oak (*Quercus virginiana* Mill.) trees that were planted with root flares up to 18 cm deep and saw no effect of planting depth on trunk or height growth after five growing seasons in Florida. In Virginia, Day and Harris (2008) found no effect of planting depth on Turkish hazelnut (*Corylus columa* L.) Trees 7 years after planting with root flares up to 30-cm deep but showed that a flooding event adversely affected the deep trees. Both studies noted potential trunk-girdling roots on the deep trees, many of which arose from the rootball (i.e. non adventitious roots).

Our objectives for this study were to test the long term effect of deep planting and root collar excavations on growth and stability of two common amenity tree species in the eastern United States The study that we present below contains data from ten growing seasons for red maple and nine growing seasons for Northern red oak.

2. Materials and methods

Red maple trees, originally 2-m tall, branched bare-root trees obtained from J. Frank Schmidt and Son nursery (Boring, OR) and grown for an additional 1.5 growing seasons at the Urban Horticulture Center near Virginia Tech's campus in Blacksburg, VA, were transplanted from 55 cm-diameter (trade 50 l) containers with pine bark substrate on 14 June 2004. Four treatments were arranged in a completely random statistical design. Treatments were: (1) top of rootballs at grade (G), (2) top of rootballs 30 cm below grade (D), (3) top of rootball 30 cm below grade with a "trunk sleeve" installed (DS, see below), and (4) same as Treatment 2 but designated for root collar excavation in 2009 (DX). Ten additional trees were designated for root collar excavations to observe adventitious rooting and potential for girdling roots and were not included in the growth and stability assessment. Trunk sleeves for DS were constructed from thin-walled PVC sewer pipe (35-cm long and 15-cm diameter). Pipe sections were cut length-wise into two sections and were rejoined around trunks extending from rootballs upwards with duct tape. Sleeves effectively kept soil from touching trunks and were a potential conduit of oxygen from the surface to soil below grade.

Trees were planted in single nursery rows with rows and individual plants spaced approximately 4 m and 2.5 m apart, respectively. There were 10 trees per treatment (total = 40). For DX, root collars were excavated between 23 June and 1 July 2009. Soil was removed with a Supersonic Air Knife (Allison Park, PA) to a depth of 30 cm (i.e. top of the rootball), with a bottom diameter of 30 cm and diameter at grade of 80 cm, resembling a truncated cone. Nursery bed areas were fertilized annually in March with 1.5 kg N/100 m^2 (3 lb/1000 ft^2) broadcast evenly across planting beds throughout the experiment. Red maple beds were mulched with approximately 4 cm of shredded hardwood bark soon after planting and replenished once approximately 1 year later with pine bark chips. Planting beds were kept weed free thereafter by hand weeding and spot spraying with glyphosate herbicide.

A corollary experiment was conducted with Northern red oaks. Trees were obtained from J. Frank Schmidt and Son nursery as lightly branched, bare-root, 1-m tall seedlings in February 2005 and held in cold storage until planting on 11 April 2005. Treatments, replications, and cultural information were the same as described above for red maples, except stability tests were not conducted and trees were mulched soon after planting with approximately 4 cm of pine chips. Planting depth was measured from approximately 1 cm above the first structural root on the bare-root oak trees. Root collars were excavated on 29 July 2010. Irrigation for all trees of both species was applied periodically during drought periods (no significant rainfall for 3 weeks) with a manually operated micro-spray system.

The effect of treatments on tree stability (i.e. root anchoring and trunk strength) was tested in a conventional pulling test (Alvey et al., 2009) on a subset of 5 randomly selected trees from each of the 4 treatments on 7–8 July 2009. A 12-V winch (XD 9000i, Warn Industries, Inc., Clackamas, OR) bolted to the bucket of a skid-steer loader (Bobcat® S185, Bobcat Co., Gwinner, ND) applied the load to each tree at a height of 30 cm above grade. Peak load was measured at 60 Hz with a Dillon EdXtreme lad cell (Weigh-Tronix, Fairmont, MN). The peak load (P) was used to calculate bending (σ) and shear (τ) stress in the trunk (considered as a circular cross-section) using Eqs. (1) and (2) respectively:

$$\sigma = 32Pl/(\pi d^3) \quad (1)$$

$$\tau = 16P/(3\pi d^2) \quad (2)$$

Values of d (trunk diameter) and l (lever arm length) were adjusted for three locations at which σ and τ were calculated: just above the root flare, and 15 cm and 30 cm above the root flare. The value of l was 30 cm greater for trees in D, DS, and DX than G because they were planted 30 cm below grade. At 30 cm above the root flare, σ was not calculated for G trees because $l = 0$. Applying loads 30 cm above the soil line minimized trunk deflection, which was visually estimated during each test. Trees were pulled until failure or, for 6 trees that did not fail, until it was visually obvious that the trunk was bending enough to reduce l. Trunk taper was calculated in the 30 cm above the base as the difference between diameter at base and diameter at 30 cm divided by 0.30 m. Volumetric soil moisture was measured on the day of testing.

Trunk circumference 30 cm above soil line was measured on all trees immediately after planting and annually in November throughout the experiment (2004–2013). Circumference values were converted to trunk cross-sectional area, assuming the trunk was a circle. Data were natural log transformed and analyzed by multivariate repeated measures analysis in the GLM procedure of SAS (version 9.3; Cary, NC). Failures (stress test) were characterized