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IBA AND SOME IBA-SYNERGIST INCREASES OF ROOT REGENERATION OF LANDSCAPE-SIZE AND SEEDLING TREES[1]

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Abstract. *Sprays of 3000 ppm indole-3-butyric acid (IBA) onto the fresh-cut roots of 250-300 cm. tall, fall dug sugar maple (Acer saccharum) and red oak (Quercus rubra) held in cold storage and spring-treated, increased lateral root number. Similar treatments of spring dug sugar maple, European birch (Betula pendula), littleleaf linden (Tilia cordate) and both spring and fall dug green ash (Fraxinus pennsylvanica var lanceolata) did not increase root numbers compared to controls. The addition of auxin synergists (B-naphtol, nicotinic acid and phloroglucinol) with IBA applied to the roots of red oak and littleleaf linden increased root number compared to controls but the increase was no greater than IBA alone. The synergists had no effect on sugar maple. Dipping the roots of one year seedlings of European birch and wild plum (Prunus americana) into IBA plus B-naphtol or nicotinic acid resulted in significantly greater new leaf and root growth compared to IBA alone or controls. Several of the treatments may be commercially feasible.*

Many trees have difficulty becoming established quickly after transplanting, even when edaphic and climatic conditions are adequate and proper cultural practices are followed. Slow establishment is often attributed to poor or inadequate regeneration of new roots (12, 17).

Survival and growth of transplanted trees has been correlated to the inherent root growth capacity of the plant at planting time (18, 23). Root growth capacity appears to be influenced by lifting date, storage regime (23, 30), moisture status and chilling requirements (26, 29), and endogenous factors such as hormonal balance (18, 26). Root growth capacity is also periodic. Peaks in root growth have been correlated with increased sugar content in white oak (15) roots and competition for photosynthate (11). Thus, survival and growth depends on the inherent capacity of a plant for rapid root initiation and the ensuing development of a vigorous root system.

Researchers have shown a positive correlation between survival and root dry weight (25) and between shoot growth and root number (16). Teskey & Hinkley (27) concluded that the number of growing roots appeared to be a key factor in the survival of white oak trees under moisture stress. Root numbers rather than elongation rate, is important in determining the size and extent of the root system, resulting in a greater rate of water uptake (10).

Endogenous plant growth substances (auxin, cytokinins, gibberellins, ethylene and abscisic acid) influence root initiation. Auxin acts directly, the others indirectly, through their control of shoot growth (3). Direct manipulation of endogenous growth substance levels with applications of growth regulators has been widely used (2) in order to stimulate root regeneration resulting from increased numbers of lateral roots or development of adventitious roots from callus which may have formed at the pruning wound.

Maki & Marshall (14) studied the effect of IBA on root growth and seedling survival of several species. Root soaks in solutions ranging from 1 to 160 ppm IBA stimulated root development of red oak but substantial increases in root development were obtained at the expense of reduced survival.

[1] Presented at the annual conference of the International Society of Arboriculture in Louisville, Kentucky in August 1982.

Working with Bartlett pear seedling rootstock, Looney & McIntosh (12) substantially increased new root growth by inserting toothpicks impregnated with IBA into the roots. Root dips and soaks in IBA stimulated root regeneration of seedlings of black tupelo, redbud, scarlet oak, and white oak, and both spring and fall dug black walnut (17). Using alternative methods of auxin application on scarlet oak (IBA impregnated string and toothpicks) Moser (17) induced a greater number of new roots at the point of insertion on the root; an indication of the localized influence of IBA.

Several chemicals when used in combination with auxin have stimulated root regeneration. Kinetin plus IAA induced the most growth of red oak seedlings (7). The phenols, 1-naphtol and (*B*)2-naphtol with IAA, NAA or 2,4-D increased root number of pea cuttings; *B*-naphtol being the most active (6). Phloroglucinol, also a phenol, had a synergistic influence with IBA in root initiation of micropropagated M9 apple rootstock (8). The naturally occurring B vitamins, nicotinic acid and thiamine stimulated lateral root induction and primordia emergence of pea seedlings (31).

The purpose of this research was to determine the effect of auxin and auxin synergist applications to the roots of several species of landscape-size and seedling trees.

Material & Methods

Experiment 1. Barefoot deciduous trees (250-300 cm tall) of sugar maple, European birch, green ash, red oak and littleleaf linden were dug mechanically from two commercial nurseries. Digging times were fall (1979) for red oak, fall and spring (1980) for sugar maple and green ash, and spring for European birch and littleleaf linden. Fall dug trees were held in cold storage at the nurseries until spring. For treatment, (May 1980) all roots between 5 and 15 mm diameter were pruned-back to healthy tissue and sprayed with 3000 ppm IBA in 50% ethanol. The ethanol without IBA was the control. All trees were planted in raised beds of sphagnum peat. The trees were staked and watered as required through the season. Water soluble 20-20-20-(20N-9P-17K) including micronutrients was used for every fourth watering at 200 ppm N.

In late September the trees were removed from the peat and the number of lateral roots originating within 5 cm of the cut surface was determined. The experiment was a completely randomized block design consisting of 5 replicates with 2 trees per treatment.

Experiment 2. In May 1981, bareroot trees of 3 species; sugar maple, red oak and Glenleven linden (*Tilis cordata* 'Glenleven') (150 cm tall) were dug mechanically from a commercial nursery. Within 4 days of digging, all roots were fresh-cut with hand shears and sprayed with one of 7 treatments: 1) control (50% ethanol), 2) IBA, 3) IBA sodium salt, 4) IBA plus *B*-naphtol (1×10^{-6}M), 5) IBA plus phloroglucinol (1×10^{-3}M), 6) IBA plus nicotinic acid (1×10^{-3}M) and 7) NAA (3000 ppm). IBA in all solutions was 3000 ppm. For treatments 4, 5 and 6 the IBA solution was allowed to dry for several minutes then the additional solution was sprayed. After treatment the trees were planted in 45 L plastic bag pots in a 1:1:1 (v/v) soil:peat:perlite mix. The trees were staked, watered as required and fertilized as in Experiment 1.

In late September the trees were removed from the pots and the number of lateral roots originating within 5 cm of the cut surface was determined. The experiment was a completely randomized design with 2 to 3 trees per treatment.

During January, fall dug, bareroot red oak trees (150 cm) were brought from the nursery cold storage to the greenhouse. The 4 root spray treatments were: control (50% ethanol), IBA (3000 ppm) and IBA (1500 ppm) plus *B*-naphtol (5×10^{-4}M). The combination solutions were applied as a single spray. The trees were potted as noted above and maintained for 3 months after which the regenerated lateral roots were counted. This trial was a completely randomized block design with 7 single tree replicates.

Experiment 3. One year seedlings of European birch and wild plum (*Prunus americana*) were brought from nursery cold storage to the greenhouse in early March 1982. The roots were washed, pruned-back to healthy tissue and dipped for 30 seconds to provide 6 treatments: 1) control (50% ethanol) 2) IBA, 3) IBA plus nicotinic acid (1×10^{-3}M), 4) IBA plus *B*-naphtol (1 ×

10^{-6}M), 5) IBA plus gibberellic acid (GA_3, 500 ppm) and 6) IBA plus GA_3 (175 ppm) plus benzylaminopurine (BAP, 175 ppm). IBA in all solutions was 3000 ppm. For treatments 3, 4 and 5 the roots were dipped for 15 seconds in each solution. Treatment 6 was used as a single solution. Seedlings were planted in 15 cm plastic pots and watered as needed.

Five weeks after treatment, the dry weight of new shoot and root growth was determined. The experiment was a completely randomized block design consisting of 4 replicated with 4 plants per treatment.

Results

Experiment 1. Root sprays with 3000 ppm IBA more than doubled the number of roots regenerated from fall dug sugar maple and red oak (Table 1). However, there were no differences in the number of roots from spring dug sugar maple green ash, European birch or littleleaf linden. Fall dug sugar maples not treated with IBA had fewer lateral roots than spring dug trees. The number of roots thus produced was similar to that for spring dug trees. In contrast, fall dug, untreated green ash regenerated more roots than the spring dug trees, yet IBA had no effect on root number of either spring or fall dug trees (Table 1).

Experiment 2. The application of growth substances known to enhance root development did not result in significant differences in the number of roots regenerated from spring dug sugar maple (Table 2). The most effective treatment for Glenleven linden was the IBA sodium salt but new lateral root number was not different from IBA and IBA plus *B*-naphtol or IBA plus phloroglucinol (Table 2). For red oak the chemical treatments, except for NAA, produced more roots than the control. However, there was no difference among IBA and IBA plus *B*-naphtol or phloroglucinol.

Results from the winter greenhouse rooting of red oak (Table 3) were somewhat similar in that IBA and IBA plus phloroglucinol produced more roots than the control but were not in themselves different. Reducing the concentration of IBA with phloroglucinol was effective, although this was not true for *B*-naphtol (Table 3).

Table 1. Average number of new lateral roots per treated root of bareroot trees (250-300 cm tall).

		Treatment	
Species	*Digging season*	*Control*	*IBA (3000 ppm)*
Red oak	fall[1]	3.9	12.8**
Sugar maple	fall	5.4	13.0**
	spring	12.7 *	15.9
Green ash	fall	8.8	7.9
	spring	3.1 *	3.2*
European birch	spring	6.2	5.6
Littleleaf linden	spring	7.5	10.7

[1] Fall dug trees were held in cold storage until spring.
Mean separation by t-test; * .05 level, ** .01 level.

Table 2. Average number of new lateral roots per treated root of spring dug and treated bareroot trees (150 cm tall).

	Species		
Treatment[1]	*Sugar maple*	*Glenleven linden*	*Red oak*
Control	11a[2]	6d	3b
IBA	24a	22abc	13a
IBA Na salt	20a	56a	—
IBA + *B*-naphtol	13a	30abcd	14a
IA + phloroglucinol	18a	32ab	18a
IBA + nictonic acid	—	9bcd	—
NAA	11a	6cd	7ab

[1] *B*-naphtol (1 × 10^{-6}M); phloroglucinol (1 × 10^{-3}M); nicotinic acid (1 × 10^{-3}M); all IBA solutions at 3000 ppm.
[2] 1s column mean separation, 5% level.

Table 3. Average number of new lateral roots per treated root of fall dug red oak (150 cm), held in cold storage until January and treated.

Treatment	*Root number*
Control	3.5 b
IBA (3,000 ppm)	10.0 a
IBA (1,500 ppm) + *B*-naphtol (5 × 10^{-4}M)	4.5 b
IBA (1,500 ppm) + phloroglucinol (5 × 10^{-4}M)	10.0 a

Mean separation by Duncan's multiple range test, 5% level.

Experiment 3. Birch seedlings treated with IBA plus nicotinic acid or *B*-naphtol had the greatest shoot dry weight (Fig. 1). IBA plus GA_3 or GA_3 plus BAP resulted in intermediate shoot dry weight which was not different from IBA alone. Although IBA alone did result in somewhat more shoot growth it was not significantly different from the control. Root dry weight followed a nearly similar pattern except that IBA plus *B*-naphtol produced the most growth (Fig. 1).

Treatment effects were evident during the growing period of the experiment. Shoot growth 3 weeks after treatment was greatest for IBA plus *B*-naphtol and progressively less for IBA plus nicotinic acid, IBA and the control (Fig. 2). This same trend was evident for root growth when the experiment was terminated at 5 weeks (Fig. 3). Similar results were obtained for wild plum seedlings. Both IBA plus nicotinic acid or *B*-naphtol stimulated more growth than the other treatments, but these two treatments were not significantly different (Fig. 4). Both IBA plus nicotinic acid or *B*-naphtol significantly increased new growth, calculated as a percentage of total plant growth, over IBA and control treated birch and plum seedlings (data not shown).

Discussion

Root system development is controlled by external factors such as water, temperature, light and storage regime and by internal factors such as hormone balance, carbohydrate levels and enzyme activity. Root growth also varies yearly, seasonally and diurnally, within and between species and with plant age (9). Still, manipulation of root system form is potentially very great (24).

The response of the large trees to IBA seemed to be influenced by cold storage, but may also be a reflection of the physiological status of the plant at time of lifting (5). Results indicate that root development of red oak and sugar maple, which were fall dug, placed in cold storage and planted in the spring, was stimulated by IBA. Ritchie and Dunlap (18) noted that root growth capacity of seedlings may increase, decrease or remain unchanged during cold storage, dependent upon interactions with bud dormancy (hence, production of endogenous plant growth substances) and carbohydrate reserves.

Root growth capacity of sugar maple appears to be reduced during storage, indicated by lower lateral root number of the fall dug control trees in comparison to spring dug controls. The application of IBA apparently overcame this lack of root growth perhaps through mobilization of sugars (21) or increased carbohydrate metabolism necessary for root growth at the site of high auxin content. IBA has been found to increase utilization of total sugars in mango cuttings (19) resulting in root promotion apparently related to the utilization of carbohydrates in the root forming region.

Spring dug European birch, littleleaf linden and sugar maple did not respond to the application of IBA, perhaps because of an inherently optimal capacity for root growth at this time. Moser (17) stimulated root regeneration with a 3000 ppm IBA root soak on a wide range of species but these were younger plants which may have had a greater capability to respond to IBA than our larger trees.

Treatment with IBA on both spring and fall dug green ash did not enhance root growth although both treated and untreated trees from cold storage had the greater root numbers. This could be attributed to an accumulation of growth substances at the cut surface of the root during cold storage (28, 31). White ash seedlings (29) did not show a period of innate dormancy; roots were regenerated at all times with variable intensity. Possibly, varying but continually optimal levels of plant growth substances may be present in green ash trees, rendering a minimal effect of IBA. Similarly, spring dug sugar maple treated with IBA and synergists (*B*-naphtol, phloroglucinol or nicotinic acid) did not produce a significant increase in lateral root number in comparison to the control or IBA treatments, nullifying the use of a chemical stimulant on spring dug sugar maple.

Glenleven linden (150 cm whips) reacted differently from larger littleleaf linden. IBA alone and in combination with synergists increased root production compared with control plants. This response may have been due to age or physiological differences. The addition of auxin synergists did not result in significant differences compared with IBA alone, although a small sample size and considerable variability may have obscured treatment differences.

Lateral root number was consistently enhanced in spring dug red oak with a chemical treatment in agreement with previous results (13). Red oaks treated in late January displayed treatment differences, IBA at 3000 ppm or IBA at half the concentration with the addition of phloroglucinol increased lateral root number in comparison with the control. Increased root initiation usually accompanies increased auxin concentration up to a toxic level, thus phloroglucinol, which is known to increase root number in the presence of IBA, may be potentially useful in maintaining a high rate of root initiation concomitantly with lower less toxic auxin concentrations. In general, NAA appeared

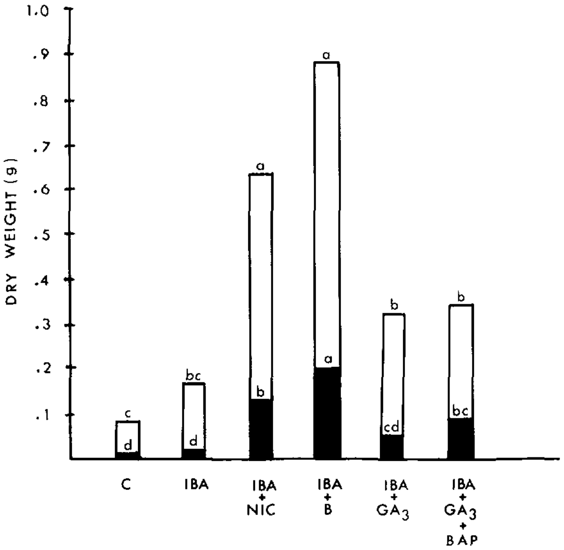

Fig. 1. Average shoot (open) and root (shaded) dry weight of one year-old, fall dug European birch seedlings treated in March. C = control; N1C = nicotinic acid (1 × 10^{-3}M); B = *B*-naphtol (1 × 10^{-6}M); GA_3 = gibberellic acid (500 ppm); BAP = benzylaminopurine (175 ppm). IBA was at 3000 ppm. Mean separation above open and shaded bars by Duncan's multiple range test, 5% level.

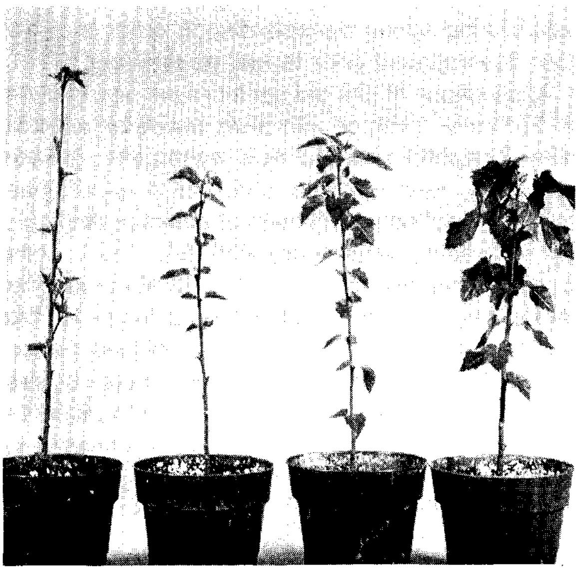

Fig. 2. One year-old, fall dug European birch seedlings photographed 3 weeks after treatment in March. Left to right: control, IBA, IBA plus nicotinic acid and IBA plus *B*-naphtol. Concentrations as in Fig. 1.

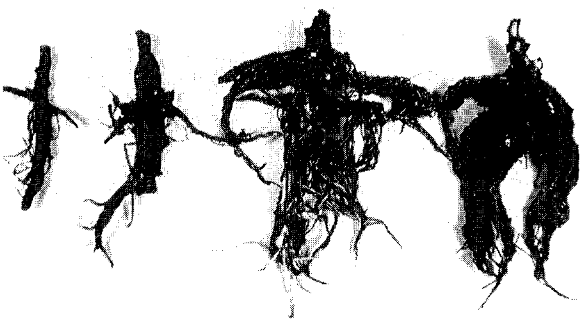

Fig. 3. Representative roots of one year-old, fall dug European birch seedlings photographed 5 weeks after treatment in March. Left to right: control, IBA, IBA plus nicotinic acid and IBA plus *B*-naphtol. Concentrations as in Fig. 1.

Fig. 4. Representative roots of one year-old, fall dug wild plum seedlings photographed 5 weeks after treatment in March. Left to right: IBA, IBA plus nicotinic acid and IBA plus *B*-naphtol. Concentrations as in Fig. 1.

to be a less effective root stimulant than IBA, in agreement with other researchers (17, 24).

Shoot growth of the red oaks grown in January initially occurred at different rates but no treatment differences were evident in the final dry weights. In general, control trees leafed-out more quickly than the IBA treated trees while the IBA plus *B*-naphtol or phloroglucinol treated trees were more variable. Such a delay may be beneficial during spring transplanting in order to allow root development prior to leaf emergence.

Applications of IBA did not increase new growth of European birch or wild plum seedlings but IBA plus *B*-naphtol resulted in a synergistic growth response. Also nicotinic acid, which used alone had no effect on root growth of pine seedlings (1, 4), reacted synergisitically with IBA. These combination treatments may be advantageous for maximizing new growth of seedlings treated in the winter and grown in unstressed conditions (for example, in the greenhouse as these were) before planting out or for obtaining a larger plant more quickly. Initial plant size has been correlated to survival; larger plants grew better and maintained a size advantage (16).

The balance between plant hormones may also influence plant growth. Smith & Schwabe (20) found that maximum shoot growth of 4 year-old English oak seedlings resulted when IBA, GA_3 and BAP were applied together. Our results indicate that total plant growth of birch seedlings was increased with this treatment in comparison to the control but was less than that obtained with auxin synergists. Total plant growth of wild plum was not enhanced with this treatment, but, with the omission of BAP, increased growth was obtained with respect to the control. Root dry weights of European birch and wild plum were also significantly greater with the auxin synergists.

Summary

Treatment with plant growth substances can stimulate new root and shoot growth. IBA seem useful on several species of landscape-size trees, having the potential two-fold effect of increasing lateral root number while delaying shoot emergence. This may allow for more rapid establishment.

In general, IBA treatments were more successful on plants obtained from overwinter cold storage. This may allow fall digging of species not normally stored overwinter.

Auxin synergists appear to be ineffective for spring dug landscape-sized trees. However, the auxin synergists were very effective on 2 species of winter stored seedlings, treated in late winter at the peak of their root growth capacity. Several of the treatments used may be commercially feasible.

Acknowledgement

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ABSTRACT

Tattar, Terry A. 1982. **The causes and prevention of construction injury.** Am. Nurseryman 155(12): 53-56.

Construction disrupts trees probably more than any other human activity. Construction activities directly affect trees and all other environmental elements. Tree health may be affected immediately by the construction, or it may decline progressively. Sometimes evidence of this may not appear until several years after construction has been completed. Because of the time that often occurs between damage and symptom onset, construction injury is frequently misdiagnosed. This article will examine the major categories of construction injury — grade changes, trenching and surface grading — and the ways to prevent and minimize construction injury. Raising the grade even a few inches can result in root suffocation and eventual death. On the other hand, lowering the grade even a few inches can result in severing and removing much of the roots. Trenching is a very common form of injury around street trees, but it is often overlooked because there is little evidence of it after construction.