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

In the previous edition of EssentialARB Dr Glynn Percival of the R.A Bartlett Tree Research Laboratory outlined pre-planting techniques that should be taken into consideration to reduce transplant mortalities of trees. In this article techniques that, if applied at the time of planting, can further enhance transplant survival and establishment are discussed.

Know your species

Obviously the simplest strategy is to use trees that are tolerant to transplanting shock. Table 1 presents the relative tolerance of trees to transplanting based on published literature (Skinner, 1985; Harris, 1999; Watson 2001) and the authors experience of monitoring post planting performance of over different 1000 tree species when head of Auchincruive Arboretum based at the Scottish Agricultural College in Ayr. A summation of this research can be found by reference to Percival and Hitchmough (1995) *Arboricultural Journal.* **19(4),** 357-371.

Shoot/Root Pruning

Benefits of shoot pruning include not only restoration of the root:shoot ratio but importantly a reduction in the leaf surface area which in turn lowers evaporative demands thus reducing the water stress imposed by transplanting. Indirect benefits of shoot pruning also include removal of poor quality wood, such as weak twigs, dead or diseased branches and damaged stems so that the vigour of the plant can be directed as required.

Contrary to this however, it has been argued that shoot pruning is detrimental to post planting survival of trees, in that tree growth and vigour depends on their net rate of photosynthesis. Since the leaf is the main photosynthetic organ a reduction of leaf area by pruning reduces photosynthates available for plant growth. Indeed high rates of photosynthesis are associated with "robustness" in an urban planting situation. Researchers in Australia also argue against shoot pruning since the plant hormone auxin which is responsible for root initiation and development is produced in the apical meristems and young leaves and then transported to the base of the tree to stimulate root growth. Obviously shoot pruning will reduce the amount of auxin produced by a tree which in turn reduces subsequent root growth and development.

Studies on the benefits of root pruning in enhancing transplant survival are also contradictory. If the correct technique is used, root pruning can produce a root ball with several times more fine root than that of an unpruned plant. However, many studies agree that the amount of reserve carbohydrate in the root systems of young planting stock is crucial for successful establishment. Consequently, root pruning may reduce these carbohydrate reserves and limit root regeneration.

To investigate further the benefits or disadvantages of root and shoot pruning on transplant survival and subsequent growth a trial was conducted at the University of Reading using bare rooted half standard *A.incana*, *A.campestre*, *F.excelsior* and *S.aria* subjected to shoot and root pruning singly and in combination prior to transplanting. Mortality, growth rates and girth extension of surviving trees were recorded over the following season (Table 2). Although it could be argued that lifting the tree from the nursery bed prior to transporting to the trial site was itself a form of root pruning; root pruning in this instance refers to "tidying up" of the root ball by cutting out damaged and or frayed roots manually using secateurs, further reducing the root system by 5-10% to produce "clean" wounds.

As results of Table 2 show, irrespective of tree species, root pruning alone had no major effect upon shoot growth and only in one instance with field maple was a positive influence on girth established. In contrast, shoot pruning alone or in combination with root pruning in the majority of trees studies increased growth and reduced mortality over the following season. Consequently, results of this experiment support the beneficial effects of shoot pruning after trees have been transplanted to increase tree growth and survival. In support of this researchers at Canada demonstrated that as site conditions worsen and survival decreases, shoot pruning in the nursery improved the chances of survival of several tree species to include lime, cherry, green ash and pecan trees. Likewise in further shoot pruning trials the growth of top-pruned trees with time surpassed that of non-pruned trees. The authors suggested this was due to the fact that non-pruned trees never fully recovered from the shock of transplanting.

Irrigation

Irrigation is vital to ensure successful tree establishment. There are many reports of increases in girth of trees (a important indicator of growth) over a growing season being highly correlated with rainfall or a water deficit. Typically newly planted standards have a rooting volume of 0.1m which means they can extract water from the soil they are planted into for about 8 days in the absence of rain or irrigation. After this time period they begin to suffer from water stress. It is important to note that once widespread visible injury i.e. leaf necrosis is observed as a result of prolonged drought then no amount of watering is likely to be successful. It has been calculated that large tree species use up to 100 litres a day whilst a smaller species such as *Malus* may require only 5 litres. As a useful guide in dry weather 27-30 litres per day is recommended for a large standard.

To ensure successful tree establishment then it is important to irrigate before the tree is lifted from the nursery to ensure roots are well saturated. Cover and protect the roots from drying out during transit. Soak the roots 5-10 minutes prior to planting and make sure the soil around the roots is not allowed to dry out completely for the first two years after planting. In conclusion any irrigation is likely to assist the establishment of trees. If resources are limited then irrigation is best applied during leaf expansion i.e. early spring.

Mulching

Mulching as a form of weed control, conserving soil moisture and fertilisation is vital for successful transplant survival. The influence of mulches has been discussed in detail by the author in a previous edition of EssentialARB.

Water-holding gels

The practical limitations of applying irrigation schemes to landscape schemes consisting of thousands of trees and/or shrubs has led to the development of a range of synthetic water holding gels (SWHG's). According to manufacturers SWHG's absorb hundreds of times their own weight of water and are capable of releasing at least 95% of it to plants (Photo 1). The hydration of the granules forms a stable gel of non toxic granules. Manufacturers claim many benefits from using SWHG's. In sandy soils it is said to be possible to increase the available water holding capacity by 300-800%, allowing for extended intervals between irrigation.

Increased survival of plants under drought conditions, bulking up of substrates, improved soil structure and aeration, enhanced seed germination, plant growth and establishment are also claims made by the manufacturers of these products.

The use of SWHG's as a means of increasing transplanting success of amenity trees (*Tilia, Fraxinus, Acer, Pinus spp*) were initially examined by researchers from the Forestry Commission in the 1980's. They concluded that despite marked improvements in the available water capacity of treated soils, SWHG's were of little or no use in sustaining the growth of newly planted trees. Indeed, in some cases the application of a SWHG's had greater detrimental effects on tree growth as rather than release water to the tree root system the opposite occurred in that the gel withdrew water from the root system placing the tree under greater drought stress! Since then, however, developments in polymer technology have led to the formulation of a range of alternative SWHG's with different active ingredients (starch co-polymers, polyvinyl alcohol co-polymers, hydrophilic polymers and acrylamide-sodium acrylate co-polymers) to those trialled in the 1980's. Several studies have shown that these polymers can be beneficial to plants grown under water stress and saline conditions. Consequently, these polymers are recommended as a means of reducing root desiccation and post planting mortalities. However, several studies have also shown the opposite with the conclusion that SWHG's have no positive influence in terms of transplant survival and establishment. Results of a recent TREE FUND funded study based at the Bartlett Tree Research Laboratory has indicated that many other factors influence the effectiveness of SWHG's to include species, soil volume and salinity, dose rates, watering frequency, soil texture, transplant size, choice of polymer and form of incorporation. Further research is required before the use of synthetic water-retaining polymers alone should be used as a viable option to reduce transplant losses of bare-rooted woody plants.

Fertilisers

According to several researchers transplant growth can be regulated to a large extent by nutrient levels present in a fertilizer with nitrogen (N) identified as the macronutrient having the greatest influence. However, the effect of N fertilizers upon survival of trees post planting are conflicting. Proliferation of tree root systems in a moist N rich environment has been demonstrated by researchers at the Forestry Commission while work elsewhere also concluded that fine root turnover of forest trees increased exponentially with soil N availability. Work using Sycamore (*Acer pseudoplatanus* L.) and Sitka spruce (*Picea sitchensis* (Bong.) Carr.) as test species reported provision of nitrogen stimulated greater root growth compared to non N fertilized trees with an increase in root mass and root diameter with N supply. The addition of N to severely nitrogen deficient china clay wastes increased root extension of birch resulting in a ten fold exploitation of soil volume compared to non N fertilized control trees while an association between N fertilization and improved root growth has also been documented. Researchers at the Morton Arboretum in the USA concluded only application of granular N significantly increased root density of honeylocust (*Gleditsia triacanthos* var. inermis) and pin oak (*Quercus palustris*) compared to granular potassium and phosphorous fertilizers when applied via a soil coring technique.

Contrary to this researchers in Israel studying the influence of high nitrogen N:P:K (20:10:5) fertilisers on alterations to root:shoot ratios in seedlings of *Hopea odorata* and *Mimusops elengi* demonstrated enhanced shoot over root growth. These results are consistent with those obtained from other studies using *Pseudoacacia menziesii*, *Liriodendron tulipifera*, and *Azadirachta excelsa* as test species where N fertilization had a grater impact on shoot over root growth. Reasons for these discrepencies between researchers could be due to the fact that resource allocation of plants in response to N fertilisation has been shown to be highly complex, influenced by natural root lifespan, herbivore pressure, root function (storage, transport, structural support), competition from other plants, soil moisture and temperature, growing season and mineral nutrient conservation. An example of this complexity can be gained from the fact that rsearchers in Sweden demonstrated N fertilization reduced root production at a soil depth of 0-20cm yet significantly increase root production at soil depths between 41-85cm. In addition inherent stress tolerance characteristics between species may significantly influence resource allocation. One feature of waterlogging tolerance is carbon reallocation from below ground (roots) to above ground (shoots) as indicated by an increased shoot:root matter ratio. Such an alteration decreases the amount of root tissue and therefore the oxygen demand of the root system. Conversely drought tolerance is linked to enhanced root over shoot growth to explore a greater volume of soil. Species dependent stress adaptations coupled with a combination of soil factors mentioned above may account for the discrepancy between workers.

Regarding use of N based fertilisers as a means of reducing transplant stress the conclusions reached by most researchers are:

1. In general applications of N fertilizers result in a more balanced growth vital for plants growing in harsh urban environments where competition for water and nutrients is high.
2. Plant trees in a well drained, aerated soil which contains an adequate supply of nutrients. Ideally cores of soil should be sent to a reputable laboratory for soil analysis prior to planting and any nutrient deficiencies remediated with appropriate fertilisation.

Auxins

It is known that the auxins indole-3-acetic acid (IAA), indolebutyric acid (IBA) and naphthaleneacetic acid (NAA) can induce roots from woody plant cuttings and are routinely used throughout the nursery stock industry for vegetative propagation purposes. The effects of rooting hormones on an existing or badly damaged root system to promote root vigour of deciduous and evergreen trees has also been the subject of several investigations. The consensus reached by the majority of researchers is that applications of auxins increased survival rates and root vigour of several difficult to transplant tree species with auxin application promoting root initiation and increasing the numbers and length of existing roots 6-18 fold in some instances. All forms of auxin application prove successful (spray, soil drench, trunk injection) in reducing transplant losses. Table 3 demonstrates the influence of auxins applied as a root drench on root dry weight of four tree species at week 25 after treatment. Likewise Photo 2 shows the influence of a IAA + IBA combination on root vigour of *Pinus* transplants.

However a number of problems exist when using auxins to improve transplant survival. The type of auxin present in a product can have a marked effect on tree growth depending on species. For example, work by the author showed application of IBA and IAA applied singly and in combination as a drench following severe root pruning of containerized stock improved root vigour and tree vitality of red alder (*Alnus rubra*) rowan (*Sorbus aucuparia*), and lime (*Tilia* x *europea*) but had little effect on oak (*Quercus robur*). They also demonstrated NAA alone had little effect on root vigour of *A. rubra, S. aucuparia*, and *T.* x *europea* but significantly enhanced that of *Q. robur*. Likewise, work at Horticultural Research International demonstrated applications of IBA increased root initiation, root elongation, shoot growth, and leaf area of beech but had no promontory effects on vitality or growth of English oak. Researchers in the Netherlands found that IBA at 1000, 2000, or 3000 mg litre increased the number of roots of scarlet oak and pistachio. On the other hand, it was observed that IBA was not effective in improving root initiation of palms.

As planting of bare rooted trees are generally performed when they are dormant (November-January) then auxin application at this time are unlikely to have any effect as auxins are broken down by naturally existing soil bacteria and fungi. Application of auxins after planting during Spring when dormancy has been broken increases labour costs i.e. repeat visits for auxin applications and adjustments to standard aftercare management procedures. As a means to overcome this problem the use of a synthetic water holding gels (SWHG's) in combination with auxins at the time of planting (January) was investigated by the author. Results demonstrated SWHG/auxin combinations a) decreased the time for new root initiation, b) increased the number of root initiated, and c) increased root elongation rate of silver birch (*Betula pendula* Roth.) and beech (*Fagus sylvatica* L.), two difficult-to-transplant species, under field conditions. Effects on root vigour were recorded by week 8 after bud break indicating short-term promontory effects that were still manifest i.e. significantly improved root and total plant dry weight at the end of the growing season. A 1:1 combination of liquid IBA:NAA and a SWHG at the time of planting was most effective for root regeneration, growth, and tree vitality compared to other treatments (Photos 3-4).

Sugars

One of the simplest and most promising compounds tested to promote root vigour and reduce transplant losses has been low concentrations of sugars. Trees are planted in urban environments for their practical, ecological and psychological benefits. However, taken from the trees "point of view", survival, establishment and reproduction (seed set) are critical for the success of the next generation. The only way a tree can achieve these three objectives is by the production and expenditure of energy and the only way a tree can produce energy is by photosynthesis i.e.

$$CO_2 + H_20 \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} C_6H_{12}0_6 + 0_2$$

Interestingly, we know what happens to tree growth in the presence of high and low concentrations of carbon dioxide, water and oxygen. However, the end product of photosynthesis is sugar or more accurately sucrose in most tree species, the same type of sugar we use to sweeten our tea and coffee. This then begs the question, what happens to root and shoot growth patterns when a tree is supplied low concentrations of sugars dissolved in water and applied to the root system as a drench, i.e. the main process by which a tree establishes, survives and reproduces is no longer of such importance since the end products of photosynthesis (sugars) are supplied as a dilute solution?

Initial studies using four year old containerized stock of *Betula pendula* (silver birch), *Q.rubra* (red oak), *Prunus avium*, (cherry) and *Sorbus aucuparia*, (rowan) demonstrated a positive increase in root vigour following the application of sugars such as sucrose when applied as a root drench. Since then a wealth of studies have shown a positive association between sugar application and root stimulation in a range of plant species. Work at the Scottish Agricultural College demonstrated that supplementing root systems of plants with sugars significantly increased lateral root branching and root formation compared with non-supplemented controls. Further work demonstrated applications of sucrose to a range of tree species enhanced root vigour in terms of root length, number of new roots formed and root dry weight compared to water treated controls. Experiments using soil injections of sucrose to established mature horse chestnut (*Aesculus hippocastanum* L.) silver birch (*Betula pendula* Roth.) cherry (*Prunus avium* L.) and English oak (*Quercus robur* L.) recorded a significant increase in fine root dry weight compared to water injected controls (Photo 5).

Reasons for enhanced root over shoot growth following sugar application include gene expression alteration influencing carbon remobilization in favour of root growth. For example, reserchers ta the University of Florida have clearly demonstrated that sugars function not only as substrates for growth but affect sugar sensing-systems that initiate changes in gene expression and subsequent plant growth. For example incubation of root systems in sucrose or glucose leads to the repression of photosynthetic genes, decreased rates of net photosynthesis and carbon remobilisation in favour of enhanced root development. Other researchers have shown that sugars induce changes in soil microbial and fungal rhizosphere populations altering plant nutrient uptake patterns in favour of root growth. Alternately the process of recovery following root severance is dependent on the ability of a tree to manufacture abundant photosynthetic carbohydrates such as sucrose. As carbohydrates function as a direct substrate for growth then an abundance of photosynthetic products at and around the root zone are available for immediate use. Likewise the importance of high concentrations of carbohydrate reserves within root tissue for survival and growth following transplanting are well recognized. Root growth for example is an energy-consuming process occurring at the expense of available carbohydrate reserves. Root uptake of dissolved sucrose in water and applied as a root drench may contribute to elevated root carbohydrate levels facilitating greater root formation, root elongation and subsequent root dry weight.

A note of caution should be expressed when applying sugars to promote root vigour. At present it is more than simply mixing a bag of sugar with soil or compost and then planting the tree. If the sugar concentration is to high this can put the tree under osmotic stress and/or encourage the build up of pathogenic fungi within the soil. However, the practical benefits of using sugars as a means of reducing transplant losses should be of interest to anyone involved in the planting and aftercare of amenity trees. Sugars are inexpensive, non-toxic to humans, plant and animals and can easily be incorporated into existing management strategies with no capital investment and only small adjustments to standard operating procedures for the aftercare of trees following out planting. In addition recent research show that plants suffering from salt (NaCl) damage were able to recover quicker when sugars were applied as a root drench indicating a protective role of sugars against salt induced stress.

Biostimulants

Products sold as biostimulants differ from traditional nitrogen, phosphorous and potassium fertilizers in that their active ingredient consists of a range of organic compounds such as plant hormones, humic acids, marine algae extracts, sea kelp, vitamins, wing of bat, eye of newt (I made the last two up) and other chemicals that vary according to the manufacturer. Investigations into the efficacy of biostimulants in enhancing root vigour of urban trees have been conflicting. Workers in Scotland evaluated a range of biostimulant products on root growth of three transplant sensitive tree species (*Quercus robur*, *Betula pendula*, *Fagus sylvatica*) and demonstrated a significant increase in root vigour. Humic acids, an integral component of many biostimulant products have been credited with increasing root growth and water uptake of red oak and olive, while sea kelp extracts contain high levels of cytokinins which may be beneficial to trees under water stress conditions. Contrary to this, a range of biostimulants and humate-based products marketed as aids to plant establishment in balled and burlapped red maple (*Acer rubrum* L. ‘Franksred’) had little beneficial effects on root growth. Further work investigating the interaction between fertilization, irrigation and biostimulants on red maples and washington hawthorns (*Crataegus phaenopyrum* (Blume) Hare) again found little effect of these products on root growth.

With the wealth of biostimulant products “flooding” the amenity market, testing them all is impossible, however, a rapid and effective system is available to test many of these products under a short time period. Trials use 4 year old transplants that are lifted from the nursery and then containerized. A range of biostimulants are applied both as a foliar spray and root drench and at week 8 after treatment trees are lifted from the pot, and the root system gently washed with water. Improvements in root vigour were determined by measuring the root growth potential or RGP. Basically root vigour is composed of increases in the length of existing roots and formation of new roots. Newly formed roots can be easily identified as they are white. The total number of new white roots is known as the RGP. Importantly a RGP of 5 is associated with survival after transplanting.

Although over 20 biostimulant products were tested results for only 10 are presented in Table 4. Red oak, birch and beech were chosen as experimental species as these trees are known to be transplant sensitive. Table 4 highlights two of the problems of using biostimulants that are frequently encountered not just in our Bartlett Tree Research trials but elsewhere. These are;

1. Many of the products tested do not live up to the root promontory claims of the manufacturers. Indeed no beneficial effects on root vigour were recorded in the 10 products not mentioned!

2. In instances where a root promoting effect is observed this was species dependent. For example both Redicrop 2000 and Crop Set almost doubled the RGP of red oak but had no effect on birch and beech. Contrary to this Axon proved useful when applied to birch and beech yet had little effect on root vigour of red oak i.e. few of the biostimulant products tested worked on all three test species. Such a response is disadvantageous to professionals involved in urban tree care where products with universal applicability for a wide range of species are preferred rather than individual products for specific tree species.

This then begs the question as to why do we see these marked differences between species? The answer may lie in the fact in that the active ingredient present in each biostimulant product tends to vary. For example we know Generate contains a range of zinc complexes combined with acetate. Fulcrum on the other hand is derived from molasses, a sugar based compound while Maxicrop is formulated from seaweed. In many cases manufacturers are extremely “cagey” about informing exactly what is present in the product using the vague term “natural plant extracts” or “organic molecules” on the product label. Previous research does exist supporting the idea that the effects of biostimulants on plant growth can differ as a result of differing active ingredients such as auxins, cytokinins, vitamins and salicylic acid present in the product. Likewise, even when the active ingredient is the same, effects on tree vitality can differ from marked increases to no significant effects depending on tree species.

Biostimulants the take home message: Based on results of our work over the past five years, much of which has not been presented here, in combination with work that has been published by other workers we would conclude that:

1. Biostimulants can improve root vigour following transplanting and in turn promote tree vitality however, selection of an appropriate biostimulant is critical as effects on growth and vitality can vary widely between tree species possibly as a result of the differing active ingredient used in the formulation of a product.

2. With the influx of biostimulants released into the marketplace, each containing differing active ingredients, evaluating all of them independently may prove difficult. Consequently, where independent scientific data is not available to support the claims of manufacturers, growers and urban tree managers should be aware of the potential disadvantages highlighted above when these products to improve transplant survival rates.

VAM (Vesicular Arbuscular Mycorrhizas)

The roots of most trees growing in a woodland or forest are generally infected by symbiotic fungi that do not cause root disease, but instead are beneficial to their plant hosts. These infected roots are transformed into unique structures called mycorrhiza. The mycorrhizal fungus obtains all or most of its carbon and energy requirements from the plant while keeping its partner supplied with organic minerals obtained from the surrounding soil.

Benefits from this type of mycorrhizal association include;

1) Striking growth responses of tree seedlings leading to large increases in dry weight between mycorrhizal and non mycorrhizal seedlings grown in poor soils or under drought conditions.

2) Increased root area as a result of the radial elongation of outer cortical cells thus increasing the roots surface area for nutrient uptake. In addition there are usually hyphae or mycelial cords growing out into the soil increasing the overall absorbing area of the root and exploring a greater volume of soil.

3) Mycorrhiza formed by a variety of fungi on *Pinus taeda* and *P.echinata* conferred resistance to infections by zoospores and mycelium of *Phytophthora cinnamomi*. Non mycorrhizal seedlings showed reduced top growth, chlorosis, restricted root development and eventually death.

4) Examination of several coal spoils in the USA have shown that pine seedlings infected with mycorrhiza were capable of withstanding low pH and high soil temperatures. Similar results to these have been recorded with trees growing on sites contaminated with heavy metals and other pollutants such as arsenic.

However, the results outlined in point 1-4 were obtained from trials undertaken many years ago where inoculating trees with a mycorrhiza required the digging and grinding of mycorrhizal root systems and then inoculating the experimental trees; a time consuming and laboratory based process. Since then a range of commercial mycorrhiza have become available which can be applied to root systems as a soil amendment or water based solution. Consequently, the use of VAM fungi as an aid to urban tree establishment has been aggressively marketed by many commercial companies using earlier research to support their scientific claims. When, however, commercially available VAM fungi have been trailled independently by researchers at the University of West Virginia and University of Florida no direct evidence has been forthcoming that they actually work for all trees. In a study of ten commercial products few of the products tested actually successfully managed to form a symbiotic relationship with the tree. Another researcher found that of eight products tested none had living spores of mycorrhiza and that many products were contaiminated with bacteria and other fungi. Indeed the overall conclusion from several independent research trials is that there is little effect on enhanced survival of newly planted landscape trees and subsequent growth following VAM application.

Conclusions

Most of the concepts discussed in this article are not new. Indeed, they have been the key to good cultural practices for many years. Adoption of these planting practices are essential if high levels of amenity tree planting losses are to be minimised especially when dealing with transplant sensitive species mentioned in Table 1. Particular attention must be given to the merits of factors discussed in this article and importantly their effects on root, rather than shoot growth.

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Percival, G C (2007). EssentialARB. Issue 23.

Table 1. Relative tolerance of genus (half standards or greater) to transplanting commonly used in UK landscapes

HIGH	INTERMEDIATE	LOW
Alnus	*Juglans*	*Betula*
Sorbus	*Prunus*	*Aesculus*
Tilia	*Fraxinus*	*Malus*
Salix	*Castanea*	*Carpinus*
Populus	*Crataegus*	*Acer*
Ginko	*Pyrus*	*Quercus*
Platanus		*Fagus*
Robinia		
Pinus		

Table 2 Influence of shoot and root pruning singly and in combination on tree growth

Tree Species	Treatment	New Growth (cm)	Girth (cm)	Mortality (%)
S.Aria	No pruning	16.2	1.90	20
	Shoot Prune	26.5	2.11	0
	Root Prune	14.3	1.93	15
	RP+SP	24.0	1.93	0
A.campestre	No pruning	14.5	0.89	15
	Shoot Prune	19.0	1.14	10
	Root Prune	13.4	0.93	20
	RP+SP	20.6	1.09	5
F.excelsior	No pruning	7.6	0.91	30
	Shoot Prune	11.2	0.96	15
	Root Prune	7.1	1.07	25
	RP+SP	12.8	0.88	10
A.incana	No pruning	22.4	2.11	0
	Shoot Prune	32.5	2.49	0
	Root Prune	25.0	1.89	0
	RP+SP	36.2	2.77	0

All values average of 8 trees
RP+SP = Root Prune and Shoot Prune
Percival (unpublished)

Table 3 The influence of auxins applied as a root drench on shoot and root dry weight (g) of trees 25 weeks after root removal

	Root dry weight (g)			
Tree Species	***Quercus robur***	***Tilia* x *europea***	***Sorbus aucuparia***	***Alnus rubra***
Control	15.4	11.7	11.6	6.2
IAA	29.0*	38.2*	23.2*	28.8*
IBA	31.0*	41.0*	32.4*	24.6*
NAA	25.4*	21.0*	7.2	6.8
IAA+IBA	42.6*	50.4*	36.6*	23.0*
IAA+IBA+ NAA	30.2*	40.6*	18.4*	22.0*

All values average of 10 trees
* = root dry weight significantly higher than controls. No * = not significant from controls
After Percival and Gerritsen (1998). *Journal of Horticultural Science and Biotechnology*. **73(3),** 353-359.

Table 4. The influence of biostimulants on RGP of three urban tree species

	Root Growth Potential (RGP)		
Tree Species	**Red Oak**	**Birch**	**Beech**
Biostimulant			
Control	4	7	5
Generate	8	12	9
Fulcrum CV	7	11	12
Fulcrum Blade	8	8	10
Redicrop 2000	7	6	4
Crop Set	9	7	6
Axon	3	10	10
Bioplex	4	11	7
Axis	3	6	4
Maxicrop	6	5	6
Seamac	3	3	6

All values mean of 10 trees

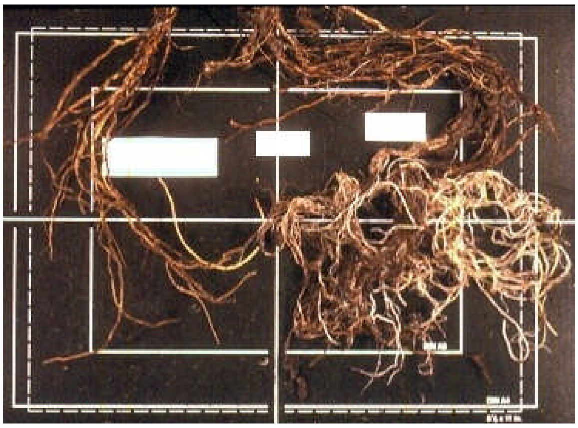

Photo 1

Photo 2

Photo 3

Photo 4

Photo 5