The Ohio Chapter ISA’s research committee is responsible for locating and disseminating research findings that affect Ohio tree care professionals and tree care. This is a summary of the findings provided by the committee.

Title: The Underground Movement

It is now recognized that trees and shrubs planted within towns and cities face a multitude of environmental stresses detrimental to their health. Drought and heat waves have become more predominant over the past few years with record heat temperatures recorded world-wide annually. Consequently, inappropriate species selection can be short-lived planting schemes as 100'000's of plants degenerate and die as they fall victim to drought and/or heat. This talk will discuss the processes by which trees are selected for urban plantings and if the right choices being made? If not, what alternative options are available to enable more appropriate species/site selection. These questions will become of greater importance as future resource allocations to urban tree management are likely to decline, increasing pressure to deliver superior services at less costs. Results from ongoing research trials by the author will show how many tree species exist that possess superior drought and heat tolerance which are under-utilized in urban planting schemes. In addition, this talk will address important physiological characteristics within a tree that confer robustness to heat and drought stress and so offer a means to identify tree species with inherent heat and drought tolerance. Finally, the importance of provenance selection will be highlighted as a means of offering an abundance of largely untapped genetic resource to select for stress tolerance.

The underground movement

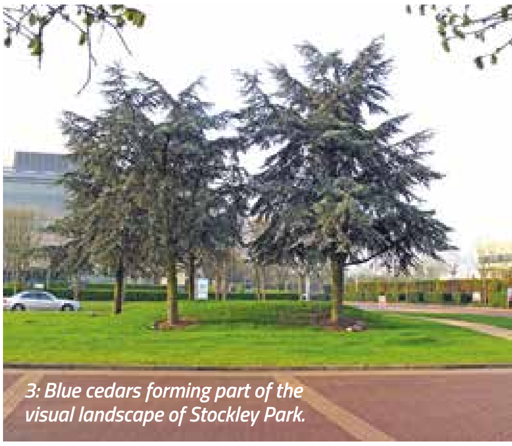
In this article **Dr Glynn Percival**, **Sean Graham** (Bartlett Tree Experts), **Pieter Borchardt** (Stockley Park) and **David Challice** (Challice Consulting Ltd) discuss the results of an ongoing long-term project which aims to develop a sustainable system for decompacting urban soils.

1: Maples that are declining due to soil compaction caused by parked cars.

Stockley Park, Uxbridge, is one of Europe's most successful business parks. Since its inception in the early 1980s, over 140,000 trees and shrubs have been planted. From the original remit of basic maintenance to the present day, involvement in proactive management has included initiatives such as the composting and disposal of green waste, the development of wildflower swards, improved natural habitats such as 'floating islands' and continually seeking ways of enhancing and improving the Park landscape.

2: Vista of maples providing shade and windbreak functions.

However, like all highly manicured urban landscapes, Stockley Park has to contend with a number of environmental issues such as soil compaction caused by landscape machinery and pedestrian footfall, drought (as water infiltration and soil volumes are limited) and elevated atmospheric pollutants from vehicular traffic (Photographs 2–3). These environmental stresses have impacted detrimentally on the health and vitality of planted trees and shrubs, resulting in poor canopy coverage, limited stem extension growth, sporadic branch, stem and leaf dieback, stem lesions, yellowing and chlorotic leaves (Photographs 1 and 4). In addition, trees in a weakened state are more susceptible to attack by pests such as horse chestnut leaf miner and oak processionary moth.



3: Blue cedars forming part of the visual landscape of Stockley Park.

4: Symptoms of leaf yellowing/chlorosis caused by soil compaction.

Under such circumstances the 'norm' for business parks is to wait until the tree is no longer recognised as providing any aesthetic and/or functional benefits or is deemed structurally unsound and a potential danger to traffic, buildings and pedestrians and then remove it. Tree removal is, however, a flawed approach as it removes all the functional benefits trees provide, such as shade, deflecting and absorbing noise, reducing wind velocity and glare, filtering out dust and ultraviolet light and absorbing car pollutants. In addition, the removal and replanting of large trees can be an expensive and labour-intensive process

For this reason, we have developed a proactive, sustainable and holistic approach to tree and shrub care that is designed to remediate the problems mentioned above and at the same time be as environmentally benign as possible.

Site assessment

It is now recognised that 80–90% of problems displayed by trees above ground (leaves yellowing, canopy dieback etc.) are caused by issues below ground. Consequently, over 100 soil samples were collected throughout Stockley Park and analysed for their macro- (N, P, K, Ca, Mg, Mn) and micronutrients (Fe, Cu, B, Na), pH, heavy metals and organic matter content (Photograph 5). In addition, soil compaction levels throughout the site were determined using bulk density analysis, and the soil biology was assessed by analysing the degree of root/mycorrhizal association as well as the number of worms (a measure of soil fertility) per square metre of soil. Based on these analyses, a number of soil-related problems were identified throughout the Park, including:

Soil analysis:

- pH values are too high (7.1–8.9 rather than optimum at ~6.5)
- low potassium, nitrogen, calcium and magnesium levels
- high levels of salinity (high conductivity values)
- high sand soil content
- low organic matter

Compaction analysis:

- high soil compaction levels, i.e. 1.7–1.9 (as a means of comparison, brick = 2.2)
- trees were planted too deep (Photograph 6)

Soil biology:

- no presence of worms
- no or limited mycorrhizal root association

The challenge: development of a sustainable long-term soil decompaction system

As Stockley Park consists of 60 hectares, with at least 50–60% of this area designated greenspace, decompacting the entire landscape was economically and practically unviable. For this reason, the challenge was to try to develop a system whereby a specific area of 100 square metres was decompacted and then the decompacted soil amended in a way that would permit the compacted area outside it to naturally decompact over time.

It was agreed that this would be achieved using the following process:

Vertical mulching

Trees were subjected to soil core removal (7.5cm wide, 30cm deep; at 50cm spacings under the tree crown, photograph 7). The removed soil cores were disposed of and the holes left behind were refilled with one of the following:

1. Biochar (5%) + John Innes soil (92%) + slow release organic fertiliser (3%) covered with a 5cm layer of woodchip mulch

2. Biochar (5%) + John Innes soil (92%) + slow release organic fertiliser (3%) + worms covered with a 5cm layer of woodchip mulch

3. Biochar (5%) + John Innes soil (92%) + slow release organic fertiliser (3%) + area sown with clover

4. Biochar (5%) + John Innes soil (92%) + slow release organic fertiliser (3%) + worms + area sown with clover

5: Removal of soil samples for nutrient analysis.

6: Symptoms of deep planting.

7: Instigation of vertical mulching trial.

5. Control: no cores were removed and the ground remained compacted

While it is appreciated that vertical mulching as a decompaction system is rarely considered by professionals involved in the management of urban trees due to the potential damage to the root system caused by soil core removal, in this case vertical mulching was used for two reasons:

1. Given the high degree of soil compaction there was little root growth within the compacted area at the onset of the trial.

2. 8 square metres of ground could be decompacted using vertical mulching in the time it would have taken to decompact 1 square metre of soil using an AirSpade. Consequently, vertical mulching represented a substantial saving in time and labour.

Worms

Within a woodland/forest environment, soil decompaction naturally occurs due to the action of subterranean organisms and fauna. Earthworms are often described as 'ecosystem engineers' because of their physical and chemical roles in pedogenesis (soil formation), decomposition and nutrient recycling. Indeed, the use of earthworms by humans for composting and improving soil fertility of agricultural land has been a common practice for many years. Earthworms eat leaf mold, decomposing wood particles, dead insects and organic matter. As the materials pass through their digestive systems they are 'broken down' and excreted as worm castings which are a biological form of nitrogen freely available to plants. When worms die, their carcasses become part of the organic mix which further improves soil fertility and structure. Earthworms also loosen compacted soil and improve structure by creating tunnels and burrows which aerate soil and allow water to percolate more readily. As they eat, they carry the materials to new locations before eliminating them. Consequently, both organic and inorganic materials are constantly being 'churned up' throughout the soil profile. Earthworms can improve soil porosity by as much as 400%.

The practice of introducing earthworms for the purposes of soil decompaction in urban landscapes has received little, if any, attention. For the purposes of this study two species of native earthworm were used, *Dendrobaena veneta* and *Lumbricus terrestris*, each of which operates in a different plane in the soil. One operates in a vertical plane and the other in a horizontal plane, providing a mixing action down to a depth of 1m. The worms were obtained commercially in boxes, each box containing 50 earthworms; the boxes were spaced 3m apart. The worms were removed from the box and placed in a 45cm wide × 45cm deep hole. The hole was then gently backfilled with soil and watered thoroughly (Photographs 8–9).

8: Trial set-up just before the addition of worms.
9: Inset: Soil amendment with worms.

Tree health

Three species of tree were used for purposes of the experiment: maple, small-leafed lime and the white flowering horse chestnut. A minimum of ten trees were used per treatment.

Tree health was then monitored over three years, including leaf size, leaf colour (i.e. greenness using a leaf chlorophyll content (SPAD) meter), leaf photosynthetic efficiency (using chlorophyll fluorescence), stem extension, girth increment, crown canopy coverage, root growth, mycorrhizal status and soil respiration rates.

Results to date

Root density

It is beyond the scope of this article to discuss all the results to date. However, given the fact that the main purpose of these studies was to develop a system by which once an area was decompacted, the soil microbial and subterranean fauna would, in essence, 'push out' into the surrounding compacted soil, in turn creating more hospitable soil conditions for root growth, only data for root density within the decompacted area, i.e. under the canopy, and the non-decompacted area, i.e. 1m beyond the canopy drip line, is shown in Table 1.

10: Visible worm casts indicating the movement of worms from the decompacted soil into compacted soil.

The results in Table 1 clearly show that all decompaction systems had a significant positive influence on root density irrespective of whether worms were present or not. Importantly, however, the results also clearly show that only treatments where worms were added resulted in a significant influence on root density outside the treated area. Indeed, photograph 10 clearly shows the presence of worm casts outside the treated area, indicating that worms are moving from the decompacted into the non-decompacted soil and in turn creating conditions 'below ground' which are more conducive for root growth (Photograph 12).

Canopy growth

Photographs 11–12 show the results of decompaction treatments at year three, namely improved visual appearance, enhanced crown coverage and root growth, reduction of leaf yellowing and chlorosis, improvement in leaf photosynthetic efficiency, increased stem extension and girth increments and reduced crown dieback.

Finally, the functional benefits of the increase in canopy coverage (Photograph 13) as a result of the decompaction treatments were quantified, including increased shade and UV protection, increased CO_2 sequestration and oxygen production, increased removal of particulate matter pollution (1–10ug/cm^2 leaf area) as well as atmospheric heavy metals (cadmium, chromium, zinc, lead, nickel copper). This is evident in photograph 13 where soil

Table 1. ***The influence of vertical mulching, woodchip mulch, worms and clover on root density of lime.***

	Root density (dry mass g per cm^3)	
	Under the canopy (decompacted soil)	**1m outside the canopy area**
No treatment (control)	0.0019	0.0011
Vertical mulching + woodchip	0.0244	0.0008
Vertical mulching + woodchip + worms	0.0218	0.0311
Vertical mulching + clover	0.0324	0.0009
Vertical mulching + clover + worms	0.0220	0.0187

11: Untreated lime (left-hand side) vs treated lime (right-hand side).

12: Treated horse chestnut (left-hand side) vs untreated horse chestnut (right-hand side).

13: Increase in crown canopy area caused by soil decompaction and subsequent enhanced root growth.

decompaction has resulted in a larger canopy coverage (area circled). This extra canopy growth alone equates to an extra 0.4kg CO_2 sequestered and 2.2kg O_2 produced per year, 4.0mg of particulate matter removed per day, 28% more UV protection and removal of the metals cadmium (0.2mg), chromium (0.4mg), zinc (3.9mg), lead (12.0mg), nickel (2.3mg) and copper (8.0mg) every growing season. These increased benefits in turn increased the assigned monetary value of the tree to £2,200 compared to a monetary value of £1,300 for the control tree to the left, which more than outweighs the decompaction costs of circa £80–120 per tree.

Conclusions

Over the past four years a range of soil decompaction and amendment management systems have been implemented at Stockley Park. Treatments have included the addition of a high quality top soil (John Innes), worms, biochar, organic slow-release fertilisers, woodchip mulch and a clover crop. Over time improvements in tree health were recorded including improved leaf colour, increased root growth and reduced canopy dieback. Importantly, results show that treatments using worms have the potential to decompact a compacted soil without the need for expensive machinery. It should be emphasised that native UK worm species were used and that this system is primarily developed for use in highly manicured urban landscapes with high density human populations where soil compaction poses a major threat to tree populations. Further investigations and long-term monitoring of tree health are ongoing.