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Gary Watson
Landscape Below Ground IV: Introduction to a Special Issue 237

Abstract. This special issue is dedicated to research presented at the 2018 Landscape Below Ground IV conference. We describe highlights from the ten original research articles included in this issue. With these articles, we aim to support the advancement of tree care practices and inform managers and policymakers to choose, site, plant, and care for healthier, longer-lived trees by focusing on their critical and vulnerable root systems and the soil that surrounds them.

Keywords. Anchorage; Infrastructure; Root Development; Site Design; Stability; Tree Planting and Establishment.

Gregory M. Moore, Alicia Fitzgerald, and Peter B. May
Soil Compaction Affects the Growth and Establishment of Street Trees in Urban Australia....... 239

Abstract. Growing conditions for street tree roots are generally harsh with restricted space and soils compacted from streetscape infrastructure. *Allocasuarina littoralis, Corymbia maculata, Cupressus sempervirens* var. *stricta, Eucalyptus polyanthemos, Lophostemon confertus, Olea europaea*, *Quercus palustris*, and *Waterhousea floribunda* were grown in compacted and uncompacted soils for 20 months in experimental blocks. The bulk density and penetrative resistance of the soils and height, canopy spread, trunk diameter, leaf area, and chlorophyll fluorescence were measured regularly. Root and shoot biomass were determined after harvesting. Since the bulk density of compacted compared to uncompacted soil was root growth limiting, it was hypothesised that species would have reduced growth in compacted soils. However, *C. maculata* and *E. polyanthemos* grew better, *C. sempervirens*, *Q. palustris*, and *W. floribunda* grew well, and *A. littoralis*, *L. confertus*, and *O. europaea* were the worst performing in compacted soil. *E. polyanthemos*, *L. confertus*, and *Q. palustris* had higher canopy:root ratios in compacted soil. *Q. palustris* had greater mass below ground than above, which has implications for its use in confined sites. In a field study, *C. maculata, E. polyanthemos, L. confertus, O. europaea*, and *Q. palustris* growing as street trees were surveyed to determine their rates of establishment and growth under urban conditions. In addition to the soil and tree parameters mentioned above, a Visual Tree Assessment (VTA) was undertaken. *E. polyanthemos* had the largest trunk diameter, height and canopy spread, indicating its potential for rapid establishment in streets. It was the only species with a larger mean leaf area in compacted soil. *E. polyanthemos* and *O. europaea* were the only species classed as healthy from chlorophyll fluorescence but there was no significant difference in fluorescence between compacted and uncompacted soils. VTA showed that *C. maculata* and *O. europaea* performed best and that *E. polyanthemos, L. confertus*, and *Q. palustris* had reduced but acceptable growth in compacted soil. Soils ranged from non-saline to moderately saline and were slightly to strongly acidic. All soils were compacted to some degree and penetrative resistance was at root limiting levels. The results suggest that careful species selection and soil amelioration for species prone to the effects of compaction would facilitate street tree establishment.

Keywords. Australian Street Trees; Soil Compaction; Street Tree Establishment; Street Tree Growth.

Angela Hewitt, Frank Balestri, Marvin Lo, and Gary Watson
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Keywords. Root Growth; Oxygen; Waterlogging.

Gary Johnson, Chad Giblin, Ryan Murphy, Eric North, and Aaron Rendahl
Boulevard Tree Failures During Wind Loading Events.......... 259

Abstract. Wind loading events vary in their intensity and degree of damage inflicted on urban infrastructure, both green and gray. Damage to urban trees can begin with wind speeds as low as 25 miles per hour, especially when those trees harbor defects that predispose them to structural failures. The tree damage triangle integrates the three main factors that influence tree failures during wind loading events, namely the site characteristics, the (wind) loading event and any defects of the trees in question. The degree of damage that trees experience is generally a function of these factors overlapping each other. For instance, when the potential damage from wind loading events is exacerbated by poor tree architecture and compromised site conditions, the likelihood of significant damage is realized. Two studies on the damage to urban trees and the predictability of damage are reviewed; one study is a long-term gathering of wind loading events and accompanying damage to trees while the other is a case study of one storm in one city on one day. Both studies revealed critical pre-existing conditions that left trees vulnerable to whole tree losses: large trees in limited boulevard widths and severed roots as a result of sidewalk repair.

Keywords. Construction Damage; Tree Architecture; Wind Loading Events.

Jason W. Miesbauer, Andrew K. Koeser, Gary Kling, Gitta Hasing, and Marvin Lo
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Keywords. Bending Moment; Photogrammetry; Root Architecture; Tree Biomechanics; Tree Physiology; Tree Planting.

Andreas Detter, Philip J. E. van Wassenaer, and Steffen Rust
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Keywords. Partial Uprooting; Pulling Test Method; Restabilization; Storm Damage; Tree Biomechanics.

Jason Grabosky
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Keywords. Edge Effect; Wind Exposure; Zone of Rapid Taper.

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Keywords. Ground Penetrating Radar; Porous Asphalt; Root Growth; Shoot Growth; Structural Soil; Urban Trees.

E. Thomas Smiley, James Urban, and Kelby Fite
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Keywords. Cornell Soil; Gravel-Based Structural Soil; Limited Soil Volume; Sand-Based Structural Soil; Structural Soil; Suspended Pavement; Urban Tree Planting.

Gregory M. Moore, Susan Bendel, and Peter B. May
Root Penetration of Polyvinyl Chloride (PVC) Stormwater and Sewer Pipes 315

Abstract. Two experiments investigated factors influencing root penetration of polyvinyl chloride (PVC) pipes. *Eucalyptus leucoxylon, Allocasuarina littoralis, Lophostemon confertus, Callistemon salignus, Acer palmatum*, and *Pyrus calleryana* seedlings were grown in containers containing 150-mm lengths of sealed 75-mm PVC stormwater pipe with cracks 0.04 mm, 0.66 mm, or 1.48 mm wide on their upper surface. The buried pipes contained water, water and stormwater, soil, or soil and stormwater. There were six replicates and 432 plants. There was no significant difference in the mass of roots entering the pipes for the two larger crack widths with 70% of pipes penetrated and strong growth inside the pipes. While the roots of all species penetrated cracks greater than 0.66 mm, only roots of *C. salignus, E. leucoxylon*, and *L. confertus* penetrated 0.04 mm cracks. Roots penetrated 50 to 60% of pipes containing soil, or soil and stormwater, and 40% of pipes containing water, or water and stormwater were penetrated. The plants with roots penetrating pipes containing water and stormwater grew tallest. No roots penetrated the welded caps of the stormwater pipes. A second experiment using *E. leucoxylon, Melaleuca ericifolia, Ficus macrophylla, A. littoralis*, and *Salix fragilis* investigated root penetration of different sized holes in polycarbonate plates. The plates, installed in containers with growing medium above and below, had either 2 × 4 mm holes, 8 × 2 mm holes, 127 × 0.5 mm holes, or a mixture of holes (1 × 4 mm, 2 × 2 mm and 32 × 0.5 mm holes), total pore area in all being 25.14 mm^2. Below the plates, the growing medium was capillary irrigated with stormwater or water. All species grew through 0.5-mm holes and had strong root growth below the plates. When irrigated with stormwater, all species were taller and had greater biomass, and most species had a greater root mass below the plates. In general and regardless of hole size, the more holes in the plates, the more roots penetrated them. Properly installed PVC pipes are impenetrable, but the width and number of openings in a pipe influence the capacity for penetration and subsequent root growth so protocols minimizing damage to pipes should be enforced. Since species have different capacities for penetrating stormwater pipes, appropriate species selection for urban environments where damaged pipes may occur could reduce incidences of pipe damage.
Keywords. Root Penetration; PVC Pipes; Tree Roots and Pipes; Street Trees and Pipes.

Kelby Fite, Liza Holmes, and Elden LeBrun
Comparing the Missouri Gravel Bed and a Wood Chip Production Method for Tree Growth 328

Abstract. Tree root defects from current nursery production practices influence short- and long-term tree performance and survivability. The Missouri Gravel Bed (MGB) system, a production method using gravel as a substrate, has been used to prevent many of these defects from occurring. MGB production involves planting bare root stock into a bed of gravel with frequent drip irrigation in order to produce a root system with relatively few defects. MGB production methods have also been purported to allow for summer transplanting of many species, as opposed to traditional dormant transplanting.

Because gravel has low water- and nutrient-holding capacity, biochar (5% by volume) was incorporated into one plot as a possible means of improving both water- and nutrient-holding capacity over gravel alone. Wood chip mulch was also investigated as a growing substrate in place of the gravel in a growing system. In 2015, three species, *Quercus bicolor* (swamp white oak), *Taxodium distichum* (baldcypress), and *Tilia cordata* (littleleaf linden), were studied in pea gravel (PG), biochar-amended pea gravel (BC), and wood chip mulch bed (MB) growing environments. Very few differences occurred over the growing season with above- or belowground parameters indicating that the minimal-to-no-cost, more readily available substrate of wood chip mulch should be considered in these growing systems.

Keywords. Bare Root; Biochar; Irrigation; Root Growth; Tree Planting; Tree Production.