United States
Department of
Agriculture

Forest Service

**Northeastern Forest
Experiment Station**

Research
Paper NE-513

1982

Effect of Planting Procedures on Initial Growth of *Acer rubrum* L. and *Fraxinus pennsylvanicum* L. in a Parking Lot

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Manuscript received for
publication 11 November 1981

Abstract

Five-year old red maples, *Acer rubrum* L. 'October Glory', and green ash, *Fraxinus pennsylvanicum* L. 'Marshall Seedless', were planted in 8 ft x 8 ft openings in an asphalt parking lot with two planting stocks (bare-root, BR, and balled and burlapped, B&B) and two fertilizer levels (a control and 1.36 kg of 10-10-10 fertilizer along with 1.36 kg of dolomitic limestone per tree). After two growing seasons, survival of the 32 trees was 100 percent, and they grew better than trees similarly planted off the lot. Fertilizer reduced growth of BR green ash; increased shoot growth, but not height or crown width growth of BR red maples; and had a negligible effect on growth of B&B trees of either species. BR red maples and unfertilized BR green ash generally grew better than corresponding B&B trees.

Introduction

Urban development has altered our physical environment by replacing native soil and natural vegetation with large areas of impervious surfaces such as parking lots. This development leads to extremes of heat and radiation which create an undesirable urban climate. Solar radiation impinges directly on pedestrians and is absorbed by asphalt surfaces. The surfaces are heated and act as sources of longwave radiation and of sensible heat to the air above them. Trees can ameliorate undesirable parking lot environments by shading people, vehicles, and parking lot surfaces.

Trees may be established in many parking lots with very little loss of space for parking cars (Nelson and Porter 1976). To achieve environmental benefits in a reasonable time, it is necessary to plant them by methods that promote rapid adaptation, growth, and development. However, there is little information about planting methods, nutrient needs, and desirable species for urban environments (Cool 1980).

Many ordinances and landscape specifications require that large trees be planted with roots balled and burlapped (B&B) rather than bare-root (BR), because it is presumed that B&B trees have greater survival and initial growth rates. However, there is little evidence from formal studies in the literature to support this supposition. B&B trees are more expensive to lift, transport and plant than BR trees. The BR method of planting may be more attractive if survival and growth rates are comparable to those of the balled and burlapped stock.

Fertilization at planting time is another practice with insufficient research data to support a standard recommendation. Some contend that because of root damage during transplanting, trees may be unable to use added nutrients; and further, newly developing roots may be injured by a fertilization treatment. Others maintain that the soil backfill must be enriched with fertilizer because that is likely to be the only fertilizer the plant will ever receive.

A study was therefore initiated to improve guidelines for introducing trees into the urban setting, with particular emphasis on the urban parking lot. The primary study objective was to evaluate the effect of two planting methods (stocks) and a fertilizer treatment on early survival and growth of two deciduous species. A secondary objective was to provide a demonstration of the functional and aesthetic benefits of trees in a parking lot. This paper presents the results of growth measurements after the first and second growing seasons.

Methods

Thirty-two trees of two deciduous species (16 trees of each) were planted in openings cut in a large parking lot. The two species were red maple (*Acer rubrum* L.) cultivar 'October Glory' and 'Marshall Seedless' green ash (*Fraxinus pennsylvanicum* L.). These two species have proven to be relatively tolerant of urban stresses (New Jersey Federation of Shade Tree Commissions 1974). The trees were 5 years old and averaged about 2.5 m tall. Half of the trees of each species were balled and burlapped and half were bare root. Half of the trees received a fertilizer treatment at the time of planting.

The parking lot, located on the Cook College Campus at Rutgers University in New Brunswick, NJ, is about 190 m long and 50 m wide. The surface slopes slightly toward storm-sewer drains along one side. Before construction of the lot, the land was used for field crops, and during the course of this experiment, the surrounding land on three sides remained in field crops and experimental turf plots.

The parking lot was constructed on poorly-drained Nixon silty clay loam soil. During construction of the lot in 1972, a layer of soil was removed. Much of this soil, including the topsoil, was stored in a low pile along the edge of the lot. After removal of the soil layer, a 30-cm sand base was laid down and covered with asphalt. The present slope approximates the slope of the land before construction.

The experimental design was a factorial combination of eight treatments (2 species x 2 planting methods x 2 fertilizer levels) with four replications representing four blocks. The blocks were used to separate possible gradients in soil fertility and moisture availability along the length of the parking lot.

In order to accommodate our trees, 32 planting sites were cut in the asphalt between parking stalls using a "diamond" pattern. This arrangement, suggested by Nelson and Porter (1976), allowed inclusion of the trees in the lot with no loss of parking spaces. Each site was 2.6 m by 2.6 m (Fig. 1).

The planting sites were distributed across the lot at a density of about one tree per 10 stalls. The spacing was based on requirements of typical municipal landscape ordinances (Cherry Hill, New Jersey, Ordinance 69-24 and Hillsborough, New Jersey, Ordinance 75-13).

After removal of the asphalt with jack hammer and backhoe, the planting sites were prepared by excavating the sand and soil to a depth of approximately 45 cm below the top of the asphalt. Then, four railroad ties were permanently anchored around each planting hole to act as curbing. The holes were then refilled with the silty clay loam soil from the pile created during construction of the lot. The surface of the added soil was 10 to 15 cm above the top of the asphalt. Physical and chemical characteristics of the backfill, soil stored during lot construction, are listed in Table 1.

Table 1.—Physical and chemical characteristics of the backfill soil.

pH (water)	5.0
Organic matter (L.I., % dry weight)	3.9
Texture analysis:	
Silt percent	59
Clay percent	35
Sand percent	6
Classification	silty clay loam
Exchange capacity (meq/100 g) (extraction with NH_4OAc, pH = 7)	15.60
Available nutrients (ppm):	
Nitrogen (assumed as 2% of total N)	14
Phosphorus	11
Potassium	50
Magnesium	307

The trees were acquired from a local nursery and planted in late April. They were 3.0 to 4.0 cm in caliber at 30 cm above the soil line, and between 2.0 and 3.6 m in height. The B&B trees had soil balls approximately 40 cm in diameter and 45 cm in depth. Reasonable care was taken to minimize root desiccation of the bare-root stock during the time between receipt and planting.

The fertilization and lime treatment consisted of an application of a complete inorganic fertilizer (10-10-10) and pulverized dolomitic limestone (min. $CaCO_3$ 51.5%, min. $MgCO_3$ 44.0%). The soil amendments were based on a nutritional study of seedling red maples conducted before the beginning of this project by Pham et al. (1978). They related the existing nutrient status of the planting soil (Table 1) to acquire results based on growth responses, and calculated the treatment rate at 1.36 kg of the N-P-K fertilizer and 1.36 kg of the pulverized limestone. The soil amendments were hand mixed in the appropriate planting sites with approximately 0.3 m^3 of planting soil, immediately before tree planting at

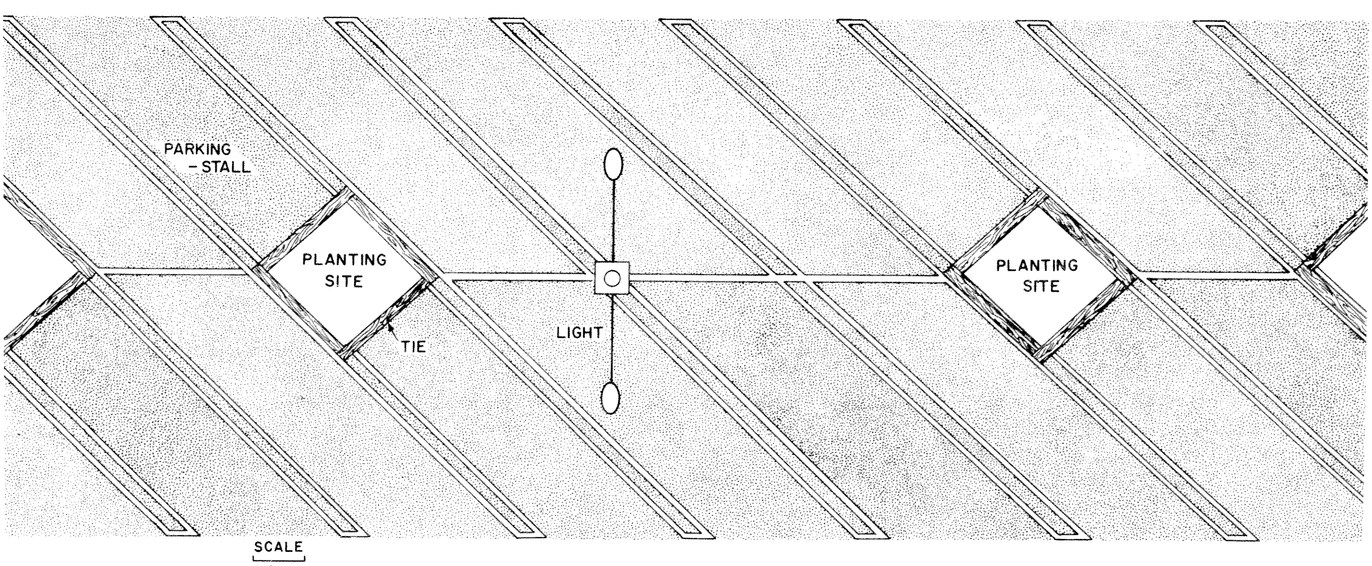

Figure 1.—Diamond planter pattern used within the diagonal parking stalls.

each of the treated sites. After planting, the fill gradually settled and a thin layer of wood chips was added to control weeds and conserve soil moisture.

At the time of planting, trees were pruned according to guidelines established by the New Jersey Federation of Shade Tree Commissions (1974). Approximately two-thirds of the crown was removed from the bare rooted trees of each species. Pruning on the balled and burlapped trees of both species consisted of the removal of broken, dead, or conflicting branches from the crown.

Soil temperature and moisture were not considered as variables in this study. However, thermocouple psychrometers were installed at each planting site in September of the first growing season, and observations of temperature and moisture were made weekly through the second growing season.

Soil moisture was quite high during the second growing season. During the weekly observations, only one planter box was found to have soil moisture below -1 bar tension. Soil psychrometers are limited to measuring soil tensions of about -1 bar or less. The soil tensiometers indicated soil moisture between 3 and 37 centibars tension, but there were differences among the five planting sites. The ranges of observed moisture tension were 3 to 6, 4 to 7, 4 to 9, 5 to 18, and 8 to 37 negative centibars for the five sites.

Additional information about moisture conditions was obtained from 1.2-m-deep ground water wells at four widely-spaced planting sites across the lot. During most of the summer, measurements showed a relatively high water table, probably due to rain water flowing across the lot surface and seeping beneath the ties into the relatively large planting openings, generally poor horizontal drainage of the site, and the lack of upward movement of water through the impervious asphalt, which limited evaporation. Our observations did not show any general soil-moisture gradient across the lot.

The second season had 48.8 cm of rain, (April through August), which is close to the long-term norm. We believe that moisture was not severely limiting during the first growing season, although rainfall was only 37.3 cm, about 24 percent below normal.

No severe soil temperatures were noted in the weekly measurements between November following the first growing season and the January following the second season. Maximum soil temperatures exceeded control temperatures by 3° C beneath the parking lot trees and up to 10° C beneath the asphalt cover (Halverson and Heisler 1981).

Treatment effects were determined by a variety of different measurements of tree growth after the first and second growing seasons: total tree height, crown width, crown height, diameter at 30 cm above the soil, average shoot growth, and average leaf area and dry weight. Crown width and crown height were averaged to form a composite "average crown dimension" (ACD).

Crown width was measured in both the north-south and east-west directions. Measurements were taken horizontally through the widest point of the crown in each direction.

Shoot elongation was measured on six shoots on each tree. Three shoots of similar diameter were chosen from the north and south sides of each tree at midcrown height.

Leaf area and dry weight were recorded as the average of 30 leaves from each tree. The leaves were collected in mid-August from the midcrown and upper crown of the north and south side of the trees. Petioles were separated from the blade, and blade area was recorded with a leaf area meter[1] immediately after collection. Leaf blades were then ovendried at 70°C and their dry weight was recorded.

Observations of leaf area, dry weight, shoot growth, and height growth are available for both growing seasons. Data for diameter growth and crown width growth are available for the second growing season only.

Analysis of variance was used to test for significant treatment effects. Duncan's multiple range test (Steel and Torrie 1960) with $\alpha = 0.05$ was used for mean separation.

Eight planters similar to those on the lot were constructed about 3 m off the lot in a row parallel to the southern end of the lot. Random species and stock treatments were applied to trees planted there so that there were four green ash and four red maples with two trees of each stock in each species; but no fertilizer was applied. Soil moisture and temperature were measured during the second growing season in the same manner as for on-lot sites. The eight trees off the lot provide something of a control against which to compare growth of on-lot trees.

An important difference between on-lot and off-lot planters was that off the lot the original surface soil was not disturbed except for a hole in the center large enough to plant the tree. Hence, below the 15 cm of soil added to bring the soil level up near the top of the ties, the soil was quite dense, except for the looser soil in the planting hole. This is in contrast with the soil on the lot, which had been hauled in and was relatively loose.

Results

All of the trees survived the first two growing seasons. After rather slow growth during the first season as they were becoming established, the trees generally put on good growth during the second growing season.

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[1] Portable area meter, model LI-3000, manufactured by Lamda Instruments Corporation, Lincoln, Nebraska.

Analysis of variance of the growth responses showed significant interactions between the main effects of species, stock, fertilizer, and year. Mean separation for each growth response was done by four separate analyses of the four treatments within each species and year group. This analysis provides comparisons of stock and fertilizer treatment effects within species for each year (Table 2).

Many comparisons of treatment show no statistically significant differences. The measurements of diameter growth, which were made for the second year, showed no significant differences due to treatments for either species.

Response to Fertilizer

B&B trees did not respond to the fertilizer treatment during the first growing season. In the second year, B&B red maple responded to fertilizer by increased leaf area and leaf dry weight, but B&B green ash still showed no statistically significant response to fertilizer.

The BR trees did respond to fertilizer during the first growing season; but the response was in different directions. Red maple showed a positive response by in-

Table 2.—Summary of treatment means and mean separation analysis. Within each group of four means for a given year and species combination, means with the same letter superscript are not significantly different.

Year	Treatment	Leaf area	Leaf dry weight	Shoot growth	Height growth	Diameter growth	Crown width growth	ACD growth
First		*cm²*	*g*	*cm*	*cm*	*cm*	*cm*	*cm*
	Red maple							
	B&B, Control	25[a]	0.18[a]	3[a]	8[a]			
	B&B, Fertilized	26[a]	.20[a]	3[a]	8[a]			
	BR, Control	47[b]	.36[b]	18[a]	18[b]			
	BR, Fertilized	43[b]	.38[b]	58[b]	22[b]			
	Green ash							
	B&B, Control	57[a]	.46[a]	9[a]	16[a]			
	B&B, Fertilized	50[a]	.44[a]	11[a]	13[a]			
	BR, Control	72[b]	.59[b]	20[b]	26[b]			
	BR, Fertilized	57[a]	.39[a]	9[a]	16[a]			
Second								
	Red maple							
	B&B, Control	44[a]	.49[a]	36[a]	66[a]	.155[a]	65[a]	65[a]
	B&B, Fertilized	53[b]	.57[b]	45[ab]	61[a]	.165[a]	66[a]	64[a]
	BR, Control	53[b]	.60[b]	138[bc]	103[a]	.173[a]	72[a]	88[a]
	BR, Fertilized	52[ab]	.55[ab]	194[c]	69[a]	.170[a]	90[a]	79[a]
	Green ash							
	B&B, Control	117[ab]	1.19[a]	16[a]	41[a]	.108[a]	16[a]	28[a]
	B&B, Fertilized	125[a]	1.29[a]	52[ab]	81[a]	.128[a]	20[a]	50[ab]
	BR, Control	130[a]	1.29[a]	88[b]	86[a]	.115[a]	44[b]	65[b]
	BR, Fertilized	98[b]	1.05[a]	37[a]	45[a]	.098[a]	19[a]	32[a]
Sum								
	Red maple							
	B&B, Control			38[a]	73[ab]			
	B&B, Fertilized			48[a]	68[b]			
	BR, Control			155[b]	121[a]			
	BR, Fertilized			252[c]	91[ab]			
	Green ash							
	B&B, Control			25[a]	58[a]			
	B&B, Fertilized			62[ab]	94[ab]			
	BR, Control			108[b]	112[b]			
	BR, Fertilized			46[a]	61[a]			

creased shoot growth, although leaf area, leaf dry weight, and height growth were unchanged. In contrast, response of BR green ash to fertilizer was negative, with a large reduction in all four measures of growth that were observed. In the second year, BR red maple trees had no significant response to fertilizer. Response of fertilized BR green ash trees was again generally negative, with significantly less leaf area, shoot growth, crown width growth, and average crown dimension growth.

Comparison of B&B Versus BR

During the first growing season, growth of BR red maples exceeded that of B&B trees in leaf area, dry weight, and height growth. Shoot growth of fertilized BR trees was much greater than shoot growth of red maples in any other treatment (Table 2).

First year response among the green ash treatments was mixed. Control BR trees grew better than control B&B trees; but fertilizer depressed growth of BR green ash, and there were no significant differences in growth between fertilized BR and B&B trees.

During the second growing season, fertilized BR red maples produced more shoot growth than B&B red maples. Leaf area and weight, and shoot growth of BR controls were greater than leaf area and weight and shoot growth of B&B controls.

In green ash, second-year response was also mixed because of the fertilizer-stock interaction. For control trees, leaf area and leaf dry weight were not significantly different; but BR trees had greater shoot, crown width, and ACD growth. Means for fertilized green ash BR trees were lower than means for fertilized B&B trees, although only the difference in leaf area was statistically significant.

Total Crown Size

For comparisons of total crown size after the two growing seasons, all eight treatment means were compared (Table 3). It was assumed that the species had equal variances. Fertilized BR red maples produced the widest crowns after 2 years, 1.65 m—significantly wider than green ash in any treatment. In contrast, fertilized BR green ash had an average crown width of 0.84 m—significantly less than any other treatment of either species. However, green ash crowns are generally taller and narrower than red maple crowns, at least for sapling size trees; and when ACD was examined in a multiple comparison test, there was no statistically significant difference between the treatments, although fertilized BR green ash had the smallest ACD of all treatments.

On-lot Versus Off-lot Growth

The unfertilized trees on the lot generally grew better than the eight trees planted off the lot (Table 4). A contributing factor to the growth differences may have been that maximum soil temperatures were about 3°C warmer beneath the trees on the lot than beneath those off the lot (Halverson and Heisler 1981). There was also a difference in soil structure, the looser backfilled soil

Table 3.—Mean total crown width and average crown dimension (ACD) after two years with results of Duncan's mean separation. Differences in the means of ACD were not statistically significant. Means with the same letter superscript are not significantly different.

Treatment	Mean total crown width	Treatment	Mean ACD
	cm		*cm*
Red maple, BR, F	165^{d}	Green ash, B&B, C	206
Red maple, BR, C	157^{cd}	Green ash, BR, C	206
Red maple, B&B, C	153^{cd}	Green ash, B&B, F	205
Red maple, B&B, F	152^{cd}	Red maple, BR, C	201
Green ash, B&B, C	136^{bc}	Red maple, B&B, F	189
Green ash, B&B, F	135^{bc}	Red maple, BR, F	177
Green ash, BR, C	116^{b}	Red maple, B&B, C	173
Green ash, BR, F	84^{a}	Green ash, BR, F	158

Table 4.—Mean height and crown width growth of trees in all four treatments (red maple and green ash, BR and B&B) off the lot compared to growth of trees with the same treatments on the lot. All differences between on-lot and off-lot trees are significant at $\alpha = 0.05$. Means are in cm.

Treatment	Number of trees	Height growth 1st year	Height growth 2nd year	Crown width growth 2nd year
On the lot	16	17	74	49
Off the lot	8	12	38	36

in the planting holes of the lot being better for tree growth. The soil moisture measurements made with psychrometers during the second growing season showed no soil moistures below -1 bar off the lot and only one on the lot, but there may have been soil moisture differences in the 0 to -1 bar range that contributed to growth differences.

Discussion and Conclusions

The two species chosen, red maple and green ash, and the transplanting techniques used, were apparently suitable for our urban site, since there was no tree mortality. This is in contrast to experience in other areas where transplant mortality was high, especially with bare-root stock (Cool 1980).

Even before the lot was built, the site of this study was generally flat and soil was moist to poorly-drained. Soil moisture was ample during the second season, and probably was not particularly stressful during the first season, although measurements were not made then. Soil moisture is generally the most important factor in plant survival and growth.

The generally negligible response of B&B trees of both species to fertilizer indicates that addition of fertilizer to fill may not be effective for B&B trees, at least during the first 2 years. Roots evidently did not penetrate the fill to come in contact with the fertilizer during the first year. Green ash BR trees showed a definite negative response to fertilizer that may have been due to root damage caused by high concentrations of soil amendments.

The fact that the fertilizer treatment was relatively ineffectual, even when tailored for the species as it was for red maple, and even on a moist site where fertilizer is generally most effective, suggests a general recommendation that fertilizer not be used at planting time. However, this recommendation may not hold for considerably impoverished soils.

The two species produced similar-sized crowns at age 7 years on this site, although crown shape was different. Red maple tended to have shorter, wider crowns than green ash, so that when crown width and crown height were averaged, there were no statistically significant differences between species. Although BR trees were heavily pruned when planted, their faster growth made their crowns about equal to B&B crowns after 2 years.

Heavy pruning may not be necessary. The reason generally given for it is that crowns must be reduced to compensate for loss of roots and resulting reduction in soil water absorption capabilities. Pruning should thus minimize the chance for severe internal water deficits as the new root system is developing. However, Whitcomb (1979) has suggested that pruning may not be necessary for some species. Bare-root transplants lifted from the nursery with a U-blade may actually retain more of the root system than trees balled and burlapped (Personal communications with William Flemer III and William Collins, 1978). If pruning were not required, it would significantly reduce the already low cost of transplanting by the BR method.

The results of this experiment suggest that bare-rooted sapling-size red maple and green ash trees may be transplanted as successfully as balled and burlapped stock, at least where moisture is not severely limiting. This is of considerable practical significance, since bare-root planting is the least costly method.

Differences in soil moisture between planting sites within the range 0 to -1 bar may have added to within-treatment growth variability and obscured some treatment differences. Future experiments of this kind, with trees in isolated planting sites, should include detailed measurements of the entire range of soil moisture.

Parking lots seem to be promising sites for establishment of urban forests with unfertilized BR stock. At least where good quality planting soil is used in adequate planting openings, and where soil moisture is ample, survival and growth should be excellent.

Acknowledgments

C. H. Pham, a research associate at Rutgers University during the establishment of this study, provided considerable input into study design and assisted with first year measurements. He is currently with Westvaco, Inc.

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Survival of 32 5-year-old red maple and green ash trees planted in holes in the asphalt cover of a large parking lot was 100 percent after 2 years. Fertilizer reduced growth of green ash planted bare-root, but had little effect on bare-rooted red maples or trees of either species planted balled and burlapped. Bare-rooted red maples and unfertilized bare-rooted green ash generally grew better than corresponding balled and burlapped trees.

ODC 237.41

Keywords: Bare-root planting, balled and burlapped planting, crown growth, fertilization, soil moisture, soil temperature, transplanting, tree pruning, urban environment.

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