

Soil Aeration Systems--Do they really improve tree root zone conditions under fill and paving?

Karen Townsend, Donald Ham, Ansel Miller, and Timothy Chesnut
Department of Forestry, Clemson University

Abstract

Documented successes of soil aeration systems use in the field appear to conflict with results of a controlled, scientific investigation on the effect of fill on tree welfare. In this two-year study of white pines subjected to 20 cm of fill and pavement-like surface cover over the root zone, conditions under fill alone were not severe enough for any "improved" effect to be noticed from the use of an aeration system with fill. Soil/atmosphere air exchange was only slightly altered and tree physiological processes remained largely unchanged. These results underscore the need for further quantitative studies of conditions created by various fill and paving procedures to better ascertain the usefulness of elaborate and expensive aeration systems.

Introduction

Soil aeration systems are routinely recommended by urban tree care experts when construction plans call for raising the grade around a tree. The theory behind these systems of ventilation pipes and porous fill is that they facilitate better gas exchange between the root zone and atmosphere than fill soil alone. Gas exchange is essential to tree function because roots, during the process of respiration, utilize O₂ present in soil macropores and in turn, release CO₂. Under normal conditions, most soil/atmosphere exchange of CO₂ for O₂ occurs when water saturates the soil macropores and flushes soil air out. As water drains from the saturated soil, new air is drawn into the macropores. Anaerobic conditions develop when exchange is inadequate, causing roots to lose their ability to absorb nutrients and water and to lack the vigor necessary for new soil exploration. Above ground, photosynthesis rates decline, stomata close, and shoot growth slows. Studies have shown that this deterioration of tree health occurs when root zone O₂ content falls below 10% (2).

Compacted soils, or those covered by materials such as asphalt and soil fill, present a barrier to water infiltration and consequently to gas exchange within the root zone. Yelenosky (4) compared soil air composition under fill and paving to that of an undisturbed site. In the undisturbed forest, soil air consisted of no less than 18% O₂ and no greater than 2% CO₂. In contrast, the soil surrounding trees under clay fill was very poorly aerated, with O₂ contents as low as 1% and CO₂ contents over 20%. Anaerobic conditions also developed rapidly in soils subjected to compaction and asphalt paving, with O₂ content dropping from 20% to 4% in two weeks.

Soil aeration systems, consisting of various configurations of piping and porous fill, have been proposed as a means of maintaining air circulation at the original soil surface under nonporous surfaces or deep fills (1 and 3). Harris (1) recommended an aeration system with the following components: a tree well wall encircling the tree trunk to prevent fill from coming in contact with the base of the tree, load-bearing geotextile fabric spread on the original soil surface to lend even support to the weight of the fill, a horizontal grid system of perforated pipes connected together and vented to the tree well and final fill surface, a layer of gravel fill surrounding the pipes, and finally a second layer of geotextile fabric between the gravel and soil fill to prevent the layers from mixing.

Scientific and Case Study Results

Individual cases of tree survival following grade increases in which soil aeration systems were incorporated, are often held up as testament to the effectiveness of these systems. The number of these successes paints a convincing picture. However, soil aeration systems have not yet been subjected to thorough scientific scrutiny. Other urban tree care measures, such as cavity filling and wound painting, were also founded on "conventional wisdom" and widely accepted by a public that felt that doing "something" was an improvement over no treatment at all. Just as scientific study proved those techniques ineffective, research may show aeration systems to be equally questionable.

A two-year, controlled field study of aeration systems was conducted on 11-year old white pines (*Pinus strobus*) growing in a plantation near Clemson, South Carolina. Trees without fill were compared to those whose root zone grade had been raised 6 to 8 inches by 6 tons of fill. Clayey subsoil fill, having no components of an aeration system, was compared to crushed rock fill (Figure 1), with and without aeration piping. All fill treatments contained the load-bearing geotextile base recommended by Harris (1) and a top surface cover of water-repellent geotextile and tar paper, intended to simulate the water-shedding properties of asphalt paving.

Anaerobic conditions under the fill treatments were less severe than anticipated (Table I). Soil fill reduced O₂ and increased CO₂ content slightly, but not nearly enough to produce concentrations unfavorable to tree growth and development. Soil aeration under rock fill, with and without piping, was equivalent to that of trees with no fill or covering.

Physiological processes of the trees were largely unaffected by the fill and cover treatments. Treated and untreated trees were equally active photosynthetically and produced similar amounts of shoot growth. Measurements of predawn water potential of the foliage showed that treated trees received an adequate supply of water in spite of the water-shedding tar paper which covered their root zones. Predawn potential, an indicator of root zone water availability, ranged from -3 to -9 Bars throughout the growing season, but was consistent among treated and untreated trees on individual days of measurement. Water was not a limiting growth factor, as some of the highest photosynthetic rates appeared on days when predawn potential was lowest.

Why did these fill treatments not produce the severe conditions observed by Yelenosky (4)? As a simulation of construction site conditions, this study differed from most actual situations in several important ways. Study trees were treated individually with islands of fill and "paving" surrounding them. Hence, the study trees may have gained some access to air and water at the outer edges of the treatment areas, while a tree located within a vast parking lot would have little advantage from edge effects.

Another confounding factor observed on construction sites but not addressed in this study is the effect of soil compaction on root zone aeration. Fill materials were placed on load-bearing geotextile fabric with a front-end loader which stayed outside of the treatment areas. Consequently, significant compaction did not occur. Soil bulk densities beneath the fill were low--averaging 1.08 g cm⁻³ with pore space comprising 59% of soil volume. Although similar precautionary measures can be taken in actual practice, soils are often so compacted prior to fill application by other construction activities that soil aeration is already limited. This was probably the case in Yelenosky's study where measurements were taken in soils under fill layers that had been rolled and packed down with grading equipment in preparation for asphalt paving.

Confounding factors and the limited scope of this study make it difficult to give conclusive statements regarding the usefulness of soil aeration systems. Further studies must first be designed and conducted which address the following factors: varying species tolerance to poor soil aeration,

effects from greater depths and different types of fill, and soil compaction's role in aeration problems. The results thus far seem to indicate, however, that fill may not be as large of a culprit in creating poor soil conditions and tree decline as the other damaging activities that normally accompany it. Perhaps more important than the actual soil aeration system in insuring a tree's survival following grade changes is the increased level of care and protection from damage afforded to that valued tree on the construction site.

Literature Cited

1. Harris, R.W. 1992. *Arboriculture: Integrated Management of Landscape Trees, Shrubs, and Vines*, 2nd Edition. Englewood Cliffs, New Jersey: Prentice Hall.
2. Kozlowski, T.T. 1985. "Soil aeration, flooding, and tree growth." *Journal of Arboriculture*. 11(3): 85-96.
3. Schoeneweiss, D.F. 1982. "Prevention and Treatment of Construction Damage to Shade Trees." *Journal of Arboriculture*. 8(7): 169-175.
4. Yelenosky, G. 1963. "Soil aeration and tree growth." *International Shade Tree Conference Proceedings*. 40:127-147.

Table 1. Average percent soil air composition by volume within the root zones of *Pinus strobus* treated with crushed rock or soil fill.

Soil Air Constituent	Percent by Volume		
	Control	Rock Fill	Soil Fill
Carbon dioxide	0.25	0.26	0.58*
Oxygen	20.60	20.47	20.18

*denotes significant difference from the control.