A NEW LOOK AT THE IMPACT AND MANAGEMENT OF FILL SOIL AROUND TREES

By Laurence R. Costello and Susan D. Day

Topics in Plant Health Care is a regular column, featuring information on pests, beneficials, and Plant Health Care practices. If you have a topic you'd like to see in the future or if you wish to submit something, contact Ian Wilson at iwilson@city.kelowna.bc.ca.

Figure 1. To establish a level surface for new buildings, fill soil (approximately 4 feet deep) was placed over the root zone of these pines (*Pinus* spp.), and wells were not installed. Needle necrosis and tree decline occurred a few months after fill installation.

Figure 2. Fill was placed on one side of this incense cedar (*Calocedrus decurrens*) following construction of the building in the background. Although a well was installed, the tree canopy thinned extensively and some branch dieback occurred. It is not known whether soil compaction or root injury occurred during fill installation.

In this month's column, the authors review relevant research findings on the topic of fill soil. Conducting a "literature review" allows a researcher to examine literature pertinent to a selected topic. For an explanation of why literature reviews are important to practicing arborists, please see the article on page 30.

The placement of fill soil around established trees has been viewed generally as having a negative impact on tree health. Fill is thought to act as a barrier to the diffusion of atmospheric oxygen into the root zone, causing an aeration deficit that impairs root function. To prevent or minimize aeration deficits, aeration systems have been prescribed when fill soils are installed. However, recent research studies and field observations have provided indications that a new look at the impact and management of fill soil around trees is warranted. This article addresses conflicting evidence regarding the impact of fill on tree health, discusses the possible causes of injury following a fill event, describes factors that may contribute to the severity of an impact, and provides suggestions for the management of fill.

DOES FILL HAVE AN IMPACT ON TREE HEALTH?

Field observations provide conflicting views of the impact of fill on tree health. In some cases, trees appear to be severely affected (Figures 1 and 2); in other cases, little or no damage is evident (Figure 3). In one case, injury was not evident after

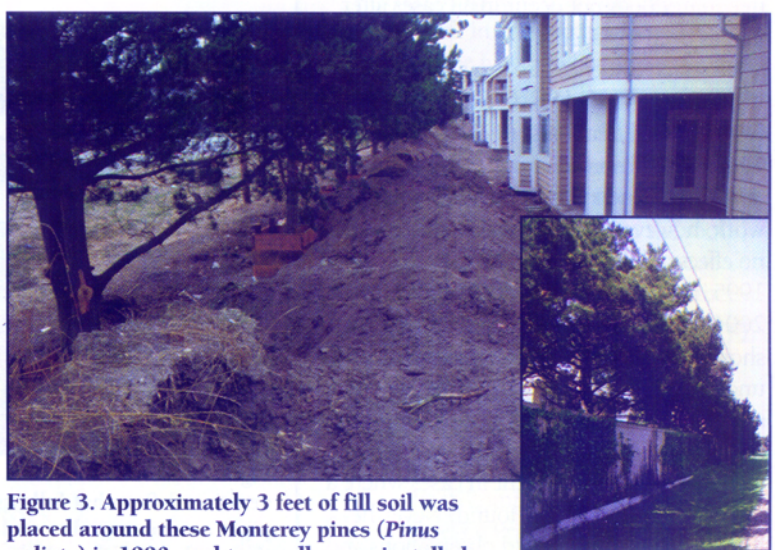

Figure 3. Approximately 3 feet of fill soil was placed around these Monterey pines (*Pinus radiata*) in 1990, and tree wells were installed. After 14 years, the trees appear to be in good condition (inset), although their growth rate is less than that expected for Monterey pine at this site.

►

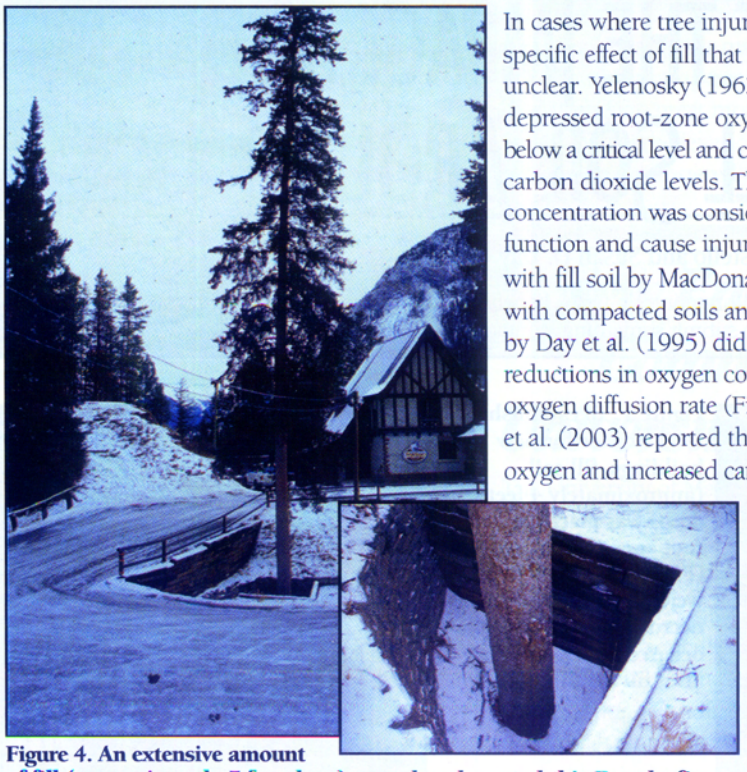

Figure 4. An extensive amount of fill (approximately 7 feet deep) was placed around this Douglasfir (*Pseudotsuga menziesii*) during road construction and site development in Alberta, Canada. The tree is estimated to be 80 years old, and the fill and tree well (inset) were installed approximately 20 years ago. Despite the severity of the fill event, the tree appears to be in good condition.

7 feet of fill soil was placed over the entire root zone of an established tree (Figure 4). Species and site conditions vary in observational assessments, however, and certain factors other than fill that contribute to tree injury may be present in one case and not in another. Nonetheless, indications are that tree injury does not occur in all cases after fill has been installed.

Research evidence also provides a conflicting assessment. Early research by Yelenosky (1963) found that forest trees were severely injured by fill spread over their root zones during construction of a road. In more recent work, however, studies have found little or no effect of fill on tree health (Smith et al. 1995; Day et al. 2001; MacDonald et al. 2004). Both mature and juvenile trees have shown similar responses to compacted and uncompacted fill. Again, however, species and site conditions were not equivalent across these studies. Factors critical to tree injury may not have been present in cases where a negative impact was not found. Nevertheless, it is evident from field observations and from research that injury does not always follow a fill event.

Specific Effects of Fill

In cases where tree injury has occurred, the specific effect of fill that leads to injury is unclear. Yelenosky (1963) reported that fill depressed root-zone oxygen concentration below a critical level and concurrently increased carbon dioxide levels. This change in gas concentration was considered to impair root function and cause injury. However, studies with fill soil by MacDonald et al. (2004) and with compacted soils and aeration systems by Day et al. (1995) did not find significant reductions in oxygen concentration or the oxygen diffusion rate (Figure 5). Townsend et al. (2003) reported that "soil fill reduced oxygen and increased carbon dioxide slightly but not nearly enough to produce concentrations unfavorable for tree growth and development." In all three studies, the authors questioned the role of soil aeration deficit as the key factor causing tree injury and indicated that other factors may play an equally important role. Specifically, altered water relations, soil compaction, and mechanical injury to roots were noted as possibly having an equal or greater effect on tree health than aeration.

In two of these studies, restricted water percolation through the fill into the base soil was thought to play a role in fill-induced injury. Day et al. (2001) reported that the base soil was drier than the fill, presumably because of poor water infiltration through the fill layer (Figure 6). MacDonald et al (2004) reported difficulty applying a sufficient amount of water to wet the base soil: Copious amounts were needed over an extended period of time to reach field capacity. It is possible that water deficit in the root zone resulting from restricted water percolation into the base soil may be an important factor contributing to fill-induced tree injury.

Fill soil contact with trunk tissues is an additional factor to consider. It has been observed that infections by pathogens and decay fungi occur under such conditions. Harris et al. (2004) noted that placing fill over trunks of trees is ill advised because gas exchange is disrupted and because many trees are subject to collar rot if the trunk remains moist. In California, oak root fungus (*Armillaria mellea*) infections are not uncommon when fill soil has been placed in contact with the trunk of mature oaks (*Quercus* spp.). The effect of soil on trunk tissues may be an area for which tree species plays an important role, however. In a follow-up to their fill study, Day et al. (2001) observed that trunk tissue of sweetgum (*Liquidambar styraciflua*) appeared healthy and normal under fill soil, while trunk tissues of white oak (*Quercus alba*) appeared soft, light, and "punky."

In addition to disease, wood decay and structural strength loss may be an important consequence to consider. In examining trees that failed during Hurricane Fran in North Carolina, Smiley et al. (1998) reported that 33 percent of all trees that failed had fill soil above buttress roots, while only 8 percent of trees that did not fail (control group) had fill soil. It appears that fill soil placed in contact with tree trunks contributed to

Figure 5. Aeration systems often are specified to counteract a perceived aeration deficit that follows a fill event. Here, multiple vertical aeration pipes are connected to underlying horizontal pipes that radiate out from the tree base. Although this system is thought to improve aeration status in the root zone, research has not supported a positive impact of similar systems on oxygen concentration or oxygen diffusion rate in the root zone.

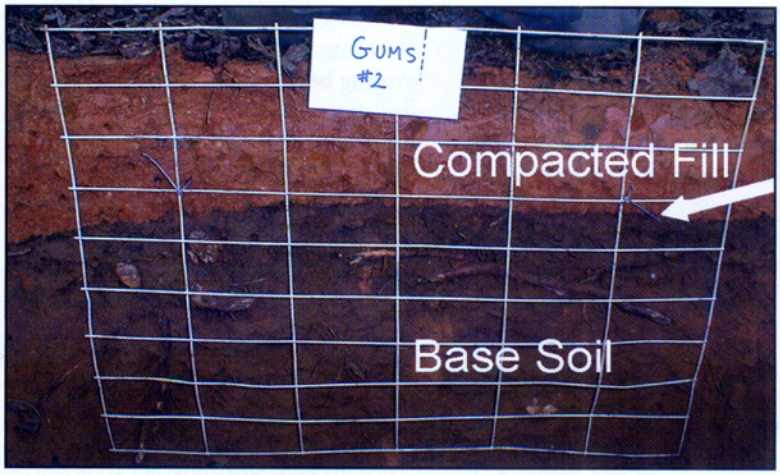

Figure 6. Moisture in the root zone may be affected by fill soils. Here, the underlying soil is relatively dry compared to the overlying fill. The difference in soil texture between the fill and base soil might have restricted water movement into the base soil. In some cases, rainfall and water applications may not be sufficient to percolate through the fill and wet the base soil.

decay development and subsequent structural failure. Where tree wells have not been installed, both disease and decay resulting from fill soil contact with trunk tissues are important consequences to consider.

Collectively, research and experience tell us that applying fill to trees is not an all or nothing proposition. Clearly, many trees survive and thrive under a layer of fill, while others do not. Although soil aeration may be affected, it probably is only one of several factors that may lead to a negative impact on tree health. Whether the impact is mild or severe will depend on plant, fill, and base soil factors that need to be assessed prior to fill events.

Factors That May Contribute to the Severity of Injury

Whether the specific impact of fill is on soil aeration or moisture relations (or both), three groups of factors likely contribute to injury severity: plant factors, fill soil factors, and base soil factors. Each of these factors should be considered when assessing the potential for tree injury.

Plant Factors

Plant factors include tree species, age, condition, and root distribution. Certain species likely are more sensitive than other species to fill soil. Matheny and Clark (1998) provide anecdotal assessments of the relative tolerance of selected species to development impacts and include relevant literature citations. Included in some of these assessments are evaluations of species' sensitivity to fill. Generally, younger trees are more capable than older trees of tolerating conditions that lead to injury. Likewise, trees in good health often are less sensitive to injury than trees in poor health. Trees that recently have suffered other injuries may be more susceptible to damage from fill, even if effects on tree health are not yet apparent. Therefore, information about the tree's history can be helpful. Tree species with naturally vigorous growth habits—such as green ash *(Fraxinus pennsylvanica)* and red maple *(Acer rubrum)*—are more likely to be able to grow quickly enough to recover from damage. Trees with wide and deep root distribution are less likely to be injured than those with shallow and restricted distribution. Trees tolerant to flooding may be more tolerant of wet fill soil contacting trunk tissues or of compacted soils where drainage is poor.

Fill Soil Factors

Fill soil factors include fill depth, texture, moisture content, bulk density, and the extent of the root zone covered by fill. It may be expected that the deeper the fill and the larger the area covered, the more pronounced the impacts on tree health. Conversely, partial fills that cover a section of the root zone are likely to have a less severe impact than fill that covers the entire root zone. Soil texture is probably most significant if it is markedly different from the underlying soil. Abrupt changes in soil texture tend to restrict water movement through the soil profile. Ideally, roots will grow into the fill soil. However, if the fill is overly wet or compacted, then root growth may be limited to the base soil.

Base Soil Factors

Physical and chemical characteristics of the base soil (such as hardpan, high water table, and salt layer) may limit root distribution to a shallow layer in the profile. As such, there may be a greater potential for injury from fill in shallow soils than if the soil is deep and roots are widely distributed. In addition, shallow roots are more likely than deeper roots to sustain mechanical injury from equipment during fill installation. As in any tree injury situation, base soil that offers poor growing conditions (such as low nutrient availability, limited water, or rooting area restricted by compaction or hardpans) could potentially limit resources to the tree that would normally aid in its recovery.

Managing Fill to Minimize Impacts

To prevent or minimize tree injury from a fill event, it is important to develop a management plan. Plans should address all pertinent factors that apply before, during, and after fill installation. The following is a list of items to consider.

Before Fill Installation

- **Injury assessment:** Using the plant, fill, and base soil factors described in the previous section, conduct an assessment of the potential for damage (see sidebar). When assessing plant factors, be sure to include other damages that plants might incur during, before, or after the fill process. If the potential for injury is high, then make appropriate adjustments, such as reducing the depth of fill, using a coarse-textured fill, and reducing the amount of root zone covered by fill.
- **Tree wells and drainage:** Include a tree well in fill specifications. The larger the well, the better. Be sure to include a provision for water drainage from the well.
- **Aeration systems:** Research studies have not shown that aeration systems improve aeration status in the root zone (Day et al. 1995; Smith et al. 1995; MacDonald et al. 2004); therefore, it is not recommended that they be included in fill mitigation plans.

During Fill Installation

- **Avoid base soil compaction.** Do not allow vehicles, equipment, or foot traffic to compact the soil surface (Figure 7). Prior to fill installation, light surface cultivation may be useful to reduce the potential for restricted

Assessing the Potential for Tree Injury Prior to Fill Installation

Based on an evaluation of plant, fill, and base soil factors, the following two scenarios describe conditions in which fill has been installed and the potential for tree injury may be expected to be either high or low.

Scenario 1: High Potential for Injury

Plant Factor

Fill was placed around an old basswood *(Tilia americana)* in poor condition. Roots are abundant near the soil surface.

Fill Soil Factor

A 5-foot layer of clay soil was placed around the entire tree, from the trunk to beyond the drip line. The fill soil was compacted during installation. Precipitation and water applications have not been sufficient to wet the base soil.

Base Soil Factor

The base soil is clay loam with an underlying hardpan at 12 inches.

Assessment

Older trees operate on a tighter resource budget than younger trees, and this basswood likely does not have many resources to draw on. Its poor health, shallow root system, and lack of tolerance to fill (Matheny and Clark 1998) make it susceptible to injury. Combined with the extent, depth, and density of the fill; the lack of a tree well; and the potential for water deficit in the root zone, this tree's chances for survival are rated as very poor. In addition, soil contact with the trunk will increase its potential for structural failure.

Scenario 2: Low Potential for Injury

Plant Factor

This vigorous, 15-year-old London plane (*Platanus* × *acerifolia*) tree is in good health. The species is well adapted for the site. Roots are distributed to a depth of 4 feet.

Fill Soil Factor

An uncompacted, 18-inch layer of well-structured sandy loam was placed over half of the root zone. Fill soil does not contact the trunk because a tree well (with drainage) was installed. Water moves readily through the fill into the base soil.

Base Soil Factor

The base soil is a deep and well-drained sandy loam soil. The surface was not compacted during fill installation. Water applied after fill installation readily percolated into the base soil.

Assessment

This tree was assessed as having a low potential for injury because it is a young, healthy, well-adapted species with a relatively deep root system. The species has been reported to exhibit tolerance to development impacts (Matheny and Clark 1998), if the fill is relatively shallow and porous and does not cover the entire root zone. With a tree well, lack of surface soil compaction, and ample water in the root zone, this tree may be expected to tolerate the fill event with little or no injury.

water penetration from fill into the base soil, provided that doing so will not damage roots to any significant degree.

- **Avoid mechanical injury to roots.** Do not allow roots to be cut, crushed, torn, or otherwise injured by vehicles or equipment during fill installation.
- **Avoid compaction of fill.** Do not allow vehicles or equipment to compact fill during installation. Manually placing the fill over the base soil and settling with water is preferable to using heavy equipment.

Figure 7. During site development, equipment and vehicles can severely damage roots and compact the soil surface. If that occurs before or during fill installation, then tree injury may be expected to result from these impacts as well as from the fill soil.

After Fill Installation

- **Maintain adequate moisture content in the root zone.** Apply a sufficient amount of water to pass through the fill and wet the root zone. To ensure that adequate amounts have been applied, it is recommended that soil moisture sensors (such as Watermark electrical resistance blocks) be used in the base soil to monitor moisture levels. Sensors can be installed prior to fill installation.
- **Monitor tree health, and treat significant pest problems.** Do not allow the tree to be subjected to additional stress (such as defoliation) while it responds to impacts caused by fill.
- **Monitor the tree well for water accumulation.** Do not allow water to collect in the bottom of the well for extended periods of time.

Keep in mind that when fill is applied, it is likely to be one of a suite of site alterations that take place. For example, if grading occurs to build a road, soil (and the roots in it) might be cut away or compacted. Heavy equipment might cross root zones, severing roots. The road itself can, at times, act like a dam, causing water to pond on one side. Neighboring trees may be cut, exposing previously sheltered trunks to the sun. Individual trees that might have been able to overcome one of these factors can succumb when subjected to some or all of these stresses at once.

Multiple factors most likely contribute to tree injury following a fill event: aeration deficit, water deficit, soil compaction, and mechanical injury to roots. The magnitude of the contribution of each varies with site

conditions (tree, fill, and base soil factors) and fill installation practices. Although aeration systems have not been shown to improve aeration status in the root zone, tree wells are considered to be very important for most species. Management plans for fill events should address all potential factors that may play a role during the pre-fill, fill installation, and post-fill phases. By developing a careful and complete plan, the potential for tree injury likely can be minimized.

References

Day, S.D., N.L. Bassuk, and H. van Es. 1995. Effects of four compaction remediation methods for landscape trees on soil aeration, mechanical impedance and tree establishment. *Journal of Environmental Horticulture* 13(2):64-71.

Day, S.D., J.R. Seiler, D.W. Smith, and R.E. Kreh. 2001. Overlaying compacted or uncompacted construction fill has no negative impact on white oak and sweetgum growth and physiology. *Canadian Journal of Forest Research* 31(1):100–109.

Harris, R.W., J.R. Clark, and N.P. Matheny. 2004. *Arboriculture: Integrated Management of Landscape Trees, Shrubs, and Vines* (4th ed.). Prentice Hall, Englewood Cliffs, NJ. 578 pp.

MacDonald, J.D., L.R. Costello, J. Lichter, and D. Quickert. 2004. Fill soil effects on soil aeration and tree growth. *Journal of Arboriculture* 30(1):19–27.

Matheny, N., and J.R. Clark. 1998. *Trees and Development: A Technical Guide to Preservation of Trees During Land Development.* International Society of Arboriculture, Champaign, IL. 183 pp.

Smiley, E. Thomas, Thomas R. Martin, and Bruce R. Fraedrich. 1998. Tree root failures, pp. 131–137. In Neely, D., and Gary W. Watson. *The Landscape Below Ground II: Proceedings of an International Workshop on Tree Root Development in Urban Soils.* International Society of Arboriculture, Champaign, IL.

Smith, K., D. Ham, A. Miller, and T. Chesnut. 1995. Soil aeration systems: Do they work?, pp 17–21. In Watson, G.W., and D. Neeley (Eds.). *Trees and Building Sites: Proceedings of an International Workshop on Trees and Buildings.* International Society of Arboriculture, Champaign, IL. 191 pp.

Townsend, K., D. Ham, A. Miller, and T. Chesnut. 2003. Soil aeration systems: Do they really improve tree root zone conditions under fill and paving? *Western Arborist* 29(4):40–41.

Yelenosky, G. 1963. Soil aeration and tree growth. *International Shade Tree Conference Proceedings* 40:127–147.

Larry Costello is an environmental horticulture adviser, University of California Cooperative Extension, San Francisco, California. Susan Day is a research assistant professor in the Forestry Department at Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Photos courtesy of Larry Costello.