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TRANSPLANTING SHOCK, GETTING TO THE ROOT OF THE PROBLEM: PRE-PLANTING CONSIDERATIONS

Planting trees is easy, getting them to survive is hard. In this article, Dr Glynn Percival of the R.A Bartlett Tree Research Laboratory outlines pre-planting techniques that can reduce transplant mortalities of trees.

As the old saying goes “failure to prepare is to prepare for failure”. Such a saying never had more relevance than when it comes to planting trees. Evidence still shows that, failure rates for amenity tree planting are commonly 30%, and can reach 70% with disturbing regularity. These losses can prove to be a heavy financial burden on local authorities. It is now widely recognized that root and soil disorders are the leading causes of premature decline of landscape plants, resulting in more than 80% of early failures. Roots grow when soil conditions are favorable, however, most urban and suburban soil conditions do not promote vigorous new root growth. Soil compaction, lack of organic matter, poor nutrition, drought and low levels of beneficial fungi create an environment that is unfavorable to root growth. Proactive care for declining trees and shrubs involves analyzing and correcting soil conditions to enhance root development. Root growth drives all other tree functions such as trunk growth, flower, leaf, fruit and seed production, branching and defense against pests and diseases. Consequently, ideal soil conditions prior to planting can go a long way to ensuring lower transplant mortalities. The following pre-site preparations are recommended.

SOIL COMPACTION

In urban areas, there are many forces acting to compact the soil (Photos 1-2). These forces include pedestrian or vehicle traffic, construction equipment and vibration from nearby traffic. Compaction affects the pore component of the soil. This creates an environment less favourable for root growth. Compacted soils do not readily absorb water or allow for water drainage. There is less air to provide oxygen to the roots and carry carbon dioxide away, and there are fewer spaces for roots to grow. It is best to address compaction problems prior to planting. This is done by determining the bulk density of the soil.

What is Bulk Density?

Bulk density is a measure of the dry weight of a certain volume of soil. It is the standard number used by soil scientists to quantify the degree of compaction in the soil. Solid rock has a density of 2.6 g/cc and water has a density of 1 g/cc. Some non-compacted forest topsoil actually have a density less than one, so it would float on water if it were sealed against leakage. The threshold line for bulk density that separates compacted from non-compacted soil is often not a distinct line. It is dependent on soil texture and the plant species that is to be planted. Table 1 provides a chart of commonly accepted values.

Table 1. Soil attributes, by soil texture class, where root growth becomes significantly limiting

Soil Texture	Root-limiting bulk density (g/cc)	Root-limiting % pores normally filled with air
Sand	1.8	24
Fine sand	1.75	21
Sandy loam	1.7	19
Fine sandy loam	1.65	15
Loam	1.55	14
Silt loam	1.45	17
Clay loam	1.5	11
Clay	1.4	13

After Morris and Lowrey 1988

Measuring bulk density

Measuring the degree of soil compaction is a very simple procedure but unfortunately one that is rarely used in the UK.

1. Collect an undisturbed core of soil.
2. Cut the soil core to an exact size.
3. Measure the soil core height and diameter.
4. Calculate the volume of the soil core using the equation $\pi r^2 \times h$ where $\pi = 3.14$, r = radius and h = height of soil core.
5. Dry the soil core for 24h in an oven and weigh
6. Calculate Bulk Density = soil core volume/soil core dry weight.

See Photo 3.

Example 1. If the soil volume was $30cm^2$ and dry weight of 20g then 30/20 = a bulk density of 1.5

Table 2 shows the relationship between soil compaction and planting survival.

Table 2. Relationship Between Bulk Density and Planting Failure

Bulk Density	Planting Success
1.25 – 1.34	Successful: 100%
1.35 – 1.44	Mostly Success: 60%
1.45 – 1.54	Partial Failure: 33%
1.55 – 1.64	Mostly Failure: 10%
>1.65	Total Failure: 0%

Alleviating soil compaction

A number of systems exist to alleviate soil compaction to include radial trenching and use of soil augers to create 3.7cm diameter holes, 30-50 cm deep at 450cm spacings. In the most severe cases, radial trenching in the primary rooting zone provides continuous pathways for roots to grow. Trenches are dug from slightly beyond the drip line toward the trunk until significant roots (>1.25cm diameter) are encountered. The trenches are then filled with a blend of equal amounts of soil and organic matter such as wood chips or composted yard waste. In addition to the soil mix, this is an ideal time to add fertilizer and mycorrhiza if required. Generally surface mulches are applied after the trenches are filled (see issue 20 of EssentialARB for guidelines).

One of the most common systems used in the UK for soil decompaction is the Terravent™ that works on the principle of injecting high-pressure gas into the soil to a depth of 15 to 45 cm. Similar systems to the Terravent™ includes the Grow Gun, Aero-Fertil Gun and Terralift. Modifications to these high-pressure injection systems include the injection of nitrogen gas or fill material such as perlite or organic matter. While all of these systems have their strengths and weaknesses, our own “in house” research indicates the air spade superior in terms of speed and soil decompaction efficacy (Photo 4). Consequently the air spade is the system used by the Bartlett Tree Experts. The air spade was originally developed by the US army to uncover unexploded ordnances. An air spade cultivates the soil to a depth of 15-25 cm using compressed air to excavate soil with minimal disturbance or damage to tree roots. Since there is so little damage, larger areas can be excavated. The result is that more root growth can occur in non-compacted soil. Prior to excavation the tree rooting area within the

drip line should be partitioned into eighths or smaller areas. These areas should be marked on the soil surface after any existing mulch has been raked off. If desired once the soil has been decompacted with the Air Spade, compost, manure, wood chips and/or other organic matter can be worked into the soil using the air spade.

Fertilisation

Newly planted trees require essential nutrients to function and grow. Amenity or urban trees, however, may be planted into soils that do not contain sufficient nutrients for satisfactory growth and development. Topsoil is often removed during construction, leaves and other plant parts are removed in landscape maintenance, disrupting nutrient cycling, and the return of organic matter to the soil. It may be necessary therefore to fertilise or to adjust the soil pH to increase nutrient availability.

The most accurate way to determine a tree's nutrient needs is via laboratory analyses to consider:

1) Foliar nutrient analysis to determine the nutrient content of the leaves.
2) Soil nutrient analysis to determine soil nutrient levels and salt content.
3) pH analysis to determine the acidity or alkalinity of the soil.

Foliar nutrient analysis is used to determine the current nutrient content of leaves. Results provide information on which nutrients have been absorbed and translocated within the plant. This is the most accurate method of determining deficiencies of most elements. However it does not provide information on why the nutrients are deficient. Foliar nutrient analysis is usually significantly more expensive than soil analysis.

A soil analysis can provide information about the presence of essential elements, soil pH, organic matter, and cation exchange capacity. The pH and salt content (especially in arid regions) are most important for recommending treatments and selecting fertilisers. Matching the fertiliser nutrient content to the deficient elements will ensure that the proper nutrients are applied to correct the deficiency. By adding only the elements required, excess elements will not be added to the environment. The process of conducting analyses, setting plant health goals, and selecting a fertiliser to achieve the goal is called Prescription Fertilisation.

Soil organic matter (OM) is usually seen as the "blackness" in soil. If there are high levels of organic matter, there will usually be high levels of beneficial soil microorganisms and nutrients available to the plant. The reported level is a percent of the weight of the soil. Levels of 3% or more are preferable for most plants; higher levels are beneficial for macronutrient availability.

The Cation Exchange Capacity (CEC) of the soil is one measure of the soil's ability to retain certain elements. When CEC values are low, more frequent fertilisation may be required and the risk of leaching is higher. When the CEC is high, applications should be required less frequently and the risk of leaching is lower.

pH is a measure of the acidity or alkalinity of a soil. At a low pH (<5.5; acid) aluminium and manganese become toxic to plants. At a high pH (7.5-8.2; alkaline) mineral elements such as iron, zinc, and manganese become deficient. For the majority of UK trees aim for a pH of between 6.0-6.5. Most fertilisers will affect the pH of the soil with regular application. Soil pH will also affect the availability of many fertilisers. Therefore, when selecting a fertiliser, soil pH should be considered. General considerations are as follows:

1) If pH is less than 5.0, a non-ammonical source of nitrogen should be used.
2) If pH is above 7.2 or if the soil is too alkaline for the plant species, an acidifying fertiliser is preferred.
3) If pH is between 5.0 and 7.2, most other fertilisers can be used.
4) If soil pH is too acidic for the plant species, apply lime with the fertiliser or use an alkaline form of fertiliser.

When taking a soil sample, six to ten cores should be taken from representative locations of the entire area under the canopy drip line and root zone. Typical sampling depth is to 25cm, the location of the majority of fine roots. These cores should be mixed together in a clean non-metallic container or soil sample bag. This will give results that are averaged over the entire area. Any soil test is only as good as the sample, so it is important to collect a representative sample of the site. Avoid unrepresentative areas where nutrient levels may be very high or very low. Photo 5 shows the soil profile as determined using a soil core. Note the brown colour of the soil at the top of the core indicating a well drained media, however, note

how the soil changes colour to a more greyer texture towards the bottom of the core indicating a low soil oxygen content caused by waterlogging.

A soil analysis will have greater value if done in conjunction with a foliar analysis. In addition, there is still debate about what levels of various elements are critical for tree growth. Thus, interpretation may be difficult. One way to facilitate interpretation is to compare foliar nutrient samples with samples from healthy trees of the same species. Leaf samples taken from symptomatic areas may help diagnose certain deficiencies or toxicities. However, a soil analysis or foliar analysis alone can be misleading. It is possible for certain minerals to be deficient in the leaves, but plentiful in the soil and unavailable due to the soil pH. Table 3 shows leaf analysis standards associated with levels of deficiency in a range of woody plants.

	Species			
Nutrient	*Abies alba* (Silver fir)	*Betula pendula* (Silver birch)	*Fagus sylvatica* (European beech)	*Fraxinus excelsior* (Common ash)
Nitrogen (%)	<1.30	<2.50	<1.90	<1.70
Phosphorous (%)	<0.13	<0.15	<0.15	<0.15
Potassium (K)	<0.50	<1.00	<1.00	<1.10
Calcium (Ca)	<0.40	<0.30	<0.30	<0.30
Magnesium (Mg)	<0.15	<0.15	<0.15	<0.20
Copper (ppm)	<5	<6	<5	<6
Zinc (ppm)	<15	<15	<15	<15
Manganese (ppm)	<50	<30	<35	<30
Boron (ppm)	<20	<15	<15	<15
Molybdenum	<0.06	<0.05	<0.05	<0.05

After Cresswell and Weir (1997)

Drainage

Water is essential for plant growth. However, either too little or too much water can result in decline and death of plants. For this reason, internal drainage characteristics of soils are possibly the one biggest factor that will determine which types of plants will grow on a particular landscape site. When soils retain too much water, or restrict water movement through them, the result can be root suffocation, root disease, and eventual root death.

On somewhat poorly drained sites plants may not die, but instead show chronic decline symptoms associated with root loss. These symptoms may include yellowing of leaves (chlorosis), defoliation, marginal scorching, dwarfed foliage, and dieback. Trees and shrubs experiencing root decline from excess water are also more susceptible to attack and invasion by secondary diseases and insects. See issue 21 of EssentialARB for guidelines on soil moisture defecit measurements and instrumentation available to measure soil moisture content.

Determining Soil Drainage Characteristics

There are a couple of techniques used to assess the drainage characteristics of a soil. The most reliable technique utilizes a soil expert to visually examine a soil, looking at texture, colour patterns, and limiting layers. Indicators of wetness include grey or white mottling.

Another simple method of assessing internal soil drainage is called a percolation test. The soils should not be excessively dry or saturated when this test is performed.

Instructions For Performing A Percolation Test

1. With a spade or soil auger, dig a hole 45-60 cm deep. The hole diameter should be a minimum of 10 cm. The diameter of the hole should be uniform from top to bottom with the bottom being flat.

2. Fill hole with water to the top and allow to stand for at least an hour to pre-wet the soil.

3. Refill hole to within a 5 cm of the top. Don’t overflow the hole.

4. To aid in measurement, place a stick across the top of the hole and use a ruler or measuring tape to mark periodic drops in water level.

5. Allow the hole to drain for at least one hour. A longer period of time (2 to 3 hours) will give a more accurate reading of average percolation rates.

6. Determine the average drop in water level per hour and refer to the table below to interpret results.

If water level in hole drops….	Site is….
Less than 1.25 cm per hour	Poorly drained and suited to wet-site Species
1.25-2.50 cm per hour	Moderately well drained and acceptable for many species including wet site species
More than 2.5 cm per hour	Well drained and suitable for all species including sensitive species

See photo 6.

Contaminated Soils

Soil contamination can be caused by excess de-icing salt application, hydrocarbon (petroleum, oil, diesel etc) spillage, chemical herbicide residues in landscape maintenance or heavy metal toxicity. In may cases it is not until symptoms of tree decline become visibly apparent (leaf necrosis, branch die-back, death) post planting is it realized a problem exists. Laboratory methodologies to identify these types of contamination damage include dose response assays, radio labelled compounds or the measurement of metabolic processes at the cellular level. These identification systems are labour intensive, expensive and require sophisticated analytical equipment and therefore unsuitable for large numbers of plant samples. There is, however, two very simple techniques arborists can undertake to at least identify if a soil contamination problem exists prior to large scale planting.

Identification of hydrocarbon contamination

This simple system works on the premise that hydrocarbons and water do not mix. Place a handful of soil into a suitable container and add boiling water. Any hydrocarbon (petrol, diesel, oil etc) present in the soil will be seen as a film on the water surface. Crude but effective!

Identification of other contaminants

Laboratories have used the cress seed bioassay since the 1950's to identify potential soil contamination. The system works on the premise that cress seed germination is extremely sensitive to any form of soil contamination. Consequently cress seed is sown into two separate trays, one containing a commercially available compost i.e. John Innes, the other containing the soil to be tested. Normally 20-50 seeds are sown per tray and relative seed germination determined using the simple equation:

$$\frac{\text{Number of seeds germinated in the test compost}}{\text{Number of seeds germinated in the John Innes compost}} \times 100$$

In addition, the growth of any germinated cress seedlings in the contaminate soil is compared to growth of seedlings in the John Innes compost. Any adverse effects observed such as leaf distortion to include cupping, curling, abnormal elongation of leaf margins (epinasty), spotting, parallel leaf venation and chlorosis are key symptoms. Shoot growth may be twisted and flattened. If these symptoms are observed then further identification into the soil properties are warranted.

Conclusions

As stated earlier "root and soil disorders are the leading causes of premature decline of landscape plants, resulting in more than 80% of early failures". The measures outlined in this article are simple to perform and provide the necessary information to ensure trees are planted into ideal soil conditions to promote vigorous new growth. A full pre-planting survey should take into account a soil analysis to provide information about nutrients, pH, organic matter, soil penetrability, compaction and drainage. Where necessary this information can be supported with two simple but effective measures of soil contamination. Appropriate remedial techniques include air spading, fertilisation and drainage. Adoption of these systems goes a long way to ensure potential large-scale transplant losses are avoided. Photo 7 shows the stages of soil conditioning to include mulching, soil decompaction and fertilisation plus a un-decompacted soil.

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Photo 1

Photo 2

Photo 3

Photo 4

Photo 5

Photo 6

Photo 7