THE EFFECT OF BACKFILL SOIL TEXTURE AND PLANTING HOLE SHAPE ON ROOT REGENERATION OF TRANSPLANTED GREEN ASH[1]

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Abstract. Forty-five Summit green ash trees (*Fraxinus pennsylvanica* 'Summit') were planted on a compacted clay soil site. Unamended soil, amended soil, and friable topsoil were used as backfill, in combination with holes slightly larger than the root ball, twice, and 3 times the diameter of the root ball. Numerous roots were able to penetrate the interface between backfill soil and clay subsoil in all treatment combinations. Root densities were higher in all backfill soils, but not significantly, due to the differences in soil characteristics rather than inability to grow through the interface. Larger planting holes with sloped sides helped to direct roots up to the more favorable soil at the surface if they were not able to penetrate the clay subsoil, preventing them from being trapped in the planting hole.

Planting hole preparation is an extremely important factor in the transplanting success (3). Root incursion decreases in compacted and hard to penetrate soils (5). Well aerated soils around the root ball assist in more rapid growth after transplanting (1). Large planting holes can result in greater root development (2). When the backfill soil differs from the site-soil, roots may have difficulty crossing the interface and may be restricted to the planting hole, resulting in reduced growth (4,6). These studies were conducted on agricultural soils. The purpose of this study is to examine the role of planting hole design and backfill soil type in root development on a site with compacted, high clay content soil, typical of those encountered in many urban areas.

Materials and Methods

Forty-five B&B Summit green ash (*Fraxinus pennsylvanica* 'Summit') were planted on a site with man-made, compacted, clay loam subsoil and 10 cm (4 in) of fine-loam topsoil. Drainage was so poor that the open planting holes quickly filled up with water when it rained, and stayed full of water for many days. The soil was typical of disturbed soils often encountered in the suburban landscape of the midwest. The trees were 5-7 cm (2 to 2 1/2 in) diameter with 50-55 cm (20-22 in) diameter root balls when planted in April of 1988. Three hole shapes and three backfill materials were used as treatments. The hole shapes (Fig. 1) were described as 1) slightly larger than the root ball (1.2x where x = root ball diameter) with vertical sides, 2) twice the root ball diameter with sloped sides (2x) and, 3) three times the root ball diameter with sloped sides (3x). The three backfill soil types were 1) unamended clayey site-soil that had been removed from the holes, 2) site-soil amended with 2 mm sand and composted organic matter (50%, 40%, 10% by volume, respectively) resulting in a coarse-loam soil, and 3) medium-textured loam topsoil. Bulk density of the topsoil and clay subsoil from the site were 1.1 and 1.5 g/cc, respectively. Unamended, amended and topsoil backfill bulk densities were 1.1, 1.3 (the sand component raises bulk density), and 1.0 g/cc, respectively. Bulk density of the root ball soil was 1.1 g/cc.

All possible combinations of hole shapes and backfill soils were used in nine treatment combinations. Each of the treatments was replicated five times. Trees were placed on 4.25 m (14 ft) centers in a random design. The soil around each tree was mulched with a 15 cm (6 in) deep, 3 m (10 ft) square area of wood chips to minimize evaporational losses from the soil.

In the first year, each tree was watered with 48-60 liters (12-15 gallons) of water, up to three times per week, as needed to insure survival. No supplemental water was applied to the trees for

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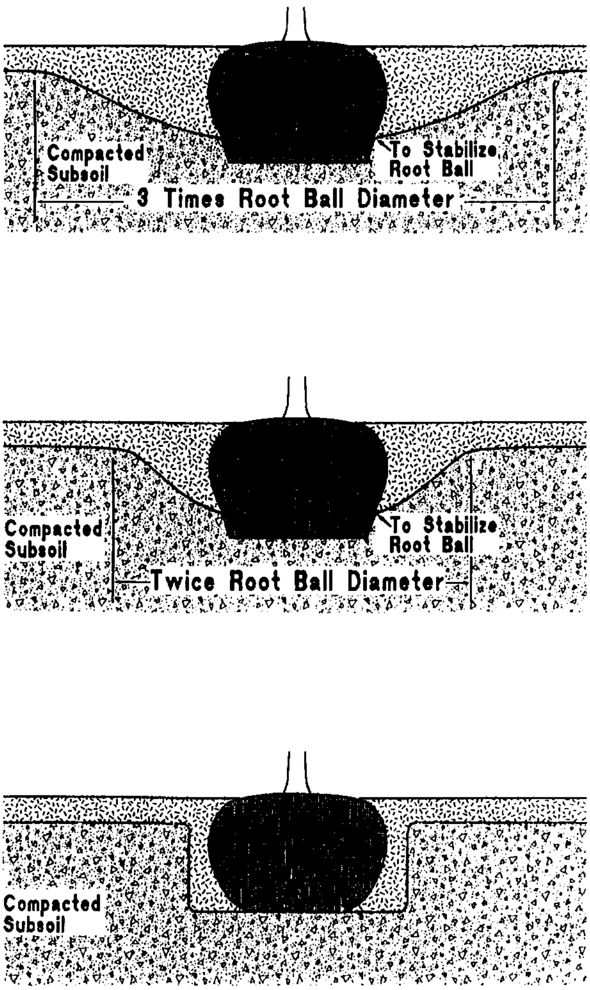

Figure 1. Diagram of the three planting hole configurations used. Larger hole designs were intended to provide a larger volume of quality backfill soil while minimizing effort required to dig them and also to eliminate the veritical wall which could trap roots in the whole if they were not sucessful in penetrating the compacted site soil.

the 1989 season, because loss of the trees was no longer feared. The soil was allowed to dry out as weather patterns dictated. The mulch squares were kept weed-free with both glyphosate herbicide and hand-weeding.

Core samples 7.5 cm (3 in) diameter and 30 cm (12 in) deep were used to evaluate root development in the backfill and soil surrounding the planting hole. Cores were removed at 15 cm (6 in) and 30 cm (12 in) from the edge of the root ball on August 8, 1988. Extremely dry soils prohibited sampling anytime in the fall of 1989 as planned. On May 30, 1990, cores were removed at 15 cm (6 in) and 60 cm (24 in) from the root ball. Sampling locations were chosen to provide the best possible information on root densities inside and outside the planting holes as well as the extension of regenerated roots, while also keeping the number of samples at a manageable level. Cores were subdivided into backfill (or topsoil where no backfill was included) and clay subsoil. Root surface area of each subsample was measured (7).

Trunk diameter was measured annually in August from a permanent mark 30 cm (12 in) above the ground. Terminal growth was measured on branches in the middle of the crown, using 8 branches from each tree evenly distributed in all directions.

Response to treatments were analyzed using One-way Analysis of Variance. Newman-Keuls test at the 5 percent level was used for analysis of mean separation. Differences in root density between the backfill soil and the clay subsoils were determined using the T-test at the 5% level.

Results and Discussion

Schulte and Whitcomb (6) described total inhibition of root growth outside of the planting hole when the backfill soil was amended. In this study, roots were able to penetrate the interface between backfill soil and clay site soil within the first season after transplanting, regardless of treatment. Roots were present in every subsoil sample. T-tests showed no significant differences between root density in the backfill soils and clay subsoil outside the planting hole near the end of the first season (Table 1). After two years, significant differences were noted for some treatment combinations, but they were not related to any specific hole size or backfill treatment. The scattered significant differences noted are probably due to the different soil types (5) rather than to difficulty crossing the interface. When backfill soils were carefully removed without disturbing the roots, the roots could be seen growing into the clay subsoil (Fig. 2). Penetration seemed to take place at cracks and other natural

Table 1. Green ash root densities in backfill (BF) and compacted clay topsoil (CL) samples

		15 wks after planting				57 wks after planting			
		15 cm[1]		30 cm		15 cm		60 cm	
Hole	Backfill	BF	CL	BF	CL	BF	CL	BF	CL
1.2X	unamended	1.9	1.7	0.4	0.6	5.9	4.3	5.8	2.9
1.2X	amended	4.4	0.5	1.2	0.3	7.2	3.4*	4.5	2.4
1.2X	topsoil	3.5	1.9	1.0	0.3	6.9	5.3	6.7	3.1*
2X	unamended	3.0	0.5	2.0	0.3	6.7	4.2*	4.3	2.5
2X	amended	3.1	1.8	0.8	0.5	5.9	3..3*	5.7	3.7
2X	topsoil	2.2	1.0	1.5	0.4	6.7	4.3	5.9	3.0
3X	unamended	2.4	1.0	0.8	0.3	6.9	5.0	4.3	1.8*
3X	amended	1.9	1.8	1.4	0.3	5.3	4.2	3.8	2.2
3X	topsoil	1.8	0.9	0.9	0.7	4.3	3.5	5.7	2.4*

1.Distance from the root ball
* Significant difference between backfill soil and clay subsoil at the same location and sampling date at the 5 percent level using two-tailed T-test. There were no significant differences among the data in each column using Newman-Keuls test for mean separation at the 5 percent level.

openings in the otherwise dense soil. In the 2x and 3x holes with sloped sides, roots that had no opportunity to penetrate the subsoil grew along the interface, up towards the topsoil at the surface.

Green ash was chosen because is is well suited to the site. Other species that were less adapted to poor drainage and low aeration may have been less successful at growing across the interface simply because of their inability to tolerate the compacted clay soil outside of the planting hole. An inappropriate mix of species and soil type may have been the used in previous studies where roots were unable to grow across the interface. In these previous studies, inhibition of root growth across the soil interface was associated with large amounts of organic matter as soil amendments, while smaller, more realistic amounts of organic matter, such as those used in this study, were not associated with a reduction of root growth across the interface.

Root density was similar in all backfill soils with no significant differences among treatment combinations at similar sampling locations or dates (Table 1). Once the compacted clay soil was broken up by digging the hole, and mixed with some of the topsoil in the process, root density increased in this soil as well. Root development in the compacted subsoil was generally lower than in the backfill, but also not significantly different among treatments for similar sampling locations and dates, providing additional evidence that soil interfaces did not inhibit root development outside the planting hole.

Root density increased between sampling dates in both the backfill soil and compacted subsoil. Root density in the backfill was similar to previous reports for transplanted green ash, but lower than for established trees (11,12). Several years are apparently required for maximum root densities to develop in the soil.

Tree growth, measured as terminal growth and trunk diameter increase, was not significantly different for any treatment combination (Table 2). If expansion of the root systems was not restricted by the soil interface in any treatment, then growth should be similar for all trees. Growth of these 5 cm (2 in) caliper trees was reduced for the first two years after transplanting. Growth of 10 cm (4 in) caliper trees was reduced for 4 years (14). One year for each 2.5 cm (1 in) trunk diameter seems to be a reliable estimate of the normal establishment period in a temperate climate.

The purpose of providing a large planting hole filled with quality soil is to provide a favorable environment for the initial stages of root regeneration. During the first half of the establishment

Table 2. Terminal growth and trunk diameter increase of green ash following transplanting.

Hole	Backfill	Terminal growth					Trunk diameter increase
		1987	1988	1989	1990	88-90	88-90
1.2X	unamended	26.6	1.9	3.0	28.1	32.9	2.24
1.2X	amended	30.3	2.4	1.8	39.3	43.5	2.04
1.2X	topsoil	27.1	1.8	1.9	26.8	32.2	1.98
2X	unamended	19.6	1.6	2.4	29.9	33.9	1.96
2X	amended	24.9	2.5	2.6	38.1	43.3	1.96
2X	topsoil	26.2	3.3	2.1	28.3	33.7	1.96
3X	unamended	24.7	2.5	2.3	32.2	36.9	2.14
3X	amended	24.1	2.6	1.9	20.1	24.7	2.18
3X	topsoil	24.1	1.9	3.1	32.8	37.8	2.08

There were no significant differences among treatments for any column using Newman-Keuls test for analysis of maan separation.at the 5 percentlevel.

Figure 2. Roots grew readily from the backfill soil into the compacted site-soil without any apparent interface restriction.

period, the 3 - 5 percent of the root system that is transplanted with the tree (10,13) increases to approximately 25 percent (8). Until the root system is at least 25 percent regenerated, top growth is very slow (9).

In this study, roots were more than twice as dense in the backfill soil midway through the establishment period (after the first year). As calculated from soil volumes and root densities, the root system of trees in the 2x and 3x holes were 53 and 82 percent larger after one season than trees planted in the smallest holes. With a larger root system, it would be natural to expect increased growth, but this was not the case. With 95 percent of the root system lost during transplanting, and little regeneration occuring in the few weeks between planting and spring growth, regardless of treatment, top growth of all trees is drastically reduced by water stress during the first season. Buds formed under this stress are also small, and resulted in uniformly slow growth the second year for all trees. The spring and early summer of the second year, the time when top growth occurs, was extremely dry (soil moisture tensions exceeding -700 mbars). Extremely dry soils throughout the root zone, would also slow the growth of all trees. By the third growing season, the trees were nearly fully established with growth equal to pre-transplanting levels. Had larger trees been used, requiring several more years for establishment, the increase in root growth may have been reflected in top growth after the first two years.

Conclusions

Soil interfaces resulting from different planting hole backfill soil and the site soil do not necessarily interfere with root development, as previously reported. Roots of green ash readily grew across this interface into compacted clay soil, when three different backfill soil types were used. Compaction or other difficult conditions in the soil outside the planting hole, combined with the capability of the species chosen to tolerate these conditions, may be more important than the interface. Root development was good in the unamended soil used as backfill, presumably because of the reduction of compaction and increased aeration which resulted from digging the hole. There is no reason to fear amending the backfill soil, but there may also be little incentive to amend it for trees of this size, since it produced no increase in growth. Faster root regeneration is possible in the additional backfill soils provided by a large planting hole (at least twice the root ball diameter). Sloped sides directed those roots that did not penetrate the dense site soil out of the planting hole, thus preventing them from being trapped.

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Résumé. Quarante-cinq frêne de Pennsylvanie Summit (Fraxinus pennsylvanica) étaient plantés dans un sol argileux compacté. Un sol non amendé, un sol amendé et un sol fait de terre arable friable étaient employés pour le remplissage en combinaison avec des trous légèrement plus grands que la motte, du double et du triple du diamètre de la motte. De nombreuses racines étaient capables de pénétrer l'interface entre le sol de remplissage et le sol argileux environnant, et ce pour toutes les combinaisons de traitements. La densité en racines était plus élevée pour tous les types de sol de remplissage, mais pas significativement, et ce plus en raison des différences de caractéristiques de sols que de l'incapacité de croître au travers de l'interface. Les trous plus larges avec des flancs inclinés favorisent le développement des racines in direction de la surface, vers un sol plus favorable, si ces dernières n'ont pas la capacité de pénétrer le sol argileux environnant et ainsi préviennent ces dernières de se voir piéger à l'intérieur de trou de plantation.

Zusammenfassung. 45 Eschen (*Fraxinus pennsylvanica* "Summit") wurden gepflanzt auf einem Standort mit dichtem Lehm. Unverbesserter, verbesserter und aufgebrochener Boden wurden als Füllmaterial für die Pflanzgrube benutzt in Kombination mit unterschiedlich großen Pflanzlöchern, die entweder geringfügig größer als der Wurzelballen, doppelt oder dreimal so groß waren. Bei allen Behandlungsvarianten war es mehreren Wurzeln möglich, in die Schicht zwischen dem Füllmaterial und dem lehmigen Untergrund vorzudringen. Die Wurzelhäufigkeit war in allen Füllmaterialien höher, jedoch nicht signifikant. Wenn die Wurzeln nicht in der Lage sind, in den lehmigen Untergrund einzudringen, unterstützen größere Pflanzlöcher mit schrägen Seiten das Wurzelwachstum in Richtung Oberfläche mit besseren Bodendedingungen. Sie werden so vor der Einengung im Pflanzloch geschützt.