ROOT BARRIERS AND WINDTHROW POTENTIAL

by E. Thomas Smiley[1], Albert Key[2], and Craig Greco[3]

Abstract. This study was developed to determine if commercially available ribbed barriers reduce or increase the stability of trees under severe lateral stress. Green ash *(Fraxinus pennsylvanica)* were planted in November 1996: 6 in surrounding-type tree root barriers and 6 without barriers. Half of each group was pulled over in July 1999 under dry (14% water) soil conditions and the other half was pulled over under saturated (33% water) soil conditions. The force required to pull the trees over was measured as was the wind resistance of the trees. Slightly more force was required to pull over the trees grown within root barriers than the control trees. The force required for the weakest tree, however, was far greater than that exerted by a 100-mph (160-kph) wind. The reason for the increased strength of the root barrier trees appeared to be the deeper root system.

Key Words. Sidewalk damage; root barrier; windthrow; tree failure

Curb and sidewalk damage resulting from interaction with tree roots continues to be a common problem in cities throughout the world. A statewide tree assessment in New Jersey estimated that 25% of street trees were involved with sidewalk damage (Cradic 1996). Sidewalk repair costs were cited as the highest tree care related costs facing municipalities today (McPherson and Peper 1995). Many of these problems may be due to inadequately engineered sidewalks (Sydnor et al. 2000; Steve Sanford, pers. comm.). Until these design and construction problems are commonly managed, arborists will continue to use many techniques to manage the interaction of roots and concrete structures. Commercially available plastic root barriers frequently are a selected solution. In California, a survey of municipalities showed that 60% of communities use root barriers on a regular basis (Bernhardt and Swiecki 1994).

Previous studies with tree root barriers have addressed root growth after the interaction with the barrier to ascertain the effectiveness of the treatment (Barker 1993; Gilman 1995; Costello et al. 1997; Peper 1998; Wagar 1985). These studies found that surface rooting of trees was significantly reduced close to the installed barrier, with no statistical difference in tree growth. With the exception of Gilman (1995), all studies were conducted with barriers surrounding the root ball, rather than linearly along one side. To gather the data, all studies included root excavation and counting, thereby eliminating the opportunity to test tree stability.

There has been concern that circling root barriers may reduce the stability of trees under extreme wind condition. It has been observed that trees growing near various subgrade structures are more susceptible to windthrow (Francis and Gillespie 1993). This study was developed to determine if commercially available ribbed barriers reduce or increase the stability of trees under severe lateral stress.

MATERIALS AND METHODS

Thirty-six 1.5-in. (4-cm) caliper green ash *(Fraxinus pennsylvanica)* were dug with a 32-in. (81-cm) diameter tree spade set to cut an 18-in. (46-cm) diameter root ball and planted on November 11 and 12, 1996. Half of the trees were installed centered in 22-in. (55-cm) top diameter by 18-in. (46-cm) deep round preformed tree root barriers (Deep Root Partners, L.P., San Francisco, CA, Product #RP22-30-18) planted according to manufacturers recommendations (Figure 1). The other half were planted in backhoe-dug holes, twice the width of the root ball. No wire baskets or burlap were used. All trees were irrigated during drought periods and fertilized equally in the fall of 1997 and 1998.

On July 20, 1999, three trees growing in the barrier and three control trees were attached to a 0.25-in. (6.3-mm) steel cable using a nylon sling attached 24 in. (61 cm) above soil level (Figure 2). The opposite end of the cable was attached to a Dillion 4,000 lb (1,800-kg) peak recording mechanical dynamometer (Weight-Tronix Inc., Fairmont, MN) then to a tractor.

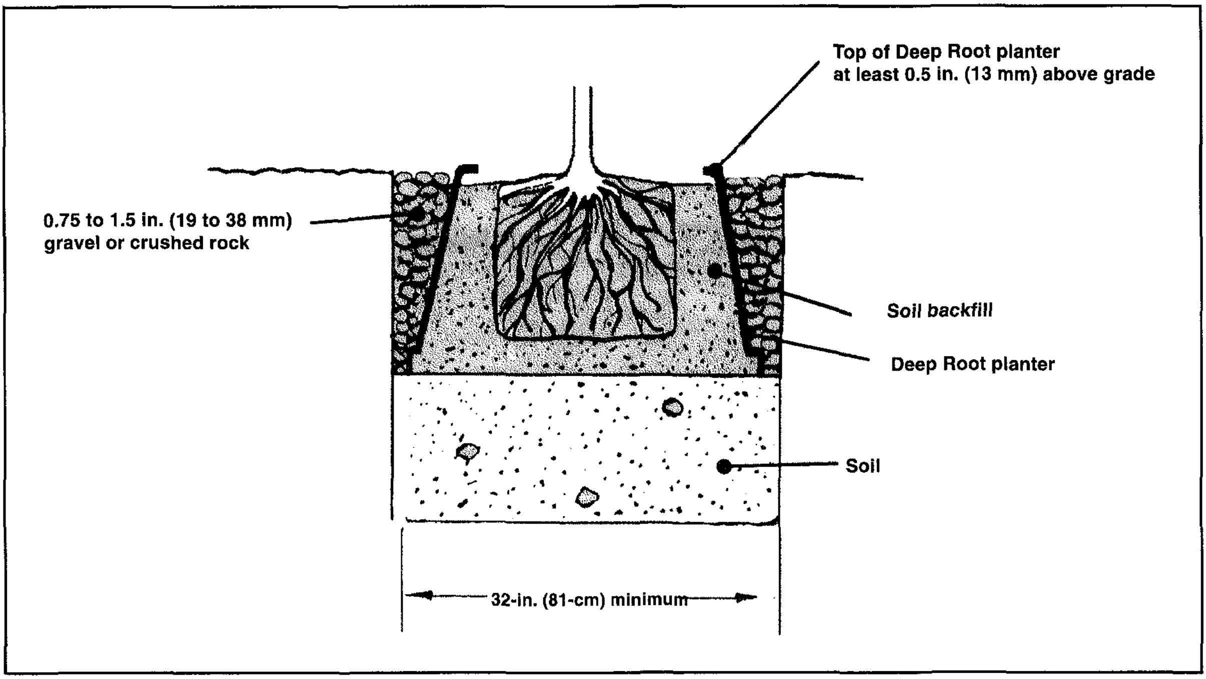

Figure 1. Planting specifications for Deep Root surround planter (RP 22-30-18).

Trees were pulled until they either broke or were pulled out of the ground. Tree height, spread, caliper at 6 in. (15 cm) above soil level, and force required to pull it over were recorded. Mean breaking strength, diameter, height, and branch spread were statistically compared using a T-test.

Soil at the site was a Cecil sandy clay loam (CeB2). Soil samples were collected from around the tree roots to determine soil moisture content. Samples were dried to a constant weight and moisture was determined gravimetrically. After six trees were pulled, the field was flood irrigated for a total of 5 hours before the next set of trees were pulled. A second set of six trees was then pulled after the soil was saturated.

After each set of two trees was pulled, the trees were severed near the soil line, mounted in the back of a pickup truck (Figure 3) and driven at set speeds. The trunk of the tree was tied to a Dillion HR 2000 electronic dynamometer at 24-in. (61 cm) above the original ground level, to record the force of the wind on the tree. The base of the tree was contained loosely within a wooden frame, and ropes were loosely connected from the trunk to the sides of the truck to prevent excess lateral movement. Vehicle speed was monitored with a Garmin GPS 45 global positioning system. Wind resistance was measured on the first six trees. Results were statistically analyzed using a regression analysis.

The remaining trees will be pulled over in 3 to 5 years to determine if stability changes as size increases.

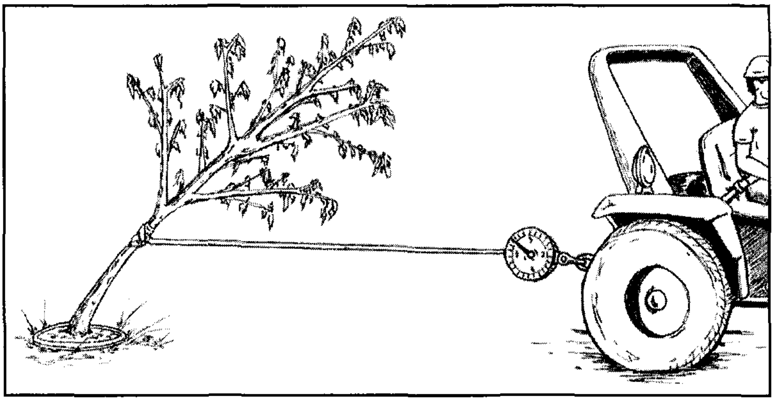

Figure 2. Ash trees planted 2.5 years before in surrounding barriers or open soil were attached to a dynamometer using a nylon sling and steel cable and pulled until they broke or came out of the ground.

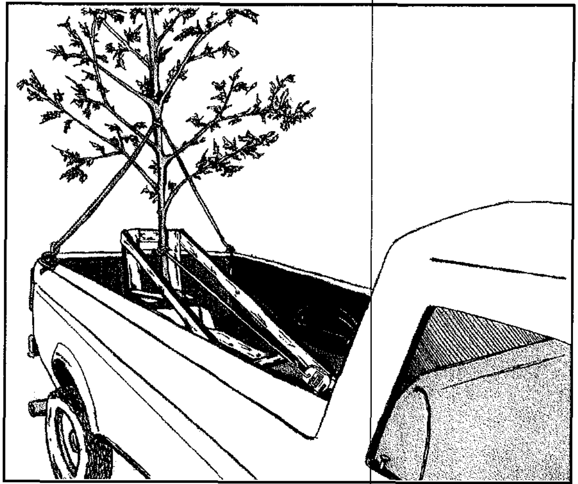

Figure 3. Tree mounting system used to measure the wind resistance of ash trees. Note that there are only two contact points for the system—the dynamometer connecting line and the base of the platform that restrains movement of the bottom of the trunk. The guy lines going to the corners of the truck were not under tension unless the tree moved laterally.

RESULTS

Under dry soil conditions, the trees within the root barriers were pulled out of the ground at an average force of 2,341 lb (1,060 kg, Table 1). These trees failed after the roots in the 1-to-2-in. (2-to-5-cm) diameter range broke. The control trees broke with an average force of 1,961 lb (888 kg) when the lower stem/root collar broke. Average soil moisture was 14.5 % water (w/w).

Under saturated soil conditions, the trees within the root barriers pulled out of the ground with an average force of 2,860 lb (1,296 kg, Table 1). These trees failed when the root system broke. The control trees failed with an average force of 2,063 lb (934 kg).

Table 1. Force in pounds required to pull over ash trees growing within surrounding root barriers or open grown, under two levels of soil moisture. Means are not significantly different when analyzed with a T-test.

	Treatment			
	Soil dry		Soil saturated	
Tree	Barrier	Control	Barrier	Control
1	2,000	1,735	3,030	1,290
2	2,800	2,150	3,550	1,725
3	2,225	2,000	2,000	3,175
Average	2,341	1,961	2,860	2,063

The control average may be high because one tree was pulled 2 hours after the other trees—and the force to pull it out was over twice the average of the other two. The control trees all failed when their root systems pulled out of the soil. Average soil moisture content when the last tree was pulled was 33% water.

The measure of wind resistance showed a linear increase with vehicle speed (Figure 4). Using the calculated regression line to extrapolate beyond the data to a 100 mph (160 kph) wind speed, the force would be 365 lb (165 kg). This value is one third less than

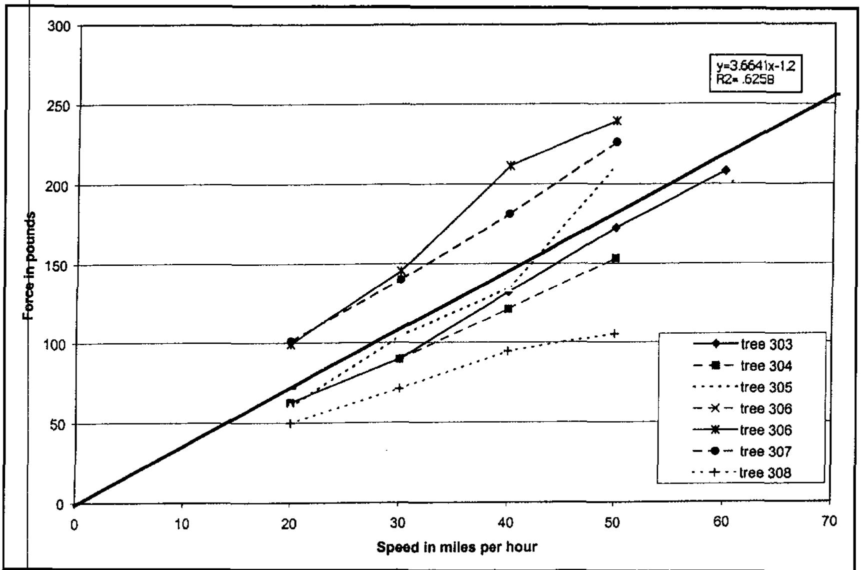

Figure 4. Wind resistance of green ash *(Fraxinus pennsylvanica)* measured at various speeds 24 in. (61 cm) above original grade. Odd-numbered trees were grown within root barriers. Bold line is the regression line for all trees.

the lowest value (1,290 lb [584 kg]) required to pull a treated or control tree over under saturated soil conditions

Visual observations indicated that root barrier grown trees appeared healthier. Average caliper, height, and branch spread of root-barrier-grown trees, however, were not significantly greater than controls (Table 2).

DISCUSSION

Young ash trees were very wind stable with or without surrounding root barriers. The wind speed equivalent force required to break or throw these trees was far in excess of 100 mph (160 kph).

There were different failure patterns between barriers and control trees. Under dry conditions, the barrier treatments allowed the roots to move more, increasing the breaking force required. Because the root system did move, there were no trunk failures with the barrier. The control trees failed at the root collar or when the stem broke.

Under saturated conditions, the pattern of failure was the same for all trees: The roots pulled out of the ground with breakage occurring in roots 0.25 to 0.5 in. (0.6 to 1.3 cm) in diameter. The force required to pull the trees out differed depending on treatment. Trees with root barriers were able to withstand higher forces than the control trees. It appeared that the reason for this increased resistance was deeper rooting of the barrier-surrounded trees. Roots grew beneath the barrier to a depth typically 12 to 16 in. (30 to 40 cm) deeper than the control trees. After growing under the barrier or through the slots near the bottom of the barrier, root growth varied. Most roots turned upward in to the soil outside of the gravel that surrounds the barrier, then became horizontal at a depth of 4 to 10 in. (10 to 25 cm). No girdling roots were observed; many roots inside the barrier were deflected downward by the ribs in the surface of the barrier.

Table 2. Size comparison between treatments on ash trees. None of the differences was significant when analyzed using a T-test.

	Average			
Treatment	Caliper (in.)	Height (in.)	Branch spread (in.)	n
Barrier	2.78	142.5	87	6
Control	2.65	140	80	6

The root system configurations of trees surrounded by root barriers were very different from the control trees. After three growing seasons, this difference resulted in ash trees being more resistant to windthrow within root barriers than nontreated trees. The long-term effects of circling root barriers needs to be studied to determine if these trends continue.

LITERATURE CITED

Barker, P. 1993. Root barriers for controlling damage to sidewalks. In Watson, G.W., and D. Neely (Eds.). The Landscape Below Ground: Proceedings of an International Workshop on Tree Root Development in Urban Soils. International Society of Arboriculture, Champaign, IL. 222 pp.

Bernhardt, E., and T.J. Swiecki, 1994. The State of Urban Forestry in California. California Department of Forestry and Fire Protection, Sacramento, CA. 20 pp.

Costello, L., C. Elmore, and S. Stainmaus. 1997. Tree root response to circling barriers. J. Arboric. 23(6):211–218.

Cradic, A. 1996. Trees in Crisis—A Statewide Assessment of New Jersey's Street Trees. New Jersey Department of Environmental Protection, Division of Parks and Forestry's State Forest Service, Trenton, NJ. 8 pp.

Francis, J., and A. Gillespie. 1993. Relating gust speed to tree damage in hurricane Hugo. J. Arboric. 19(6):368–373.

Gilman, E. 1995. Root barriers effect root distribution. In Watson, G., and D. Neely (Eds.). Trees and Building Sites: Proceedings of an International Conference Held in the Interest of Developing a Scientific Basis for Managing Trees in Proximity to Buildings. International Society of Arboriculture, Champaign, IL. 191 pp.

McPherson, G., and P. Peper. 1995. infrastructure repair costs associated with street trees in 15 cities. In Watson, G., and D. Neely (Eds.). Trees and Building Sites: Proceedings of an International Conference Held in the Interest of Developing a Scientific Basis for Managing Trees in Proximity to Buildings. International Society of Arboriculture, Champaign, IL. 191 pp.

Peper, P. 1998. Comparison of root barriers installed at two depths for reduction of white mulberry roots in the soil surface. In Watson, G.W., and D. Neely (Eds.). The Landscape Below Ground II: Proceedings of an International Workshop on Tree Root Development in Urban Soils. International Society of Arboriculture, Champaign, IL. 265 pp.

Sydnor, T.D., D. Gamstetter, J. Nichols, B. Bishop, J. Favorite, C. Blazer, and L. Turpin. 2000. Trees are not the root of sidewalk problems. J. Arboric. 26(1):20–25.

Wagar, J. 1985. Reducing surface rooting with control planters and wells. J. Aboric. 11(6):165–171.

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Résumé. Cette étude a été créée pour déterminer si les barrières à rainures qui sont disponibles sur le marché peuvent réduire ou accroître la stabilité des arbres soumis à des stress latéraux sévères. Des frênes de Pennsylvanie *(Fraxinus pennsylvanica)* ont été plantés en novembre 1996: 6 entourés de barrières racinaires et 6 sans barrière. La moitié des arbres de chacun des groupes ont été renversés en juillet 1999 sous des conditions de sol sec (14% d'eau) et l'autre moitié l'ont été sous des conditions de sol saturé (33% d'eau). La force requise pour renverser les arbres a été mesurée comme si c'était celle de la résistance face au vent des arbres. Une force légèrement plus importante a été requise pour renverser les arbres qui s'étaient développés à l'intérieur d'une barrière racinaire que ceux sans cette barrière. Quoiqu'il en soit, la force requise pour renverser le plus faible des arbres a été beaucoup plus élevée que celle exercée par un vent de 160 km/h. La raison de l'accroissement de la résistance des arbres à l'intérieur d'une barrière racinaire s'expliquerait par un enracinement plus profond.

Zusammenfassung. Diese Studie wurde entwickelt, um zu bestimmen, ob im Handel erhältliche gerippte Barrieren die Stabilität von Bäumen mit großem lateralen Stress reduzieren oder unterstützten. *Fraxinus pennsylvanica* Wurde im November 1996 gepflanzt: 6 mit einer umgebenden Wurzelbarriere und 6 ohne Schutz. Die Hälfte jeder Gruppe wurde im Juli 1999 unter trockenen Bodenverhältnissen (14 % Wasser) und die andere Hälfte bei wassergesättigen Verhältnissen (33 % Wasser) umgezogen. Die aufgewendete Kraft, sowie der Windwiderstand der Bäume wurde gemessen. Für die Bäume mit der Wurzelbarriere war bei beiden Bodenverhältnissen etwas mehr Kraft erforderlich. Die erforderliche Kraft für den schwächsten Baum lag dennoch viel höher als die Windkraft mit 100 mph (160-kph). Der Grund für die ansteigend aufzubringende Kraft für die Bäume mit Wurzelbarriere schien in dem tieferen Wurzelsystem zu liegen.

Resumen. Este estudio fue desarrollado para determinar si las barreras reforzadas, disponibles comercialmente, reducen o incrementan la estabilidad de los árboles bajo condiciones severas de estrés lateral. Árboles de fresno *(Fraxinus pennsylvanica)*, fueron plantados en noviembre de 1996: 6 con barreras para raíces del tipo común en la zona y 6 sin barreras. La mitad de cada grupo fueron extraídos en julio de 1999 bajo condiciones de suelo seco (14% de humedad) y la otra mitad fueron extraídos bajo condiciones de suelo saturado (33% de humedad). La fuerza requerida para sacar a los árboles fue medida como la resistencia al viento por parte de los mismos. Se requirió levemente más fuerza para sacar a los árboles que crecieron con barreras que los de control. La fuerza requerida para extraer al árbol más débil, sin embargo, fue mucho mayor que la ejercida por un viento de 160 km/h (160 mill/h). La razón de la mayor resistencia de los árboles, con raíces en barreras, parece ser su sistema más profundo de raíces.