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Evaluating Root Crown Excavation as a Treatment for Deeply-Planted Landscape Trees

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Abstract. An experiment was conducted over a four-year period to evaluate root crown excavation (RCE) as a treatment for deeply-planted landscape trees. Tree growth, leaf chlorophyll, stress, and pest activity were monitored to determine plant response to RCE. Four of the sites, including shingle oak (*Quercus imbricaria* Michx.) street median strip trees, blue spruce (*Picea pungens* Engelm.) park trees, and honeylocust (*Gleditsia triacanthos* L. var. *inermis* (L.) Zab.) parking lot island and street trees failed to show any influence of RCE on tree growth and leaf chlorophyll. Two sites with maple (*Acer spp*.) park and street trees where RCE included removal of potential girdling roots resulted in a detrimental effect on twig extension and leaf chlorophyll. Measurements of chlorophyll on ash (*Fraxinus* spp.) park trees, and tree height and twig extension on lacebark elm (*Ulmus parvifolia* Jacq.) street trees, demonstrated a positive influence of RCE. The RCE treatment did not influence stress or pest activity at any of the experimental sites. Since tree disorders frequently require many years to develop it is speculated that a longer observation period may be necessary to see a greater impact of RCE on plant growth and health.

Key Words. Deeply-Planted; Main Lateral Root; Root Crown Excavation; Root Flare; Trunk Flare.

It has been suggested that 80% of shade tree disorders can be attributed to the soil environment (Patterson et al. 1980). One soil-related cause of unhealthy trees in urban landscapes can be the deep planting of a tree's root system.

The tree care industry is becoming increasingly aware of the problem of trees growing too deep in the soil profile. Surveys of parkway trees (Watson et al. 1990) and nursery trees (Rathjens et al. 2007) underscore the widespread nature of the problem. Likewise, research has shown that deeply-planted trees suffer detrimental effects on plant growth and development including increased mortality, decreased growth, nutrient deficiencies, and the formation of stem girdling roots (Browne and Tilt 1992; Broschat 1995; Arnold et al. 2005; Wells et al. 2006).

Among the options for the remediation of deeply-planted trees are replanting and root crown excavation (Watson 2005). The replanting option is recommended for recently planted trees and is limited to trees that have experienced no more than two to three months of root growth. Root crown excavation (RCE) is generally performed on established landscape trees. Root crown excavation involves the removal of excess soil from a tree's root (trunk) flare and main lateral roots. This treatment can be performed by hand digging or by water or air excavation. Many tree care professionals perform RCE using air excavation. This method uses compressed air, directed to the soil surface through a handheld wand and nozzle. The high-pressure airstream breaks up and removes excess soil.

Some arborists offer testimonials that RCE treatment to unhealthy trees results in improved growth and health. However, little research exists to support the practice of RCE. The present research evaluates potential benefits and risks of RCE treatment for landscape trees with excess soil on the root flare and main lateral roots.

MATERIALS AND METHODS

Site Description

During the autumn of 2003 and spring of 2004, an experiment was initiated to determine the effect of RCE on landscape trees that had excess soil on the root flare and main lateral roots. The experiment was performed at eight sites. A description of the sites including the locations, planting areas, tree species, number of trees, age of planting, and plant depth are outlined in Table 1.

The experiment was conducted in the state of Ohio, which is in the Midwestern United States. The sites were located in three cities including Cincinnati in southwestern Ohio, Dublin in central Ohio, and Strongsville in northeast Ohio. The planting areas included trees planted along city streets, in a public park, and in automobile parking areas.

The sites included six tree genera. Most individual sites contained a single tree species. At the Dublin park site however, the ash and maple trees were first identified as green ash (*Fraxinus pennsylvanica* Marsh.) and red maple (*Acer rubrum* L.). Subsequent examination identified the ash planting as a mixture of green and white ash (*Fraxinus americana* L.) and the maple planting as a mixture of red and Freeman (*Acer* × *freemanii*). Many of the planting sites contained forty trees. The age of the planting (time since the trees were installed) at the time of treatment ranged from 0.5 to 9 years. Considering the average life of a tree, the plants at the sites could be considered in a juvenile stage of growth.

Plant depth was determined by probing down into the soil immediately adjacent to the trunk. Depth to the uppermost lateral roots for the eight sites ranged from 6.8 cm (2.7 in) to 20.3 cm (8 in). The amount of soil over the root system is consid-

Table 1. Description of the Ohio root crown excavation experimental sites.

Location	Planting area	Tree species	Number of trees	Age of planting years	Plant depth cm Mean (SD)
Cincinnati	Street median strip	Shingle oak (*Quercus imbricaria* Michx.)	30	2	8.8 (3.5)
Cincinnati	Street tree	Lacebark elm (*Ulmus parvifolia* Jacq.)	20	9	6.8 (3.5)
Dublin	Park	Ash species (*Fraxinus* spp.)	40	0.5	16.2 (4.5)
Dublin	Park	Maple species (*Acer* spp.)	40	0.5	20.3 (6.0)
Dublin	Park	Blue spruce (*Picea pungens* Engelm.)	40	0.5	10.1 (6.0)
Strongsville	Parking lot island	Honeylocust (*Gleditsia triacanthos* L. var. *inermis* (L.) Zab.)	20	6	13.7 (3.8)
Strongsville	Street tree	Honeylocust (*Gleditsia triacanthos*)	20	5	11.6 (3.3)
Strongsville	Street tree	Hedge maple (*Acer campestre* L.)	40	1	17.7 (4.5)

SD = Standard Deviation.

ered excessive by both nursery and green industry standards (American National Standards Institute 2004; Watson 2005).

The name and the taxonomic class for the soil in each of the sites is provided in Table 2. The soil at the Dublin location was a silt loam soil (Soil Survey Staff 2009). The remainder of the locations contained highly disturbed soils typical of many urban tree plantings.

The experiment was conducted in cooperation with municipal arborists or horticulturalists. During the experimental period, municipal arborists maintained the trees. All trees received applications of mulch every 1–2 years. In addition, some trees, including the Cincinnati shingle oak and the Strongsville honeylocust, received periodic fertilizer and/or pesticide treatments as determined by the municipality. Approximately 1.5 years after the initiation of the treatment, the excavated areas were inspected. At this time, soil, fallen tree leaves, and grass clippings were removed from the excavated area using hand tools.

Tree mortality during the experiment was low with the exception of two sites. Eighteen percent of the Cincinnati shingle oak and 20% of the hedge maple trees in Strongsville died or were removed due to automobile accidents, construction, or poor health.

ROOT CROWN EXCAVATION

For most of the sites, the RCE was performed in the early spring of 2004. The only exception was in Cincinnati, where the trees were excavated in the autumn of 2003.

Local commercial arborists performed the RCE treatment using air excavation. Either an Air Knife® (Easy Use Air Tools Inc., Allison Park, PA) or an Air-Spade® (Air-Spade, Guardair Corp., Chicopee, MA) air excavation tool was used, the brand varying with the provider. Excess soil was removed from the root flare and in a 45.7 cm (18 in) radius outward from the trunk. The goal of the treatment, was to remove enough soil so the top of root system, or the highest main lateral roots were at the soil surface while minimizing the disruption to the appearance and function of the landscape. The area was kept as bare ground for the entire experimental period following the excavation. Control trees did not receive RCE and were left untreated.

Immediately following the RCE, potential girdling roots were removed from the trees. Generally, only one to two roots per tree were removed using hand pruners. Removal of potential girdling roots was only necessary for the

Table 2. Name and taxonomic class of the soils in the Ohio root crown excavation experiment.

Location	Planting area	Soil name	Taxonomic class
Cincinnati	Street median strip	Urban land-Martinsville complex	Fine-loamy, mixed, active, mesic Typic Hapludalfs
Cincinnati	Street tree	Urban land-Stonelick complex	Coarse-loamy, mixed, superactive, calcareous, mesic Typic Udifluvents
Dublin	Park	Crosby silt loam	Fine, mixed, active, mesic Aeric Epiaqualfs
Strongsville	Parking lot island, Hedge maple street tree	Mahoning-Urban land complex	Fine, illitic, mesic Aeric Epiaqualfs
Strongsville	Honeylocust street tree	Udorthents, loamy	Loamy, mixed, mesic Typic Udorthents

maple trees at the Dublin and Strongsville sites. Approximately 20% of the Dublin trees and 90% of the Strongsville trees required removal of potential girdling roots.

Parameters Measured

To determine the effect of RCE on trees too deep in the soil profile, measurements were made of tree growth, leaf chlorophyll, stress, and pest activity. To quantify the effect of RCE on growth, four annual measurements were made, including trunk diameter, tree height, canopy width, and twig extension. Trunk diameter was measured at 1.4 m (4.5 ft) above ground [diameter at breast height (DBH)]. Height was obtained by measuring the distance from the soil's surface to highest point on the tallest vertical branch. Canopy width was determined by measuring the distance between the ends of the widest horizontal branches on either side of the tree. For twig extension (growth), twigs were selected at random from the canopy at 1.5 m (5 ft) to 3 m (10 ft) above ground. The current season's twig extension was obtained by measuring the distance between the tip of a twig and the first ring of bud scale scars. Previous year's twig extension was estimated by measuring the distance between subsequent annual bud scale scars. A single growth measurement was taken per tree except twig extension where three measurements were taken and averaged. All growth measurements except twig extension are reported as an increase in growth. Increase in growth was calculated by subtracting the previous year's total dimension from the current year's total dimension. For example, if a tree's height was 7 m (23.1 ft) in 2005 and 8 m (26.4 ft) in 2006, an increase in height of 1 m (3.3 ft) was recorded; and if the same tree was 8.5 m (28.0 ft) in 2007, 0.5 m (1.6 ft) was recorded.

To determine the effect of RCE on chlorophyll, leaf chlorophyll was measured using a CCM-200 Chlorophyll Content Meter (Opti-Sciences, Hudson, NH). The meter does not directly measure chlorophyll but gives relative chlorophyll values by measuring the amount of energy absorbed in the red light waveband. The readings were taken in summer during July and August. Three leaves per tree were randomly chosen from the canopy at 1.5 m to 3 m above ground and measured for chlorophyll with average chlorophyll being reported.

During the early summer of 2004, the maples at the Dublin location displayed early fall color. The change in leaf color was attributed to transplant shock. The trees were visually rated for fall color on a numeric scale of one to five. A rating of one was assigned to a tree whose leaves had red color and a rating of 5 assigned to leaves having green color. In the late summer of 2007, the shingle oaks at the Cincinnati location showed scorch symptoms due to drought. A visual rating of the scorch was taken on a numeric scale of one to five. A rating of one represented a tree whose leaves were brown in color while a rating of five was leaves with normal green color. Thus with both stress ratings, higher numbers represent healthier trees.

Also at the Dublin location, the blue spruce trees experienced infestations of spider mite (*Oligonychus ununguis* Jacobi) and bagworm (*Thyridopteryx ephemeraeformis* Haworth). For the mites, the trees were visually rated for the percent of foliage discolored by the mite infestation. For the bagworms, a count of the number of bags per tree was taken.

Experimental Design and Statistical Analysis

The trees at each test site were randomly assigned to one of two treatments. One-half of the trees received RCE while the other half (controls) did not receive RCE. A completely randomized experimental design was used for each site. The measurements were subjected to an analysis of variance [ANOVA (SAS Institute 1990)]. Depending on the site, thirteen to nineteen total measurements of growth, leaf chlorophyll, stress, and pest activity were taken from 2004–2007.

RESULTS AND DISCUSSION

After four years, four of the eight sites showed no difference in growth or leaf chlorophyll between trees receiving the RCE treatment and the control trees. The sites showing no effect from RCE included the Cincinnati shingle oak, Dublin blue spruce, and the Strongsville honeylocust trees (Tables 3–6). Likewise the RCE treatment did not influence drought stress experienced by the Cincinnati shingle oak or spruce mite or bagworm severity for the Dublin blue spruce trees.

Response to the RCE treatment was observed at the remaining four sites. At the Dublin location, three growth and chlorophyll measurements (three of 16 total growth, chlorophyll and stress measurements) suggested that maple trees treated with RCE had less growth and chlorophyll than control trees (Table 7). While some responses to RCE occurred for growth and chlorophyll, RCE did not influence the stress measurements taken for the Dublin maple park trees. A similar result occurred at the Strongsville location (Table 8) with the hedge maple where control trees had greater twig extension and higher leaf chlorophyll readings (3 of 14 total growth and chlorophyll measurements). The poorer growth and reduced chlorophyll with the RCE treatment may be attributed to the removal of girdling roots present at the time of treatment. Removal of potential stem girdling roots on trees in both communities may have subjected the maples to moisture stress causing a reduction in growth rate and chlorophyll.

The 2006 chlorophyll measurements for the ash trees at the Dublin location demonstrated greater chlorophyll for the trees that received the RCE treatment when compared to those who did not (Table 9). The 2006 chlorophyll values represent one measurement of 14 total growth and chlorophyll measurements made through the experimental period. Likewise for the Cincinnati lacebark elm, trees that received the RCE treatment had greater growth (two of 16 total growth and chlorophyll measurements) than those that did not (Table 10).

Seventy-five percent of the sites showed either no effect or a detrimental effect from the RCE treatment. This occurred in spite of the fact that the trees in this experiment had excessive soil over the root system according to industry standards. Tree disorders frequently take many years to manifest themselves. For example, the constricting effect of girdling roots does not become evident until the trees are in a landscape for three to 15 years (Harris 1992). Perhaps given a longer observation period following the root crown excavation, the impact of RCE would be more evident.

Table 3. Growth, chlorophyll and stress measurements for the Cincinnati shingle oak trees with and without root crown excavation.

Growth[z]/chlorophyll/stress measurement[y]	Treatment	
	Excavation Mean (SD)	No excavation Mean (SD)
2004 trunk diameter (cm)	0.7 (0.4)	0.6 (0.3)
2005 trunk diameter (cm)	1.0 (0.5)	0.8 (0.3)
2006 trunk diameter (cm)	0.8 (0.5)	0.7 (0.4)
2007 trunk diameter (cm)	0.7 (0.2)	0.7 (0.2)
2005 tree height (cm)	32.5 (26.9)	21.7 (25.1)
2006 tree height (cm)	22.3 (29.2)	19.5 (35.0)
2007 tree height (cm)	53.9 (35.3)	40.6 (34.0)
2005 canopy width (cm)	20.3 (27.4)	15.2 (33.2)
2006 canopy width (cm)	36.5 (44.9)	41.3 (37.0)
2007 canopy width (cm)	51.5 (38.1)	44.0 (34.4)
2003 twig extension (cm)	8.3 (6.4)	6.1 (5.6)
2004 twig extension (cm)	13.1 (10.9)	14.2 (11.0)
2005 twig extension (cm)	10.2 (5.7)	9.5 (4.8)
2006 twig extension (cm)	9.9 (5.8)	10.4 (6.1)
2007 twig extension (cm)	9.5 (8.1)	9.0 (4.4)
2005 chlorophyll	23.4 (8.2)	25.2 (6.8)
2006 chlorophyll	24.4 (10.0)	25.7 (9.0)
2007 chlorophyll	26.4 (10.4)	21.7 (6.1)
2007 leaf scorch[x]	3.0 (1.8)	3.1 (1.6)

[z] Growth measurements except twig extension are increase in growth from the previous year.

[y] Analysis of variance not significant at $P < 0.05$ or $P < 0.01$ for any measurement.

[x] Scale of 1–5; 1 = brown leaves, 5 = green leaves.

SD = Standard deviation.

Table 4. Growth, chlorophyll and pest activity measurements for the Dublin blue spruce trees with and without root crown excavation.

Growth[z]/chlorophyll/pest activity measurement[y]	Treatment	
	Excavation Mean (SD)	No excavation Mean (SD)
2005 trunk diameter (cm)	1.0 (0.7)	1.0 (0.6)
2006 trunk diameter (cm)	0.1 (0.1)	0.1 (0.2)
2007 trunk diameter (cm)	0.5 (0.4)	0.6 (0.6)
2005 tree height (cm)	35.0 (11.1)	35.0 (26.6)
2006 tree height (cm)	18.3 (15.3)	27.2 (22.4)
2007 tree height (cm)	25.9 (17.9)	20.8 (17.7)
2005 canopy width (cm)	27.4 (19.5)	19.8 (17.9)
2006 canopy width (cm)	9.1 (17.4)	13.7 (18.4)
2007 canopy width (cm)	18.3 (18.2)	15.2 (18.5)
2004 twig extension (cm)	9.5 (2.7)	8.6 (3.2)
2005 twig extension (cm)	9.2 (2.2)	9.4 (3.2)
2006 twig extension (cm)	8.9 (2.6)	9.0 (3.4)
2007 chlorophyll	1.3 (0.4)	1.2 (0.4)
2004 mite injury (%)	16.0 (17.5)	24.2 (20.9)
2006 bagworm (no.)	18.6 (35.9)	4.4 (7.5)

[z] Growth measurements except twig extension are increase in growth from the previous year.

[y] Analysis of variance not significant at $P < 0.05$ or $P < 0.01$ for any measurement.

SD = Standard deviation.

Table 5. Growth and chlorophyll measurements for the Strongsville honeylocust parking lot trees with and without root crown excavation.

Growth[z]/chlorophyll measurement[y]	Treatment	
	Excavation Mean (SD)	No excavation Mean (SD)
2005 trunk diameter (cm)	0.8 (0.2)	0.8 (0.4)
2006 trunk diameter (cm)	0.4 (0.2)	0.4 (0.2)
2007 trunk diameter (cm)	0.3 (0.2)	0.7 (0.5)
2005 tree height (cm)	8.3 (14.2)	10.1 (21.5)
2006 tree height (cm)	16.6 (28.4)	33.8 (38.6)
2007 tree height (cm)	24.9 (35.5)	13.5 (22.1)
2005 canopy width (cm)	27.7 (46.1)	50.8 (37.3)
2006 canopy width (cm)	36.0 (38.1)	27.1 (23.8)
2007 canopy width (cm)	2.7 (9.1)	10.1 (21.5)
2004 twig extension (cm)	24.1 (12.6)	23.6 (12.8)
2005 twig extension (cm)	13.4 (8.9)	16.3 (12.9)
2006 twig extension (cm)	12.9 (9.3)	11.2 (9.5)
2006 chlorophyll	23.7 (10.7)	29.1 (12.7)

[z] Growth measurements except twig extension are increase in growth from the previous year.

[y] Analysis of variance not significant at $P < 0.05$ or $P < 0.01$ for any measurement.

SD = Standard deviation.

Table 6. Growth and chlorophyll measurements for the Strongsville honeylocust street trees with and without root crown excavation.

Growth[z]/chlorophyll measurement[y]	Treatment	
	Excavation Mean (SD)	No excavation Mean (SD)
2005 trunk diameter (cm)	0.7 (0.3)	0.7 (0.3)
2006 trunk diameter (cm)	0.4 (0.2)	0.5 (0.2)
2007 trunk diameter (cm)	0.4 (0.2)	0.3 (0.3)
2005 tree height (cm)	27.1 (28.3)	27.7 (21.3)
2006 tree height (cm)	40.6 (59.0)	38.8 (65.5)
2007 tree height (cm)	6.7 (13.4)	0.0 (0.0)
2005 canopy width (cm)	60.9 (54.9)	66.5 (50.6)
2006 canopy width (cm)	6.7 (13.4)	11.0 (15.3)
2007 canopy width (cm)	47.4 (37.6)	38.8 (23.9)
2004 twig extension (cm)	26.4 (12.3)	27.5 (11.4)
2005 twig extension (cm)	20.3 (9.7)	17.8 (9.2)
2006 twig extension (cm)	23.8 (8.0)	21.0 (8.0)
2006 chlorophyll	27.4 (9.3)	24.3 (9.4)

[z] Growth measurements except twig extension are increase in growth from the previous year.

[y] Analysis of variance not significant at $P < 0.05$ or $P < 0.01$ for any measurement.

SD = Standard deviation.

Table 7. Growth, chlorophyll and stress measurements for the Dublin maple trees with and without root crown excavation[z].

Growth[y]/chlorophyll/stress measurement	Treatment	
	Excavation Mean (SD)	No excavation Mean (SD)
2005 trunk diameter (cm)	0.6 (0.3)	0.8 (0.7)
2006 trunk diameter (cm)	0.7 (0.3)	0.6 (0.4)
2007 trunk diameter (cm)	0.1 (0.2)	0.1 (0.2)
2005 tree height (cm)	13.6 (20.8)	19.7 (22.6)
2006 tree height (cm)	17.6 (23.3)	15.2 (23.1)
2007 tree height (cm)	20.9(21.4)	16.0 (18.5)
2005 canopy width (cm)	13.6 (15.5)	19.7 (14.8)
2006 canopy width (cm)	25.5 (23.2)	19.7 (20.3)
2007 canopy width (cm)	15.1 (33.2)	12.7 (25.4)
2004 twig extension[x] (cm)	4.9 (3.8)	8.0 (6.3)
2005 twig extension[w] (cm)	5.1 (3.5)	7.0 (5.6)
2006 twig extension (cm)	10.8 (8.5)	8.8 (11.3)
2005 chlorophyll	14.7 (5.4)	13.6 (4.9)
2006 chlorophyll	20.2 (7.2)	19.0 (4.7)
2007 chlorophyll[x]	9.3 (5.5)	15.1 (11.1)
2004 early fall color[v]	4.0 (0.7)	4.0 (0.7)

[z] Root crown excavation included girdling root removal for approximately 20% of the trees.

[y] Growth measurements except twig extension are increase in growth from the previous year.

[x] Analysis of variance significant at $P < 0.01$.

[w] Analysis of variance significant at $P < 0.05$.

[v] Scale of 1–5; 1 = red leaves, 5 = green leaves.

SD = Standard deviation.

Table 8. Growth and chlorophyll measurements for the Strongsville hedge maple trees with and without root crown excavation[z].

Growth[y]/chlorophyll measurement	Treatment	
	Excavation Mean (SD)	No excavation Mean (SD)
2005 trunk diameter (cm)	0.5 (0.4)	0.6 (0.4)
2006 trunk diameter (cm)	0.3 (0.4)	0.6 (0.5)
2007 trunk diameter (cm)	0.4 (0.3)	0.6 (0.6)
2005 tree height (cm)	24.4 (18.7)	21.3 (22.3)
2006 tree height (cm)	12.5 (18.8)	13.7 (18.4)
2007 tree height (cm)	36.5 (32.9)	27.1 (23.1)
2005 canopy width (cm)	25.9 (22.7)	27.4 (27.7)
2006 canopy width (cm)	10.7 (18.4)	24.3 (33.6)
2007 canopy width (cm)	24.4 (23.6)	33.8 (38.9)
2004 twig extension (cm)	9.5 (8.4)	10.8 (11.5)
2005 twig extension (cm)	19.9 (12.4)	21.4 (13.3)
2006 twig extension[x] (cm)	15.0 (12.8)	21.3 (19.1)
2006 chlorophyll[w]	19.6 (5.1)	23.7 (6.2)
2007 chlorophyll[w]	23.5 (6.4)	28.0 (6.9)

[z] Root crown excavation included girdling root removal for approximately 90% of the trees.

[y] Growth measurements except twig extension are increase in growth from the previous year.

[x] Analysis of variance significant at $P < 0.05$.

[w] Analysis of variance significant at $P < 0.01$.

SD = Standard deviation.

Table 9. Growth and chlorophyll measurements for the Dublin ash trees with and without root crown excavation.

Growth[z]/chlorophyll measurement	Treatment	
	Excavation Mean (SD)	No excavation Mean (SD)
2005 trunk diameter (cm)	0.7 (0.3)	0.9 (0.4)
2006 trunk diameter (cm)	0.6 (0.3)	0.5 (0.2)
2007 trunk diameter (cm)	1.0 (0.9)	0.9 (1.1)
2005 tree height (cm)	24.3 (18.7)	31.9 (23.0)
2006 tree height (cm)	16.7 (20.8)	21.2 (28.0)
2007 tree height (cm)	36.4 (21.1)	33.4 (19.4)
2005 canopy width (cm)	18.2 (22.9)	30.4 (22.0)
2006 canopy width (cm)	21.2 (17.3)	15.2 (18.4)
2007 canopy width (cm)	25.8 (26.5)	33.4 (23.9)
2004 twig extension (cm)	6.5 (4.5)	5.6 (3.1)
2005 twig extension (cm)	8.5 (4.4)	7.7 (6.2)
2006 twig extension (cm)	8.6 (7.6)	6.5 (4.9)
2006 chlorophyll[y]	37.8 (7.5)	34.5 (8.7)
2007 chlorophyll	24.1 (8.5)	25.0 (10.2)

[z] Growth measurements except twig extension are increase in growth from the previous year.

[y] Analysis of variance significant at $P < 0.05$.

SD = Standard deviation.

Table 10. Growth and chlorophyll measurements for the Cincinnati elm trees with and without root crown excavation.

Growth[z]/chlorophyll measurement	Treatment	
	Excavation Mean (SD)	No excavation Mean (SD)
2005 trunk diameter (cm)	1.9 (0.7)	1.8 (1.3)
2006 trunk diameter (cm)	2.4 (3.4)	0.8 (0.5)
2007 trunk diameter (cm)	0.8 (0.5)	0.8 (0.6)
2005 tree height (cm)	2.7 (9.1)	24.3 (34.6)
2006 tree height[y] (cm)	155.4 (77.9)	54.8 (79.7)
2007 tree height (cm)	6.10 (12.8)	115.8 (173.4)
2005 canopy width (cm)	155.1 (63.1)	118.8 (64.9)
2006 canopy width (cm)	57.9 (85.5)	27.4 (33.5)
2007 canopy width (cm)	45.7 (45.9)	36.5 (60.6)
2004 twig extension (cm)	17.3 (10.0)	13.7 (7.1)
2005 twig extension (cm)	11.3 (4.5)	12.1 (3.9)
2006 twig extension (cm)	9.2 (5.9)	9.2 (5.6)
2007 twig extension[x] (cm)	17.6 (7.6)	13.4 (5.7)
2005 chlorophyll	33.6 (9.7)	32.3 (11.8)
2006 chlorophyll	34.7 (12.7)	31.3 (9.4)
2007 chlorophyll	29.7 (12.3)	28.3 (7.2)

[z] Growth measurements except twig extension are increase in growth from the previous year.

[y] Analysis of variance significant at $P <0.01$.

[x] Analysis of variance significant at $P <0.05$.

SD = Standard deviation.

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Résumé. Une expérimentation a été menée sur une période de quatre ans afin d'évaluer l'excavation de à la couronne des racines comme traitement pour les arbres ornementaux plantés profondément. La croissance de l'arbre, la chlorophylle foliaire, le degré de stress et l'activité des parasites ont été suivis afin de déterminer la réponse de la plante à ce traitement. Quatre des sites, incluant celui des chênes imbriqués (*Quercus imbricaria* Michx.) plantés en terre-plein de rue, celui des épinettes du Colorado (*Picea pungens* Engelm.) plantés dans un stationnement, celui des féviers (*Gleditsia triacanthos* L. var. inermis (L.) Zab.) plantés dans un îlot de stationnement ainsi que le long des rues, n'ont démontré aucune réaction par rapport à la croissance de l'arbre et la chlorophylle foliaire suite au traitement d'excavation à la couronne des racines. Deux sites avec des érables (*Acer* spp.) plantés en stationnement et le long des rues où le traitement a été appliqué, incluant l'enlèvement des racines strangulantes potentielles, ont connu des effets négatifs sur l'élongation des rameaux et la chlorophylle foliaire. Les mesures de chlorophylle chez les frênes (*Fraxinus* spp.) plantés le long des rues, ainsi que celles de la hauteur de l'arbre et de l'élongation des rameaux sur les ormes à petites feuilles (*Ulmus parvifolia* Jacq.) le long des rues, ont montré une influence positive reliée au traitement. Le traitement d'excavation à la couronne des racines n'a pas influencé le degré de stress ou l'activité des parasites sur aucun des sites expérimentaux. Du fait que les désordres sur les arbres requièrent souvent plusieurs années pour se développer, on peut spéculer qu'une observation sur une plus longue période pourrait être nécessaire pour voir un plus grand impact du traitement d'excavation à la couronne des racines sur la croissance et la santé de la plante.

Zusammenfassung. Wir führten über 4 Jahre ein Experiment durch, um die Wurzeltellerfreispülung (RCE) als eine Behandlung für zu tief gepflanzte Straßenbäume zu bewerten. Baumwachstum, Blattchlorophyll, Stress, und Krankheitserreger wurden überwacht, um die Reaktion des Baumes auf die Behandlung zu bestimmen. An vier Standorten, einschließlich *Quercus imbricaria* Michx. Mittelstreifenbepflanzung, *Picea pungens* Engelm. Parkbäume und *Gleditsia triacanthos* L. var. *inermis* (L.) Zab. Parkplatzinselbepflanzung und Straßenbäume zeigte sich kein Einfluss der RCE-Behandlung auf das Baumwachstum und Blattchlorophyllgehalt. Zwei Standorte mit *Acer* spp.) Park- und Straßenbäumen, wo die Wurzelfreispülung auch ein Entfernen von Würgewurzeln beinhaltete, zeigten einen nachteiligen Effekt auf das Trieblängenwachstum und Blattchlorophyllgehalt. Die Chlorophyll-Messungen bei Eschen im Park und die Messungen von Baumhöhe und Trieblänge bei Ulmenstraßenbäumen demonstrierte einen positiven Einfluss von der Wurzelfreispülung. Die RCE-Behandlung hatte an keinem untersuchten Standort einen Einfluss auf Stress oder Krankheitsbefall. Da Baumkrankheiten mitunter einen langen Zeitraum brauchen, um sich auszubreiten, wird vermutet, dass eine längere Observationszeit vonnöten sei, um einen größeren Einfluss von der RCE- Behandlung auf das Pflanzenwachstum und Gesundheit festzustellen.

Resumen. Se condujo un experimento en un período de cuatro años para evaluar excavaciones en la corona de la raíz (ECR) como un tratamiento para árboles plantados profundamente. El crecimiento del árbol, clorofila de la hoja, estrés, y actividad de las plagas fueron monitoreados para determinar la respuesta de las plantas a ECR. Cuatro de los sitios, incluyendo árboles de encino (*Quercus imbricaria* Michx.) en calles estrechas; árboles de pinabete azul (*Picea pungens* Engelm.) en parques; y acacias aisladas (*Gleditsia triacanthos* L. var. *inermis* (L.) Zab.) en parqueaderos y árboles de calles fallaron para mostrar cualquier influencia de ECR en el crecimiento del árbol y la clorofila de la hoja. Dos sitios con maple (*Acer* spp.) en parques y calles donde el ECR incluyó la remoción de raíces potencialmente estranguladoras resultó en un efecto perjudicial en la extensión de los tallos y clorofila de la hoja. Las mediciones de clorofila en árboles de fresno (*Fraxinus* spp.) en parques, y altura de los árboles y extensión de los tallos en árbol de olmo chino (*Ulmus parvifolia* Jacq.) en calles, demostró una influencia positiva de ECR. El tratamiento ECR no influyó en el estrés o actividad de plagas en cualquiera de los sitios experimentales. Debido a que los desórdenes de los árboles requieren muchos años para desarrollarse se especula que un período de observación prolongado puede ser necesario para ver mayor impacto de ECR en el crecimiento y salud de las plantas.